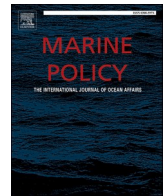




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Status and trends of moored fish aggregating device (MFAD) fisheries in the Caribbean and Bermuda

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ABSTRACT

Moored fish aggregating devices (MFADs) are promoted throughout global small-scale fisheries as tools to enhance livelihoods and shift fishing pressure onto offshore resources. A particularly large number of projects initiating and encouraging MFAD development have occurred in the Caribbean region. Despite ongoing promotion of MFAD fisheries in the region, there is limited understanding of their current extent, distribution, and management across Caribbean states. Here we integrate key informant surveys with a supporting literature review to generate the first comprehensive overview of MFAD fishery status and trends in the insular Caribbean and Bermuda. While regional growth has been substantial, we find wide diversity among states in terms of the number of MFADs deployed, MFAD ownership (private or public), fleet engagement, and the existence and enforcement of MFAD regulations. Our results suggest that despite the presence of regulations in some states, management limitations and private MFAD ownership may be associated with a rapid proliferation of deployed MFADs across the Caribbean. We discuss the critical role of management and monitoring in attaining the anticipated benefits of MFAD fisheries and reducing social and environmental risks. By documenting the diverse paths that MFAD fisheries have taken in different states, this study provides an opportunity for prospective and existing MFAD programs to better evaluate the risks and rewards associated with MFADs and to design appropriate management.

1. Introduction

The marine ecosystems that sustain small-scale fisheries are increasingly threatened, imperiling the millions of people who depend on these resources for food and income [1,2]. Small-scale fisheries that rely on coral reef ecosystems are particularly vulnerable, as these ecosystems have been degraded by overfishing, pollution, disease outbreaks, and coral bleaching [3,4]. One potential solution aimed at improving the livelihoods and food security of small-scale fishers and their communities and shifting fishing pressure from reef to pelagic species is the use of Moored Fish Aggregating Devices, or MFADs [5–8]. Consisting of floating materials anchored in offshore waters (typically 300–6000 m), MFADs capitalize on the natural tendency of pelagic fish to aggregate around a floating structure for protection and foraging [9]. By aggregating fish to known locations, MFADs can reduce fishers' search costs and increase catch per unit effort (CPUE) [10–12], facilitating access to species such as tunas (*Thunnus* spp.), mahi mahi,

(*Coryphaena hippurus*), and billfish (e.g., *Makaira nigricans*).

While MFAD fisheries can offer social and ecological benefits to small-scale fishing communities, these benefits are unlikely to be realized in the absence of effective management [13,14]. Moreover, poorly regulated MFAD fisheries can lead to undesirable outcomes including overfishing [15], conflict among users [7], and pollution of marine ecosystems as MFADs degrade and are eventually lost [16]. In unregulated open access scenarios, in which participation and harvest by fishers is unrestricted, reducing the costs of fishing through MFAD deployment may increase fishing effort beyond optimal levels, potentially resulting in overfishing [14]. This can be compounded in the absence of regulations on setting MFADs as greater numbers of MFADs are deployed. Higher MFAD densities may result in the dispersal of fish across a larger number of locations, reducing the aggregating power of each individual MFAD and requiring fishers to set more MFADs to maintain their portion of total catches [11,17–19]. Similarly, MFAD deployment may reduce the availability of fish to non-MFAD pelagic

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Table 1

Reported MFAD demographics (estimated number of MFADs currently deployed, percent of which are privately owned, and percent of total fishing fleet (number of active fishing vessels) engaged in MFAD fishing on a part-time or full-time basis) and management (the type of regulations existing regarding MFAD deployment, MFAD access rights, and fishing practices around MFADs and whether or not they are enforced) by state. Gray cells indicate no survey response was obtained and that information could not be sourced from existing literature.

State	Demographics				Management											
	Num. MFADs	% Priv.	MFAD Vessels	Fleet eng.	Deployment				Access rights				Fishing practices			
					Reg. type			Enforcement	Reg. type			Enforcement	Reg. type			Enforcement
					Formal	Informal	Drafted		Formal	Informal	Drafted		Formal	Informal	Drafted	
Anguilla																
Antigua & Barbuda	22	91%	30	9%	×			×	×			×	×			×
Aruba	0	-	0	0%												
Bahamas	0	-	0	0%												
Barbados*																
Bermuda	0	-	0	0%	×			×								
Bonaire ¹	0	-	0	0%	×					×				×		
Cayman Islands	3	100%	15		×											
Cuba	0	-	0	0%												
Curacao	24	0%				×		×								
Dominica	40	93%	275	85%									×			×
Dominican Republic ²	2500	100%				×										
Grenada	8	38%	40	50%			×			×	×	×		×	×	×
Guadeloupe	608	99%	210	40%	×				×			×	×			
Haiti ³	18															
Jamaica*																
Martinique	30	67%	223	39%	×				×				×			
Montserrat	3	0%					×				×				×	
Puerto Rico	1	0%	158		×			×					×			×
Saba	12	100%	18		×											
Saint Barthelemy	100	100%	22		×				×				×			
Saint Kitts	22	82%														
Saint Lucia	7	0%	40		×	×					×			×	×	
Saint Martin					×				×			×				
Saint Vincent & the Grenadines	8	0%	40	6%	×			×	×			×	×			×
Sint Eustatius	5	40%	4	20%	×											
Sint Maarten	2	100%	20	40%					×				×			
Trinidad & Tobago ⁴	100	100%	450	69%												
Turks & Caicos*																
Virgin Islands, British*																
Virgin Islands, U.S.	4	0%	20	17%	×			×						×		

¹ Pending anticipated deployment of 6 MFADs in 2020

² Southeastern region only, extrapolated from fisher reports

³ Southeastern region only

⁴ Tobago only; no active MFAD fishery reported in Trinidad

* No active MFAD fishery reported according to Sadusky et al. (2018)

fishers, motivating additional pelagic fishers to set MFADs [14].

While MFAD fisheries may have varied social and ecological effects, the use of MFADs has been widely promoted in small-scale fisheries

around the globe. In the Caribbean region, MFADs have become widely utilized by artisanal fishers in small (>9 m) undecked fishing vessels, with the majority of catch sold for domestic consumption [20]. Several

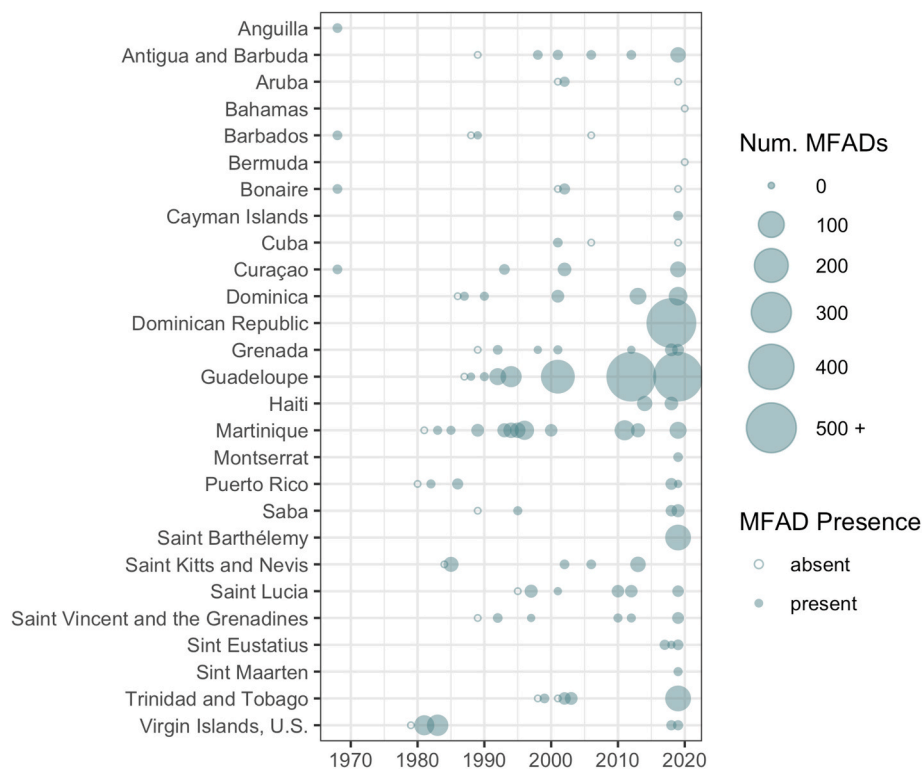


Fig. 1. MFAD introduction and adoption over time as reported in academic and gray literature (historical data) and key informant surveys (current data). Confirmed absence of MFAD fisheries is indicated by unshaded circles, while years without circles signify that no data were available.

central programs have played a key role in initiating and encouraging MFAD use in the Caribbean, including the French Research Institute for the Exploitation of the Sea (IFREMER)'s Moored Fish Aggregating Devices in the Lesser Antilles (MAGDALESA) program established in 2006 to research and establish best practices with regards to MFAD fisheries [21], and the Japanese International Cooperation Agency (JICA)'s Caribbean Fisheries Co-Management (CARIFICO) program focused on facilitating MFAD fisheries and cooperative management practices from 2013 to 2018 [22,23], with a pending follow-up CARIFICO II [24]. The Western Central Atlantic Fisheries Commission (WECAFC) ad-hoc working group on the development of sustainable MFAD fishing, organized by the Food and Agriculture Organization in collaboration with IFREMER, first met in 2001 and has since served as the primary regional forum for exchanging MFAD fishery updates and advances [25,26]. While initially focused on the Lesser Antilles, the working group has since been expanded to include all WECAFC members.

While scattered reports indicate rapid MFAD fishery expansion in the region and suggest management concerns [27,28], little comprehensive information exists regarding the current extent of Caribbean MFAD fisheries and the strength of management relative to fishery growth. If MFAD fisheries are to be promoted with sustainable social and environmental outcomes in mind, we must first assess the status of these fisheries and how they are managed across the region. Here we address this knowledge gap through a regional assessment of MFAD fishery growth and management across the insular Caribbean and Bermuda. We integrate information from academic and gray literature with key informant surveys to document historical trends and estimate current status, highlighting areas where limited management warrants concern over the likely outcomes of these fisheries. We then discuss the potential implications of these results for Caribbean fisheries, offer comparisons with MFAD development in other regions of the world, and prioritize areas for future research.

2. Methods

We reviewed both academic and gray literature to obtain information on the introduction, adoption, and growth of MFAD fisheries within the insular Caribbean (islands of the Bahamas, Greater Antilles, and Lesser Antilles) and Bermuda (see Table 1 for a complete list of locations included in this study). From this review, we compiled a dataset of reported MFAD numbers or MFAD absence by year and location. We defined spatial units as 'states', whether referring to independent sovereign countries, territories subject to external sovereignty, or other associated status. Islands of the Caribbean Netherlands (Bonaire, Saba, and Sint Eustatius) are distinguished from one another because data were reported by separate management entities and because they span a range of geographic locations. Particularly valuable in this regional historical review were reports from the 2001 and 2004 meetings of the WECAFC MFAD working group [25,26]. In these meetings, all entities present provided reports on the current status and general history of MFAD fisheries in their respective states, which we used to construct a historical overview of MFAD development in the states represented.

We also surveyed key informants from individual states to generate a more complete understanding of the current status of Caribbean MFAD fisheries. An online survey was first distributed to participants at the most recent meeting of the WECAFC MFAD working group (which has been expanded from its initial focus on the Lesser Antilles to presently include all WECAFC members) in May of 2019 and subsequently through the WECAFC mailing list in September of 2019. Individual follow-ups with states that did not initially respond or are not WECAFC members were conducted between September and December of 2019. Representatives from each state were contacted at least twice to ensure they had a chance to respond. In situations where the online survey was not convenient for respondents, surveys were conducted in person, via text message, or over the phone.

We obtained survey responses from 25 of the 31 entities contacted. The majority of our survey respondents represent fisheries departments or marine management sectors. We also sought responses from

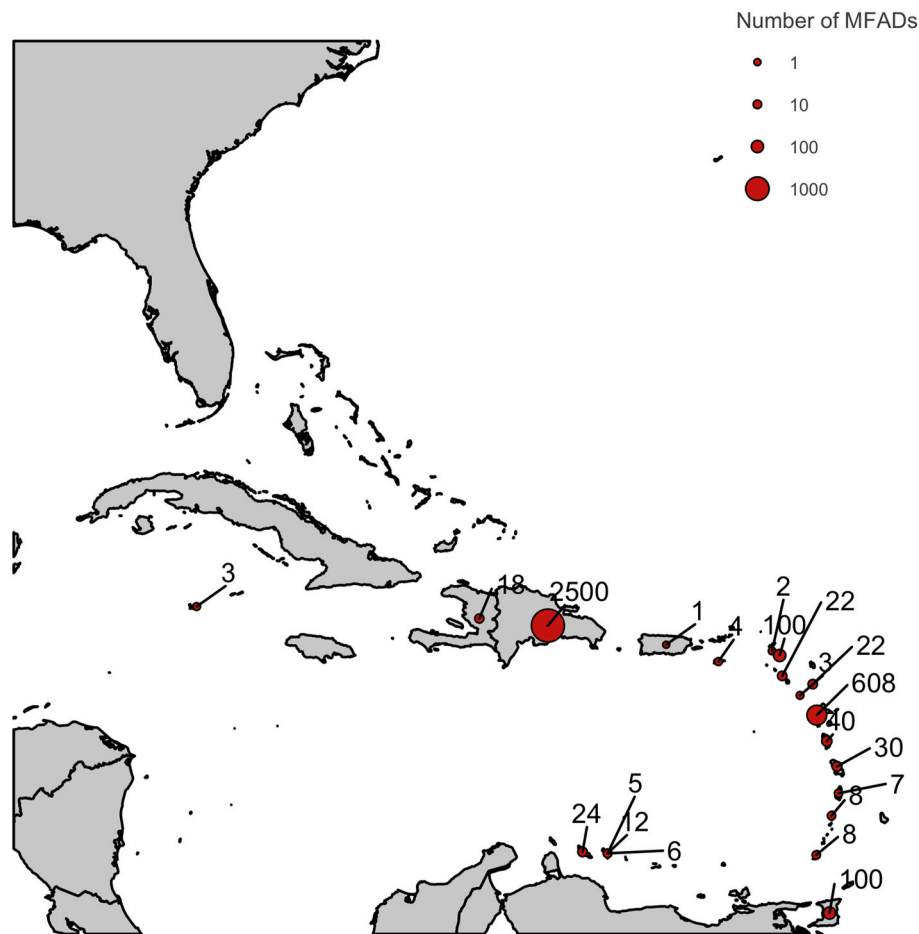


Fig. 2. Map of current estimated numbers of MFADs in the insular Caribbean.

academics and non-governmental organization representatives when their involvement with local MFAD fisheries was particularly high or when management officials could not be reached. Our survey asked respondents to report current estimated numbers of both private and public MFADs. Private MFADs refer to those owned and deployed by an individual or small groups of fishers (though they may sometimes be used by additional fishers with or without an owner's permission). Public MFADs, on the other hand, are deployed by government, non-profit, aid, or fisher organizations and are accessible to all eligible fishers (e.g., fishers belonging to a certain community or with appropriate permits). Survey respondents also reported estimated numbers of vessels using MFADs and in the larger fishing sector, as well as the existence and enforcement of various MFAD regulations categorized as MFAD deployment, fisher access to MFADs, and fishing practices around MFADs (e.g., catch or gear restrictions, minimum distances from MFADs or other vessels; full survey available in Supplemental Information). Respondents classified existing regulations as being formal legislation, informal or community-based, or drafted legislation. For states where survey data could not be obtained or where responses were incomplete, estimated MFAD numbers were obtained from gray or academic literature within the past seven years where available, providing a total sample size of 25 out of 31 states with regards to MFAD fishery demographics. For Haiti and the Dominican Republic, the only available MFAD estimates reflect a subsection of each state (see Table 1), but are provided here as the best available estimates even if they may be conservative values for the larger state. Estimates of total fishing vessels were sourced from FAO estimates when not provided in survey responses.

3. Results

MFADs were initially introduced in four states (Anguilla, Barbados, Bonaire, and Curaçao) in the late 1960s [29], and the number of states reportedly using MFADs as well as the total number of MFADs reported in the region remained relatively low until the 2000s (Fig. 1). Since their initial introduction, the estimated number of MFADs in the insular Caribbean has grown to a current estimate of over 3500 with 20 of 25 sampled states actively engaged in MFAD fishing (Fig. 2, Table 1) and two additional states in the process of introducing (Bermuda) or reestablishing (Bonaire) MFAD fisheries at the time of our survey. The Dominican Republic (here referring to the southeast region of the state) has by far the highest estimated number of MFADs, followed by Guadeloupe, Saint Barthélemy, and Tobago (Fig. 2). While no historical estimates are available for MFAD fisheries in the Dominican Republic and Saint Barthélemy, the majority of MFAD expansion in Tobago appears to have occurred since the early 2000s, while expansion in Guadeloupe occurred throughout the 1990s and early 2000s and appears to have stabilized over the past decade (Fig. 1). MFAD numbers in the U.S. Virgin Islands, on the other hand, have declined since their initial introduction.

The percentage of fishing vessels utilizing MFADs on at least a part time basis reaches nearly 85% and 70% in Dominica and Tobago, respectively (Table 1). Private MFADs make up the vast majority (over 97%) of all deployed MFADs, though the relative use of public versus private MFADs varies greatly by state, with some deploying exclusively public (e.g., Puerto Rico, Curaçao) or private (e.g., Saint Barthélemy, Tobago, Saba) MFADs (Table 1, Fig. 2).

The existence of formal or informal MFAD regulations varies across

states, with 72%, 40%, and 48% having regulations regarding MFAD deployment, fisher access to MFADs, and fishing practices on MFADs, respectively (Fig. 3). Of states with regulations present, rates of enforcement are even lower, particularly regarding the setting of MFADs. The strength of regulation and enforcement does not seem to increase with the size of a state's MFAD fishery.

4. Discussion

4.1. Patterns of MFAD fisheries and management in the Caribbean

This assessment provides the first comprehensive documentation of the growth, prevalence, and management of MFAD fisheries across the Caribbean, integrating previously disparate academic and gray literature with a wide-reaching key informant survey. Our findings show a substantial expansion of Caribbean MFAD fisheries in the last decades accompanied by a lack of management in much of the region.

While most territories show increasing numbers of MFADs over time, adoption and growth has varied widely. Some states like the Dominican Republic and Guadeloupe report hundreds of deployed MFADs while others such as Cuba and Aruba have no current MFAD fisheries despite previous introduction attempts. States where MFADs were introduced earlier do not necessarily have larger MFAD fisheries today, indicating that MFADs do not always spread within a state once they are introduced. Instead, MFAD adoption is likely shaped by numerous ecological and social contexts. Specifically, the economic capacity of fishers to deploy and fish around MFADs likely plays a key role in shaping MFAD fisheries [30]. Despite lack of restrictions of MFAD deployment in Haiti, for example, relatively low MFAD numbers are thought to be limited in part by the financial resources of fishers [32]. In the Dominican Republic, on the other hand, where the financial capacity of fishers is often still limited but arguably higher than that of fishers in Haiti, fishers can afford to deploy numerous low-cost (\$100-\$150 USD), short-lived MFADs typically made of repurposed styrofoam and plastic bottles [22], which can have detrimental consequences for marine debris inputs. Higher variability in MFAD catches relative to coastal fishing [31] may also restrict MFAD fishing to vessels with the financial capacity to absorb fluctuations in profits, potentially contributing to the limited fleet engagement observed in many states. Efforts to manage MFAD deployment and use should carefully consider the financial and material resources available to fishers. Formal and informal management can also directly affect fishers' incentives to engage in MFAD fishing, such as enforced territorial or access rights that prevent poaching and increase benefits to participating fishers [19].

Our results also highlight heterogeneity in MFAD ownership across states. Several states, such as Saba, Saint Barthélemy, and the Dominican Republic have exclusively private MFADs while others like Curaçao, Puerto Rico, and Montserrat only report the presence of public MFADs. High estimates of total MFAD numbers occur in states with high proportions of private ownership. Similar associations between MFAD numbers and ownership can be observed at a higher scale in other regions of the world. MFAD fisheries in the Indo-Pacific seem to consist primarily of public or community-managed MFADs, and privately deployed MFADs are less common than they are in the Caribbean [5,10,31,32]. Mediterranean MFAD fisheries, on the other hand, seem to consist of primarily privately deployed MFADs, which have reached extremely high densities in some areas and totaled over 19,000 among 2300 vessels in 1999 [33,34].

The proliferation of private MFADs is incentivized in unregulated open access scenarios since the installment of MFADs can delimit informal territories and secure individual access to a given stock [19,35]. Indeed, our results show that higher numbers of private MFADs tend to be associated with a lack of management of MFAD fisheries, and particularly a lack of enforcement around the deployment of MFADs. The Dominican Republic, for example, which has the highest estimated number of MFADs in the Caribbean and consists primarily of privately deployed MFADs, has no existing MFAD-specific regulations. Guadeloupe, the second highest in terms of MFAD number and also almost exclusively private, has formal legislation in place around the deployment of, rights to use, and fishing practices around MFADs, but no enforcement of these regulations. Tobago and Saint Barthélemy, the third and fourth largest MFAD fisheries with only private MFADs deployed, either have no existing MFAD regulations (Tobago) or have several regulations but no enforcement (Saint Barthélemy). In contrast, states with regulations and enforcement of MFAD deployment tend to have lower numbers of MFADs and use almost exclusively public or community-managed MFADs. For example, Puerto Rico, the U.S. Virgin Islands, and Saint Vincent have enforced MFAD deployment regulations and have relatively small MFAD fisheries composed of only public MFADs. Antigua is an exception with reportedly enforced MFAD deployment regulations and approximately two public and 20 private MFADs.

4.2. Social and ecological implications of MFAD fisheries management

While MFAD fisheries may bring some benefits to the Caribbean region, unmanaged MFAD fisheries - especially those that are private - may drive negative social and environmental consequences. The

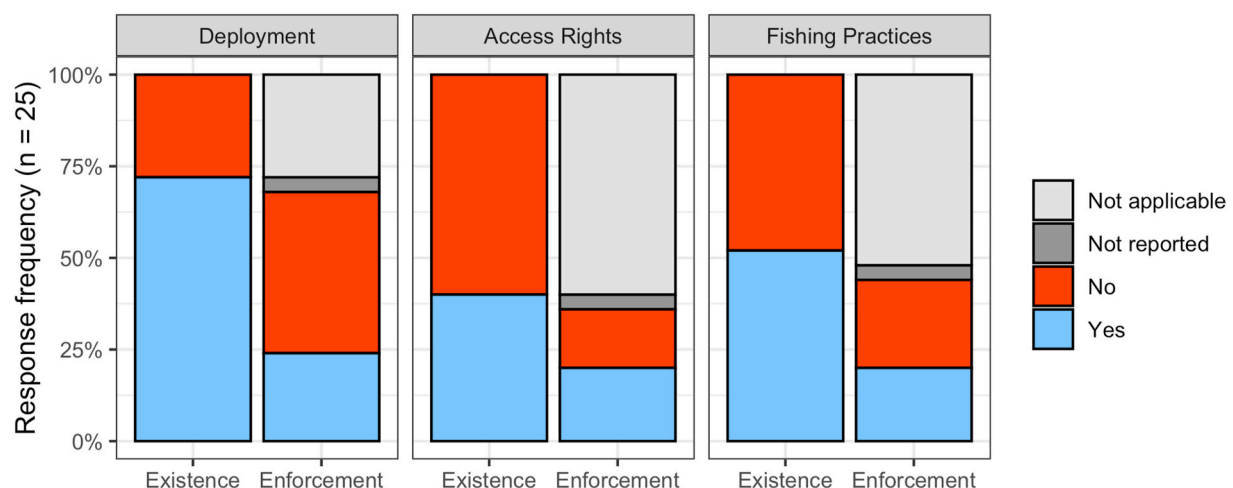


Fig. 3. Survey responses regarding the existence and enforcement of formal, informal, and/or drafted regulations regarding MFAD deployment (e.g., who can set MFADs, where can they be set), access rights (e.g., permits, exclusive access rights), and fishing practices on MFADs (e.g., catch or gear restrictions, minimum distances from MFADs or other vessels). Because nonexistent regulations cannot be enforced, enforcement was considered not applicable for these respondents.

proliferation of private MFADs that can occur without effective management likely reduces the socioeconomic benefits of MFADs to fishers [14]. As MFAD density increases, the aggregating power of each MFAD may become diluted, driving fishers to deploy more MFADs - typically at increasing distances from shore - to maintain access to a given stock [19, 36]. This reinforcing feedback loop reduces profits to fishers as deployment costs escalate and raise safety concerns as fishers travel further offshore. Moreover, poaching incidents and competition to access the stock may increase conflicts in fishing communities if formal or informal institutions are not in place [19]. A model investigating the social-ecological impacts of three MFAD governance scenarios showed that private MFADs tend to increase conflict among fishers in comparison with community-based or top-down public MFAD management [20]. Allocation of exclusive access rights to MFAD fishers via mechanisms such as permits may help ensure that fishers benefitting from MFADs are also contributing to deployment, maintenance, and monitoring costs, potentially reducing conflicts [37]. Restrictions of the number of MFADs deployed can prevent escalating costs to fishers as MFADs are set farther and farther from shore, and maximize the aggregating efficiency of individual MFADs [11].

Increased CPUE associated with MFADs may also increase the likelihood of overfishing, which is particularly concerning for overfished species such as *Kajikia albida* (white marlin) and *Makaira nigricans* (blue marlin) that are frequently caught around MFADs [38]. In addition to obvious ecological concerns, it can also lead to economic losses and reduced food security [39,40]. Alternatively, if appropriate management institutions ensure enough fish escape harvest to sustain healthy stocks (e.g., through harvest or effort controls), the reduction in fishing costs generated by MFADs may increase the profitability of a fishery as well as contributions to food security. Food security is a well-documented benefit of many community MFAD networks in the Indo-Pacific [5,10,31,32,41], it has been less explored across the Caribbean region's diverse MFAD fisheries (but see Ref. [42]) and would be a valuable area for future research. The status of MFAD-targeted stocks may also be impacted by other fisheries (e.g., industrial long-line or purse seine fleets), but data limitations preclude us from establishing the relative impacts of these different fisheries and potential implications for MFAD fisheries outcomes.

Beyond potential overfishing of pelagic resources, the assumption that MFADs will inherently relieve reef fishing pressure is impossible to realize without simultaneous efforts to improve reef fisheries management and associated markets. Small-scale fishers often employ a portfolio of fishing practices [43,44], and fishers adopting the use of MFADs are likely to continue reef fishing when inclement weather, boat issues, or market demand make it more feasible or profitable than fishing on MFADs. Even if some fishers switch completely to MFAD fishing, any excess demand for reef fish or recovery in reef fish stocks will, in theory, merely incentivize others to enter the reef fishery if access is not restricted.

The vast and growing number of MFADs deployed in the Caribbean has concerning implications for marine debris inputs. While construction practices vary across states, many privately deployed MFADs are cheaply constructed and have high rates of turnover. For example, fishers in the southeast Dominican Republic report losing half of their MFADs within the first year [28]. By shifting incentive structures from those that motivate continuous deployment of short-lived MFADs to those that encourage sustainable use, management can also reduce the total number of MFADs deployed and mitigate marine debris inputs. However, even when designed for longevity and constructed using the highest quality materials, as is the case in some high-budget public MFAD projects, all MFADs will eventually become marine debris. Increasing intensity of storm events, unpredictable bottom topography, heavy currents, and unpredictable marine traffic can shorten the life of any MFAD regardless of construction quality. For example, Hurricane Maria claimed two of Puerto Rico's nine industrially constructed MFADs in 2017, each of which had cost approximately \$8,000 USD to construct

and between \$8,000 and \$10,000 USD to deploy (W. Merten, personal communication, February 28, 2020).

4.3. Opportunities for learning and improving management

The enforcement of MFAD regulations can overcome most of the challenges presented above, while monitoring of MFAD fisheries can help ensure sustainable practices. Limiting MFAD numbers or allocating property rights can reduce perverse incentives towards MFAD overproliferation and undesired consequences. Regulations around MFAD access and fishing practices can also reduce conflicts among private MFAD users and facilitate the sharing of public MFADs by better distributing the benefits and costs of MFAD fishing. Management improvements that reduce the deployment of high numbers of private MFADs and encourage proper MFAD construction can substantially reduce marine debris inputs from MFADs, while technological advances may allow for the incorporation of biodegradable materials (as has been experimented with in drifting FAD fisheries [45,46]) or facilitate MFAD retrieval after a determined lifespan. Equally important is the monitoring of MFAD fisheries. In addition to keeping track of MFADs numbers, agencies would benefit from the collection of MFAD-specific harvest data and its reporting to Regional Fisheries Bodies such as ICCAT, CRFM, the Cartagena Convention to facilitate the proper assessment of the impacts that MFAD fisheries have on target stocks and regional ecosystems.

The diversity we have documented in MFAD fisheries among Caribbean states must be considered when promoting MFAD use, and can help inform the development of management strategies. Current estimates and trends reflect potential differences in drivers and capacities for MFAD fisheries not only across but also within states. Understanding the drivers and constraints for MFAD fishing before initiating MFAD projects is key to secure sustainable use and equitable access to MFAD-fishing benefits. For example, while MFAD fisheries consisting of low numbers of public or community-managed MFADs may be preferred due to their relatively low risk of negative social and environmental impacts, its effective functioning requires specific conditions such as high trust among members to solve the collective action problems involved [47] or conflicts may arise [19,22,48]. Likewise, given the documented management limitations associated with the overexpansion of private MFADs, agencies promoting MFAD use would benefit from restricting the deployment of private MFADs in places where regulation and enforcement are weak or nonexistent. Nonetheless, the heterogeneity among states also provides an opportunity to learn from best and worst practices across the region and among other regions such as the Mediterranean and Indo-Pacific, as well as a platform for future research investigating the drivers and outcomes of different MFAD fishery typologies. Further research can help evaluate the relative effectiveness of formal and informal regulations in different contexts. Additional investigations are also required to determine the level of transition from reef to MFAD fishing - a common goal in MFAD fishery programs - and the influence of economic, cultural, and governance factors in determining fishers' practices.

4.4. Study limitations

While this study provides a valuable overview of Caribbean MFAD fishery status and development, we acknowledge several limitations in data availability. First, obtaining exact MFAD numbers or fleet sizes was not feasible at the scale of this assessment. It is possible that private MFAD numbers are underestimated here due to lack of reporting and secrecy around deployment [19,38], which would further support concerns regarding management limitations and uncontrolled expansions. It is important to note that MFAD numbers for the southeastern Dominican Republic were reported based on extrapolations from the number of MFAD fishers and number of MFADs per fisher, but this estimate was the best available and aligns with widespread reports from the Dominican

Republic and neighboring islands that MFADs are prolific in Dominican waters, and is likely an underestimate as it reflects only a subsection of the state. It is also important to note that our timeline of MFAD growth is limited to data reported in academic or gray literature, and therefore would underestimate historical MFAD numbers in cases where those were not reported. We thoroughly reviewed historic gray literature discussing regional MFAD development at different stages in the Caribbean timeline helped to ensure major participants were captured, and do not claim to establish precise growth rates but instead broader trends in MFAD use throughout the region. While data limitations preclude the detailed quantitative analyses (e.g., stock assessments, harvest dynamics, mobility and aggregation patterns) required to establish the actual impacts of MFAD fisheries on targeted stocks, we draw on theory to provide insights as to the likely role of management in determining MFAD fishery sustainability and ultimate social and ecological outcomes. Even with these limitations, this regional assessment fills a critical knowledge gap in our understanding of Caribbean MFAD fisheries and provides a valuable baseline for future fishery assessments.

5. Conclusions

Since their initial introduction in the late 1960s, MFADs are now used in the majority of Caribbean states and the number of reported MFADs deployed has grown to over 3500, most of which are privately promoted. As these fisheries continue to expand and be actively promoted, it is critical that we recognize their current extent and understand potential positive and negative social and environmental outcomes. While MFAD fisheries are endorsed as mechanisms for increasing fisher incomes, and reducing pressure on inshore reefs, these fisheries may not necessarily confer these benefits and also come with numerous important and underappreciated risks. Lack of management plagues MFAD fisheries across the region and threatens the optimization of social and environmental outcomes. In order to promote ecologically and economically sustainable Caribbean fisheries, new MFAD fisheries should be implemented with caution and dedicated attention should be given to improving management of existing MFAD fisheries.

CRedit authorship contribution statement

Margaret W. Wilson: Conceptualization, Methodology, Data curation, Writing - original draft. **Julia M. Lawson:** Conceptualization, Methodology, Data curation, Writing - review & editing. **Maria Ignacia Rivera-Hechem:** Conceptualization, Methodology, Data curation, Writing - review & editing. **Juan Carlos Villaseñor-Derbez:** Conceptualization, Methodology, Data curation, Visualization, Writing - review & editing. **Steven D. Gaines:** Conceptualization, Writing - review & editing.

Declaration of competing interest

None.

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