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Trends in the activity pattern, fishing yields, catch and landing composition between 2009 and 2013 from onboard observations in the Portuguese purse seine fleet

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ABSTRACT

In Portugal mainland, the purse seine fishery is one of the most important fisheries, accounting for about 50% by weight of landings. At present, these fleets mainly target sardine (*Sardina pilchardus*) and chub mackerel (*Scomber colias*). This work aimed to study the Portuguese purse seine fleet activity (vessel length > 16m) and catch composition using onboard observations from 2009 to 2013. Data were collected during 179 trips and 229 fishing sets. Short trips (mean 9.38 h) with one to two sets (duration time 1.39 h/set) were observed, where most of the trip was dedicated to searching (43.7% of total trip duration) and fishing (23.5%). Fishing time depended of the number of sets and search time, which increased due to the growing scarcity of fish and distance to and from fishing grounds to the homeport. *S. colias* was the main species captured followed by *S. pilchardus*, although there were an inverse trend in the two species landings. Other pelagic species such as horse mackerel (*Trachurus trachurus*), Atlantic mackerel (*S. scombrus*), blue jack mackerel (*T. picturatus*) and anchovy (*Engraulis encrasicolus*) were also caught but represented small volumes of the catch. The average capture and landings observed were 4.47 (±S.D. 7.64) and 3.19 (±S.D. 4.46) tons per set. Capture and landings were both higher in the North, intermediate in the South and lower in the Centre. Differences between fish captured and fish landed are due to slipping. Slipping was more frequent in the North, mainly because of the implementation of daily limit quotas. In the South, usually was the result of the mixture of *S. pilchardus* with non-commercial species that would decrease its landing price. Throughout the study period, *S. pilchardus* landings peaked of 64 000 ton in 2008, decreased 20% until 2011 and dropped sharply after 2012. Landing patterns of *S. colias*, the second most important species, have been inverse, increasing continuously since 2009. On the overall, the decline of *S. pilchardus* landings has been compensated by increasing capture and landings of *S. colias* along the country.

1. Introduction

The purse-seine fishery is the most important Portuguese fishery in terms of landings (52% by weight) (DGRM, 2016), targeting small pelagic species, primarily sardine (*Sardina pilchardus*) and others such as chub mackerel (*Scomber colias*), horse mackerel (*Trachurus trachurus*), blue jack mackerel (*Trachurus picturatus*), Atlantic mackerel (*Scomber scombrus*) and anchovy (*Engraulis encrasicolus*). Due to the high captures, price at first sale has been usually low representing a moderate economic importance to the country (26% by value of first sale) (DGRM, 2016). The purse seine fleet has approximately 158 vessels (Length overall—LOA 6–27 m), of those 88 (LOA > 18 m) fully dedicate their activity to purse seining, while 70 smaller multi-gear (or polyvalent) vessels (LOA < 18 m) use purse seining on a seasonal basis, usually in the summer

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when market demand and sardine prices are high (Feijó, 2013). Around 60% of the purse seine vessels have their homeport in the North, 30% in the South and 10% in the Southwest (INE, 1990–2009; INE, 2010–2016; DGPA, 2006–2011; DGRM, 2012–2016). The fishery employs about 2000 fishermen and crew sizes are of 15–20 fishermen depending on the size of the vessel (Marçalo, 2009; Feijó, 2013).

Purse seine fishing activities are carried out during daily trips, usually at dusk or dawn, close to the fishing port within the shallower half of the continental shelf and take on average about 8 h (range 3–15 h) (Stratoudakis and Marçalo, 2002; Wise et al., 2007; Feijó, 2013). Fish schools detected by echo-sounders are encircled rapidly with nets 500–1000 m in length and 90–150 m deep (Portaria, 2000); nets are then hauled, first mechanically and, towards the end, manually by all crew members. Fishing operations (shooting, closing and hauling the net and fish transfer onboard) can take about 1.5–2 h depending on the size of the net and mechanical equipment onboard (Stratoudakis and Marçalo, 2002; Marçalo, 2009; Feijó, 2013). Due to the regulation of daily catch limits or to market demand, slipping may occurred the end of purse-seine fishing operations. Slipping is a process where total or part of the catch is released by rolling the fish over the headline (floating line) of the net after partially hauling or "drying-up" the net while it is still in the water (Stratoudakis and Marçalo, 2002; Marçalo, 2009). Finally the skipper may choose, or not, to proceed with a new search and net setting depending on time available and catch necessities (species and amount) or return to port. Skippers act autonomous from other skippers in the fleet, although cooperation (e.g. exchange of information about catches and fishing spots, leaving the harbour at the same time, fishing in the vicinity of other vessels) is common, especially in the North of Portugal (Carvalho et al., 2008; Feijó, 2013).

The southern stock of *S. pilchardus*, also known as the Atlantic Iberian sardine stock or sardine in divisions 8.c and 9.a (Cantabrian Sea and Atlantic Iberian waters), covers the area extending from the Gulf of Cadiz in the South, the whole Portuguese coast (ICES area IXa) and following the Spanish coast up to the inner Bay of Biscay in the North (ICES area VIIIc) (Silva, 2003, 2007; ICES, 2017). *S. pilchardus* abundance is coupled to the magnitude of recruitment, and recruitment has been low, which have been absent in the southern Iberian stock (up to the last year of analysis in this study) since 2004, leading to an historical recent low level of biomass (Silva et al., 2008, 2015; Malta et al., 2016; ICES, 2017). Up to 2009, there were no limits to *S. pilchardus* catch although other management measures, such as maximum number of fishing days per year and weekend fishing bans (limits on fishing effort), time and area closures, and daily landing limits (North of Peniche) were taken in place (DGRM, 2012a; ICES, 2012–2013). However, to recover from the low level of *S. pilchardus* biomass, strict regulations were implemented from 2011 onwards by Portuguese and Spanish administrations as a multi-annual management plan for the Atlantic Iberian sardine stock with severe restrictions on annual catches (DGRM, 2012a). This leaded to sharp decreases of Portuguese landings of 35% from 2011 to 2012 and 51% from 2013 to 2014. *S. pilchardus* landings for this stock in 2014 were only 7% of the amount landed in 1981 (15 500 ton as compared to 217 000 ton). As such, to maintain economic viability, during the period of the "sardine ban", the purse-seine fishing sector targets other important small pelagic species, such as *S. colias* and *T. trachurus*. These two species have shown a recent increase in importance in terms of biomass off the Portugal-Cadiz region and in the case of *S. colias* an increase of the spatial overlap and an inverse relationship with sardine recruitment dynamics has also been found (Martins et al., 2013; Garrido et al., 2015; Bachiller et al., 2016; ICES, 2016).

Despite changes in *S. pilchardus* abundance and the enforcement of annual catch limits, the number of active purse-seiners suffered only small changes in recent years (DGRM, 2013, 2014; Silva et al., 2015). Furthermore, most of *S. pilchardus* catches and landings continue to be made by the purse seine fleet operating to the North of Lisbon (DGRM, 2016), which is an area of high adult *S. pilchardus* abundance and always referred as a key recruitment area for the species (Correia et al., 2014; Malta et al., 2016; Rodríguez-Climent et al., 2017). However, the decline of the sardine abundance may have led to other changes at the operational level of the fleet such as changes in fishing effort, catch-per-unit effort (CPUE) or slipping patterns which are important to manage the fishery.

The main purpose of this work was to use data collected on board observations from 2009 to 2013 to study the Portuguese purse seine fleet activity, including annual variations of operational activities (fishing, search times), catch composition (with the analysis of variance of CPUE and LPUE) and patterns of slipping and discards, using data collected during on board observations from 2009 to 2013.

2. Material and methods

2.1. Study area

The Portuguese mainland coast is 860 km long, ranging from Caminha (41°50′N, 8°50′W) to Vila Real St. António (37°12′N, 7°25′W) (Fig. 1). The upper ocean layers of the Portuguese shelf are generally characterized by a summer coastal upwelling (Fiúza, 1983, Mason et al., 2005). Nonetheless, different upwelling patterns occur along the coast due to several topographical features, which allowed to split the coast in three main areas (Fig. 1): North (from Caminha to Nazaré canyon; ports: Viana do Castelo, Matosinhos, Aveiro and Figueira da Foz), Centre (from Nazaré canyon to Cape São Vicente, ports: Peniche, Sesimbra, Setúbal and Sines) and South (from Cape São Vicente to Vila Real St. António; ports: Portimão and Olhão).

The North represents a wider and flat continental shelf (40–70 km), and it is characterized by a strong, fairly homogeneous upwelling, with northern wind regimes resulting in colder waters with high productivity. The Centre has a narrower continental shelf (10–20 km wide) and weaker upwelling associated with the near shore deep features of the Lisboa and Setúbal canyons, resulting in warmer waters with less productivity. Finally, the South represents a very narrow continental shelf (5–20 km wide), with warmer waters and prevailing southern winds. This region is locally affected by upwelling events under favourable, westerly winds, which blow only occasionally (Fiúza, 1983; Mason et al., 2005).

2.2. Data collection

For all trips, data on set characteristics (number, depth, geographic position), duration of fishing operations (search, net deployment, hauling, fish transfer, resting activities, slipping, and steaming from and to port) and catch composition (total biomass and species composition for retained, slipped and discarded catch) were collected by observers onboard commercial vessels (Length-overall—LOA >16 m) operating along the Portuguese coast between 2009 and 2013. Data for 179 trips and a total of 229 sets were recorded (Table 1). The sampled fleet (Table 1) was composed of 53 different vessels (mean $\pm$ SD Length $= 22.25 \pm 2.53$ m). Most trips (99) were carried out within the framework of the European Commission Data Collection Regulation (PNAB/EU-DCF—*Programa Nacional de Amostragem Biológica*/EU-Data Collection Framework) (Reg. EC No 1543/2000) using a standard protocol in which trips observed are allocated to fishing areas and quarters each year in broad agreement with the area-quarter distribution of landings the year before (∼24 trips per year) (Feijó et al., 2012). Since 2010,

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