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Research Paper

North Atlantic oscillation affects the physical condition of migrating bullet tuna *Auxis rochei* (Risso, 1810) from the Western Mediterranean Sea

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ABSTRACT

Climate oscillations exert direct control over the environment in which they occur and may influence the physical condition of migratory marine species, such as tuna, as reported by several authors. The main aim of this study was to explore the association between the potential effects of the North Atlantic Oscillation (NAO) on the fitness condition of bullet tuna (*Auxis rochei*) migrating to the Spanish Mediterranean Sea. A total of 2357 length-weight pairs of data obtained from individuals collected on the Spanish Mediterranean coast were analysed. A non-parametric Spearman test was used to investigate correlations between the atmospheric oscillation indexes and two physical condition indexes. The results suggest that, in general, positive phases of the NAO index improve the physical condition of fish migrating to spawning grounds in the Mediterranean Sea. These results could be explained by changes in the dominant winds, which could favour pre-spawning migration, and by nutrients availability, which guarantees their recovery after the spawning period.

1. Introduction

The bullet tuna *Auxis rochei* (Risso, 1810), the smallest member of the migrant tuna species, represents an important fishery resource worldwide (Valeiras and Abad, 2006; Collette et al., 2011). Moreover, due to their high abundance, bullet tuna are considered to be an important component of the trophic chain because they are the prey of other commercial species, such as other tuna species, pelagic sharks, billfish, and other large pelagic species (Olson 1982; Mostarda et al., 2007).

The bullet tuna is distributed worldwide in tropical and subtropical coastal waters. It is a neritic pelagic species that is associated with the continental shelf. Rodriguez-Roda (1966) observed seasonal movements through the Strait of Gibraltar, which connects the Atlantic Ocean and Mediterranean Sea. However, Di Natale et al. (2011) considered bullet tuna to be an intra-Mediterranean migratory species. It is known that bullet tuna migrate annually towards their spawning grounds in the Mediterranean Sea. These grounds are reported to be close to the Balearic Islands (Garcia et al., 2005) and next to the coast (e.g. Alvarez-Berastegui et al., 2014). Thus, bullet tuna spawning locations are more likely to be in areas where salinity is spatially homogeneous (Alvarez-Berastegui et al., 2014) and water temperature allows optimal breeding conditions (Schaefer, 2001). Mature individuals can be observed from May to September in the Mediterranean Sea (Piccineti et al., 1996; Macías et al, 2005; Kahraman et al., 2010). Subsequently, they leave the Mediterranean via the Alboran Sea, which acts as a migratory pathway, and pass through the Strait of Gibraltar (Rodriguez-Roda, 1966). Nevertheless, the complete migratory behaviour of bullet tuna is yet to be fully understood (Reglero et al., 2012).

The North Atlantic Oscillation (NAO) index has been widely used to model climate oscillation effects on marine ecosystems and climate variability in the Atlantic Ocean (Báez et al., 2013a,b) and Northern Hemisphere and can therefore be applied to the Mediterranean Sea. This index is based on the difference between the high-pressure centre located over the Azores archipelago and the low-pressure centre in the Atlantic Ocean near Iceland. The NAO acts as the main source of climate variability in the North Atlantic by modifying the intensity of the westerlies (Hurrell, 1995). The index not only undergoes interannual variability but also intraannual variability, which mainly occurs during winter (Hurrell, 1995). In addition, a temporal lag has to be considered when studying the biological effects caused by atmospheric oscillation shifts, because these oscillations and their biological impact may be

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