NORTH ATLANTIC OSCILLATION LEADS TO THE DIFFERENTIAL INTERANNUAL PATTERN DISTRIBUTION OF SEA TURTLES FROM TROPICAL ATLANTIC OCEAN

J.C. Báez[1], P. Pascual-Alayón[1], Mª L. Ramos[1], F.J. Abascal[1]

SUMMARY

Observer records from Spanish purse seiners targeting tropical tunas indicate by-catch of six different sea turtles species in the Atlantic Ocean. Incidental catch of sea turtle from the purse seiners fisheries targeting tropical tunas occur, but the mortality is very low, and not significant. However, the incidental catch of sea turtles could provide relevant information about the species' distribution. The North Atlantic Oscillation (NAO) is the principal atmospheric oscillation that module the trade winds in the North Atlantic Ocean. The principal aim of present study is understanding the effect of the NAO in the interannual pattern distribution of sea turtle incidental catch by this fishery. The number of total sea turtle records in years with positive NAO phases is significantly higher that the number of sea turtle interactions in years with negative NAO phases.

RÉSUMÉ

Les registres d'observateurs de senneurs espagnols ciblant les thonidés tropicaux indiquent des prises accessoires de six espèces différentes de tortues marines dans l'océan Atlantique. Des captures accessoires de tortues marines se produisent dans les pêcheries de senneurs qui ciblent les thonidés tropicaux, mais la mortalité est très faible et n'est pas importante. Cependant, les prises accessoires de tortues marines pourraient fournir des informations pertinentes sur la répartition des espèces. L'Oscillation Nord-Atlantique (NAO) est la principale oscillation atmosphérique qui module les alizés dans l'océan Atlantique Nord. Le but principal de cette étude est de comprendre l'effet de la NAO dans le schéma de distribution interannuelle des prises accessoires de tortues marines réalisées par cette pêcherie. Le nombre total de registres de tortues marines au cours des années marquées par des phases positives de NAO est significativement plus élevé que le nombre d'interactions avec les tortues marines au cours des années marquées par des phases négatives de NAO.

RESUMEN

Los registros de observadores de la pesquería de cerco española que se dirige a los túnidos tropicales indicaban captura fortuita de seis especies diferentes de tortugas marinas en el océano Atlántico. Se producen capturas fortuitas de tortugas marinas en las pesquerías de cerco que se dirigen a los túnidos tropicales, pero la mortalidad es muy baja y no es estadísticamente significativa. Sin embargo, la captura fortuita de tortugas marinas podría proporcionar información relevante sobre la distribución de las especies. La Oscilación del Atlántico Norte (NAO) es la principal oscilación atmosférica que modula los vientos alisios en el océano Atlántico norte. El objetivo principal del presente estudio es comprender el efecto de la NAO en la el patrón de distribución interanual de la captura fortuita de tortugas marinas de esta pesquería. El número de registros totales de tortugas marinas en años con fases NAO positivas es significativamente mayor que el número de interacciones con tortugas marinas en años con fases NAO negativas.

KEYWORDS

Atmospheric oscillation, Atlantic Ocean, migration, sea turtles

[1] Instituto Español de Oceanografía (IEO), Centro Oceanográfico de Canarias. Vía Espaldón, dársena pesquera, Parcela 8 38180 Santa Cruz de Tenerife. josecarlos.baez@ca.ieo.es; pedro.pascual@ca.ieo.es; mlourdes.ramos@ca.ieo.es; francisco.abascal@ca.ieo.es

1. Introduction

Six endangered sea turtle species are distributed in the Atlantic Ocean: loggerhead (*Caretta caretta*), green turtle (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricate*), Kemp´turtle (*Lepidochelys kempii*) and olive ridley (*L. olivacea*) (Márquez, 1990). For these species, except for the leatherback turtle, there is a larger number of breeding females in the western part of the Atlantic Ocean (Marine Turtle Specialist Group, 1996; Erhart *et al*., 2003; Abreu-Grobois & Plotkin, 2008; Mortimer & Donnelly, 2008; Witt *et al*., 2009). Incidental catch of sea turtles from the purse seiners fisheries targeting tropical tunas occur, but the mortality is very low, and not significant (Bourjea *et al*., 2014; Montero *et al*., 2016). However, the incidental of sea turtle from purse seine fisheries targeting tropical tunas can provide relevant information about sea turtle distribution.

The North Atlantic Oscillation (NAO) is the principal atmospheric oscillation that modules the trade winds in the North Atlantic Ocean. The NAO index has been widely used to model climate oscillation effects and climate variability in the Atlantic Ocean (Báez *et al*., 2013a). 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; Hurrell *et al*., 2003).

Several authors have suggested that migratory marine species (such as large pelagic fish, sharks, or sea turtles) may respond to climate oscillations by alterations in their phenological characteristics, abundance, distribution, recruitment and physical condition (Mejuto 2003; Chaloupka *et al*., 2008; Mazaris *et al*., 2008; Graham and Harrold, 2009; Báez *et al*., 2011a,b, 2013b). According to Robinson *et al*. (2009), the NAO could modify the migration movements of highly migratory animals.

The principal aim of the present study is understanding the effect of the NAO in the interannual distribution pattern of sea turtle incidental catch by purse seiners targeting tropical tuna in the Atlantic Ocean.

2. Material and Methods

2.1. Fisheries data collection

The Spanish Institute of Oceanography (IEO) observers on board commercial purse seiner freezer vessels follows a scientific programme, implementing the EU Fishing Data Collection Programme (PNDB) (Parliament and Council Regulation (EU) No 2017/1004 of 17 May 2017). The data collection and processing methodology is common for the Atlantic and Indian oceans (Ariz *et al*. 2010) and involves three research bodies of the European Union: Institut de Recherche pour le Développement (IRD, France), Centro Tecnológico en Investigación Marina y Alimentaria (AZTI-Tecnalia, Spain) and Instituto Español de Oceanografía (IEO, Spain). Sample forms from this observer program can be dowloaded from ICCAT website https://www.iccat.int/Documents/SCRS/Manual/CH4/Annex%201%20to%20Chapter%204.zip.

The main aim is obtaining direct information on catches and discards of target and by-catch species (e.g. catch and by-catch species, number of individuals, size, and other biological data). In the present study, we used data recorded by IEO from 2003 to 2016 from the above-mentioned programme.

The scientific observers onboard are, inter alia, trained to identify sea turtles, and to record all sea turtle interactions with purse seiners.

2.2. Atmospheric data

The monthly values for the NAO for the period studied (2003-2016) were provided by the National Oceanic and Atmospheric Administration (NOAA) (available at: http://www.noaa.gov). We used the average value of the NAO index calculated for the current year. However, we expected a delay between NAO and effect in the turtle migrations, for this reason we used different delay, between one months and nine months (NAO1, NAO2, NAO3, NAO4, NAO5, NAO6, NAO7, NAO8, and NAO9).

2.3. Statistical analysis

We tested the probability to catch a number of sea turtle per each species major than the average for this species in the study period. Binary logistic regression is widely used for study the relationships between NAO and the probability of response of target variables (for example Báez *et al*., 2013). We used a binary logistic regression to estimate the probability to obtain a sea turtle per each species value of a particular year higher than the average sea turtle for this species the years. Consequently, we assigned the value 1 when the sea turtle of a particular species of a particular year was higher than the mean sea turtle of the study period pooled together, while we assigned the value 0 when the mean was lower within of the study period. The explicative variables used were: number of fishing operations per year, NAO1, NAO2, NAO3, NAO4, NAO5, NAO6, NAO7, NAO8, and NAO9. We used a performed forward-backward stepwise logistic regression. To evaluate the models we assessed their goodness of-fit, by means of the R^2 Nagelkerke and Omnibus test of the model.

3. Results

We observed 1284 sea turtles incidental catch within of purse seiners during the studied period (since 2003 to 2016) round of Western-central Atlantic Ocean (**Figure 1**). Near to the 99% of sea turtle observed were released alive to the sea. The olive ridley is the most frequency turtle (653 individuals).

We found that the probability to catch a number of olive ridley turtles presented in years with positive NAO9 phases is significantly high that the number of sea turtle presented in years with negative NAO9 phases. The logit function (y) derived from logistic regression presents the form:

$$\text{Logit} = -4.787 + \text{Number of fishing operation} * 0.019 + \text{NAO9} * 2.056$$

R^2 Nagelkerke= 0.806; and Omnibus test of the model, ji-squared= 31,275, $P<0.001$.

4. Discussion

In a previous study, Báez *et al* (2011a) found a relationship between positive NAO phases and loggerhead abundance around the Strait of Gibraltar in turn related to the link of the NAO with wind and temperature patterns. In a similar way, the findings of the current study suggest a relationship between NAO phases and the distribution of olive ridley in the Atlantic Ocean.

As Visbeck *et al*. (2001) reported, a positive NAO phase results in stronger-than-average westerly winds across northern mid-latitudes. These prevailing westerlies could benefit sea turtles born on American beaches that are attempting to cross the Atlantic Ocean; however, they could be detrimental to olive ridley present in the Eastern Atlantic Ocean to cross to the Western. This would lead to sea turtle accumulating around the Western Central Atlantic Ocean areas during positive NAO phases. Therefore, the probability of bycatch an olive ridley during positive NAO phases would also increase.

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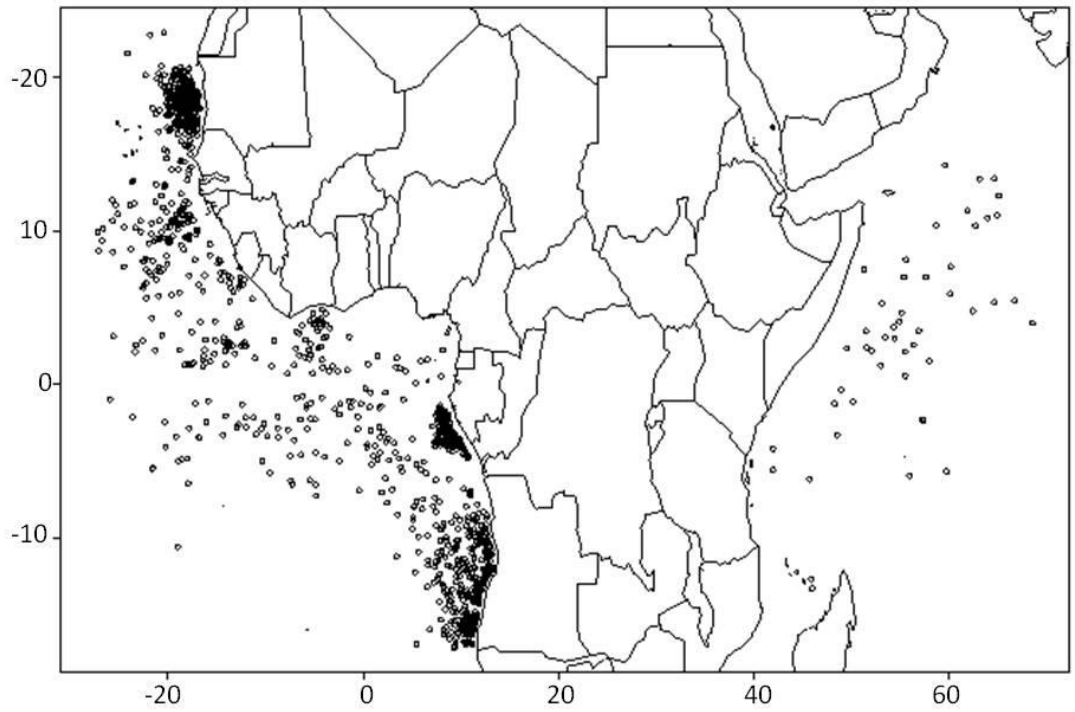

Figure 1. Distribution sea turtle bycatches from the purse seiners fisheries targeting tropical tunas.