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An analysis of the impacts of climatic variability and hydrology on the coastal fisheries, *Engraulis encrasicolus* and *Sepia officinalis*, of Portugal

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Abstract

The notion that climate change may impact coastal fish production suggests a need to understand how climatic variables may influence fish catches at different time scales. Evidence suggests that the effect of climatic variability and fishing effort on landed catches (as proxy of fish abundance) may vary at the regional scale. This study aims to assess the sensibility of two commercial species with a short life cycle (*Engraulis encrasicolus* and *Sepia officinalis*) to climatic and fisheries effects across different regions of the coast of Portugal: northwestern, southwestern and southern Portugal. The effect of environmental explanatory variables, i.e. NAO index, sea surface temperature (SST), upwelling (UPW) index, river discharge, wind magnitude (WmaG), wind direction (Wdir), and fishing variables (fishing effort) on catch rates time series were studied between 1989 and 2009. The sensibility of the species studied to climatic variability differed among regions and were explained by different climatic variables. River discharge had a significant effect on catch rates of the two species, region independently. However, wind driven phenomenon and UPW were the variables that better explained the observed fishing trends across the three regions. Changes in catch rate trends among the studied regions, at a given time, were mostly associated with the reproduction periods of the species. Therefore, regional analyses will significantly contribute to a better understanding of the relationship between climate change and coastal fisheries, aiming to improve integrated coastal zone management.

Key words: climate variables, fishing trends, dynamic factor analysis, river discharge, fishing effort, wind driven phenomenon, integrated coastal management.

1. Introduction

The field of coastal ecohydrology is growing and providing new theoretical frameworks and methodological approaches for understanding the complex interactions between biota, such as fisheries resources and climatic factors (e.g. river discharges) at multiple scales. Among several climatic factors, riverine discharge is proved to be an important factor for coastal fisheries (FAO 1995). Application of Ecohydrology concept (Zalewski *et al.* 1997; Zalewski 2000) for sustainable freshwater fisheries resource management is now well recognized in the scientific community (Zalewski 1998, 2003). A rapid growth in the research of coastal ecohydrology and hydrology, emphasizing on estuarine and coastal fisheries, has also been observed in the last decade (Chícharo *et al.* 2001a; Wolanski *et al.* 2004, 2006; Chícharo *et al.* 2009; Sohel, Ullah 2012). However, most studies that addressed the relationship between ecohydrology and fisheries dealt mostly with estuarine resources and particularly with river discharge (hydrology) as a single environmental variable (Chícharo *et al.* 2001a; 2006). In contrast, those works that attempt to link coastal fisheries with climatic factors (multi-pressures), under the ecohydrological framework, are scarce (Chícharo *et al.* 2001b).

It is recognized that climate induced variability is a strong driver of changes in fish populations and in fisheries (Roessig *et al.* 2004; Lehodey *et al.* 2006). Besides, increasing pressures from over-fishing, habitat destruction and water quality degradation, natural variability of atmospheric and oceanic systems is increasingly affected by climate change, and thus species are forced to physiological or behavioral adaptation to rapidly changing environments (Balston 2009). These changes could be very crucial for instance in small pelagic fish and in species with short life cycles (e.g. cephalopods). Small pelagic fish are contributing up to 50% of the total landing of marine species (Lluch-Cota *et al.* 1997) and occupy an important position in the intermediate levels of the food web, connecting the lower and upper trophic levels (Cury *et al.* 2000). Despite constant progress in understanding the complex processes involved in the variability of pelagic stocks, especially at short and medium time scales, our ability to predict abundance and catches is limited (Fréon *et al.* 2005). This also limits our capacity to properly manage the fisheries and ensure sustainable exploitation. This remains difficult because small pelagic fishes, such as anchovy, showed important long-term natural fluctuations in their abundance (Lluch-Belda *et al.* 1989). Furthermore, the impact of changing freshwater flow from rivers into coastal waters throughout the world proved to be a crucial factor for this fisheries (Chícharo *et al.* 2001a; 2001b; Palomera *et al.* 2007; Bergeron *et al.* 2010). Thus, a favorable hydrological and biological conditions is vital for successful recruitment of larvae fish (Wilson *et al.* 2008) which may consequently affect fishing yields (Hare *et al.* 2010).

Portugal is likely to face rapid alterations in temperature and precipitation, which are expected to be more accelerated than the global mean alteration rate (IPCC 2001). Studies carried out in the coastal waters of Portugal were basically focused on the influence of certain environmental variables on the recruitment of fish species, on a very short time scale, and their association with suitable nursery grounds. The relationship between a set of long term climatic variables and marine production of commercially important species was not highlighted except by few works (Santos *et al.* 2001; Borges *et al.* 2003; Erzini 2005; Santos *et al.* 2007, 2012). Consequently, there is a lack in terms of understanding potential combined role of climate driven river runoff, sea surface temperature (SST), upwelling (UPW), North Atlantic oscillation (NAO) and wind on the coastal fisheries across the different regions of Portugal (different oceanographic and hydrological regimes). Most studies are limited to specific geographic areas and do not address the issue of climate variability simultaneously across all Portuguese coast (Borges *et al.* 2003; Erzini 2005; Santos *et al.* 2007; 2012), that is known to have different climatic regimes (Bettencourt *et al.* 2004). Since several approaches (such as knowledge-driven approach models, data-driven approach to modeling and hybrid modeling approach) for Ecohydrological modeling are currently available to scientists, the choice of data analyses is made in accordance with the goals and available data sets (Ben-Hamadou *et al.* 2011). This work used empirical or data-driven model that is based on a statistical fit to data as a way to statistically identify relationships between stressor (climate variables) and response variables (trends of two commercial species, *Engraulis encrasicolus* and *Sepia officinalis*).

2. Materials and methods

2.1. Study area

The sensibility of the two species to climatic variability and fisheries was evaluated across three regions with different oceanographic regimes (Bettencourt *et al.* 2004): northwestern, southwestern and south Atlantic coast of Portugal (Fig. 1). The northwestern Portuguese coast is characterized by littoral drift currents having a dominant north-south direction, except local deviations due to specific hydrodynamic processes (e.g. near river mouths). The oceanographic conditions along the western