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Evolution and current state of the technology of echo-sounder buoys used by Spanish tropical tuna purse seiners in the Atlantic, Indian and Pacific Oceans

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ABSTRACT

Despite important technological changes in the tropical tuna purse seine fishery industry since the 1980s, the influence of these changes on the fleet efficiency and behaviour has not yet been investigated in depth. In this study, the practical use, fishing strategy and state of echo-sounder buoy technology applications were studied using personal interviews over three consecutive years (2010–2012) with approximately half of the Spanish tropical tuna purse seine fishing masters and licensed captains operating in the Atlantic, Pacific and Indian Oceans. The results suggested that echo-sounder buoys have significantly impacted drifting fish aggregating device (DFAD) fishing strategies since their introduction into the fishery in the last decade, favouring the expansion of DFAD fishing grounds. In addition, fishers are starting to be able to remotely discriminate species, which increases the fleet efficiency. Additionally, the number of echo-sounder buoys used by each vessel has been increasing each year, which demonstrates the utility of the information provided by this tool for the Spanish fleet. Various aspects of these devices' use, consequences for fishing strategy, search time, nominal effort and potential future applications are discussed.

1. Introduction

Today, over 50% of all principal market tunas are caught in drifting fish aggregating device (DFAD) associated purse seine sets (Fonteneau et al., 2013). Even fleets that have traditionally relied on free school sets are moving towards DFAD-based strategies. In addition to skipjack (*Katsuwonus pelamis*), the principal target species, DFADs also attract small yellowfin (*Thunnus albacares*) and bigeye (*Thunnus obesus*) tunas, as well as non-tuna species. The extensive use of DFADs by the purse seine fishery industry increases the possibility of a number of negative impacts, including a reduction in yield per recruitment of target tuna species, increased by-catch and perturbation of the pelagic ecosystem balance, and alteration of the normal movements of the species associated with DFADs (Bromhead et al., 2003; Fonteneau et al., 2000; Morgan, 2011). However, these effects are difficult to estimate.

In tropical tuna purse seine fisheries, the time devoted to searching for tuna schools (i.e., search time) is the metric traditionally used to reflect nominal effort (Fonteneau et al., 2013). However, DFAD fleets have clearly introduced significant improvements in the purse seine efficiency in recent decades, which resulted in changes in the fishing patterns and strategy. This change hinders a proper definition of the effective effort and thus introduces biases and uncertainties to the catch per unit effort (CPUE)–biomass relationship (Fonteneau et al., 2013). In the mid-1980s/early 1990s, the introduction of DFADs significantly increased the CPUE of tunas compared to traditional free-school fishing (Fonteneau et al., 2004; Watters and Maunder, 2001). Since then, gradual changes in the purse seine fleet efficiency have occurred (i.e., sonar range increase, bird radar, tender vessels), which have increased both the catchability and performance of fleets over time (Sakagawa, 2000). For example, the use of tender vessels (i.e., auxiliary vessels that help purse seiners in several DFAD-related activities) for purse seiners in the Pacific Ocean is prohibited, as they significantly increase the capture and efficiency of their mother vessel (Arrizabalaga et al., 2001).

The rapid advances in the effective effort gained in the last decade are particularly important due to the increasing use of DFADs with buoys used to track them that incorporate an echo-sounder to remotely and continuously inform of the presence and size of tuna aggregations. This new technological device

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reduces the searching time (i.e., enables remote identification of DFADs with associated tunas) and provides new information for fishers to learn more about the location and behaviour of tuna and other associated species. Several indicators suggest that echo-sounder buoys could be as important or more important than other significant technological developments in this fishery industry, such as the introduction of sonar. For instance, even though fishers are still learning to fully use this technology, we observed that (i) the ratio of echo-sounder to non-echo-sounder buoys bought by fleets has been rapidly increased and (ii) the explored geographical areas for active DFAD fishing are expanding due to the biomass information beneath the DFAD, and as shown by Delgado de Molina et al. (2012a, 2012b) search time of a vessel between two floating object sets has been decreasing.

Currently, very little is known about the change in the utilisation and state of the technology of echo-sounder buoys. Failure to account for the efficiency changes due to this powerful search tool could strongly bias fleet fishing effort estimates and the estimates of stock status and productivity. Unlike a vessel's characteristics, such as the horse power or carrying capacity, the important fishing gear information for each vessel, such as the number and brands of echo-sounder buoys used per trip and the way fishers utilise them, has not yet been recorded by the Tuna Regional Fisheries Management Organisations (T-RFMOs), although the FAD management plans that have been adopted by some T-RFMOs may lead to such data collection (Anonymous, 2012). Nevertheless, a critical period that began at the onset of the use of echo-sounder buoys will not be represented by these plans. Although several types of DFAD tracking buoys (i.e., radio buoys, GPS buoys, echo-sounder buoys) with different communication ranges and lifetimes have been utilised in this fishery industry during the last 30 years (Fig. 1), this key technology and its use have surprisingly not been documented in detail, which limits the ability of scientists to estimate the search time and fishing strategy effects.

Due to the lack of standard fishery data on buoys with echo-sounders (i.e., logbooks, observers), we use an alternative approach in this study that was based on the Fishers Expert Knowledge (FEK) (Johannes et al., 2000; Mackinson, 2001) obtained via interviews with key Spanish fishing masters and licensed captains to provide knowledge of the change and present use, strategy, and state of the technology of instrumented buoys. This important information is needed to refine tuna stock assessments and estimate more accurately the impact of tropical tuna purse seine fisheries on pelagic ecosystems.

2. Material and methods

Identifying the most appropriate experts in the subject area is essential to obtain qualitative FEK data (also described as LEK, Local Ecological Knowledge) (Johannes et al., 2000). The Spanish tropical tuna purse seine fleet was among the first fleets to adopt DFAD fishing, and their catches are presently very reliant on the use of DFADs (Moreno et al., 2007a). The Spanish fleet has historically been one of the most technologically advanced; it has been among the first to adopt state-of-the-art equipment (i.e., sonar, echo-sounders, bird radars, oceanographic maps service, etc.), which significantly improved the fishing efficiency. Studying the changes in the operational strategies of leading fleets, such as the Spanish fleet, is important because it can help predict the actions of the remaining fleets in the future, as for the generalisation of DFAD fishing or use of tools such as bird radars. In addition, the Spanish fleet is the only fleet that operates globally, and consequently it is present in all T-RFMO regions (Inter-American Tropical Tuna Commission, IATTC; International Commission for the Conservation of Atlantic Tunas, ICCAT; Indian Ocean Tuna Commission, IOTC; Western and Central Pacific Fisheries Commission, WCPFC).

2.1. Data collection framework

The data were obtained via structured, personal interviews with the primary fishing master and licensed captains of Spanish purse seine vessels and some tender vessels. At the time of the interviews (2010–2012), the Spanish purse seine fleet consisted of 54 vessels, including vessels under Spanish and non-Spanish flags that were managed by Spanish fleet owners (18 in Atlantic Ocean, 23 in Indian Ocean, 12 in the Eastern Pacific Ocean, and 1 in the Western and Central Pacific Ocean). A total of 62 fishing masters and 37 licensed captains were interviewed, which covered approximately 50% of the global Spanish fleet.

The interviewed Spanish fishing masters had an average of 17.89 years of personal experience in the industrial tropical tuna fishery (SD = 9.88 years), while licensed captains had 16.65 years of experience (SD = 9.01 years). The accumulated time spent at sea with DFAD experience, which was calculated by summing all interviewed fishing masters' and licensed captains' years at sea, was 554.5 and 308 man-years of practical DFAD experience for fishing masters and licensed captains, respectively. The vast majority of interviewed fishers (98%) had been active in the fishery during the last decade since the start of echo-sounder buoy use, which allowed them to account for changes in the DFAD fishing strategy with instrumented buoys. In addition, 64.3% of the interviewed fishers have been operating in more than one ocean and could thus identify the most relevant ocean-dependent differences. At the time of the study, 54.5%, 23.23% and 22.22% of the interviewed fishers were operating in the Indian, Atlantic and Pacific Ocean, respectively.

2.2. Interview design and strategy

The data were collected over three consecutive years (2010, 2011, and 2012) and spatially and methodologically separated into 2 stages. During the first data collection stage (2010 at Port Victoria, Seychelles), semi-structured personal interviews were conducted with Spanish fishers. The interviews gathered information on individual experiences at sea and the DFAD fishing strategy in relation to echo-sounder buoys. The questions were classified into 3 different categories, (i) practical use of echo-sounder buoys, (ii) fishing strategy with echo-sounder buoys, and (iii) echo-sounder buoy state of technology.

This first set of interviews covered a total of 19 interviewees from 17 vessels belonging to 6 different companies. The responses obtained during this first stage were utilised to subsequently create standardised questions. These questions were answered both by Spanish fishing masters and licensed captains at the second part of the data collection stage during the International Seafood Sustainability Foundation (ISSF) workshops held in 2011 and 2012 at AZTI-Tecnalia headquarters, close to Bermeo (Spain), the hometown of most of the Spanish tropical tuna purse seine fishers. The workshops, which were organised by company, were presented to small groups of fishers by scientists. This "petit comité" strategy appeared to be very effective in terms of fishers' participation because it tended to address company confidentiality concerns. Moreover, the questionnaires were completed anonymously to preserve and encourage the sharing of trustful information on the subject. In total, 80 questionnaires (31 in 2011 and 49 in 2012, from 8 companies) were collected. Across all interviews (stage 1) and questionnaires (stage 2), a final dataset with 99 interviews was obtained.

In all data collection processes, the fishers were instructed to decline answering any question that might be considered strategically or operationally sensitive, rather than provide misinformation