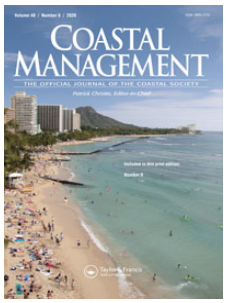

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The IUU Nature of FADs: Implications for Tuna Management and Markets

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ABSTRACT

World tuna catches reached 5.2 million metric tons in 2018, more than doubling since the early 1990s, primarily due to the introduction of Fish Aggregating Devices (FADs). The widespread use of drifting FADs has increased the economic efficiency of the fleet by making it easier to aggregate and locate tuna schools, but at a high ecological cost, including: significant catches of juvenile tunas; bycatch of endangered, threatened and protected species; and "ghost fishing," marine pollution, and sensitive habitat destruction by abandoned FADs. Recent analysis indicates that most deployed FADs are eventually lost, stolen, beached, or abandoned, continuing their destructive impacts. This paper examines the legal regime, market forces, and other factors that frame FAD use. We demonstrate that, because deployed FADs are legally considered to be fishing, when they drift into closed areas or otherwise contravene national or international agreements or regulations, they are Illegal, Unreported, and/or Unregulated (IUU); vessels using such FADs are therefore IUU. We suggest that introducing a transparent FAD ownership tracking system and requiring FAD owners to mitigate their impacts could substantially improve the effectiveness of tuna Regional Fisheries Management Organizations (RFMOs) and redirect market incentives to properly support tuna management.

KEYWORDS

FAD-Free tuna; FAD impacts; FAD liability; FAD ownership; IUU; tuna markets; tuna RFMO management; tuna sustainability

Introduction

World catches of the main market species of tuna[1] reached 5.2 million metric tons in 2018, more than doubling since the early 1990s. Much of this growth is attributable to the introduction of drifting Fish Aggregating Devices (FADs), which have allowed the international tuna purse seine fleet to more efficiently aggregate, locate, and catch schools of tuna throughout the world's oceans (Dagorn et al. 2013; Hall and Roman 2013). A FAD is a man-made object consisting of a floating raft supporting hanging nets and/or ropes, usually with an attached, sonar-equipped satellite buoy to allow

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tracking of its location and the amount of tuna aggregated beneath. FADs may be anchored, but the vast majority are drifting; this paper exclusively focuses on drifting FADs.

While the widespread use of drifting FADs has increased the economic efficiency of the fleet, this has come at a high ecological cost. The major negative impacts resulting from fishing on FADs are:

- Significant catches of juvenile tunas, impacting the overall condition of the targeted stocks (Fonteneau, Pallares, and Pianet 2000; Leroy et al. 2013);
- Bycatch of endangered, threatened and protected (ETP) species such as sharks, turtles, rays, and others, which are incidentally caught in the process (Romanov 2002; Chanrachkij, Siriraksophon, and Loog-On 2009; Amandè et al. 2011; Gilman 2011; Filmalter et al. 2013; Gaertner et al. 2015; Moir Clark et al. 2015; Eddy, Brill, and Bernal 2016; Blasi, Roscioni, and Mattei 2016; Castro et al. 2020);
- Creating possible "ecological traps," or negative impacts to the distribution, migration, and reproductive ability of tuna stocks, as FADs attract tunas into habitats that provide less food or are otherwise less hospitable (Dagorn et al. 2013; Hallier and Gaertner 2008);
- "Ghost fishing" by accidentally or deliberately abandoned FADs that have drifted too far away to be useful, the impacts of which are difficult to measure (Chanrachkij and Loog-On 2003; Smolowitz 1978)[2];
- Destruction of sensitive coral reefs and other sensitive habitats by drifting FADs (Zudaire et al. 2018);
- Marine pollution from FADs that have been lost, beached, or sunk (Moir Clark et al. 2015; Zudaire et al. 2018; Banks and Zaharia 2020; Sinopoli et al. 2020); and
- Unauthorized and unsupervised "fishing" as the FADs drift in and out of the Exclusive Economic Zones (EEZs) of Coastal States, Marine Protected Areas (MPAs), and/or areas "closed" to FADs by Regional Fisheries Management Organizations (RFMOs; Arias and Pressey 2016; Hanich et al. 2019).

Thus, current proliferation of FADs is negatively impacting both tuna stocks and the environment and is placing at risk the future availability of tuna in the market. A recent analysis of FAD data gathered in the western and central Pacific estimated that only 10 percent of deployed FADs are retrieved by fishing vessels, with the remainder lost, beached, or left to drift at sea (Escalle et al. 2019). As we demonstrate in this paper, current actions taken by Coastal States, RFMOs, Non-governmental Organizations (NGOs), and tuna retailers are not effectively addressing this problem.

We argue that the inability of tuna RFMOs to manage and mitigate the negative impacts of FADs is primarily due to the fact that FAD ownership is not clearly identified and tracked. Because no one openly accepts ownership of deployed FADs, no one is or can be held responsible for mitigating the adverse impacts noted above.

We point out that RFMOs generally do not consider FADs as fishing devices in and of themselves or treat regulatory infractions by FADs as Illegal, Unreported, and/or Unregulated (IUU).

At the same time, market incentives that could serve to deter misuse of FADs and improve the long-term viability of tuna stocks are instead concealing and supporting unsustainable tuna fishing and management practices. Market forces (in this case, driven primarily by the RFMO "IUU Vessel Lists" and sustainability programs such as the Marine Stewardship Council's [MSC] certification) that have worked in other contexts to align fishing behavior with conservation objectives have failed with respect to FADs; this is due to a misunderstanding of the concept of IUU as it applies to FADs, as well as the way market choices have been framed as "FAD-Caught" vs. "FAD-Free" tuna.

We demonstrate in this paper that the legal framework for identifying FADs as fishing devices and treating their regulatory infractions as IUU is already firmly in place. Thus FADs, drifting and "fishing" without permission in EEZs and closed areas while they continue to aggregate undersized fish and cause other environmental damage, often contravene international agreements, national laws, and tuna fisheries management regulations and are therefore IUU. We show how Coastal States and RFMOs have been attempting to manage proliferating FADs but have not taken full advantage of the concept of IUU.

We argue that, without consequences for FAD misuse, individual FAD owners and other industry players have little incentive to stop the proliferation of FADs and their associated impacts on the environment and on the future abundance of tuna. Recognizing the IUU nature of FAD fishing does not necessarily mean, however, that drifting tuna FADs should be banned. On the contrary, this paper suggests that the introduction of a transparent system for assigning and tracking FAD ownership and associated liability in real time could substantially improve RFMO effectiveness and redirect market incentives to properly support tuna management. Identifying FAD owners and requiring that they mitigate their impacts would ensure the long-term survival of tuna stocks and provide truly sustainable tuna to satisfy market demand.

Purse seine fishing on FADs

Of the total world catch of the major market species of tunas in 2018, tropical tunas caught by approximately 650 purse seiners accounted for 2.4 million metric tons (92% of all tunas caught by this gear type). The West-Central Pacific (44%) and Eastern Pacific Ocean (22%) areas jointly produced most of the global purse seine catches of tropical tunas, with the Indian and Atlantic Oceans contributing 19% and 13%, respectively. This production is the source of most canned tuna.[3,4]

Most of the 650 vessels in the industrial purse seine fleet depend substantially on the use of FADs (Davies, Mees, and Milner-Gulland 2014; ISSF 2020; Maufroy et al. 2017). This practice reduces the time needed to search for tunas and significantly reduces fuel costs, which constitute the main component of fishing costs (Suuronen et al. 2012). This reduced searching time allows tuna vessels to make more fishing trips per year, effectively increasing the fishing capacity of the fleet (Fonteneau, Pallares, and Pianet 2000; Hall and Roman 2013).

The actual numbers of FADs in the world oceans is not known. In 2015, Pew Charitable Trusts estimated the number to be around 121,000 FADs, but it is likely that a greater number are present today (Gershman, Nickson, and O'Toole 2015).

What is a FAD?

A drifting FAD is a man-made device designed to attract fish. It is usually composed of: (1) a floating structure or raft made of bamboo or PVC that stays on or near the surface of the ocean and has an appendage, usually consisting of large pieces of used fishing net that hang below the raft; and (2) a state-of-the-art satellite buoy that allows the vessel owner/operator to track the location of the FAD by GPS and determine, via an echosounder, the biomass, and some cases, the species composition of tunas aggregated underneath[5] the FAD (Dagorn et al. 2007).[6]

Several theories exist as to why tropical tuna species tend to associate with floating objects such as FADs. They may use floating objects as indicators of food-rich, environmentally productive areas (Gooding and Magnuson 1967) or as meeting points to develop larger schools and gain protection against pelagic predators (Dagorn and Freon 1999). Adult tunas typically begin arriving on a FAD within one or two weeks of its deployment, although fishermen usually leave FADs to drift for at least a month to aggregate a sufficient amount of tuna to make the catch worthwhile (Dagorn et al. 2007; Orue et al. 2019).

FADs are relatively inexpensive to build; in U.S. dollars, the floating materials cost about $120, the satellite buoy costs around $1000, and the annual fee for the satellite service is approximately $4,000 per FAD (M. Silva, tuna vessel owner, personal communication, May 2020). On average, about 35 tons of tuna (Lopez et al. 2020) valued at $1,000 per ton (GLOBEFISH 2020) are caught per set on a FAD, and a vessel may monitor anywhere between 100 and 300 FADs at a time (Gershman, Nickson, and O'Toole 2015). Thus, a relatively low investment of around $5,200 for a FAD (in the context of regular fishing costs) can yield a gross income of $35,000 dollars or more in one single set.

Vessels regularly carry spare satellite buoys and materials on board to build and deploy new FADs. The life of a FAD may vary from about 3 months up to 2 years, depending on many factors. In general, for all three ocean areas, it is estimated that 4 out of 10 FADs deployed are stolen; 3 out of 10 are lost or deliberately abandoned (drift too far away from the vessel to make it attractive to be pursued); and only 3 out of 10 deployed FADs remain available to be monitored and set upon (Faustino Velasco, Satlink, and Amaia Ormaechea, Zunibal, personal communications, April 2019)[7]. When FADs are stolen, abandoned, or lost, vessel owners stop paying for satellite communication services and/or can cheaply replace them. Like other "disposable" items, the low cost and attractive cost/benefit ratio of FADs have resulted in their extensive and rapidly expanding use in the world's tuna fisheries (Gershman, Nickson, and O'Toole 2015).

Depending on what happens to the FAD, its owner can request that the satellite communication Service Provider remotely activate, deactivate, or reactivate the FAD's satellite functions, thus choosing when to pay the fees for communication services, which helps to maximize economic returns (Escalle et al. 2019). Vessel owners value FAD information highly and keep it confidential, since it provides a strategic competitive edge.

FAD-Caught vs. FAD-Free tuna purse seine fishing operations

Once the amount of fish aggregated beneath a FAD is determined to be economically attractive (via echosounder data transmitted by the satellite buoy), the vessel travels to the FAD's location. The vessel generally sets its nets around the FAD before daybreak because tunas tend to congregate more during the night. Once the set is completed, the FAD is left to start collecting fish again and the tuna seiner moves to another FAD. Tuna caught this way is referred to by RFMOs and identified in the market as "FAD-Caught tuna."

While traveling from one FAD to another, fishermen also use powerful binoculars to search for free-swimming tuna schools (unassociated with a FAD) feeding on the surface. These schools tend to be associated with flocks of seabirds also feeding on the same school of small fish; vessels supplement their binocular searches with bird radars, which are designed to detect flocks of birds as much as 60 miles away. Finding and setting the nets around free-swimming schools can only be done during daylight hours (unlike setting on FADs). This unassociated catch is recorded by RFMOs and identified in the market as "FAD-Free tuna".

It should be noted, however, that the concept of FAD-Free tuna has been interpreted in various ways. In general, to be "FAD-Free," a set around a free-swimming school should not have any association with a man-made FAD or a natural floating object. "FAD-Free" has been interpreted by some RFMOs (Atuna 2017), however, as a set made around tunas that are at least one nautical mile away from a FAD (e.g., Western and Central Pacific Fisheries Commission [WCPFC] CMM2008-01). This definition does not appear to be aligned with scientific best practices, which suggest that a distance of 2 to 5 miles from a FAD would be more appropriate to ensure that the free-swimming school lacks any association with a FAD (Moreno, Herrera, and Moron 2016).

The "one-mile" interpretation has also been used in the context of the MSC sustainability certification program to differentiate potentially MSC-certifiable FAD-Free tuna from generally non-certifiable FAD-Caught tuna in the West-Central Pacific[8] (WCPFC 2009; Moreno, Herrera, and Moron 2016).

In some cases, onboard human observers play an important role in distinguishing between "FAD-Free" and "FAD-Caught" tuna, although they often face difficulties in doing so (Moreno, Herrera, and Moron 2016). Sea conditions and the low profile of FADs in the water may interfere with observers' ability to accurately establish the distance between a school and a FAD. In addition, according to the NGO Human Rights at Sea International Ltd (Human Rights at Sea International Ltd 2020), observers may experience pressure to declare a set "FAD-Free," given the price differential of $100 to $150 dollars per ton compared to "FAD-Caught" tuna.

Furthermore, vessels that make sets around free swimming schools during a trip often make sets around FADs, too, and even though the tuna caught by the two different types of sets may be kept in separate fish wells (for certification and/or marketing purposes), the entire fishing operation is strongly linked to FAD use[9] (Moreno, Herrera, and Moron 2016).

The issues associated with the term "FAD-Free" described here have important implications for tuna markets and management; these are discussed in subsequent sections.

Other operational considerations

Fishermen can be opportunistic. If they find a FAD deployed by another vessel, they commonly set their net around it, collect the fish, and replace the satellite buoy of the prior owner with their own to facilitate future tracking of the FAD. This "pirating" of FADs can lead to conflict among fishermen (Defoe 2004). On a similar opportunistic basis, they may also catch tuna that have aggregated around "natural floating objects" such as dead whales, shark whales, kelp beds, or logs. These sets are categorized by the RFMOs under terms such as "natural object, log and/or associated sets", but fishermen usually place satellite buoys on the objects after setting on them, effectively converting these natural floating objects into man-made FADs going forward.

With the exception of the Eastern Pacific Ocean area, tuna seiners around the world also use support[10] vessels in their FAD fishing operations. The support vessels do not catch tuna but increase the efficiency of the tuna vessels by deploying, repairing, servicing, monitoring, and scouting FADs. Support vessels maintain communications with one or more associated tuna vessels to confirm the biomass of tuna that have aggregated around FADs planted by the support vessel, the purse seine vessel or other companies' vessels.

Legal analysis of the IUU nature of FADs

One concern surrounding FADs is the question of their legality, given the lack of clarity around their ownership, behavior, and use. This section discusses how legally binding agreements define IUU fishing and how leading-edge treaties address FAD fishing in ways that meet the IUU definition. For over ten years, Coastal States and RFMOs have been regulating FAD fishing and, in some cases, enforcing against FAD use that meets the definitions of IUU fishing.

It should be noted that the agreements referenced in this section are typically binding on parties to the agreement. In some cases, certain provisions may be more broadly recognized as customary international law. The purpose of this discussion is to demonstrate that the legal tools to regulate FADs exist; to identify examples of enforcement treating FADs as illegal; and to suggest ways that regulators and the market can apply these concepts.

Are FADs "fishing"?

FADs are "fishing" as defined by international agreements. Specifically, Article 1 of the Agreement on Port State Measures to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (PSMA; approved in 2009 and entered into force in 2016) (FAO 2009) defines "fishing" as "searching for, attracting, locating, catching, taking or harvesting fish or any activity which can reasonably be expected to result in the attracting, locating, catching, taking or harvesting of fish."

As noted above, a FAD is designed to "attract" fish and can be reasonably expected to do so (NOAA Fisheries 2020; MSC 2018; Dagorn and Freon 1999; FAO 2020). Webbing on a typical FAD "catches" or "takes" fish as bycatch and can be reasonably expected to do so (Romanov 2002; Chanrachkij, Siriraksophon, and Loog-On 2009; Amandè et al. 2011; Gilman 2011; Filmalter et al. 2013; Gaertner et al. 2015; Moir Clark

et al. 2015; Eddy, Brill, and Bernal 2016; Blasi, Roscioni, and Mattei 2016; Castro et al. 2020). Satellite buoy locator signals are designed to "locate" fish and can reasonably be expected to do so (Zunzibal 2020). FADs, therefore, meet the definition of fishing, a point recognized by Banks and Zaharia (2020) and Hanich et al. (2019).

In addition, some legally binding agreements such as Article I of the Convention establishing the WCPFC (WCPFC Convention; United Nations (U.N.) 2000) explicitly define FADs to be "fishing." Such specificity adds clarity but is not required, because FADs already meet the definition of "fishing." Significantly, this definition does not require a vessel's participation. FADs meet this definition regardless of whether any vessel ever sets on them or brings a catch on board; once deployed, the FAD is fishing, as defined by international agreements and national laws, for its entire lifetime in the ocean.

When is FAD fishing "illegal?"

The PSMA adopts the definition provided by the Food and Agriculture Organization (FAO) International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (IPOA), which specifies three broad categories of Illegal Fishing, each of which can apply to FAD fishing (PSMA [FAO 2009] citing the IPOA [FAO 2001]).

Activities in an EEZ

The PSMA's first definition applies to fishing activities conducted by national or foreign vessels "in waters under the jurisdiction of a State" when such activity occurs without the State's permission, or in "contravention of its laws and regulations." FAD fishing meets this definition of Illegal Fishing. As discussed above, using a FAD is "fishing" as defined in the PSMA and other legally binding instruments, so unless a vessel obtains permission to use a FAD in an EEZ, such FAD use is illegal. In one note-worthy example of enforcement against illegal FAD use that illustrates this Illegal Fishing category, a $7,000,000 penalty was assessed in 2010 to the Spanish company flag vessel *F/V Albacora Uno* for lack of permission to use FADs deployed in the U.S. EEZ (The Fish Site 2010; Seafood Source 2010a; 2010b). It was the FADs' presence that constituted fishing without permission, not any specific harvesting activity by the vessel, such as setting on or near the FAD.

Similarly, if FAD fishing results in fishing that contravenes a Coastal State's laws or regulations, such FAD use is illegal. For example, a FAD that results in taking prohibited species or occurs in prohibited areas or closed seasons is contravening a conservation measure and is thus "illegal." The U.S. National Oceanographic and Atmospheric Administration (NOAA) has documented numerous examples of FAD-related illegal fishing from 2010 to 2019.[11] Most of these incidents involved violations of the WCPFC Convention. These violations include deploying, setting too near, or servicing a FAD. Certain notices of violations specify the activity occurred during FAD closures.

Conceptually, the laws and regulations need not be specific to FADs; if the FAD used by the vessel violates more general laws and regulations, such activities constitute Illegal Fishing. In addition, the vessel associated with the FAD need not be actively setting on

the FAD. The FAD itself is fishing and if the FAD violates any conservation measure, that constitutes Illegal Fishing under this definition.

Activities within an RFMO's jurisdiction

The PSMA's second definition applies to fishing activities conducted by vessels flying the flag of States that are parties to a relevant RFMO but operate in contravention of the conservation and management measures adopted by that organization and by which the States are bound, or relevant provisions of the applicable international agreement (PSMA [FAO 2009] citing the IPOA [FAO 2001]). FAD fishing meets this definition of Illegal Fishing when a FAD being used by a vessel in RFMO managed areas contravenes the RFMO's management measures. In this definition, the vessel must be under the flag of a participating State. As was the case with the first definition, the conservation measures need not specify FADs; rather, the FAD's impact on the resource is critical in meeting this definition. If a conservation measure governs the impact (e.g., take of prohibited species, coral reef damage), the FAD and associated vessel are contravening the RFMO's conservation measures.

In addition, FAD activities that violate applicable international agreements would also make the vessels' FAD use "Illegal." This addition is significant because it categorizes certain FAD activities as illegal even if the RFMO has not yet adopted conservation measures. International agreements that impose a variety of conservation obligations on Flag States include the 1982 United Nations Convention for the Law of the Sea (UNCLOS; United Nations (U.N.) 1982), the 1995 United Nations Fish Stocks Agreement, and the PSMA (Hanich et al. 2019).

Activities that violate national laws or international obligations

The PSMA's third definition of Illegal Fishing is the broadest. It applies to activities that violate "national laws or international obligations." As noted above with respect to the first two definitions of Illegal Fishing, FAD fishing in specific situations violates the UNCLOS and PSMA obligations. Specified FAD fishing also contravenes the WCPFC Convention and national implementing legislation (NOAA Notices of Violation; and Banks and Zaharia 2020).

Notably, this third definition is not tied to a vessel or "vessel conduct." A highly reported and analyzed example of FADs meeting this definition of Illegal Fishing is the high concentration of FADs found in Kiribati's Phoenix Islands Protected Area (PIPA), which is closed to commercial fishing activities (Hanich et al. 2019). Because these FADs are attracting fish and therefore constitute the act of fishing, their presence in the protected area is Illegal Fishing.

Because this definition is not tied to vessels activities, it also applies to non-vessel actors, such as satellite buoy tracking Service Providers, whose activities tracking FAD locations and communicating such information to fishing vessels constitute "fishing activities" that become "illegal" when the activity contravenes national laws or international agreements and obligations. As discussed later in this paper, management authorities are beginning to explicitly prescribe requirements that Service Providers must follow (Parties to the Nauru Agreement 2020). Such explicit treatment of Service

Providers may create more clarity regarding the obligations of these providers but is not necessary for the activities of Service Providers to meet the third definition of "fishing" and for such activities that violate national laws or international agreements to be Illegal Fishing.

When is FAD fishing "unreported?"

PMSA Article 1 adopts the IPOA, which defines two broad categories of "Unreported Fishing", each of which can apply to FAD fishing. The first definition applies to fishing activities that are "not reported or misreported" to a national authority "in contravention of national laws and regulations." The second definition applies to fishing activities that are not reported or misreported to an RFMO "in contravention of the reporting procedures of that organization." The next section on RFMO FAD management measures provides examples of reporting requirements specific to FADs, such as reporting by on-board human observers (where present), and specific FAD data demands. However, since FADs constitute "fishing," more general reporting requirements that do not specifically identify FADs would also apply and should be enforced when contravened.

When is FAD fishing "unregulated?"

The IPOA's definition of "Unregulated Fishing," adopted by the PSMA, applies to two circumstances. First, it applies within an RFMO's Convention Area to activities by unflagged vessels or Flagged vessels of countries not party to the RFMO that contravene or are inconsistent with the RFMO's conservation or management measures. Such vessels are "unregulated" in that RFMO regulations do not apply to such vessels under the relevant RFMO agreement. FADs that meet the definition of Unregulated may also be Illegal and Unreported as described above.

The second definition is a catch-all clause that governs "fishing activities" in situations where there are no conservation measures in place, but the activity is inconsistent with State conservation responsibilities. UNCLOS establishes obligations regarding conservation that apply to Coastal, Flag and Other States (Hanich et al. 2019). FADs that are inconsistent with these responsibilities constitute "Unregulated Fishing."

Who is or should be legally responsible for IUU FAD fishing?

The discussion above indicates that legal responsibility broadly applies to vessels conducting fishing activities related to FADs. This includes vessels deploying the FAD or searching for and/or setting on a FAD that is illegally fishing. The vessel and the company that owns the vessel engaged in these activities are conducting IUU fishing, whether or not they are the documented owner of the FAD itself. In addition, the legal definitions more broadly apply to non-vessel entities engaged in fishing. For example, Article I of the WCPFC Convention defines "fishing" to include "aircraft" involved in searching for fish. Service Providers play a similar role as aircraft in searching for tuna and reporting their location to fishing vessels. Service Providers already meet the Convention's broad definition of fishing. RFMOs can clarify this point by explicitly including Service Providers.

In summary, this section demonstrates that existing international agreements and national laws define FADs as fishing and establish binding rules and obligations that FADs routinely contravene in a manner that makes such FAD fishing IUU. This discussion further identifies where such vessels and companies have been assessed substantial penalties for contravening national laws, including those implementing international obligations. We identify areas where such laws are not applied or enforced and offer additional ideas for recognizing a broader number of actors for their responsibility in FAD fishing.

As a practical matter, many FADs are likely to meet one or more of the above definitions of IUU fishing for much if not all of the time they are in the water. Given the significant reliance of tuna purse seine vessels on FADs and the multiple definitions of IUU that could apply to FADs, we infer that FAD use results in far more IUU-caught tuna than is currently recognized.

Some stakeholders, such as Greenpeace, argue for banning FADs outright, whether immediately or through a phased approach (Anon 2010). The purse seine industry's dependence on FADs is so complete, however, that such a ban would be difficult to implement and could be expected to result in a counterproductive response from the tuna industry, Flag States, and Coastal States that depend heavily on fishing license revenues. To continue using FADs under a ban, vessel owners would likely switch flags and/or operate outside the RFMO legal framework, perhaps including withdrawal from the RFMOs.

Destabilized international management cooperation would result in less, rather than more effective conservation, possible eventual stock collapse, and market uncertainty. Given these potential outcomes, we do not argue that all FAD fishing should be banned. Instead, we propose more concerted legal and market-based efforts to bring FADs under a feasible and effective management scheme based on identifying FAD owners and requiring them to mitigate the impacts of their FADs, so that tuna fisheries become ecologically as well as economically sustainable.

The next two sections discuss how (1) RFMOs that have not focused on identifying FADs as IUU have been unsuccessful at managing their impacts; and (2) NGOs and retailers have thus far failed to properly link these legal concepts to FAD-caught fish in the market. As a result, market pressures, which have been effective in incentivizing other sustainable fishing practices in the past (Lubchenco et al. 2016; Barner et al. 2015; Fisher 2013), are failing with regard to FAD fishing.

RFMO management of FADs

Four RFMOs manage the world's tropical tunas and associated species: the InterAmerican Tropical Tuna Commission (IATTC) in the Eastern Pacific Ocean; the WCPFC; the International Commission for the Conservation of Atlantic Tunas (ICCAT); and the Indian Ocean Tuna Commission (IOTC).[12]

All four tuna RFMOs have adopted conservation measures intended to mitigate FAD impacts; these vary from region to region. Generally, FAD-specific measures supplement other fisheries management measures, such as area and seasonal closures[13] that are not specifically aimed at the FADs themselves but at vessels (Wadsworth 2019). The IATTC

Scientific Advisory Committee, for example, recommended in 2019 expanding the scope of a conservation and management measure (a 72-day mandatory seasonal closure for all vessels) to include limitations on the number of FAD sets vessels could make (IATTC 2019). In addition, RFMOs are increasingly expanding observer coverage of purse seine fleets, particularly for larger vessels.

RFMOs have also developed formats for FAD data requirements and submission, but these are not homogenous across all RFMOs, are not on a real-time basis, and compliance is very limited[14]. Most RFMOs also require that Flag States submit FAD management plans; the IATTC does not presently have such a provision but does require logbook data submission and FAD location information (but not on a real-time basis). FAD management plans vary greatly in their requirements and level of detail, but once filed, they are rarely, if ever, updated, and generally appear to be seen as a bureaucratic requirement with little practical, enforceable value.[15]

The RFMOs have passed resolutions for recommended handling and live-release procedures to reduce the mortality of bycatch species associated with FADs, and the Joint Tuna RFMOs FAD Working Group (JTRFWG) continues to evaluate the feasibility and effectiveness of non-entangling and biodegradable FADs to reduce death by entanglement of ETP species. RFMOs have also considered notification procedures for when abandoned FADs appear to be drifting into sensitive areas (JTRFWG 2019).

In addition, the RFMOs have all established limits on the number of FADs that each vessel can use, varying from 70 to 450 FADs per vessel, depending on the RFMO and vessel size (Wadsworth 2019). No RFMO appears to be effectively enforcing such limits, however; furthermore, the basis for determining specific limits is unclear. In some cases, limits are placed on the number of "active" FADs being monitored, but vessel owners can remotely activate and deactivate FADs as desired, so the established limits do not actually restrict the number of FADs in the ocean. Furthermore, most RFMOs do not address FAD limits for support vessels. The IOTC specifies a limit of 500 satellite buoys that can be purchased for each fishing vessel but does not stipulate how this applies to support vessels (IOTC 2019). If most vessels were to take full advantage of the FAD limits per vessel established by the RFMOs, it appears that the total count of FADs in the world's oceans would likely increase rather than decrease.

Because of lack of transparency and inadequate observer coverage, RMFOs have no way of knowing if vessels are complying with their recommendations regarding ETP species entanglement, FAD piracy, deliberately abandoned FADs, or FADs drifting in protected or unauthorized waters. Reasons for RFMOs' lack of effectiveness in FAD management include insufficient, real-time information on FAD activities; lack of clear FAD management objectives; difficulties in coming to consensus to adopt strict regulations; and vessel owners' confidentiality concerns and unwillingness to accept FAD ownership responsibility with full transparency.

One tool the RFMOs have not yet used to help manage FADs is the IUU Vessel List. Each RFMO has established a list of vessels believed to have participated in IUU fishing activities that undermine the effectiveness of conservation measures adopted in their respective Convention Area; inclusion in the IUU Vessel List can have serious consequences for selling or trading the vessel's catches in the marketplace. Criteria that would qualify a vessel to be listed in an RFMO's IUU Vessel List include infractions such as

harvesting tuna while not on the RFMO's Regional Vessel Register; making false reports of catches; engaging in fishing activities in a closed area or during a closure period; using a prohibited fishing gear or method; conducting unauthorized transshipment operations at sea; and fishing without nationality. The process to include or remove a vessel from an RFMO IUU Vessel Lists is not automatic or simple; it requires a number of steps and extensive documentation.[16]

Adaptation of the IUU Vessel List for purposes of FAD management would require the ability to register and transparently track FAD ownership in real time (just as vessel ownership is registered and tracked), as well as streamlining the process for inclusion or removal from the List.

The roles of consumers, NGOs, and retailers

Advocacy and consumer demand

Canned tuna consumers and environmental groups have a long history of influencing the management of tuna fisheries. In the 1970s, activist NGOs and the American public were largely responsible for pushing the U.S. National Marine Fisheries Service (NMFS) to institute bycatch limits and a mandatory observer program for the eastern tropical Pacific yellowfin tuna fishery, effectively changing industry practices to drastically reduce tuna fishing-related dolphin mortality (Scott et al. 2012; Smith 2012). This advocacy led the U.S, Congress to pass legislation to minimize dolphin bycatch and gave rise to the concept of certification programs for "Dolphin-Safe" tuna (IATTC 1998, 2010; Gerrodette 2009). As an unintended consequence, restrictions on dolphin-associated fishing are at least partly responsible for paving the way for today's FAD-based tuna industry, as fishing fleets developed alternative catch methods (Hall and Roman 2013).

In recent years, some NGOs and consumers have turned their focus to ensuring that canned tuna offered in the major markets originates from lawful (non-IUU), well managed, and sustainable sources that minimize negative impacts on ocean ecosystems.[17] Unlike past market successes in influencing fishing behavior, however, market forces are failing with respect to FADs. Despite a clear legal framework indicating that FADs may constitute IUU fishing, tuna retailers and third-party sustainability certification programs do not treat FAD fisheries as potentially IUU and have sent mixed messages to consumers that tend to reinforce unsustainable fishing practices.

Third party certification programs and retailer sourcing policies

"Sustainable tuna" has been defined for consumers by certain NGOs and tuna retailers as tuna caught by either pole and line or "FAD-Free" purse seine methods (Leadbitter and Benguerel 2014; Marine Stewardship Council 2020). A major cornerstone of the "sustainable tuna" concept is that the product originates from non-IUU fisheries. To this end, canned tuna retailers have established sourcing policies aimed at satisfying consumer needs while supporting the retailers' own corporate social responsibility (CSR) criteria. As shown in Table 1, retailers have generally been guided by the following primary criteria: (1) avoid sourcing IUU tuna; (2) source tuna approved under the MSC's certification scheme (considered the "gold standard" for sustainability

Table 1. Tuna sourcing criteria used by selected major market retailers.

	Catch method requirements			Preferred third-party certification methods and sustainability programs				Additional requirements and standards as stated in sourcing policies		
Retailer	Sources tuna from fisheries that use FADs	All tuna sourced from FAD-Free net fisheries or pole-and-line, troll, or hand-line fisheries	All tuna sourced from pole-and-line, troll, or handline fisheries	Adheres to ISSF sustainability measures, which allow for FAD-Caught tuna	Preference for GSSI-recognized options	Preference for MSC-certified options	Does not source from purse seine fisheries in FIPs	Explicitly aims to avoid sourcing from IUU fisheries	Encourages development of vessel registries and uses vessel information for traceability when available	Additional explicit supply chain traceability measures or requirements
Walmart	x			x[a]						
Asda[b]	x			x				x		
Kroger	x			x				x		
Whole Foods			x			x[c]	x	x	x	x
Sainsbury		x[d]			x	x	x	x	x	x
Tesco		x[d, e]				x	x	x	x	
Marks and Spencer			x[e]		x		x	x	x	x
METRO Cash and Carry	x			x				x	x	
Mercadona S.A.	x			x						

FADs = Fish Aggregating Devices; FIPs = Fishery Improvement Projects; GSSI = Global Seafood Sustainability Initiative; ISSF = International Seafood Sustainability Foundation; IUU = Illegal, Unreported and/or Unregulated; MSC = Marine Stewardship Council

[a]By 2025.

[b]Asda, a UK supermarket chain, is a wholly owned division of Walmart.

[c]All Whole Foods tuna options that are not MSC-certified are rated at least "good alternative" by the Monterey Bay Aquarium/The Safina Center.

[d]Some of these retailers' standards are governed by their signature of the Environmental Justice Foundation's Charter for Transparency, which is a joint commitment of UK retailers that aims to "help supermarkets ensure their seafood supply chains are free from illegal fishing and human rights abuse."

[e]For several years, Tesco and Sainsbury offered only 100% pole and line caught tuna. They began to provide FAD-Free (net caught) options in 2017 and 2018.

Sources:

Links to sustainable seafood procurement policies:

- Walmart: https://corporate.walmart.com/policies#seafood-policy.
- Asda: http://s7d2.scene7.com/is/content/asdagroceries/Asda.com/7.%20Sites/Environment/Seafood%20policy_0.pdf.
- Kroger: https://www.thekrogerco.com/wp-content/uploads/2018/07/The-Kroger-Co_Seafood-Sustainability-Policy_2018-July.pdf.
- Whole Foods: http://assets.wholefoodsmarket.com/www/departments/seafood/Whole_Foods_Market_Canned_Tuna_Sourcing_Policy_102017.pdf.
- Sainsbury: https://www.sainsburys.co.uk/webapp/wcs/stores/servlet/gb/groceries/get-ideas/values/sustainable-fishing?storeId=10151&langId=44&krypto=UArDdLkXOYvi6Yq0XeHIlVu1r9vVL6fCjpAKZ2RJOCTkOZtzGsIK8AsDaeZR8NT4AXhb7VV46TD%2Fr44YgjgnFIXJWjil0TkRgmouJKHzkjgHUPcNDDsB%2BuvqTuUyb7hMtp%2B9ZInXh5eX2gAoijZP4XcHXWIn8Z9yMJ3eaxQ2Z38%3D&ddkey=https%3Agb%2Fgroceries%2Fget-ideas%2Fvalues%2Fsustainable-fishing.
- Tesco: https://www.tescoplc.com/blog/tuna-fish-sourcing-tesco/
- Marks and Spencer: https://corporate.marksandspencer.com/documents/plan-a-our-approach/foods/m-and-s-seafood-sourcing-standard.pdf.
- METRO Cash and Carry: https://www.metro.ca/en/products-to-discover/fish-seafood/our-sustainable-fisheries-policy.
- Mercadona, S.A.: https://info.mercadona.es/en/customer-service/frequently-asked-questions/sustainability-in-fishery-canned-tuna/faq.

Table 2. 2018 Purse Seine catches of tropical tunas by RFMO and set type (metric tons).

RFMO/Ocean region	Classification of set types by RFMO	Authors classification of set typesa	Yellowfin	Bigeye	Skipjack	Total
IATTC Eastern Pacific	Object = Man-Made + Natural (1)	*FAD Caught*	63,877	60,409	217,206	341,492
	Not Associated = Free Schools (2)	*FAD Free*	23,655	632	73,264	97,551
	Dolphin (3)	*Other*	143,518	1	2,504	146,023
WCPFC West-Central Pacific	Drifting FADs (4)	*FAD Caught*	34,941	12,853	172,810	220,604
	Log = Natural (5)	*FAD Caught*	15,648	1,337	33,809	50,795
	Unassociated (6)	*FAD Free*	231,784	6,986	435,874	674,644
	Anchored FADs (7)	*Other*	28,973	1,563	72,295	102,830
	Other (8)	*Other*	4,968	311	7,788	13,068
ICCAT Atlantic Ocean	FADs (9)	*FAD Caught*	34,380	20,146	185,994	240,520
	FSC = Free Schools (10)	*FAD Free*	46,182	5,145	24,846	76,173
IOTC Indian Ocean	Log Schools = Man-made FADs + Natural Objects (11)	*FAD Caught*	111,593	37,573	282,589	431,755
	Free Schools (12)	*FAD Free*	14,844	2,841	4,443	22,128
	Unclassified (13)	*Other*	7	–	31	39
All RFMOs/All Oceans	Total Purse Seine (all Set Types)		754,371	149,797	1,513,454	2,417,622
	Total Purse Seine %		31.2%	6.2%	62.6%	100.0%
	"FAD Caught" (1)+(4)+(5)+(9)+(11)	*FAD Caught*	260,439	132,318	892,408	1,285,166
	"FAD Caught" %		20.3%	10.3%	69.4%	100.0%
	"FAD Free" (2)+(6)+(10)+(12)	*FAD Free*	316,465	15,603	538,428	870,496
	"FAD Free" %		36.4%	1.8%	61.9%	100.0%
	"Other" (3)+(7)+(8)+(13)	*Other*	177,466	1,876	82,618	261,960
	"Other" %		67.7%	0.7%	31.5%	100.0%

Sources: IATTC: Public PSTunaSetType, Accessed May 20, 2020; ICCAT: t2cePS91-18bySchool.xlsx, Accessed May 20, 2020; IOTC: https://iotc.org/data/datasets/latest/CESurface. Accessed May 20, 2020; WCPFC: https://www.wcpfc.int/doc/purse-seine-yearmonth. Purse_Seine CSV, Accessed May 20, 2020.

[a]Authors' classification of set types for analysis:

FAD = Man-made + Natural. Sum of Lines (1)+(4)+(5)+(9)+(11).

FAD Free = Not Associated/Free Schools + Unassociated + Free Schools. Sum of lines (2)+(6)+(10)+(12).

Other = Dolphin + Anchor FADs + Unclassified + Other. Sum of lines (3)+(7)+(8)+(13).

programs)[18]; and/or (3) source tuna originating from fisheries currently engaged in a Fishery Improvement Project (FIP). FIPs are generally endorsed by and follow "best practices" established by the International Seafood Sustainability Foundation (ISSF)[19] and claim to have eventual MSC certification as their goal.[20]

At question is whether reliance on MSC certification, FIPs, and other NGO guidance ensures that the canned tuna sold does not derive from IUU fisheries. Embedded in the MSC Standard (MSC 2020) are assurances that no fishery may achieve MSC certification if it engages in IUU fishing activities.[21] Similarly, FIPs are designed to bring fisheries up to meet the MSC Standard, so they will be evaluated against the same MSC criteria.[22] Despite these avowed standards, however, most canned tuna retailers continue to source from FAD-based fisheries. Furthermore, as we explain below, even when retailers seek to source only "FAD-Free" tuna, the fish they buy may still be IUU. As our legal analysis demonstrates, specific FAD-associated fishing meets the legal definition of IUU fishing under the current legal and management framework. Programs that do not recognize and properly apply these concepts perpetuate IUU practices and are thus incompatible with retailers' own sourcing policies.

How much canned tuna is IUU?

Table 2 details the 2018 purse seine catches of tropical tunas by RFMO and set type, grouped for our analysis into "FAD-Caught", "FAD-Free", and "Other" categories. Our analysis of this RFMO data (the most recent complete dataset available) indicates that as much as 53% to 89% (1.3 to 2.2 million metric tons) of the 2018 supply of tropical tunas serving the major canned tuna markets may have been the product of IUU FAD fishing operations; this range depends on whether only "FAD-Caught" tuna is included or also "FAD-Free" tuna (which, despite the RFMO classification, may not necessarily represent truly "FAD-Free" tuna, from the MSC and/or a marketing perspective, as previously discussed). The remaining 11% represented purse seine catches made in association with dolphins and/or other set types not involving FADs.

Because the definition of "FAD-Free" tuna is variable and unclear, the upper range estimate seems more likely. Overall, with the exception of the relatively small amount of pole-and-line caught canned tuna available, the vast majority of canned tuna marketed as "sustainable" appears to be derived from IUU FAD fisheries.

Increasing consumer and retailer awareness of the IUU aspects of FAD fisheries, combined with traceability and transparency regarding which tuna products are associated with FADs, would bring to bear public pressure on third-party certifiers to revise their criteria, and on retailers to more closely adhere to their own sourcing policies, thereby pushing RFMOs and the tuna industry to change FAD-related practices.

A new basis for RFMO FAD management

To mitigate the negative impacts of FADs, the parties responsible for causing harm must be held liable. To date, RFMOs have not identified and/or initiated actions that could lead to sanctions on RFMO Contracting Party FAD owners, requiring them to mitigate their impacts. Establishing FAD ownership is the first step in assigning liability.

Critical questions around FAD ownership definitions are currently being debated by the JTRFWG, but no consensus has yet been reached (JTRFWG 2019).[23] In general, this group has focused on defining the FAD owner as the individual or company that deploys the FAD with satellite buoy attached and catches the aggregated fish, but these responsibilities are often delegated to fleet managers, vessel operators, or skippers, and widespread FAD turnover and piracy complicates ownership definitions. Nevertheless, effective FAD management requires an accurate and accepted definition of FAD ownership. Such a definition should encompass both the FAD structure and the satellite buoy and should establish clear legal liability for both vessel owner/operators and providers of satellite communication services, both of which, according to our legal analysis, engage in "fishing."

Assigning liability

With clarification of FAD ownership, each FAD could be exclusively associated with a specific tuna purse seine vessel through a FAD register linked to the RFMO vessel register.[24] The details of the registration scheme and associated requirements would determine its ultimate effectiveness, but we recommend that RFMOs incorporate the following considerations.

With RFMO FAD registers in place, RFMOs could approve resolutions requiring vessels to only set on their own RFMO-authorized and registered FADs. FADs with no clearly established ownership or that have not been duly registered would be considered IUU FADs, and vessels setting on these IUU FADs would risk inclusion in the RFMO's IUU Vessel List, with the associated market consequences. This would eliminate FAD piracy and serve as a powerful incentive to tuna vessel owners to acknowledge ownership, register their FADs, and assume liability.

RFMOs could benefit from a "FAD registration fee" to be charged to the FAD owners, the purpose of which would be to pay for an effective monitoring, control and surveillance (MCS) system and a compulsory observer program (both human and electronic monitoring) on each tuna vessel.

For enforcement purposes, owners of registered FADs and Service Providers should be obligated to provide to RFMOs real-time data on the location of each FAD and access to Vessel Monitoring System (VMS) data for the vessel. This process would take place under a very strict confidentiality structure.

FAD owners and Service Providers should be held equally responsible and liable for the use and impacts caused by their FADs, from the time the FAD with attached satellite buoy is deployed in the ocean to the time it is physically removed from the ocean. This would include responsibility for derelict FADs that are "ghost fishing" or damage sensitive habitats, beaches, or other habitats. Similarly, both parties would be responsible for obtaining authorization from a Coastal State in advance of their registered FADs drifting into or out of its fisheries jurisdictional zone. For this purpose, RFMOs could establish criteria to limit these events. As we discuss later, current technology is available that could track the movements of FADs and vessels in real time as they drift through EEZs, MPAs, or closed areas.

Consequences for infractions could include significant fines by the RFMO, reduction in the total number of registered FADs the owner would be allowed to use in subsequent seasons, and if a pattern of suspicious activity is established, listing FAD owners/vessels on the RFMO's IUU List.

The FAD and VMS data collected for MCS and enforcement purposes could reside outside the structure of the tuna RFMO. RFMOs could contract out these services to a third-party independent entity, such as OceanMind[25] or another organization with similar capabilities. This organization would be tasked with real-time collecting, processing, managing, and reporting critical registered FAD and vessel movement data to the RFMO and States when suspicious activity is detected that may constitute possible regulatory and/or management infringements. RFMOs could also use the information for market traceability purposes.

Technology is available today that could be used to monitor via satellite on a real-time basis and with a high degree of accuracy the location and movements of the FADs and of the vessels that use them. Using artificial intelligence, large quantities of data can be processed and analyzed, and reports can be automatically generated when an anomaly is detected, even to the point of identifying a vessel setting on a FAD that is not its own. This technology could be combined with observer data (human and electronic monitoring) to be used as critical data for scientific purposes as well as MCS and enforcement.

In the event that a FAD drifts into an MPA or the fisheries jurisdictional zone of a Coastal State on an unauthorized basis, the third-party independent contracted entity could immediately notify the RFMO and/or State into whose waters the FAD has entered and the Flag State of the vessel associated with the FAD in question. RFMOs and Coastal States could take action against violators, including penalties, seizure of FADs, and/or other deterrents.

Additional recommended RFMO/Coastal State FAD management measures

RFMOs may consider adopting the following types of measures and exploring the following tools to improve FAD management and limit FAD proliferation under the proposed scheme.

- Prohibiting converting natural floating objects into FADs via satellite buoy placement.
- Prohibiting FAD support vessels.
- Establishing FAD Mortality Limits (FMLs) per set (similar to the IATTC's Dolphin Mortality Limits [DMLs]) with respect to minimum target tuna sizes, maximum numbers of incidental kills of ETP species, or similar criteria. By adjusting the subsequent fishing season's FML, vessels could be rewarded for staying below their FML or penalized for exceeding it. As echosounder species and size identification technologies continue to improve, this could incentivize vessel operators to only make FAD sets when echosounder data or other observations indicate the aggregated tunas meet minimum size standards and/or to devise methods to release ETP species prior to brailing the fish into the vessel.
- Continuing to encourage tuna vessel operators to switch to non-entangling and biodegradable FADs through FML incentives or FAD registration requirements.

- Identifying existing laws and agreements that define "fishing" using terms analyzed in this document to clarify the availability of existing tools to enforce against FADs that contravene conservation measures.
- Adopting definitions such as those in the IPOA that implicitly or explicitly define FADs as "fishing" to further enable FAD management and enforcement capabilities.

Port States could also take additional steps to implement the PSMA provisions pertaining to IUU enforcement.

Conclusions: Likely impacts of FAD ownership registration and tracking

The intrinsic fishing nature of FADs operating within the context of existing RFMO conservation measures, national laws, and international agreements suggests that, from a legal and operational perspective, most or all deployed FADs may currently qualify as IUU fishing. RFMOs and Coastal States have the legal framework necessary to change this but are failing in managing FADs and mitigating their negative impacts.

A new approach of "legalizing" FADs by establishing RFMO FAD ownership registers and accompanying legal responsibility would provide needed transparency and the following benefits and impacts.

At the level of Vessel Owners and Service Providers:

- Vessel owners would likely experience higher costs due to FAD registration fees and FAD mitigations costs.
- FAD owners and Services Providers could limit their liability and costs by providing timely, accurate data to RFMOs through the independent monitoring entity and by exercising better control over deployed, abandoned and lost FADs.
- Long term stability of tuna resources would benefit vessel operators and Service Providers.

At the RFMO and Coastal State level:

- Registering and tracking individual FAD ownership through an independent entity would provide RFMOs with accurate, timely data on FADs for stock assessment, MCS, enforcement, and mitigation purposes.
- Registration fees, fines, and mitigation assessments would provide new revenue streams to devote to MCS, enforcement, and mitigation needs, and/or to support Coastal State economic development.

At the MSC level:

- A FAD ownership registration scheme and the inclusion of FADs in the Unit of Assessment would provide the MSC the ability to certify tuna fisheries under the proposed new standard (full trip basis), without having to separate FAD-Caught from FAD-Free tuna sets.

- FAD ownership registration would end the current MSC practice of certifying fisheries engaged in IUU FAD activities, against its own certification Standard.
- FAD ownership registration would provide the MSC with the possibility of certifying FAD-Caught tuna if MSC Principle 2 criteria are met via mitigation of negative impacts associated with FADs.
- MSC-certified FAD-related fisheries may be required to implement Action Plans to mitigate overall FAD ecosystem impacts to satisfy certification conditions. This would particularly benefit ETP species.

At the Retail level:

- Retailers could be confident that the available tuna purse seine supply is not IUU.
- Retailers could decide whether to continue distinguishing between "FAD-Caught" or "FAD-Free" tuna, knowing that negative FAD impacts are being mitigated.
- Retailers would have increased leverage over tuna producers and processors to ensure they comply with the RFMOs' new FAD ownership tracking system, and over FIPs fisheries to compel them to comply with the MSC standard quickly.

At the Consumer level:

- FAD ownership tracking would end misleading retailers' claims of offering consumers MSC-certified FAD-Free canned tuna products when those products are not presently satisfying IUU or MSC sustainability requirements.
- Consumers could experience higher retail prices due to the industry passing on FAD mitigation costs, but tuna in the market would be truly sustainable and legally caught.

Acknowledgement of the inherent IUU nature of most FAD fisheries and the implementation of a system of registration and real-time tracking of FAD ownership and responsibility could put industry and management practices on a course to long-term protection of tuna resources, the ocean ecosystem, and consumers.

Notes

1. The major market species are: Skipjack (*Katsuwonus pelamis*), Yellowfin (*Thunnus albacares*), Bigeye (*Thunnus obesus*), Albacore (*Thunnus alalunga*), and Bluefin (*Thunnus thynnus*, *Thunnus orientalis*, or *Thunnus maccoyii*). The first three are considered tropical tunas.
2. "Ghost fishing" describes the activities of fishing gear that has been lost, abandoned, or discarded in the marine environment and continues to trap and kill fish, crustaceans, marine mammals, sea turtles, or seabirds (Smolowitz 1978). Unlike monitored FADs, FAD "ghost fishing" mortality cannot be easily observed and managed.
3. In addition, roughly 400,000 metric tons were caught by pole and line vessels worldwide in 2018; approximately 40% of their catches (or 160,000 MT) were also destined for canning, while the remainder was consumed primarily in the local markets of Indonesia, Maldives and Japan in other forms (John Burton, Chairman, International Pole and Line Foundation

(http://ipnlf.org), personal communication May 2020). Catches by other gears such as longline are not usually destined for major canned tuna markets.

4. Catch data compiled by the authors from downloadable tuna RFMO databases: IATTC, Public PSTunaSet Type; ICCAT, t2cePS91-18bySchool.xlsx; IOTC, https://iotc.org/data/datasets/latest/CESurface; WCPFC, https://www.wcpfc.int/doc/purse-seine-yearmonth Purse_Seine CSV. All data accessed May 20, 2020.
5. Manufacturers of smart satellite buoys and echosounders are actively working to improve their capabilities for clearly identifying the size and species composition aggregated under FADs.
6. Four companies manufacture satellite buoys and provide satellite communication services to the tuna vessel owners/operators: Satlink (https://www.satlink.es/en/smart-buoys/satlink-isl-buoy/), Zunibal (https://zunibal.com/en/), and Marine Instruments (https://www.marineinstruments.es) in Spain and Kato (http://www.manufacturers.com.tw/showroom-5752-2-5-0000106816-0.php) in Taiwan.
7. These numbers differ from Escalle et al. (2019), which estimates that in the west/central Pacific only: "51.8% of FADs were lost; 10.1% were retrieved; 6.7% were beached; 14.0% were deactivated by the fishing company and left drifting unmonitored at sea; and 15.4% were sunk, stolen, or with a malfunctioning buoy."
8. Alternatively, in the case of the MSC-certified FAD-Free tuna of the Parties to the Nauru Agreement (PNA; https://www.pnatuna.com/content/nauru-agreement) countries, the MSC has accepted the concept of certifying the FAD-Free status of a load of tuna based on the observed size of the tunas and evaluation of the associated bycatch species at the time the catch is unloaded at the cannery (Brownjohn 2020). This, however, requires maintenance of a strong PNA chain of custody from the time the fish is caught, through transshipping, until the fish is finally unloaded.
9. The exceptions are the Eastern Pacific tuna fisheries on dolphins and a small New Zealand fishery that operates four months per year and does not deploy or set on FADs.
10. Support vessels are referred to as "supply vessels" by the Indian Ocean Tuna Commission.
11. NOAA Notices of Violation (NOAA Office of General Counsel 2020; https://www.gc.noaa.gov/enforce-office7.html). For example, see Case 34 of the Charged Cases and Cases 14 and 15 of the Settled Cases in the 2018 list of notices at https://www.gc.noaa.gov/documents/2018/Enforcement-Actions-12032018.pdf.
12. In addition, the Commission for the Conservation of Southern Bluefin Tuna (CCSBT) manages three non-tropical species not addressed in this paper.
13. For example, the IATTC has established fishing capacity limits, a 72-day seasonal closure, and 31-day time/areas closure for the area known as "El Corralito"; the WCPFC has a 3-month FAD closure for all areas, a two-month closure on the High Seas, and limitations on the numbers of days tuna vessels can fish; ICCAT has a two-month time/area closure for FADs; and the IOTC does not have closures.
14. Taking the IATTC as an example, see IATTC Review of Data (https://www.iattc.org/Meetings/Meetings2020/SAC-11/FAD-05/_English/FAD-05-PRES_Review%20of%20data%20provided%20under%20Resolution%20C-19-01%20and%20C-17-02.pdf).
15. FAD management plans can be viewed at: WCPFC FAD Management Plans (https://www.wcpfc.int/folder/fad-management-plans); IOTC FAD Management Plans (https://iotc.org/documents/fad-management-plans); and Resolution 16-01 Tro, Annex 6. Page 32 of ICCAT FAD Management Plans (https://www.iccat.int/Documents/Recs/COMPENDIUM_ACTIVE_ENG.pdf).
16. Refer to: IATTC Resolution C-15-01of IATTC 89th Meeting (https://www.iattc.org/PDFFiles/Resolutions/IATTC/_English/C-15-01-Active_Amends%20and%20replaces%20C-05-07%20IUU%20Vessel%20list.pdf); IOTC IUU Vessel List (https://www.iotc.org/iotc-iuu-list); WCPFC IUU Vessel List (https://www.wcpfc.int/doc/cmm-2019-07); and ICCAT IUU Vessel List (https://www.iccat.int/en/IUUlist.html).
17. See Intrafish (https://www.intrafish.com/news/video-greenpeace-slams-princes-john-west-over-fad-tuna/1-1-642067), Atuna.com (https://atuna.com/pages/tuna-ngo-s),

UndercurrentNews.com (https://www.undercurrentnews.com/2014/11/28/wcpfc-meeting-pew-calls-for-improved-fad-management-greenpeace-for-ban/), Greenpeace (https://www.greenpeace.org/usa/oceans/tuna-guide/), Huffpost (https://www.huffpost.com/entry/best-cans-of-tuna_n_58f4e224e4b0da2ff8621293), and Fishwise (https://fishwise.org/press/ngo-coalition-identifies-measures-to-protect-fisheries-observers/) for examples.

18. To date, the MSC has certified 10 tuna purse seine fisheries and 3 are in the full assessment process. Of the certified fisheries, one is a fishery on dolphins; the remainder use FADs. Setting on FADs has been certified by the MSC for three fisheries: Echebastar in the Indian Ocean, and in the West-Central Pacific, the PNG Fishing Industry Association and the Western Pacific Sustainable Tuna Alliance. The remaining fisheries have been certified only for their sets on free-swimming schools (https://fisheries.msc.org/en/fisheries/@@search?q=tuna&search=). Starting in September 2020, the MSC requires that the entirety of each and every fishing trip, including all of its sets (whether on FADs or free-swimming schools), be assessed for certification (MSC 2020).
19. For ISSF "best practices," see Restrepo et al. (2019) and ISSF Best Practices (https://iss-foundation.org/download-monitor-demo/download-info/rfmo-best-practices-snapshot-2020-fad-management/). ISSF is an NGO whose membership is composed of most of the world's largest tuna processors, tuna brands, and tuna trading companies, representing an estimated 11,000 metric tons of daily tuna processing capacity. As of May 2020, there are 12 purse seine tuna fisheries engaged in FIPs (FIP Directory: https://fisheryprogress.org/directory). See also Tuna FIPs (https://iss-foundation.org/what-we-do/fisheries-improvement/tuna-fips/).
20. Additional sources of retailer policy guidance include the Sustainable Seafood Coalition Codes of conduct (https://www.sustainableseafoodcoalition.org/codes-of-conduct/), the Global Seafood Sustainability Initiative (GSSI; https://www.ourgssi.org), the Environmental Justice Foundation's Charter for Transparency (https://ejfoundation.org/news-media/were-on-a-roll-ejfs-charter-for-transparency-gains-momentum-as-m-s-and-waitrose-sign-up), the Seafood Watch program of the Monterey Bay Aquarium (https://www.seafoodwatch.org), Earth Island Institute's "Dolphin Safe" criteria (http://savedolphins.eii.org/campaigns/dsf), and Friends of the Sea FAD-Free Certification requirements (https://friendofthesea.org), among others.
21. MSC (2014), page 146. Among other criteria, the MSC standard establishes that the Unit of Assessment should be free from IUU catches of target (P1) species.
22. There are two types of FIPs, Comprehensive and Basic; the first establishes a certain date when the fishery is supposed to achieve MSC certification, whereas the second establishes a progressive path towards certification with flexible dates. (FisheryProgress.org FIP Progress Tracking Database: https://fisheryprogress.org/resources/glossary)
23. The JTRFWG is composed of scientists and experts involved in FAD issues in their respective regional RFMOs, as well as individuals from fishing companies, satellite buoy manufacturers, NGOs, government officials, and others.
24. The PNA has done this in the past and is considering expanding this concept (MRAG Asia Pacific 2018; Parties to the Nauru Agreement 2020).
25. OceanMind is a UK non-profit that uses satellites and artificial intelligence to support monitoring, control and surveillance (MCS) for management authorities and chain of custody compliance.

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