SKIPJACK TUNA (*KATSUWONUS PELAMIS*) FEEDING HABITAT DYNAMICS AND ACCESSIBILITY TO PURSE SEINE FISHERIES IN THE ATLANTIC AND INDIAN OCEANS

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ABSTRACT

A single Ecological Niche model was developed for skipjack tuna (SKJ) in the Eastern Central Atlantic Ocean (AO) and Western Indian Ocean (IO) using data from the European purse seine fleet (fig. 1). Chlorophyll-a fronts were used as proxy for food availability while selected physical variables defined the abiotic preferences. SKJ feeding habitat spanned from latitudinal occurrence of eddy-type productive features at mesoscale in the IO to large-scale upwelling systems that seasonally shrink and swell in the AO (fig. 2). About 83% of FSC sets and 75% of dFAD sets were done within 25 km distance of preferred habitat while, in the AO, 34% of dFAD sets occurred at distances greater than 100 km (fig. 2a), mostly in the relatively food-poor Guinea Current, which is questioned to correspond to a spawning and larvae favourable area. Results emphasized higher SKJ accessibility to purse seiners in months when the habitat is reduced (fig. 3). Moreover, the positive correlation found in the IO between the annual size of preferred habitat and both the annual nominal catch rates and total catches of SKJ (fig. 4) i) agrees with the near full exploitation since the 2000s for the IO and in recent years for the AO, and ii) suggests interpreting the habitat size as an indicator of the carrying capacity of this fast-reproducing species.

KEYWORDS

Ecological Niche model, Katsuwonus pelamis, dFAD, free schools, feeding, Atlantic Ocean, Indian Ocean, dynamic fisheries management.

NB: A full peer-reviewed paper will be submitted in July 2017, therefore only an extended abstract is provided.

INTRODUCTION

Habitat studies on skipjack tuna are scarce relative to its economic importance and especially in the Atlantic and Indian Oceans where no use of the extensive purse seine data was done for such purposes. In this study, we linked the ecological traits of skipjack tuna to environmental variables through an Ecological Niche Model approach (ENM) and investigated their requirements with regards to feeding. The habitat modelling approach used daily chlorophyll fronts to track hotspots of pelagic productivity in addition to physical preferences, and therefore the habitat model is centered on the deterministic identification of specific productive fronts to mark prime areas of SKJ feeding. We gathered a substantial dataset of SKJ presence data from EU purse seiners and environmental data in both the central Eastern Atlantic and Western Indian oceans to identify a common environmental envelop which, in turn, is used to model the preferred feeding habitat.

MATERIALS AND METHODS

The methodological approach used in our ENM is composed of five main steps to: 1) identify the main behaviours and ecological traits of skipjack tuna based on literature and expert knowledge; 2) collect and process the presence-only data and environmental covariates by geographical area on a common grid; 3) perform a cluster analysis to identify a set of covariate thresholds that characterize SKJ feeding ecology; 4) derive the habitat model equation that classifies on a daily basis the degree to which each portion of the study area (i.e. model grid cell) is either suitable or unsuitable for habitat (deterministic environmental envelop) and finally 5) perform, by geographical area and fishing mode, a seasonal and interannual analysis using, as metric, the distance of presence data to the closest preferred habitat.

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Tropical tunas species were reported to aggregate at the vicinity of thermal fronts while other tuna species such as albacore (*Thunnus alalunga*) and Atlantic bluefin (*Thunnus thynnus*) have been shown to be attracted by chlorophyll-a frontal features (Druon et al., 2016; Polovina et al., 2001; Royer et al., 2004). As skipjack tuna is an opportunistic feeder and income breeder (Grande et al., 2016), we hypothesized that SKJ is also attracted by chlorophyll-a fronts as these mesoscale features stand long enough (weeks to months) to sustain zooplankton production and upper trophic levels. Therefore, the horizontal gradient of chlorophyll-a (hereafter gradCHL) was used as a proxy for food availability and primary index of SKJ feeding habitat within a specific range of surface chlorophyll-a content (CHL). The additional physical oceanographic variables considered as predictors in the feeding habitat model were sea surface values salinity, current intensity, oxygen, and depth of mixed layer that all have been shown to affect SKJ distribution at different spatio-temporal scales (Barkley et al., 1978; Dizon, 1977; Evans et al., 1981; Lopez et al., 2017).

RESULTS AND DISCUSSION

Preferred feeding habitats show high latitudinal variability between seasons in the IO while large winter-summer contraction-relaxation cycles were mostly observed in the AO (fig. 2). The number of SKJ positive sets for which a habitat was available (width of boxes, fig. 3) and SKJ habitat size (line segments, fig. 3) were both highly contrasted by season.

In the AO (fig. 3a), 61% of FSC sets were within the preferred feeding habitat and 16% were beyond 100 km of preferred habitat while for dFAD sets, 34% were within the preferred habitat and 34% were beyond 100 km of preferred habitat. Most FSC sets in the AO were done within short distance to preferred feeding habitat and in months for which the habitat size was the lowest (from October to March and in May mostly in upwelling areas). High distance of dFAD sets to closest feeding habitat was instead observed in particular from December to March. These maximum distance values mostly corresponded to dFADs in the Guinea Current. In the IO instead, the distances to preferred habitat were substantially lower for both fishing modes, and with lower differences between them, with 56% of FSC sets within the preferred habitat and 4% beyond 100 km of preferred habitat and 47% of dFAD sets within the preferred habitat and 10% beyond 100 km of preferred habitat. Overall in both oceans, 83% of FSC sets and 75% of dFAD sets were found within 25 km distance of favourable feeding grounds. In comparison, 8% of FSC sets and 13% dFAD sets were found to occur at a distance further than 100 km from favourable feeding conditions, mostly in the poor environment of the Guinea Current in the AO and during the transition of seasonal habitat in the IO.

Skipjack tunas appear in the AO, to some degree, to migrate from the productive and relatively cool upwelling areas to the poorer and warmer equatorial waters (see apparent movements by conventional tagging in Bard, 1986; ICCAT, 2014), and even if this species is known to spawn opportunistically year-round (Grande et al., 2014) near feeding grounds (income breeding), we question whether the Guinea Current may represent a privileged area for sub-adult population and/or reproduction as these environmental conditions favour larvae survival (thermal stability and lower presence of predators, satellite-undetected low levels of subsurface primary productivity). Similar poor environments in the IO particularly correspond to the observed distribution of high lipid contents in gonads (highest levels in FSC from April to May in the Mozambique Channel and elevated levels in dFAD sets in the Seychelles and Somalia surrounding waters, Grande, 2013), which could be explained by nearby rich environment at the edge of eddies (Kai and Marsac, 2010). These contrasted levels of food availability due to mesoscale features in the warm waters of the Mozambique Channel (from 27 to 29°C) suggests this area may conciliate better reproduction conditions than the Guinea Current because of the substantially lower levels of subsurface primary productivity.

Overall, and excluding the Guinea Current, the number of fishing sets with SKJ presence made in a given month (fig. 3) was found to be inversely proportional to habitat size, suggesting that habitat reduction might increase school accessibility to purse seine fishing. This could be explained by the greater ability of fishermen to detect skipjack schools when preferred feeding habitat is reduced. At the multiannual time scale, the significant positive correlation in the IO between the annual size of feeding habitat and the annual catch rates and total catches of purse seiners from 1998 to 2014 (fig. 4) is particularly intriguing, as catches appear to be related to the potential feeding habitat. The likely full exploitation of the stock over the time-series and the rapid response of SKJ populations to a change in their environment (SKJ being mature at around 6 months old, Eveson et al., 2015; Murua et al., 2017) both positively contributes to the relationship. The overall size of preferred feeding habitat in the IO may be therefore be interpreted as an indicator of the carrying capacity of the environment to sustain the growth of SKJ population, which could be considered of importance from a management perspective. There is no such correlation of catch rate with the multi-annual habitat size in the AO since variable access to some fishing grounds were attributed to the European purse seine fleet over time through specific fishing agreements.

Results show that monitoring of habitat size may provide indirect and independent information on both stock accessibility to fishing and potential through year-to-year changes in carrying capacity as a direct impact of seasonal regime shifts and climate change. Such information might be essential for interpreting changes in stock abundance observed from the assessments which are conducted within tuna RFMOs and for dynamically adapting catch levels to the available resource. A smarter dFAD deployment strategy should also limit the situations where dFAD drift towards poor environments and allow reducing the number of devices at equal catch level, thus reducing the costs.

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FIGURES

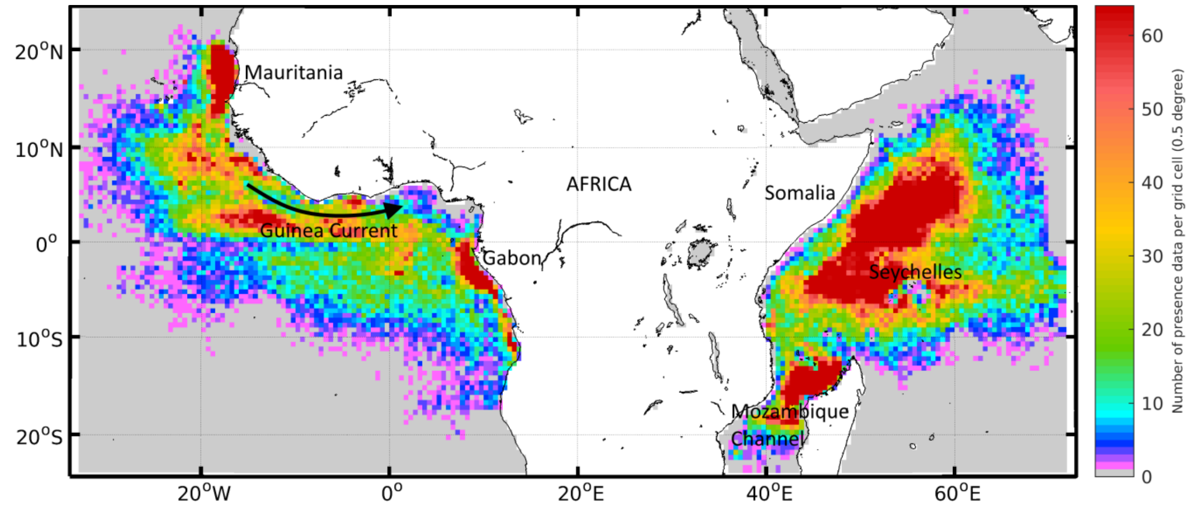

Figure 1 Geographical density of skipjack tuna presence data (for both FSC and dFADs, n = 155,064) collected from 1997 to 2015 by European purse seiners (in number of observations by 0.5 degree grid cells).

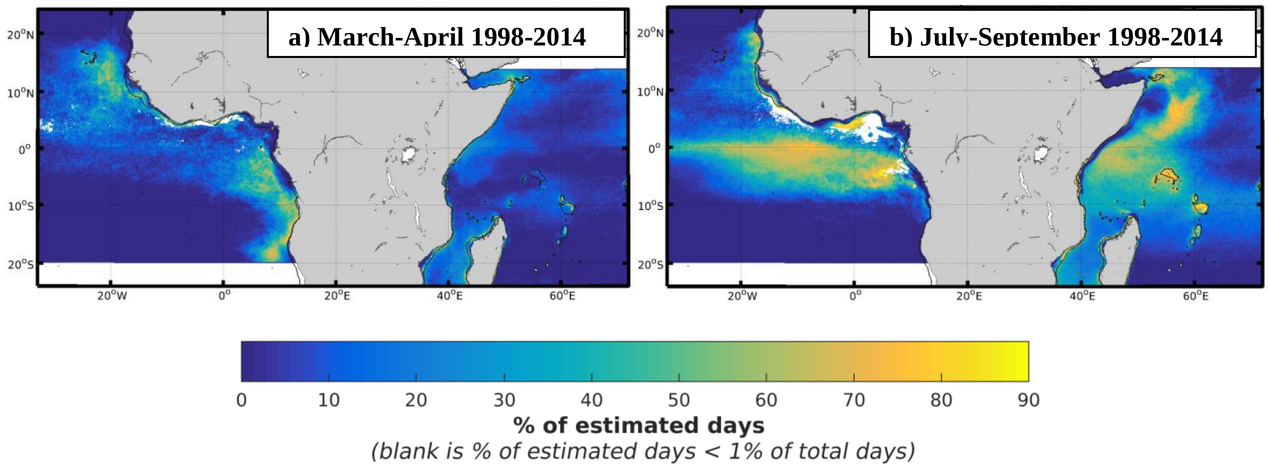

Figure 2 Preferred feeding habitat of skipjack tuna in the Eastern Central Atlantic and in the Western Indian Ocean for (a) March-April 1998-2014 (minimum size of habitat) and (b) July to September 1998-2014 (maximum size of habitat).

a) Atlantic Ocean **b) Indian Ocean**

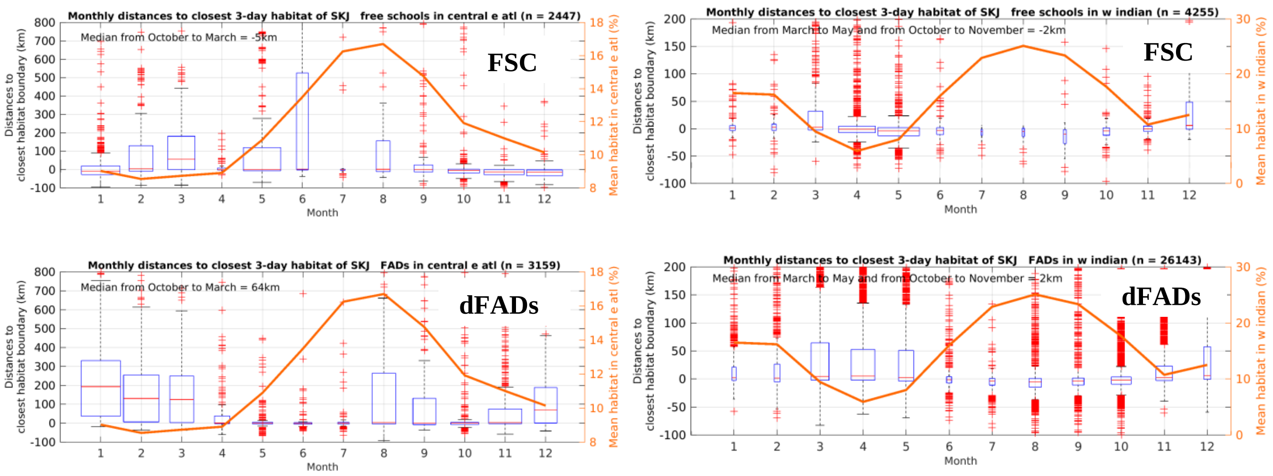

Figure 3 Monthly boxplots of distances between skipjack tuna positive sets and closest preferred habitat boundary for FSC (upper panels) and dFADs (lower panels) (a) in the Eastern Central Atlantic and (b) in the Western Indian oceans from 1998 to 2014. Negative values correspond to presence data inside the preferred habitat. **The width of boxes is proportional to the monthly number of sets.** Monthly preferred habitat size is overlaid (right axis, mean fraction of ocean area).

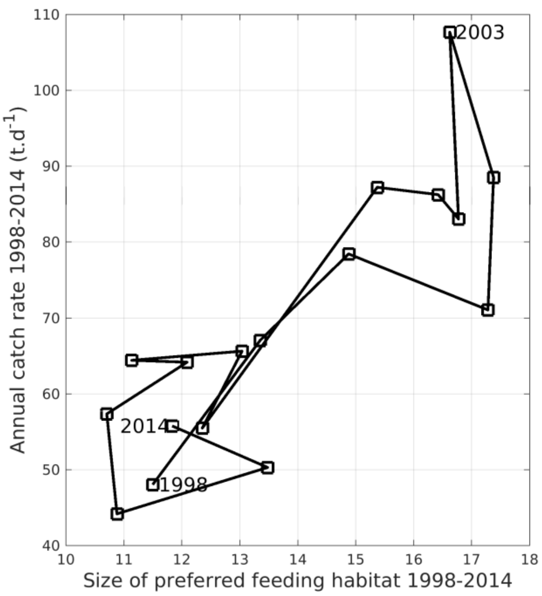

Figure 4 Annual index of habitat size against annual catch rate of skipjack tuna from 1998 to 2014 in the Western Indian Ocean. The spearman correlation coefficient is r = 0.80.