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Changes in fishing power and fishing strategies driven by new technologies: The case of tropical tuna purse seiners in the eastern Atlantic Ocean

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ABSTRACT

Technological advancements can influence both the fishing power of a fleet and the fishing strategies it employs. To investigate these potential linkages, we examined almost three decades of data (1981–2008) from French tropical tuna purse seiners operating in the eastern Atlantic Ocean. Applying a sequence of statistical methods at different temporal and spatial scales, we analyzed two indicators of fishing power (sets per boat-day on fish aggregating devices (FADs) and sets per boat-day on free-swimming schools) each of which represent a distinct fishing mode. Our results show that the increasing modernization of this fleet has led to increases in both fishing power and the available number of fishing strategies to choose from. A key output of this analysis was the breakdown of fishing power time series (for each fishing mode) into separate periods of continuous years during which catchability was assumed to be constant, thus identifying regime shifts. This partitioning allowed us to identify when key changes occurred in the fishery. Changes in FAD-associated fishing were mostly driven by the introduction of radio beacons (early 1990s) which lead to an increase in fishing effort and an expansion of fishing grounds (direct effect) and the implementation of time-area management measures which resulted in a fragmentation of the traditional fishing grounds in the 2000s (indirect effect). During the same period, fishing on free-swimming schools also increased despite the biomass of stocks decreasing and fishing grounds remaining unchanged. This suggests these increases were driven by improvements in fish detection technology (e.g., bird radars, sonar). These identified increases are not entirely unexpected: indeed it is widely recognized that fishing power in the purse seine tuna fishery has increased over time. However, these increases do not necessarily occur linearly. Thus, understanding how fishing power is changing over time (such as determining when regime shifts occur) is critical to improving the CPUE standardization procedure in tropical tuna purse seine fisheries.

1. Introduction

An integral part of fleet dynamics is the acquisition of new vessels and/or new technology for the purpose of improving the effectiveness or outcomes of a fishery (Hilborn and Walters, 1992). Such investments generally result in increased capacity or efficiency (e.g., better accessibility to current fishing grounds) and an extension to existing fishing strategies (e.g., access to new fishing grounds and/or target species). Thus, these investments commonly result in improved catchability and are considered mechanisms of fishing power creeping (Eigaard and Munch-Petersen, 2011; Eigaard, 2009; Gascuel et al., 1993; Marchal et al., 2007; Millischer et al., 1999). Stock assessments that rely on time series of

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abundance indices, derived from commercial catch per unit effort (CPUE) data, generally assume that catchability remains constant over time. When this assumption is not met, biomass declines can be masked, thus reducing the integrity of the CPUE data and resulting in biased stock diagnoses. Ultimately, this can lead to poor fisheries management decisions (Marchal et al., 2003).

Tuna purse seining is one such fishery that has undergone significant evolution since its inception, growing to represent one of the most modern and powerful fishing fleets in the world. Progressively larger vessels and longer net dimensions (Gaertner and Sacchi, 2000), as well as technological improvements (Gaertner and Pallarés, 2002; Hervé et al., 1991; Itano, 2003; Le Gall, 2000; Miyake, 2005; Morón et al., 2001), have all contributed to its increasing efficiency. Traditionally, purse seining is broken into two fishing modes that target distinct species and different size of fish: (1) targeting free-swimming schools and (2) fishing around floating objects. Originally these objects were items such as logs or palm branches that occurred naturally but now artificial, satellite-tracked buoys known as fish aggregating devices (FADs) are predominantly used (Fonteneau et al., 2000; Pianet et al., 2011). Generally, commercial CPUE time series for this fishery are standardized to account for differences in factors such as vessel power, fishing ground, and season. However, they do not account for fishing power creeping. The non-proportional shape of the relationship between CPUE and abundance in tuna purse seine fishery (a situation known as "hyperstability", common in several fisheries) may cause bias in stock diagnosis.

Previous analyses have been undertaken to determine the effects of improving vessel and gear attributes and the introduction of new technology on fishing power and catchability in tuna fisheries (Gaertner and Pallarés, 2002). Yearly changes in fishing power have also been tentatively estimated for the tuna purse seine fishery operating in the Atlantic during the 1980s (Gascuel et al., 1993) and in eastern Pacific between 1998 and 2002 (Reid et al., 2005). Further, the assumption of increasing fishing power has been considered on some occasions in the sensitivity analysis of Atlantic tuna stock assessments. However, these increases were generally based on empirical estimates (e.g., a 3% constant increase over time; ICCAT, 2011). To date, no assessment has been made on the effects of new technology to specific fishing modes and how these impacts may subsequently shape longer term fishing strategies.

In this study, we analyzed the historical CPUE data of French purse seiners that operated in the eastern Atlantic Ocean between 1981 and 2008 to investigate how the fleet's fishing power and fishing strategies were affected by the introduction of new technologies. To characterize the two distinct fishing modes we looked at two fishing power indicators, (1) sets on free-swimming schools per boat-day and (2) sets on FAD-associated schools per boat-day. Assessing each indicator individually, we identified successive time periods where catchability could be assumed constant and then compared these periods with the dates of technological innovation in the fleet. Assuming biomass remained relatively stable between successive years, we were then able to propose linkages between the introduction of specific devices and regime shifts. By taking a mode-specific approach, we were able to differentiate the effects of each new technology between the two fishing modes.

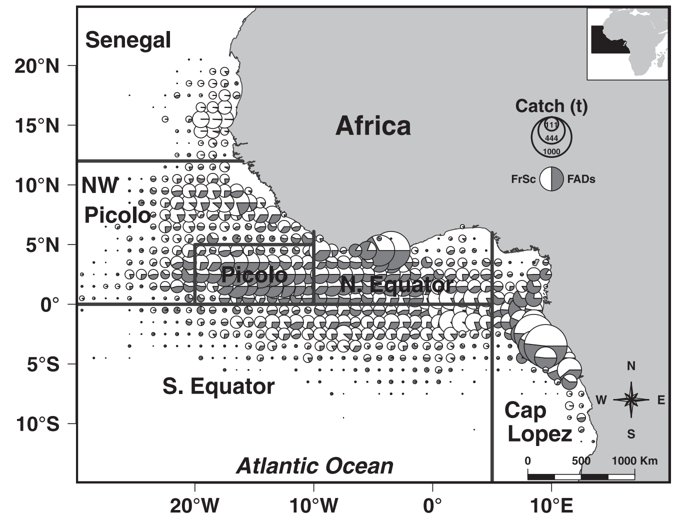

Fig. 1. Annual average catches in a 1° × 1° grid of skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), and bigeye (*Thunnus obesus*) caught by the French tropical tuna purse seine fleet in the eastern Atlantic Ocean in association with fish aggregating devices (FADs) and free-swimming schools (FrSc). The sub-regions identified correspond to the spatial samplings strata used by the International Commission for the Conservation of Atlantic Tunas (ICCAT).

2. Materials and methods

2.1. The eastern Atlantic tropical tuna purse seine fishery

The tropical tuna purse seine fishery in the eastern Atlantic Ocean is composed of vessels flying flags of Ghana, France, Spain, and other associated countries (e.g., Belize). In recent years, annual catches for this fishery have been around 200,000 t, with fish availability highly variable across both space and time due to the high motility of tropical tunas (Cayré et al., 1993). However, there are several notable exceptions to this variability. Given suitable environmental conditions, unassociated schools of adult tropical tunas are known to aggregate in large concentrations to feed and spawn. At these times, tunas are particularly vulnerable to fishing (Fonteneau et al., 2008; Stretta, 1993). Aggregations are also known to occur in association with floating objects (natural and artificial). Skipjack (*Katsuwonus pelamis*), juvenile yellowfin (*Thunnus albacares*), and juvenile bigeye (*Thunnus obesus*) are all known to form this type of aggregation although it is still not fully understood why (Castro et al., 2001; Fréon and Dagorn, 2000; Hall, 1992). Fishers also target these objects (i.e., FAD-associated fishing), mainly targeting skipjack and juvenile yellowfin. Since its introduction by purse seiners in the mid-1990s, FAD-associated fishing has undergone rapid and widespread global development. Worldwide, tropical tunas are managed through regional fisheries management organizations (RFMOs) with Atlantic stocks coming under the jurisdiction of the International Commission for the Conservation of Atlantic Tunas (ICCAT).

2.2. Fine-scale operational data

Logbook data, trip landing records, and trans-shipment records have been collected from French and associated purse seiners operating in the eastern Atlantic Ocean by the Institut de Recherche pour le Développement (IRD) since the early 1970s. Logbook data details fishing activities at the operational level (e.g., location, fishing mode, catch size, and composition). Species composition records are frequently biased due to misidentification (Fonteneau, 1976). Consequently, routine processing corrections (based on a specific sampling design and multispecies size-frequency samples collected at landing sites) have been performed since 1980 (Pallarés and Hallier, 1997; Pianet et al., 2000). However, in this study we choose to use uncorrected logbook data (between 1981 and 2008) because it better represents tuna size categories caught within the two fishing modes (Fig. 1).