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Are regional fisheries' catches changing with climate?

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ABSTRACT

Climate change affects ocean conditions, which will in turn impact marine organisms and ecosystems, with consequences for fisheries. The Iberian Peninsula has faced an increase in both air and sea surface temperature, and rainfall has decreased in intensity and frequency in Portugal. As Portugal is the third highest per capita consumer of fish in the world and its coast is located in a biogeographic transition zone, between temperate and subtropical waters, the study of the effects of climate change on Portuguese fisheries is of the utmost importance. The present work focused on Setúbal, an important fishing port in central Portugal. Landings Per Unit of Effort (LPUE) time series (1927–2012) of the most important species were analysed and their relationships with sea surface temperature (SST), rainfall and the winter North Atlantic Oscillation (NAO) index were investigated. Mean annual SST has increased 0.9 °C from 1926 to 2012. The main target species in 2012 were the same as in 1927. However, their landings have changed and have responded to changes in environmental variables, particularly SST. LPUE of the European sardine has shown a decreasing trend and was negatively correlated with SST and NAO, whereas the LPUE of the Atlantic chub mackerel has been increasing since 2000. The LPUE of the common cuttlefish has kept more or less stable through the studied time series, but it was correlated with SST. The LPUE of soles has increased with time and SST. The LPUE of the common octopus was correlated with SST and NAO and has presented higher values since 1975. Further increases in sea temperature in the future will pose challenges for fisheries in Setúbal. Purse-seine fisheries may try to compensate the expected losses in sardine landings by targeting the chub mackerel. Although landings of the most important species in multi-gear fisheries seem to have been favoured by increases in temperature, further studies on the tolerance of each particular species to increases in temperature are needed. As a recent increase in the relative importance of subtropical species in Portuguese fisheries has already been previously detected, climate change may also bring new fishing opportunities for this region.

1. Introduction

Climate change is the most widespread anthropogenic threat for ocean ecosystems (Halpern et al., 2008), affecting sea temperature, sea-level, ocean pH, rainfall and ocean circulation (Brander, 2007). These effects of climate change on ocean conditions will have an impact on ocean organisms, the composition of marine communities and ecosystem function (Brown et al., 2010), increasing the complexity of the challenges facing fisheries (Sumaila et al., 2011). Climate change impacts fish stocks either directly or indirectly. The direct impacts are mainly physiological and behavioural effects, such as changes in growth, reproduction, mortality and distribution; the indirect impacts are related with changes in productivity and in the structure and composition of marine ecosystems on which fish depend (Brander, 2010; Hare et al., 2010; Perry et al., 2005). Changes in the geographic distribution of fish species have already been documented throughout the world and are more easily detected on its northern and southern distribution limits (Brander et al., 2003; Perry et al., 2005). Several studies have predicted that changes in water temperature, driven by climate change, may lead to local extinctions and also to colonization by species previously absent in those areas (Cheung et al., 2009; Vinagre et al., 2011), which will most likely affect the abundance, distribution and composition of fisheries catches (Gamito et al., 2013; Sumaila et al., 2011).

The observation of the impact of recent climate change and predictions of climate changes in future scenarios indicate that the effects of climate change will not be homogeneous throughout the world (IPCC, 2007; Santos, 2006). Southern Europe and the Mediterranean are more vulnerable to climate change than Central and Northern Europe (Santos, 2006). The Iberian Peninsula is one of the areas where air temperature has increased most (IPCC, 2007)

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and the Iberian Coastal large marine ecosystem has suffered a rapid warming, with an increase of 0.68 °C in sea surface temperature from 1982 to 2006 (Belkin, 2009). In Portugal, there has also been a decrease in the intensity and frequency of rainfall (IPCC, 2007). The Portuguese coast, mainly North–South oriented, is located in a biogeographic transition zone, between temperate and subtropical waters, where several temperate and subtropical fish species have their southern or northern distribution limit (Briggs, 1974). Ecological responses to recent climate change have already been observed in Portuguese waters (e.g. Vinagre et al., 2009). An increase in the occurrence of species with tropical affinities and a decrease in temperate species have been reported (Cabral et al., 2001; Vinagre et al., 2009). Vinagre et al. (2011) studied the impact of climate warming upon the fish assemblages of the Portuguese coast under future emission scenarios (Nakicenovic et al., 2000) and predicted a general increase in species richness, with the appearance of new subtropical and tropical species and the elimination of only a few species.

Fishing is an activity of great traditional and cultural importance in Portugal, the third highest per capita consumer of fish in the world (Failler, 2007). There are three main fleet components in Portuguese fisheries: trawl fisheries, purse-seine fisheries and multi-gear fisheries. The main targets of trawl fisheries are the Atlantic horse mackerel *Trachurus trachurus* (Linnaeus, 1758), the European hake *Merluccius merluccius* (Linnaeus, 1758) and cephalopods, whereas the purse-seine fishery targets small pelagic species, particularly the European sardine *Sardina pilchardus* (Walbaum, 1792), the most important species in terms of total Portuguese landings, the Atlantic chub mackerel *Scomber colias* Gmelin, 1789 and the Atlantic horse mackerel. Multi-gear fishery is the largest fleet component in Portugal, using a wide variety of fishing gears, such as gill nets, trammel nets, longlines and traps. In the central coast of Portugal, the main targets of multi-gear fisheries are soles, the common cuttlefish *Sepia officinalis* Linnaeus, 1758 and the common octopus *Octopus vulgaris* Cuvier, 1797.

Fish populations and ecosystems located in areas most likely to suffer climate change impacts are more at risk (Brown et al., 2010). Not only the Portuguese coast is expected to suffer changes in temperature and precipitation more accelerated than the global mean alteration rate (IPCC, 2007), but it is also located in a biogeographic transition zone (Briggs, 1974). Therefore, this coast is particularly adequate for studies on the effect of climate change on fisheries. In fact, an increase in the relative importance of landings of subtropical fish species (Gamito et al., 2013) and higher landings of subtropical species and lower landings of temperate species in warm years (Teixeira et al., 2014) have already been reported for the Portuguese coast. Gamito et al. (2013) have also detected higher landings of subtropical species in multi-gear fisheries, which could indicate an easier adaptation of Portuguese multi-gear fisheries to the effects of climate change. However, it is yet to determine how these changes in the composition of landings will affect the landings of the most traditionally important species in local fisheries. Thus, the aim of the present study was to analyse trends in landings of the most important commercial species of different fleet components, using long time-series (1927–2012), and to relate them with trends in environmental variables. The study focused on Setúbal, an important fishing port in the central coast of Portugal, where landings cover a wide variety of commercial species and multi-gear fisheries are particularly relevant.

2. Methodology

2.1. Study area

The Portuguese coast is located in south-western Europe, with a North–South oriented western coast and an East–West oriented southern coast. The port of Setúbal was chosen for this study due to its location in the centre of the western Portuguese coast (Fig. 1), in a biogeographic transition zone.

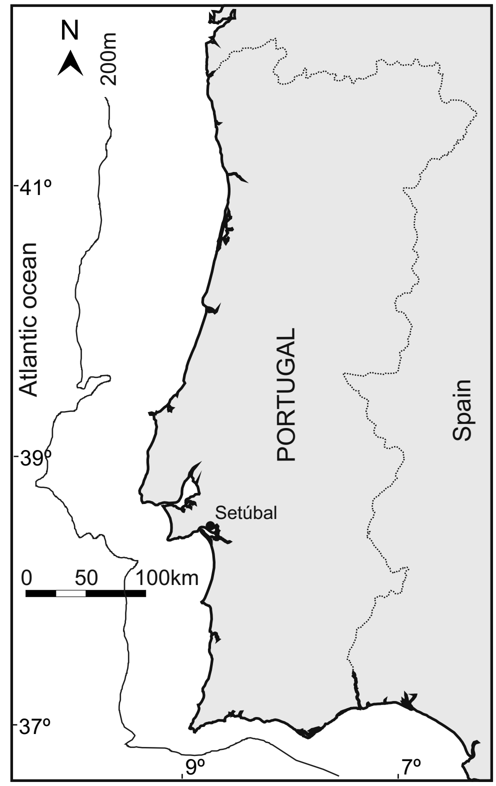

Fig. 1. Location of the port studied – Setúbal – on the Portuguese coast.

2.2. Data source

Fishing data for the period of 1927 to 2012 were obtained from official Portuguese landings. Landing data included species caught, year and number of active fishing vessels. Fleet component and fishing gear were also available for the period of 1992–2012. Monthly data on the North Atlantic Oscillation (NAO) index, based on the pressure difference between Lisbon and Reykjavik, were taken from the United States of America NOAA National Weather Service database (http://www.cpc.noaa.gov). Sea surface temperature (SST) monthly data for a $2^{\circ} \times 2^{\circ}$ grid centred in Setúbal were collected from the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) database (http://icoads.noaa.gov). Annual rainfall data taken at the Moinhola station were provided by the Portuguese Water Resources Information System (http://snirh.pt).

2.3. Data analysis

Annual mean SST was obtained by averaging monthly values for each year. Annual winter NAO indices were calculated by averaging the indices obtained for winter months (December–February). When analysing fisheries data, fishing effort should be taken into account. Several effort estimators have been used in previous studies, such as number of fishing days, number of fishing hours, number of vessels, vessel size or vessel power (e.g. Engelhard et al., 2013; Ligas et al., 2010; Tzanatos et al., 2013). In the present study, the most reliable effort estimator available for the entire time series was the number of active fishing vessels in the studied area. Although this proxy to the real effort may be biased, it is expected that this bias is stable over a large number of years, not