

A Guide To Managing Fish Aggregation Devices (FADs) in the Caribbean

Una Guía para Administrar Dispositivos de Agregación de Peces (DCP) en el Caribe

Un Guide pour Gérer les Dispositifs D'agrégation des Poissons (DEP) dans les Caraïbes

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ABSTRACT

Humans have used fish aggregation devices (FADs) for centuries to attract fish in the vast oceans making capture easier. Technological advances in recent decades have made FADs more efficient and their use has expanded to the tens of thousands. Management, however, has been slow to follow the fast developments in construction and deployment, and regional fisheries bodies have just begun to consider FADs as a tool requiring organization and regulation. In the Caribbean, FADs are rapidly being deployed by a variety of stakeholders as guidelines are lacking, which has led to conflict among user groups and questions surrounding the biological sustainability. This study aims to guide the fishery manager, researcher, or community leader in developing a FAD management plan. The current situation of FADs in the Caribbean is presented, and global examples of FAD management are examined in order to determine the steps most necessary for success. The guide ends with several suggested management strategies, and concludes with what is known to be true of FADs in the Caribbean.

KEYWORDS: Fisheries Management, FADs, fish aggregation devices, small-scale fisheries, artisanal fisheries

INTRODUCTION

Fish aggregating devices (FADs) have been used by humans for centuries, likely millennia, to attract fish to a particular object in the vast oceans and make capture easier. Technological developments in the 20th century led to improved FAD design, use, and therefore efficiency. Today they are used by the commercial tuna industry as well as by small-scale fisheries in developing nations, both hoping to attract pelagic species for an easy catch.

Despite their growing use, little is known about the effects FADs may have on the ecosystem and the fish they attract. Observation shows juvenile tunas are often caught around FADs, and research suggests fish of a particular sex for some species may be more attracted to FADs than the other. There are implications ranging from influences on the patterns of highly migratory species and their routes, to the conflict arising when fishers of different user groups vie for a spot near a FAD. Similar to the limited research on FADs, management is also minimal and regulatory fisheries bodies are only now beginning to address the questions surrounding fish aggregating devices.

In the Caribbean, the rapid expansion of FAD fishing is largely among artisanal fishers (CRFM 2015), although recreational FAD fishing is growing here as well. Again, little regulation exists regarding FAD use, development, and management in this region, despite the prevalence of this fishing gear. Multiple regional bodies have recognized the need for management of FADs and FAD fisheries, but activating the call has yet to happen.

This paper intends to serve as a guide for developing FAD management plans in the Caribbean. The region is diverse and solutions will not be the same throughout, but the final product of this research is a guide that can be applied across the board while still allowing for different management outcomes. Through global and regional examples it is clear that stakeholder involvement is the primary key to success, and is the theme of this guide. Several management strategies are offered as potential solutions, but all require the same steps for fostering co-management found in the guide.

Considering the fast-paced growth, nations and management bodies must act promptly to develop informed FAD plans and guidelines in order to avoid and mitigate biological, economic, and social consequences.

Background on Fish Aggregating Devices

Throughout time, fish have been observed around natural and manmade structures in open water, from logs and drifting seaweed to rafts and oil platforms, with diverse associated species numbering in the hundreds and including a variety of life history stages. Historically, the use of floating devices to attract fish can be seen in several parts of the world. The Romans used FADs in the Mediterranean, Japan began using FADs in the 1600s, and Southeast Asian countries began deploying aggregating devices in the beginning of the 20th century (Dempster and Taquet 2004). In the Caribbean, the first recorded use of FADs date from the 1960s and 1970s in Curacao, Bonaire, Barbados, and Anguilla in the form of bamboo rafts (CRFM 2015).

It wasn't until the second half of the 20th century that large-scale fishing on FADs began to develop. Modern FADs primarily target large pelagic species, including tunas and billfish, as well as coastal wahoo and dolphinfish. Drifting FADs are now heavily used by the tuna industry, and entered the scene in the 1970s when the U.S. tuna fleet began to purse seine around FADs in the Pacific Ocean. Purse seining rarely occurs around anchored FADs, which are instead used by artisanal or recreational fishers, who may employ the fishing techniques of trolling, pole and line, trapping, vertical longlining, drop-stone handlining, and ring netting.

In the Caribbean, moored FADs are more prevalent than drifting and used to catch pelagic species such as dolphin, wahoo, tunas, and billfish. In this region, FADs are typically deployed in three manners: a private FAD placed by an individual, a private collective FAD placed by a group of fishers, or a public FAD placed by the government or an international agency. All types have created user-conflict in the past, from cutting private lines to crowding on public FADs.

The Pew Charitable Trusts conducted a study to estimate the number of FADs deployed into the world's oceans annually, by artisanal and commercial fishers alike. It was determined that, in 2013, between 81,000 and 121,000 FADs were deployed globally, the variation depending on the sources of information included (Gershman et al. 2015). The European Commission estimates that about 91,000 drifting FADs are deployed each year, not including anchored – they estimate anchored FADs number over 73,000, most of which are in the Mediterranean and used to attract dolphinfish (Scott and Lopez 2014).

There is very little management of FAD fishing in the Caribbean, as well as at the global level. Regional fisheries management organizations (RFMOs) have only just begun to address FADs as a fishing tool that requires research and regulation. At the global scale, the FAO Code of Conduct for Responsible Fisheries offers one point on FAD management, with very limited direction or suggestions:

States should, within the framework of coastal area management plans, establish management systems for artificial reefs and fish aggregation devices. Such management systems should require approval for the construction and deployment of such reefs and devices and should take into account the interests of fishers, including artisanal and subsistence fishers, (Article 8.11.3, 1995).

In 2013, the Caribbean Regional Fisheries Mechanism (CRFM) announced an initiative for member States to expand the use of FADs. Reasons cited include taking pressure off inshore reef fishes and developing economic benefits from an under-utilized resource (CARICOM, 2013). A collaborative effort has since begun with a number of development projects and funding sources to advance FADs in the Caribbean.

The Issues

It is just as unclear how to best manage FADs as is their effects on the marine environment. The use of FADs across the oceans has grown substantially in the past decade or two, as commercial and artisanal recognize their efficacy in fishing. Even the recreational fishing sector has taken an interest in utilizing FADs to sustain or enhance the sport fishing industry.

A recurring argument in support of developing moored FAD fisheries is to reduce pressure on the overfished coastal areas that have traditionally supported reef-fish fisheries, and provide additional or alternative economic

benefits. However, it has not been proven that the introduction of FADs does in fact decrease pressure on coastal stocks: in Martinique and Guadeloupe, most fishers using FADs continued to fish the nearshore areas, while most in Dominica fished just the FADs (CRFM 2015). This evidence suggests socioeconomic and regulatory context also influence fishing pressure and behavior. Bycatch is another concern for FAD fisheries as non-target species are equally as attracted to a floating device as the desired fish. Juvenile tunas are frequently caught at FADs and more female than male dolphinfish are also caught at FADs (Dempster and Taquet 2004). High volumes of unintended catch can have an effect on fish stocks and ultimately the ecosystem.

A concerning unknown is the effect FADs may have on the marine environment and on the species that congregate. Bach et al. (1998) were unable to draw any conclusions about the horizontal and vertical movements of tunas around FADs in French Polynesia, simply stating that the biological environment does indeed have an influence. There is concern that migration patterns, the diet of pelagic species, size and sex structure of a species, and life history may all be affected by FADs. *A change in the distribution and abundance of FADs may lead to changes in the way fish are distributed in the ocean and subsequently have broader consequences*, (Dempster and Taquet, 2004). Alternatively, it has been argued that FADs increase productivity of fish due to these same factors. It is unclear whether the fish populations are actually increasing or abundance simply appears to be increasing due to the congregation of individuals around FADs.

Further, conflict over FADs has become common in the Caribbean. Artisanal fishers, individuals or co-ops, and recreational fishers all have an interest in easy capture of pelagics. This has led to clashes on the water as all users attempt to extract the greatest benefit from the common fisheries resource. Overcrowding on public FADs is often an issue, and can lead to reduced catch as well as reduced income in turn. Vandalism or severed lines of private FADs also occurs. The source of a FAD's funding—government, NGO, communal, or private—can have an influence on how it will be treated and what kinds of conflict may come out of it. Those deployed by the government or grant funds are typically open access, neither providing fishers with a sense of responsibility nor offering secured funding for maintenance. Alternatively, if a FAD is built and deployed by a single fisher, that individual expects to reap the benefits of the investment and assumes some exclusivity. Conflict then erupts when others begin utilizing the FAD to their own benefit. Fishery regulations are largely absent in the Caribbean, and those few nations that do have legal guidelines typically lack enforcement with which to follow up.

Through bioeconomic modeling, Samples and Sproul (1985) show that FAD fisheries under an open access regime fail to provide the benefits advertised, namely increasing fishermen's profits, employment opportunities, and landings of fish. In fact, deployment of unregulated FADs may generate unintended results such as decreases in the above.

Purpose of Research

While FAD research is plentiful, much of it has focused on the efficacy of FAD fishing and the best materials in FAD construction—little attention has been paid to management. It is a frequent conclusion among government publications, international conferences, and scientific papers to recognize the need for management in FAD fisheries. This paper finally provides the fishery manager, researcher, and community leader with a guide to building a FAD management plan, naming the elements for success and supplying management strategies that may be applied in the Caribbean, and perhaps beyond.

A thorough review of existing literature on FAD management globally was conducted, as was an examination of co-management research. Personal communication with a number of researchers and stakeholders in the Caribbean supports the comprehensive approach of this paper.

THE GLOBAL PERSPECTIVE

Management of fish aggregating devices has taken many forms across the world. It is recognized that sociocultural factors impact the success of a fisheries management strategy, and the Caribbean region as well as each island has its own unique community that must be considered in development plans. Many of the following examples utilized such characteristics in building their distinct FAD management plan.

FAD Management Worldwide

Recreational fishing is a pastime in Australia, where sportfishers target pelagic species such as dolphinfish, wahoo, tuna, and billfish. The Perth Game Fishing Club located on the southwest coast of the country utilizes six FADs to attract tuna, kingfish, dolphinfish, marlin, and more for its members. Membership dues of PGFC help to continue the program by funding maintenance, although private companies may also sponsor the FADs. A FAD Code of Conduct is part of the agreement as well, including provisions for respecting fishermen who are already fishing the FAD and discouraging tying to the FADs. On the southeast side of Australia, the state of New South Wales (NSW) has a history of FAD use for recreational fishing as well. The initial success of five FADs in 2002 led to five more being deployed the following year, and the popular program now handles 29 FADs in total. Research has shown that the most common fish around these FADs is dolphinfish, which makes up 95% of the catch. The state government conducts monitoring and tagging research around their FADs and has also established a FAD Code of Conduct. At the national level, the Game Fishing Association Australia has a Code of Conduct for FAD fishing. With the help of management, public FADs are successfully evolving in Australia.

In Hawaii, FAD development and experimentation goes back to the 1970s. The Honolulu Laboratory of the National Marine Fisheries Services deployed several in 1977, which were successful in increasing commercial tuna catches as well as recreational catches. The state's natural resources department soon proposed establishing a system

of FADs, which resulted in the 1980 deployment of 26 FADs in waters around the main Hawaiian Islands. There are currently 55 surface FADs monitored and maintained throughout Hawaii, funded primarily by the Federal Aid in Sport Fish Restoration Program, a national program authorized through a 1950 Act of the same name. Regulations include laws against mooring, damaging or removing FADs.

Dolphinfish in the Mediterranean Sea have been caught using FADs for decades, if not centuries (Morales-Nin et al. 2000). At the beginning of the season, typically August, artisanal boats from Italy and Spain deploy anywhere between 10 and 100 FADs each, depending on the location and surrounding benthic and fishery features. Generally these FADs are moored, although some are drifting, and are small-scale, constructed of palm fronds and cork anchored with large stones. In Malta, fishermen must apply for a permit in May in order to gain access to particular fishing sites. Licenses are then distributed, fishermen place their own FADs in their allocated area, and dolphinfish fishing commences in August. In Tunisia, FADs are given unique markings to distinguish the owner (Morales-Nin et al. 2000).

In lesser-developed countries, FADs are often promoted as an alternative form of fishing that provides access to previously hard to reach pelagic fish resources, as well as another source of income. FAD fishing can also be more cost effective and safer, as fishers do not use fuel traveling long distances searching for fish, and considering the congregating behavior of large fish, a greater catch per unit of effort (CPUE) is yielded. The FAO/UNDP initiated a FAD development effort in Mauritius in the 1980s in response to drastic declines in inshore fisheries, including demersal and lagoon species (Beverly et al., 2012). Seven pilot anchored FADs were deployed, all considered to be common property, set by government institutions. *The anchored FADs were deployed between 2.5 to 6.3 nm offshore which was where artisanal fishers normally operated. One anchored FAD was, however, later deployed 12 nm offshore*, (Beverly et al. 2012). Boats spotted around the FADs included artisanal boats who mainly used handlines or trolled, sports (tourist) boats who troll fished, and part-time fishers who handlined. Dolphinfish, yellowfin tuna, skipjack, wahoo, sharks, and billfish were commonly caught around the FADs, but tuna was most pronounced, caught year round and accounting for 78 percent by weight of the artisanal catch, (Beverly et al. 2012). Interests of user groups did not become a problem here, as it just so happened that *the artisanal fishers preferred fishing at the nearshore anchored FADs while the sportfishing boats preferred visiting the more distant anchored FADs. Big game fishers and sports fishers often caught baitfish at the FADs to be used to fish for marlin and tuna further from the anchored FADs*. (Beverly et al. 2012). It was estimated that the cost of each anchored FAD deployed off Mauritius represented only 4% of the net annual production value of the fish caught by artisanal, sport, and part-time fishers, (Beverly et al. 2012).

A study was done on anchored FADs in the Comoros, La Reunion and Vanuatu in 2000. Increased productivity

around FADs caused a 340 percent increase in pelagic fish catches in La Reunion over an eight-year period, and increased production in Comoros from 6,000 to 12,000 t during the same period (Beverly et al. 2012). While this increase may seem a triumph, the authors found that such fishing success was not sufficient for long-term success of the anchored FADs. In fact, the level of involvement of the fishers and type of management method proved to be most important for the successful persistence of FADs in these two island nations.

Vanuatu saw a greater FAD development attempt in 2014 with the help of the Japan International Cooperation Agency (JICA), an organization that also has a presence in the Caribbean. The initial program deployed 131 FADs in the 1980s, but a lack of awareness about the benefits of FADs was a challenge (Amos et al. 2014). Management and technical regulations followed, including the establishment of a committee in each area for the purpose of implementing the community FAD guidelines. Only boats registered by the committee of an area were permitted to fish the community FAD, and those who are not must apply to the committee and pay a membership fee to register and be allowed access to their FAD. These fees are then spent on fuel to monitor and maintain the FAD. Regulations were also created for FAD conduct, such as trolling must be 20 m away, dropline and deep-bottom fishing must be 300 m away, no spearfishing or gillnetting allowed around the FAD, and also discouraging mooring to the FAD.

In each above scenario, community involvement in developing or implementing the regulations was a key component in successful FAD management, as it is for any fisheries management plan. Unfortunately, this level of institutional cooperation is less prevalent among Caribbean nations and communities.

THE CARIBBEAN

Attempts at FAD Management

There is little organization regarding FADs in the Caribbean. Some countries began to experiment with FADs in the 1980s, while others are just learning of the benefits when it comes to accessing pelagic resources. The CRFM published a draft FAD management plan in 2015, however, the document fails to direct users to any concrete management schemes. The plan was never fully implemented due to the reluctance of several States to adopt any restrictive actions, and so it remains a draft with no authority.

The Japan International Cooperation Agency (JICA) has tried to implement FAD fisheries in the Caribbean, with mixed success. Their Caribbean Fisheries Co-Management (CARIFICO) project began with introducing FADs in several eastern Caribbean islands, then moved into education sessions to train fisherfolk on building and deploying FADs. Now that the program is several years in, management has become a concern, and JICA is working to introduce some sort of rights-based plan, similar to the co-management found in Japan. However, the CARIFICO project is slated for just five years, and its deadline is approaching likely with no plans for renewal. In addition,

the French Research Institute for Exploitation of the Sea (Ifremer) has been working similarly in the Caribbean through a project called MAGDALESA: *Moored Fish Aggregating Devices in the Lesser Antilles*. They work in conjunction with the FAO and the Western Central Atlantic Fisheries Commission (WECAFC), and have thus far also focused on introducing FADs to fishing communities, sharing information on best FAD materials and design, and educating fishers about fish storage and quality. Finally, the Caribbean Billfish Project, funded by the WorldBank and spearheaded by the FAO and WECAFC, is working to develop a regional management plan for billfish utilizing FAD fisheries. In some cases these external partners have simply deployed FADs; in fewer, they have worked to implement management.

As can be seen in Table 1, many Caribbean nations do not have regulation or legislation regarding FADs. Of the 32 nations and territories in or surrounding the Caribbean, just nine have some form of FAD regulation. Further, those that do often have little to no enforcement.

Regional Examples

Management has often been an afterthought when it comes to FADs — agencies and governments are so concerned with introducing the new fishing tool and developing cost-effective designs that little attention is given to how the device will be used once people begin to fish around it. Further, upkeep is often dependent upon persistent funds that are not present, or corruption leads to mistrust. Conflict then ensues as users individually try to extract the most benefit from a shared public resource.

This was the case in Dominica, where “conflict arose among fishers upon realizing that heavy exploitation of the FADs was beginning to jeopardize the viability of the fishery. After the introduction of the limited entry of vessels and/or fishers, the fishers themselves were empowered through co-management arrangements to enforce and monitor each other’s compliance with established protocol.” (CRFM 2013). In analyzing FAD fisheries of Dominica, Sidman et al. (2014) found working with the local fishers to be monumental. The researchers first talked to fishers in three communities to learn about primary concerns, then gathered data with the help of fishers, conducted an analysis, took the findings back to the local communities and together devised management strategies. Dominica has a history of private FADs, which caused conflict when the government deployed public FADs with an open access policy. These public FADs were also not maintained well since no fisher believed it to be their responsibility; they were given no resting period, and instead fishers would end up taking small fish, compromising the stock. Crowding resulted on these few FADs, reducing the fishers’ economic return. After stakeholder meetings, the following best management practices were identified: greater input from the government on deployment, maintenance, and information sharing like a newsletter; need for “code of ethics” to formalize cooperation among fishers; framework should be flexible to allow for both public and private FADs, but with spatial separation (Sidman et al. 2014). Dominica as well as Saint Lucia have since initiated bottom-up efforts and developed a draft

FAD fishery management plan with the help of CARIFICO. Conversely, attempts at this have failed in Haiti.

Such conflict was avoided from the start in Antigua and Barbuda. FAD fishery developments began here in 2013 with input from fisherfolk who worked to collaborate and enforce decisions, including establishing the fishery as limited-entry. The importance of instituting regulations from the beginning was noted at a regional FAD workshop (CRFM 2013).

Strengthening collaboration with fisherfolk has been called for in Grenada, where a number of problems surround FADs.

Fisheries laws required vessels registration numbers to be written or placed on the vessel, however this was not enforced. Poor quality FADs, inappropriate site selection, lack of establishment of FAD ownership, lack of maintenance, lack of monitoring, and theft of FAD buoys reflected the need for the establishment of a FAD management system, which was currently considered as non-existent.

(CRFM 2013). It was only recently that fishers became aware of FADs, after stumbling onto the one

Table 1. FAD legislation in all Caribbean nations

Country	Moored FAD Fishery?	Description of FAD Management
Anguilla	No	FAD deployment requires permission of Minister
Antigua and Barbuda	Yes (CARIFICO)	FAD fishery is limited entry, requires license. FAD fishers placed in zones, allowed to fish any FAD around country but each zone responsible for monitoring their own FAD. Descriptions for placing, marking, protection and designation of FADs, as well as disposal of unlawful FADs.
Aruba (Dutch Caribbean)	Some (Recreational)	None; FADs placed in 1990s and onward, benefit charter boats
Bahamas	Some (Recreational)	None
Barbados	No	None
Belize	No	None; There are no FADs in Belize
British Virgin Islands	Some (Recreational)	None
Cayman Islands	No	None
Colombia	No	FADs prohibited as of 2004, but 2014 Resolution calls for collection of data on FADs to develop management plan for future FAD use
Costa Rica	Some (Recreational)	None
Cuba	No	None
Curacao (Dutch Caribbean)	Yes	None; FADs placed in 1990s and onward benefit charter boats
Dominica	Yes (CARIFICO, MAG-DELESA)	Limited entry introduced after conflict, fishers then monitored each other's compliance
Dominican Republic	Yes	None
Grenada	Yes (CARIFICO, MAG-DELESA)	None; need has been recognized, meetings being held
Guadeloupe	Yes	Only commercial fishermen can deploy; location must be registered; no mooring; owner has exclusive rights when present
Guatemala	No	None
Haiti	Yes	None; problems rampant
Honduras	No	None
Jamaica	No	None
Martinique	Yes	FAD laws describe deployment, licensing, marking, contact with FAD and fishing techniques. Licensing: permit required before construction of boat to which license is then assigned
Mexico	No	None
Montserrat	No	FAD defined, Governor in Council provides for licensing and rights to fish around FADs
Nicaragua	No	None
Panama	No	None
Puerto Rico	Some	No nets allowed around FADs; local recreational rules including no anchoring, mooring, damaging or altering FADs
St. Kitts and Nevis	Yes (CARIFICO)	Details on use, marking, and disposal of FADs. FAD license implemented, designed with input of fishers
St. Lucia	Yes (CARIFICO)	Consult with Fisheries Dept before deploying; coordinates given to Air & Sea Authority; mark with radar, reflector, flag; no mooring to FAD; owner does not have exclusive rights; regulations in making
St. Vincent and the Grenadines	Yes (CARIFICO, MAG-DELESA)	Defines FADs and provides guidelines: requires permission from Chief Fisheries Officer, permission does not confer exclusive rights to fish in the area, person placing FAD must notify CFO within 24 hrs. Further legislation touches on designated FADs, how to mark FADs, and disposal
Trinidad and Tobago	Yes (Tobago)	None; need recognized
Turks & Caicos Islands	No	None
Venezuela	No	None

deployed by the MAGDELESA project, but it was found that they *strongly supported the principles of co-management, even to the point of self-imposing user fees*, (CRFM 2013). The final management plan for Grenada's FAD fishery remains to be seen.

FAD fishing has recently gained popularity among recreational anglers in Puerto Rico, where 11 FADs have been deployed within the past two years. Similar to the state-managed FADs in Hawaii, the initiative is funded by a U.S. Fish & Wildlife Sport Fish Restoration Program grant, and led by the non-profit Fundacion Legado Azul, which constructs and deploys the FADs. The goal, according to the project proposal, is to *provide recreational and economic benefits for Puerto Rican (and international) recreational anglers...and help perpetuate traditional fishing activities*, (Merten 2017, *Pers. communication*). An article by the San Juan International Billfish Tournament (2016) said the FADs are revitalizing the charter industry. Although no specific management plan has been outlined by Puerto Rico, user rules are listed on a website dedicated to the FAD system.

Tourism and sport fishing are popular in the Dominican Republic, where fishing is open access and conflict between user groups abounds. Both artisanal fishers and sportfishers aim to capture pelagic species on FADs. Since the resource is open access, there are no regulations or rights that that must be respected. Agreements have been attempted between charter captains and fishing communities with mixed results (Arocha 2017, *Pers. Communication*). This has so far proven successful in Punta Cana, where a captain at the Cap Cana marina will charge customers a fee to fish on a FAD, which ultimately pays fishers of the Macao village to maintain the device. A similar arrangement was attempted on the southern coast but failed: the Casa de Campo marina agreed to pay fishers of San Pedro de Macoris to service and maintain the FADs, but the middleman pocketed the money before it ever made it to the community. This has resulted in explosive conflicts on the water, as artisanal fishers chase sport fishing boats and try to pilfer their catch of marlin or sailfish. Arocha (2017) does not see a solution in these money transfer agreements, but instead calls for arrangements that can improve the fishing capabilities of artisanal fishers, such as cold storage facilities or enhancing the quality of fish being landed.

THE GUIDE

From this assessment of moored FAD management and existing tactics in the Caribbean, a guide to creating FAD management plans has been developed. The complete guide is presented in Figure 1(A,B) with explanations of each step and factors that must be considered in order to achieve success. Best practices will naturally vary based on a country or community's current situation, and this guide is intended to account and allow for that diversity. It is also intended to be applicable for scenarios where FADs have already been deployed as well as instances where FADs are not yet in place. Following the guide are four suggested management strategies that have potential to be effective with FADs.

Potential Management Solutions

Limited Entry/License Regime — It is clear that FAD fisheries cannot be managed with unlimited open access. Studies have noted repeatedly that such unrestricted access and pressure on the fish stocks will lead to collapse. The ensuing proposed solution is licensing, which would cap the number of fishermen allowed around a particular FAD by requiring they have a proper license to be there. This could be done at the community level, where fishers of one area obtain licenses for the nearby FADs, or at the national level, where a sustainable number of FAD fishing licenses are distributed to fishers all over the island. If the community level is pursued, a cooperative of fishers should be established, which then becomes the organization to grant licenses for the nearby FADs. Support would be needed from the national government in order to legitimize the co-op licenses. It is true this management technique is not without difficulties, namely that the exclusion is based on finances. Some may argue that not all have the means to purchase a license, however the fee is important in building a stable community organization—money would go towards maintaining the FAD, the source of all participants' income, and extra funds could be used for facility improvements or marketing. Of course enforcement and oversight would be a hurdle as well, but the rational thought is that the fishermen who pay to access the FAD resource would be more likely to police it and report or remove those without licenses, considering the financial stake they have in its good performance.

TURFs: location-based rights — Territorial use rights for fisheries (TURFs) have been successful with stationary resources, such as mollusks, by providing a community with exclusive access rights to a geographical area. Considering the location-based nature of TURF management, it's possible that such a strategy could be applied to moored FADs. In this scenario, a fishing community is given access rights (by the government) to a nearby area, perhaps 10 miles offshore or a two-mile radius surrounding a FAD. This zone of access should include the area where FADs have been or will be deployed. If this strategy is used, it must be uniform — each community should have their own exclusive access area, and each is responsible for managing the resources therein. In this way, the community of fishers decides how, when, and who can fish the FAD resources to which they have been granted exclusive access. This also lends a sense of ownership, giving fishers a reason to exclude others and guard their resource that provides a livelihood. A communal approach is required to make such decisions, and if such a cooperative group does not exist it will have to be created for this management scheme.

Temporal closures — Time and area closures around FAD fishing have the ability to protect the stocks while also limiting effort. Local fishers often know when particular species of interest frequent their area, and science has explained many migration routes of HMS fish. The fishing co-op would use this information to determine where and when closures around FADs should take place.

**B****1. Begin with community meeting**

- Includes researcher/fishery manager/NGO and fishermen
- First off: are FADs in your area?
 - No: Where will your FADs come from? (Community, government, NGO, other grant)
 - Yes: What kind? (private, public, shared)
 - Identify existing issues: what concerns, conflicts do fishers have regarding FADs, fish they catch on FADs, use of FADs, etc.
- What are wants/needs of fishing community? For example: more fish, exclusive use of public FAD, improved monitoring, etc.

2. Establish a fishing community coop

- Applies for all management strategies and types of stakeholders involved
- May consist of artisanal fishing community; mix of artisanal and recreational voices; between islands -- whoever is utilizing the FAD and associated fishery resource
- Fees apply: no matter the final management strategy, fishers must pay to be part of coop and have access to FAD fishery; this money will be used in maintenance of FAD to ensure fishery

3. Draft a FAD management plan

- What does the coop want out of the management plan?
- Researcher/fishery manager/NGO should help guide and inform the decision of which management strategy is best for this community to employ
- Code of Conduct needs to be included (for all strategies); how does the coop want to interact with the FAD, and each other?
- If government is not directly involved, this draft plan should be sent to appropriate fishery manager; institutional cooperation is necessary for plan to be effective
- Specifically lay out plan for use of funds--coop leader/director will be tasked with managing funds and held accountable by law

4. Secure funding

- Source may influence management (FADs deployed by government and NGOs are typically public, while communal private FADs are presumed exclusive)
- Identify original funding/deployment source and any associated terms of use; is this funding sustainable for long-term management?
- Community coop will need to manage funds

5. Implementation

- Community coop is involved in execution of the management plan
- Any bumps should be addressed in meetings (held weekly for first few months of implementation?)
- Bonus if reporting system can be developed

6. Monitoring and enforcement

- Partnership effort: community can be watchdog (capture evidence), government will have to be the teeth (enforcing the law and associated punishments)

Figure 1. (A) Simplified steps to building a FAD management plan, and **(B)** the *full guide*.

When the closures open, fishers must pay to play, a source of funding that is responsible for maintenance of the FAD. This strategy also makes monitoring easier if no one is allowed at certain times.

Regulation by gear types — Based on experience with conflict, entanglement, and successful catch, fishers often know best which types of fishing gear should be allowed around FADs, and which should not. Again, community organization is required to define this management strategy. The gear types excluded from FAD fishing can be designated to another area, also identified by the fishermen. Further, gear type may imply sector, whereby artisanal fishers may fish around particular FADs and recreational anglers may fish around others. Government cooperation would be necessary in legitimizing these gear zones, while the fishers' rational behavior (self-interest) would help enforce the rules in this instance.

Implications

It should be noted that all of these proposed solutions essentially eliminate the option for private FADs, and instead assume a system of communal FAD management for those deployed by the fisher cooperative, the government, or NGOs. Although such a transition will require on the ground effort with trainings and team building, fishing co-ops should be viewed in positive light as they have the ability to strengthen social cohesion and organization. Working together to best manage a shared resource can help eliminate the rampant mistrust among fishers in the Caribbean. Each of the above suggested management plans require input from the fishing community, who should be the ones directing the decision with support from external agencies.

Fujitani et al. (2017) show that participatory management improves ecological literacy and can build environmental capacity that leads to sustainability. Jentoft et al. (1989) noted nearly three decades ago that if *fishermen find the regulatory scheme legitimate, there is more reason to believe they will follow the rules*, (p. 139). They identified four components to indeed make regulations legitimate:

- i) Relevance (coincide with the problems fishers identify),
- ii) Equity of regulations,
- iii) Involvement in making of regulations, and
- iv) Involvement with implementation of regulations.

By addressing these last two, the first two concerns will consequently be improved.

Further, all of the proposed solutions also require some form of monitoring and enforcement. This has been a challenge to fisheries in the Caribbean thus far, and while giving a sense of ownership to the fishers will incite their rational behavior to protect their resource, their efforts can only go so far. To reinforce this, government law enforcement will be needed. However, it is not expected that law enforcement constantly patrol each community's management system. Instead, part of the fisher cooperation and organization should include discussion and trainings to

note the importance of and how to gather evidence of rule breakers. This can mean photographing an infringing vessel on one's camera phone or recording the vessel ID numbers and passing the information along to the authorities. Due to the involvement of the fishers, the government enforcement's workload will be lighter, and they will be responsible for responding to reports rather than monitoring.

Recreational Interests

The recreational fishing sector cannot be ignored in this guide. A simple way to control access is a "pay to play" strategy. There are successful examples of this in the Dominican Republic and Australia, where recreational anglers pay a marina or national fishing club and agree to a Code of Conduct in exchange for access to FADs and the big fish surrounding them. Additionally, the charter captains and marinas may be the ones responsible for paying a government or community for access to FADs, and simply pass those costs on to the customer.

Alternatively, the recreational sector may be included in the above management strategies and planning stages, where relevant. If FAD licenses are decided upon, marinas and charters may be considered an entity for purchasing licenses. In this way, individual tourist anglers are not responsible for obtaining licenses. If a TURF strategy is chosen, again the recreational sector may be given their own region, specifically for anglers from a marina or charter in the area. The same format could be followed for a gear-based management plan, in which recreational-only areas may be designated.

Some locations and nations have little conflict between sectors over FADs and the associated fish. In these cases, a fee may not be necessary for recreational FAD fishing, however, a Code of Conduct for users to abide by should be developed and well publicized.

CONCLUSION

One conclusion has become obvious: open access to FADs is destructive, socially, economically, and biologically. However, the matter of identifying an effective management scheme considering these factors--which vary by island in the Caribbean--has been elusive. A limit on fishers as well as a limit on FADs deployed is identified in the literature as a necessary piece of management, as seen in Antigua and Barbuda where limits were recognized as imperative, in Grenada where open access created problems, in Guadeloupe where poor FAD management serves as a lesson, and from experiences in the Dominican Republic where open access is causing disastrous conflict.

Regardless of the final FAD management tool used, it is clear that co-management provides the most promise for success and local fishers must be included in developing and implementing whatever mechanism they see fit. As with any resource, users are more likely to be stewards if they have a stake in its good management. This was confirmed in Grenada where fishers were willing to impose fees upon themselves for proper management (CRFM 2013). It is also necessary to have coordination among all levels of institutions, including researchers and govern-

ments, who should be in tune with these local management plans. Researchers can provide the biological, economic, and environmental factors that must be considered, and ideally, the national government could require the creation of a consortium or cooperative of fishermen—essential for all four suggested strategies—before accepting the community's draft management plans. A final, well-informed plan would then be presented to the government to be adopted, providing the force of law.

Not only are the histories and cultures and economies of each nation in the Caribbean different, but so too do these vary between island. Solutions to managing FAD fisheries will not be a one size fits all approach—numerous methods will have to be employed, depending on the socio-cultural factors present. A strategy that has worked in Japan may not work in Grenada, just as a method in Australia may not produce the same results in the Dominican Republic. However, it is important that governments, NGOs, universities and researchers work to solve these puzzles and initiate management attempts. This guide is intended to serve as a foundation—subsequent research should address how successful the above-suggested plans are in managing FAD fisheries in the Caribbean. The use of FADs is increasing across the world, as is the uncertainty surrounding them. Thousands are being deployed annually, with largely unknown biological and ecological consequences. The challenge of finding a management strategy can no longer be pushed to the side.

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