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Assessing the number of moored fishing aggregating devices through aerial surveys: A case study from Guadeloupe

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ABSTRACT

Moored fish aggregating devices (MFADs) are increasingly being used in small-scale tropical fisheries to access pelagic fish species that are otherwise difficult to harvest in large numbers. Little attention has yet been paid to monitoring MFADs in coastal areas, however. This is most likely due to the small-scale nature of most fisheries that utilize them and the presumed lower impact of those fisheries on fish stocks and their ecosystems. In this paper, we examined the abundance and density of MFADs around Guadeloupe, using aerial line transect surveys. Estimated MFAD densities were found to be high compared with previously reported densities in this area, especially within the 22–45 km range offshore. We examine and discuss possible reasons for these high densities. The main drivers appear to be the target species dolphinfish (*Coryphaena hippurus*) and yellowfin tuna (*Thunnus albacares*) and related fishing behaviour. We present different approaches for reducing and monitoring MFADs densities, including the co-management of MFAD territorial use rights by fishing communities.

1. Introduction

In many parts of the world, including the Caribbean, moored fish aggregating devices (MFADs, also called anchored fish aggregating devices) are used by small-scale fishermen to access fish species that are otherwise difficult to harvest in large numbers (Gomes et al., 1998; Rey-Valette et al., 2000; Taquet et al., 2011). Such devices are man-made structures designed to float on or near the surface in order to attract fish and thus facilitate their capture (Dempster and Taquet, 2004). An MFAD is generally made of a buoy or set of linked buoys of different sizes and colours that are attached to the seafloor with a mooring rope and a block of concrete or steel. The length of the rope depends on the depth of the water where the MFAD is set, and can vary between 200 and 5000 m (Gervain et al., 2015). In order to increase fish aggregations around an MFAD, additional devices are often tied to the rope at the surface or subsurface in order to attract fish. In Guadeloupe, fishermen commonly use pieces of trawling nets, plastic sheeting or polypropylene lashing straps, which also prevent trolling lines from becoming hooked onto the devices.

MFADs have several benefits as they create known targetable fishing resource patches, which significantly reduce search time, effort, and fuel costs for fishermen. MFAD development programs are also seen as a way to improve catch rates and, thus, the income and livelihoods of local fishing communities. They may also help to reduce fishing pressure on coastal species by concentrating fishing effort on offshore pelagic fish stocks (Taquet et al., 2011).

In contrast, drifting FADs (DFADs), which are equipped with GPS tracking devices, are mainly deployed by large offshore fleets that target tropical tunas, but also catch other species that aggregate around DFADs, e.g., dolphinfish (*Coryphaenidae*), wahoo (*Acanthocybium solandri*), blue marlin (*Makaira nigricans*) and various triggerfish species (Amandé et al., 2010). Increasing use of DFADs in recent years has raised concerns about their ecological impact (Dagorn et al., 2012). It is now recognized that the quantity and location of DFADs needs to be managed in order to ensure that they can be used in a sustainable manner (Davies et al., 2014). While the number of DFADs has increased in the Atlantic recently, their exact number is difficult to estimate (Fonteneau et al., 2015).

The literature has so far focussed very little on the management of MFADs in coastal areas. This is most likely due to the small-scale nature of most of the fisheries that utilize them in this way, and the presumed lower impact of those fisheries on fish stocks and their ecosystems. Indeed, the deployment of MFADs and evolution

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of associated fisheries is rarely documented (Taquet et al., 2011). However, this information is needed to assess the impact of MFADs on fish stocks (e.g., reduction of tuna aggregation capacity per FAD (Holland et al., 1990; Cayré, 1991; Dagorn et al., 2000)) and the benefits they offer to local fishing communities (e.g., incomes, food supply, etc.). For example, MFAD densities might affect catch rates, which are used to assess temporal changes in the abundance of the resources (Dagorn et al., 2012). Although MFADs are monitored in some countries, for example the Maldives (MFA, 2015) or La Réunion (CRPMEM, 2015), no monitoring program on private or public MFADs exists in the Caribbean area (Ramdine, 2007). Such information could be obtained through government actions (Anderson and Gates, 1996), such as by monitoring MFAD installation programs or establishing regulations requiring fishermen or fishing authorities to report the deployment of MFADs.

In the case of Guadeloupe (FAO area 31), private MFADs have been being installed since the beginning of the 1990s without any accurate knowledge of their number or location (Diaz, 2007; Guyader et al., 2013). This fishery expanded in the 1990s, with an increasing number of vessels and an extension of fishing areas from coastal waters to more distant areas (Mathieu et al., 2013). Of the 767 vessels active in Guadeloupe in 2008, 282 units were involved in MFAD fishing, with total landings of 1600 tons having a value of approximately 13 million Euros (Guyader et al., 2013). The number of active vessels has remained almost stable since the mid-2000s. Most of these local fishing vessels are between 7 and 9 m in length and open-decked with powerful outboard engines. Fishing is mainly done by trolling and drifting vertical longlines around MFADs (Diaz et al., 2005; Taquet et al., 2000). The main target species are dolphinfish (*Coryphaena hippurus*) (61%), yellowfin tuna (*Thunnus albacares*) (18%), blue marlin (*Makaira nigricans*) (8%), triggerfish (*Canthidermis maculatus*) (7%) and other miscellaneous species like wahoo (*Acanthocybium solandri*), rainbow runner (*Elagatis bipinnulata*) and other tunas (Guyader et al., 2014). The structure of fish aggregations around MFADs in the Lesser Antilles was characterized acoustically by Doray et al. (2006).

These commercial species are highly migratory and widely distributed in the Atlantic intertropical area, including the Caribbean Sea, for which Guadeloupe provides only a small proportion of the total catches. According to the Caribbean Regional Fisheries Mechanism (2010), there is no evidence for a decline in the local dolphinfish stock at current harvesting levels. However, CRFM recommends that a precautionary approach should be adopted in managing this fishery. By contrast, yellowfin tuna stocks are considered by the International Commission for the Conservation of Atlantic Tunas to be fully exploited in this area, while it recommends that blue marlin needs the balance of its stocks to be strengthened (ICCAT, 2014). In summary, the current state of the different fish stocks targeted by the MFAD-fishery around Guadeloupe further highlights the need to improve the current monitoring and management of this fishery and other MFAD fisheries in the Caribbean.

According to MFAD regulations in Guadeloupe, MFADs can be installed by commercial fishermen after authorization has been granted by the local maritime authorities (Prefectural Order, 2002). These regulations also require that fishermen equip MFADs with maritime signalling systems and report their exact positions and characteristics, as well as the identification of the fishermen operating around them. However, the quality of this information is considered to be very poor because it is difficult to enforce this regulation (Guyader et al., 2013). Underreporting of MFAD deployments is a serious issue for fishery management. Given that MFAD losses are not registered, it is almost impossible to know the real number of MFADs in use in this fishery.

To alleviate the drawbacks of this weakly-regulated private MFAD system, in 2008 and 2009, local fishing organizations decided, with the support of the local administration and public funds, to establish a network of collective MFADs within a 24-nm zone around Guadeloupe (Gervain and Diaz, 2011). The main objectives of this network were: (1) to reduce the number of MFADs and potential interactions between them, (2) to encourage fishermen to better coordinate their fishing activities around MFADs, and (3) to reduce the risk of interactions with other activities (e.g., maritime transport) and ecosystem impacts associated with the loss of MFADs (Diaz et al., 2005). At this time, 40 MFADs have been set around Guadeloupe with a distance range of 5–12 nm between them, considering the scientific literature on the size of tuna–FAD interaction zones. However, this network of collective MFADs was not successful and few of these MFADs were still in place in 2012, further highlighting the requirement for a new and fishery-independent assessment of the number of MFADs deployed around Guadeloupe.

The objective of this paper is to provide fishery-independent estimates of the number and density of MFADs around Guadeloupe through aerial line transect surveys. Line transect surveys are a common technique for monitoring animal abundance in terrestrial and aquatic wildlife management (Buckland, 2001). Aerial line transect surveys have been applied to assess the abundance of marine mammals, sea turtles and surfacing fish, including whale sharks and Atlantic bluefin tuna (Rowat et al., 2009; Fortuna et al., 2014; Bauer et al., 2015). They may also represent a suitable tool to survey the spatial distribution and densities of MFADs independently of fishermen's reports. A pilot aerial survey, carried out in 2008 in Guadeloupe, showed promising results for such an application and further suggested that the number of MFADs in this area was actually higher than thought by fisheries authorities (Guyader et al., 2011). We also sought to improve our understanding of differences in MFAD fisheries in the Caribbean by comparing abundance and density estimates obtained in this study with preliminary estimates from nearby regions. In this context, we examined different factors that could structure the deployment of MFADs around Guadeloupe (e.g., anchorage depth, distance to closest port and next nearest MFAD, fishing behaviour and target species). Different approaches to reduce and monitor MFAD densities are discussed, including the co-management of MFAD territorial use rights by fishing communities.

2. Methods

2.1. Aerial line transect surveys in Guadeloupe

Guadeloupe, in the Lesser Antilles, is a French overseas territory comprising the islands of Grande-Terre and Basse-Terre and several smaller islands in the Leeward Islands (Fig. 1).

Aerial surveys were carried out in Guadeloupe in 2012 during the month of December, a period of the year when conditions are usually particularly suitable for such surveys. Unlike the January–June period, when strong trade winds blow over the Caribbean Sea, August–December is characterized by tropical depressions interspersed by periods of low wind. June to July is not suitable for surveys because of strong currents, which increasing the risk of MFADs sinking. Line transects (102–104 km in length) were spaced at 8.9 km and orientated in the North–South direction, irrespective of the bathymetry or fishing effort data of the survey region. A Cessna 72 aircraft, without bubble windows, was chartered from Raizet airport (Fig. 1), flown by the same pilot, but employing slightly changing teams of three trained scientific observers (one in the front, two at the back) for the survey. In accordance with the limitations of the aircraft's fuel capacity, the transects were split into 6 sections, which were then each surveyed