

Effects of the North Atlantic Oscillation on Spanish catches of albacore, *Thunnus alalunga*, and yellowfin tuna, *Thunnus albacares*, in the North–east Atlantic Ocean

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Abstract

Effects of the North Atlantic Oscillation on Spanish catches of albacore, Thunnus alalunga, and yellowfin tuna, Thunnus albacares, in the North–east Atlantic Ocean.— Tuna are highly migratory pelagic species (HMPS) with great importance in commercial fishing. Several authors have highlighted the effect of climatic oscillations such as the North Atlantic Oscillation (NAO) on HMPS. This paper analyzes the effects of the NAO on two HMPS: albacore, *Thunnus alalunga*, and yellowfin tuna, *Thunnus albacares*. Fishing data from the Spanish fleet operating in the North Atlantic area were obtained from the International Commission for the Conservation of Atlantic Tunas (ICCAT) database. The results show a positive correlation between the NAO index and the Catch per Unit Effort (CPUE) for both albacore and yellowfin tuna, depicting a potential effect on their capturability.

Key words: Climate oscillation, Pelagic migratory species, Fisheries, North Atlantic

Resumen

Efectos de la Oscilación del Atlántico Norte en las capturas españolas de atún blanco, Thunnus alalunga, y de rabil, Thunnus albacares, en el océano Atlántico nororiental.— Los túnidos son considerados grandes migrantes pelágicos (GMP) y tienen un elevado interés en la pesca comercial. Varios autores han puesto de relieve el efecto de las oscilaciones climáticas como el índice Oscilación del Atlántico Norte (NAO) en los GMP. En este trabajo se analizan los efectos de la NAO en dos especies de GMP: el atún blanco, *Thunnus alalunga*, y el atún de aleta amarilla o rabil, *Thunnus albacares*. Los datos sobre pesca de la flota española que faena en la zona del Atlántico Norte se obtuvieron de la base de datos de la Comisión Internacional para la Conservación del Atún Atlántico (CICAA). Los resultados muestran una relación positiva entre el índice NAO y la captura por unidad de esfuerzo (CPUE) tanto para el atún blanco como para el rabil, lo que refleja un efecto potencial sobre su capturabilidad.

Palabras clave: Oscilación climática, Especies migrantes pelágicas, Pesquerías, Atlántico Norte

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Introduction

Tuna species are an important fishing and commercial resource and have been exploited since antiquity. Their migratory and gregarious behavior makes them especially susceptible to some fishing gear. Two tuna

species, skipjack tuna, *Katsuwonus pelamis*, and yellowfin tuna, *Thunnus albacares*, are currently among the top 10 fish catches in the world (FAO, 2010). The International Commission for the Conservation of Atlantic Tunas (ICCAT) is responsible for the conservation and management of tuna and tuna-like

fishes in the Atlantic Ocean and contiguous waters. ICCAT promotes the collection of biological and fishery data concerning tuna and tuna-like species and the analysis of statistical information related to the state of conservation and trends in abundance of these fishery resources exploited in the ICCAT competence area. According to available ICCAT data, albacore, *Thunnus alalunga*, and yellowfin tuna, *Thunnus albacares*, constitute the major part of tuna catches by the North Atlantic Spanish fleet.

Several authors have discussed the effect of climatic oscillations on migratory species (Robinson et al., 2009), particularly on various tuna species, such as the Atlantic bluefin tuna, *Thunnus thynnus* (Macías et al., 2012; Báez et al., 2013). For this reason, some authors propose modeling the response of migratory species to large-scale climatic phenomena integrating weather conditions in large areas, such as the North Atlantic Oscillation (NAO), rather than studying the effect of local conditions (Forchhammer et al., 2002; Robison et al., 2009). The NAO is considered the largest source of variability—both seasonal and interannual—affecting the climate of the North Atlantic area: Europe, North Africa and North America (Hurrell, 1995). The NAO refers to an oscillation between the anticyclone of the Azores and a low-pressure area near Iceland, which redistributes air mass from the Arctic to the subtropical Atlantic (Hurrell, 1995). Part of the Atlantic and adjacent seas (particularly the Mediterranean Sea) respond quickly and locally to the NAO by varying the surface sea temperature, the depth of the ocean mixed layer, the ocean heat content, the thickness of the ocean ice shelf, surface current circulation, and the intensity and direction of the prevailing winds (Visbeck et al., 2001).

We hypothesized that the NAO could have an effect on tuna catches. The aim of the present study was to analyze the effect of the NAO on Spanish albacore and yellowfin fishery captures in the North Atlantic.

Material and methods

ICCAT compiles capture data reported by member states by fishing gear and area (called task I); fishing effort data are also sorted by fishing gear and area (called task II). These data are freely downloadable from the ICCAT website. Fishing gear used to catch tuna in the ICCAT area mainly consists of baitboat, purse-seine and surface longline. Cases with available historical data series of more than ten years according to type of fishing gear (baitboat, purse seine, troll and longline) and species were albacore caught using purse seine and baitboat, and yellowfin tuna caught using purse seine and baitboat.

Albacore is a medium size tuna. The ICCAT recognizes two stocks of albacore in the North Atlantic region, one in the Atlantic *sensu stricto* and another in the Mediterranean Sea. The present study includes only data from the Atlantic stock because only Spanish Atlantic fleet catches were taken into consideration.

Yellowfin tuna is a cosmopolitan species distributed in open waters of tropical and subtropical areas of the three oceans, not being present in the Mediterranean. It is assumed that there is a single yellowfin tuna stock for the whole Atlantic Ocean.

NAO data were collected from the National Oceanic and Atmospheric Administration (NOAA) website: <http://www.cpc.ncep.noaa.gov>. We used the NAO average data per year for the analyses. However, as many authors (e.g., Hurrell, 1995) emphasize that the NAO has its maximum effect between November and April, we also used the NAO average of these months. This variable was called winter NAO (NAOw).

We performed linear and non-linear regression between the CPUE (Catch Per Unit Effort by species, fishing gear and year, retrieved from the ICCAT task II data) as the dependent variable, and climate indexes

Table 1. Results of the significant linear and non-linear relationships between NAO and albacore and yellowfin CPUE: R^2 . Determination coefficient; F. F-Fisher; df. Degrees of freedom; Cte. Constant; b. Slope.

Tabla 1. Resultados de las relaciones significativas lineales y no lineales entre la NAO y CPUE del atún blanco y la del rabíl: R^2 . Coeficiente de determinación; F. F de Fisher; df. Grados de libertad; Cte. Constante; b. Pendiente.

Function	R^2	F	df	P	Cte	b1	b2	b3
Albacore								
Linear	0.214	5.718	1	0.026	1.604	2.683		
Quadratic	0.418	7.188	2	0.004	0.998	4.282	4.375	
Cubic	0.606	12.074	3	$P < 0.0001$	0.276	0.755	12.734	10.431
Yellowfin tuna								
Linear	0.275	7.948	1	0.01	35.221	34.236		
Quadratic	0.401	6.695	2	0.006	29.845	48.414	38.786	
Cubic	0.493	6.152	3	0.004	24.795	23.734	97.288	72.997
Exponential	0.281	8.194	1	0.009	28.642	0.856		

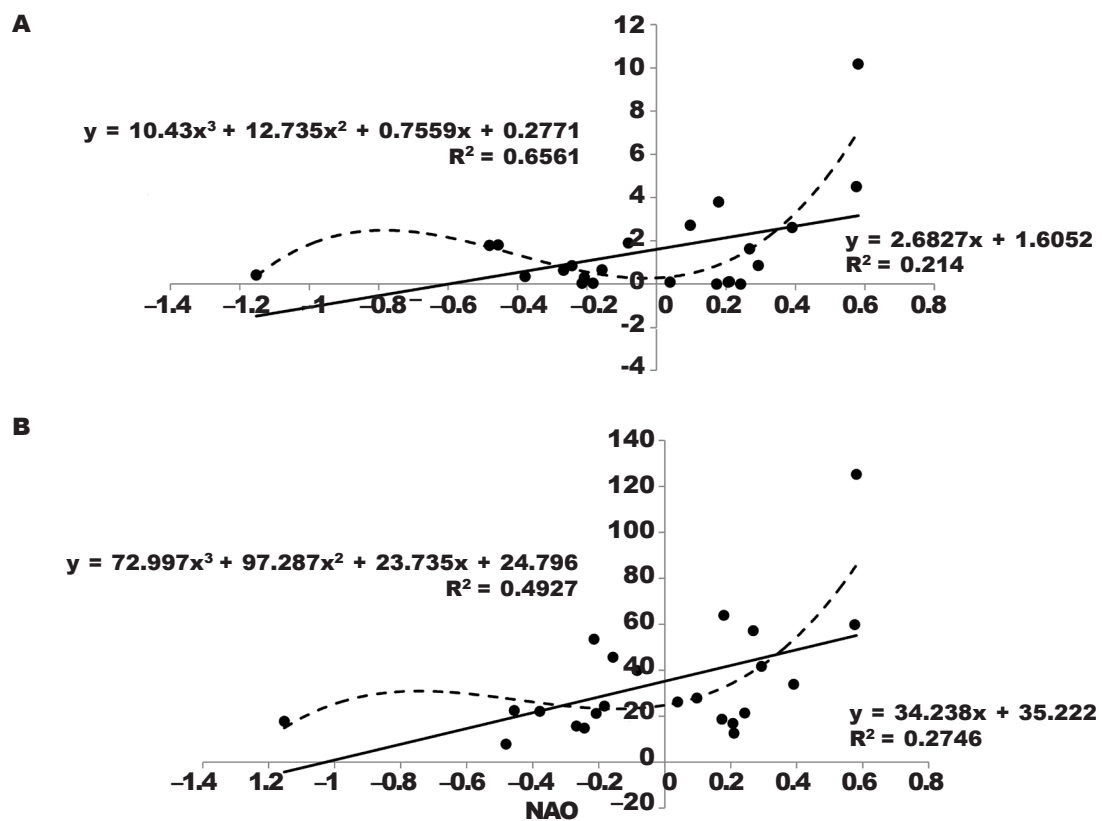


Fig. 1. CPUE of albacore (A) and yellowfin tuna (B) plotted for the Atlantic Spanish purse seine fishery, and NAO as independent variable. A positive trend towards the positive NAO values is observed. The most significant linear and non-linear relationship (together with its function) is showed. Continuous line represent the linear trend (function shown on right), dashed line represent the non-linear trend (function shown on left).

Fig. 1. La CPUE del atún blanco (A) y del rabil (B) para la pesca con redes de cerco en la costa atlántica de España representada gráficamente y la NAO como variable independiente. Se observa una tendencia positiva con respecto a los valores positivos de la NAO. Se muestra la relación lineal y no lineal más significativa (junto con su función). La línea continua representa la tendencia lineal (la función se muestra a en la derecha) y la línea discontinua representa la tendencia no lineal (la función se muestra en la izquierda).

(NAO and NAOw) as independent or explanatory variables. In all cases, the normality of the data was verified using the Kolmogorov–Smirnov test.

Results and discussion

We obtained a positive significant linear and non-linear regression between the CPUE (the unit of effort being hours at sea) for the Atlantic albacore and NAO (table 1, fig. 1A) and between the CPUE of the North Atlantic Spanish baitboat fishery and NAO (table 1, fig. 1B).

Atmospheric oscillations modify the intensity of several meteorological phenomena, such as wind, rain and storms. They increase the run-off and nutrient input to the sea, changing response to the

trophic levels of marine ecosystems (Drinkwater et al., 2003) and exploited resources. These meteorological phenomena may, in turn, affect fishery resources in at least two aspects: i) the fishing effort value, and ii) the variability of the pelagic ecosystem. When referring to fishing effort, climatic oscillations at sea, such as a severe storm, might reduce the fishing effort. Likewise, occurrences promoting favorable weather conditions (e.g., a period of stability and calm sea) might increase the fishing effort in a certain area. However, we did not observe a significant correlation between NAO and fisheries effort either in albacore fisheries ($r = 0.408$, $P = 0.053$) or in yellowfin tuna fisheries ($r = -0.367$, $P = 0.085$). Moreover, meteorological phenomena could affect the biology and behavior of large migratory species of commercial interest such as those considered

here, either affecting the trophic resources available, their migration period, or their distribution and/or local abundance. Changes in the depth of the thermocline could also affect the availability of fish (*i.e.*, catchability) (Lehody, 2000).

Our analyses of Spanish catches of purse seine albacore catches and baitboat yellowfin tuna catches in the North Atlantic showed a positive, significant regression of CPUE with the NAO as an independent variable. However, we did not find a significant correlation between fishing effort and atmospheric oscillations in any of the fisheries studied. These results suggest that the NAO effects on the variable CPUE mainly occur through effects on the pelagic ecosystem, affecting the abundance of individuals (or their catchability) of the Spanish fishery target species, albacore and yellowfin tuna, in a given area.

The relation between CPUE and NAO was positive in both species. This can be explained by the fact that, during positive NAO phases, western winds that could shift the species shoals eastward towards European and African coasts—the area where the Spanish fleet operates— increase. Furthermore, during positive NAO phases, the number and intensity of North Atlantic storms increase, contributing to the occurrence of phytoplankton blooms (Martínez-García et al., 2010; Baez et al., 2014), which in turn may attract potential prey of tuna species. According to Consoli et al. (2008), albacore tuna can be considered a top carnivore, and small pelagic fish (*e.g.*, Aulopiformes and Clupeiformes) and cephalopods are its potential prey. In this line of reasoning, Báez & Real (2011) found a significant relationship between monthly landings of anchovy, *Engraulis encrasicolus*, and the NAO around the Gulf of Cádiz. It is therefore possible that favorable conditions for small pelagic fishes also attract the top predators in certain areas.

Our findings suggest it would be desirable to incorporate NAO predictive models into current models used by ICCAT experts for fisheries management so as to enable more efficient management of large migratory pelagic fisheries.

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