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STOCK IDENTIFICATION OF ATLANTIC BLUE SHARK (*PRIONACE GLAUCA*)

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SUMMARY

*We conducted a review of all available information on genetics, tagging, and movement of blue shark (*Prionace glauca*) in the Atlantic Ocean since 2015 to evaluate stock structure and inform the upcoming stock assessment. There is evidence of a north-south movement across the equator by larger, older individuals particularly in the eastern Atlantic. However, the observed movement rates between the North and South Atlantic appear to be low enough to consider separate spatial units for stock assessment. When considering genetics, several studies found complete genetic homogeneity across the Atlantic Ocean (and globally in some cases). However, small sample size combined with the pace of drift of genetic traits and population size may impact results. Additional studies have found genetic differentiation within the Atlantic Ocean, and between the Atlantic Ocean and the Mediterranean Sea, which further confounds splitting stocks based on genetics. Outside of the Mediterranean Sea, there is no new evidence to suggest that further splitting of the Atlantic Ocean beyond a northern and southern stock is required at this time.*

RÉSUMÉ

*Le présent document passe en revue toutes les informations disponibles sur la génétique, le marquage et les déplacements du requin peau bleue (*Prionace glauca*) dans l'océan Atlantique depuis 2015 afin d'évaluer la structure du stock et d'informer l'évaluation du stock à venir. Il existe des preuves d'un mouvement nord-sud à travers l'équateur par des spécimens plus grands et plus âgés, en particulier dans l'Atlantique Est. Toutefois, les taux de déplacement observés entre l'Atlantique Nord et l'Atlantique Sud semblent suffisamment faibles pour envisager des unités spatiales distinctes pour l'évaluation du stock. En ce qui concerne la génétique, plusieurs études ont fait apparaître une homogénéité génétique complète dans l'océan Atlantique (et au niveau mondial dans certains cas). Toutefois, la petite taille de l'échantillon, combinée au rythme de dérive génétique et à la taille de la population, peut avoir une incidence sur les résultats. D'autres études ont révélé une différenciation génétique au sein de l'océan Atlantique et entre l'océan Atlantique et la mer Méditerranée, ce qui rend encore plus difficile la division des stocks sur la base de la génétique. En dehors de la mer Méditerranée, il n'y a pas de nouvelles preuves qui suggèrent qu'une nouvelle division de l'océan Atlantique en un stock nord et un stock sud est nécessaire à l'heure actuelle.*

RESUMEN

*Se llevó a cabo una revisión de toda la información disponible sobre genética, marcado y movimiento del tiburón azul (*Prionace glauca*) en el océano Atlántico desde 2015 para evaluar la estructura del stock e informar sobre la próxima evaluación de stock. Hay indicios de un movimiento de norte a sur a través del ecuador por parte de ejemplares de mayor tamaño y edad, especialmente en el Atlántico oriental. Sin embargo, las tasas de movimiento observadas entre el Atlántico norte y sur parecen ser lo suficientemente bajas como para considerar unidades espaciales separadas para la evaluación de stock. En cuanto a la genética, varios estudios han revelado una homogeneidad genética completa en todo el océano Atlántico (y a escala global en algunos casos). Sin embargo, el pequeño tamaño de la muestra, combinado con el ritmo de deriva de los rasgos genéticos y el tamaño de la población, puede influir en los resultados. Otros estudios han hallado diferencias genéticas dentro del océano Atlántico y entre éste y el mar Mediterráneo, lo que dificulta aún más la división de los stocks en función de la genética. Fuera del mar Mediterráneo en este momento no hay nuevos indicios que sugieran la necesidad de seguir dividiendo el océano Atlántico en dos stocks, un stock del norte y otro del sur.*

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KEYWORDS

Genetics, tagging, movement, stock, blue shark

1. Introduction

The last stock assessment for blue shark was conducted in 2015 (https://www.iccat.int/Documents/SCRS/DetRep/BSH_SA_ENG.PDF). At that time, the Atlantic population was considered to be composed of two stocks; a north Atlantic population and a south Atlantic population. However, there have been several new sources of published information since the initial consideration of the stock delineation of blue shark in the Atlantic, including tagging data and genetic analyses. A review of these studies is necessary to reappraise stock delineation and stock structure.

2. Methods

An unstructured literature search of peer-reviewed published studies (January 2014-February 2023), was conducted using Google Scholar to collect the most recent information on blue shark. The initial, non-systematic search was performed through a combination of the following terms: "blue shark" "genetics," "tag," "movement," "stock,", "migration," "Atlantic," "satellite," and "population." Additional sources were included based on personal communication and unpublished data.

2.1 Mark-Recapture

To the best of our knowledge, the most data available on conventional tagging of blue sharks in the Atlantic is from the National Marine Fisheries Service (NMFS) Cooperative Shark Tagging Program (CSTP). The CSTP was initiated in 1962 with an initial group of less than 100 volunteer fishermen involved in tagging feasibility studies. The program expanded in subsequent years and currently includes over 6,500 volunteers distributed along the Atlantic and Gulf coasts of North America, and Europe. An overview of the CSTP is included in Casey (1985), Kohler et al. (1998) and Kohler and Turner (2019). Kohler and Turner (2019) report that since 1962, a total of 117,962 blue sharks have been captured with a return rate of 7.0%. The maximum distance traveled was 6432.6 km and the longest time at liberty was 15.9 years. Long distance movements of the blue shark were observed between the U.S. Atlantic coast to all parts of the North Atlantic. The spatial distribution of tags and recaptures over entire range of the North Atlantic further substantiates the designation of a single North Atlantic stock for this widely distributed species. However, of all blue sharks tagged only 10 blue sharks traveled across the Equator from release locations off the U.S. northeast coast, Canada, United Kingdom, Portugal, and north of the Equator (**Figure 1**). Additionally, one blue shark tagged off Uruguay traveled north of the equator, southwest of Guinea (McCandless, unpublished).

2.2 Satellite Tagging

Campana *et al.* (2015) provided a summary of current population status of blue sharks across the North Atlantic population to aid the Special Concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), in its next population status report for blue shark. Conventional tag information indicated substantial movements but did not appear to be any obvious tendency for recaptures near the tagging location. Thus, there was no evidence of repeated annual returns to a particular location. A tagging study carried out using 23 pop-up satellite archival tags (PSAT) off Canada indicted all blue sharks moved into warmer off-shelf waters to the east and south in the winter, often in association with the Gulf Stream, but no crossings of the equator. Since 2014, Vandeperre et al. (2014) and Howey et al. (2017) investigated the migratory patterns of blue shark by life stage in the North Atlantic. In Vandeperre et al. (2014), blue sharks tagged in the central North Atlantic (n = 34) were tracked for distances up to an estimated 28,139 km over a period of 952 days. From the central Atlantic, southward migrations towards tropical and sub-tropical waters were observed but generally for larger subadults and adults (Figure 2). Howey et al. (2017) deployed 33 tags on blue sharks caught in the northwest Atlantic that were tracked for up to 273 days and the largest net displacement was 3704.1 km. All sharks tagged of the US northeast coast (juveniles and adult males) moved southeast off the continental shelf with immature females and mature males traveling further south. One mature female with mating wounds migrated from the Bahamas to the Mid-Atlantic Ridge.

Coelho *et al.* (2020) deployed 20 miniPATs and 6 SPOT tags on blue sharks captured off the northeast Atlantic, near the Cabo Verde Islands. There was no defined pattern in the movements, most animals moved west and southeast, but one blue shark that was tagged inside the Cabo Verde moved a significant distance towards the equatorial waters. In the southwest Atlantic, Carvalho et al. (2015) reported on 16 satellite tagged sharks captured off Brazil. Most sharks remained in the area of the tagging location. However, one mature female performed a trans-oceanic migration, spanning the entire equatorial Atlantic Ocean in 209 days from the northeast coast of Brazil to the Gulf of Guinea, Africa. No sharks were observed traveling north of the equator.

2.3 Genetics

A number of genetic studies on the population structure of blue shark have been conducted since the last assessment. One study published in 2017, designed to examine the global genetic population structure, show temporally stable genetic homogeneity among the three Atlantic nurseries at both nuclear and mitochondrial markers, suggesting basin-wide panmixia. In addition, comparison of mitochondrial DNA control region (mtDNA CR) sequences from Atlantic and Indo-Pacific locations also indicated genetic homogeneity and unrestricted female-mediated gene flow between ocean basins (Veríssimo *et al.* 2017). Bailleul et al. (2018) using genetic analysis of more than 200 samples collected from the Mediterranean Sea, North Atlantic and Pacific Oceans using mtDNA and microsatellite markers found a complete genetic homogeneity across the entire studied range. However, these authors caution on these results due to low sample size in some areas and the scenario of widespread genetic interdependence can hide a wide range of demographic situations leading the authors to propose the concept of “population grey zone”, i.e. the pace of drift of genetic traits and thus the accumulation of detectable genetic differentiation depends strongly on the population size and number of migrants and the population structure may be too recent or too faint to be detected. Leone et al. (2017) found no no obvious pattern of geographical differentiation but found significant differences in samples from the Mediterranean Sea and the northeast Atlantic, which appears to reject the assumption of panmixia. Nikolic et al. (2022) using an updated genetic analysis found two main groups, Mediterranean Sea and northern Atlantic samples, and the Indo-west Pacific samples (Southern population). They also found further genetic differentiation within the Atlantic Ocean, and between the Atlantic Ocean and the Mediterranean Sea.

3. Results and Discussion

The distributions and movements of blue shark suggest those tagged in the northwest Atlantic move east and southeast off the continental shelf whereas those tagged in the northeast Atlantic moved west and to the south. In the southeast Atlantic off Brazil, individuals generally stayed in the area where they were tagged. However, one mature female conducted a trans-oceanic migration, spanning the equatorial Atlantic from the northeast coast of Brazil to the Gulf of Guinea, Africa. Regardless of area, in general, adults traveled greater distances than juveniles and females tended to travel farther then males. While there is evidence of some north-south movement across the equator, the number of individuals moving between the north and south Atlantic appear to be low enough to consider them separate spatial units for stock assessment.

Several studies have found complete genetic homogeneity across the Atlantic Ocean (and globally in some cases). However, small sample size combined with the pace of drift of genetic traits and population size may impact results. The most recent study (Nikolic *et al.*, 2022) suggests genetic differentiation between blue shark from the Mediterranean Sea and the northern Atlantic Ocean which lends consideration of the revision of the management units. These results confirm previous suggestions of a differentiated Mediterranean population based on mitochondrial (Leone *et al.*, 2017) and microsatellite data (Bailleul *et al.*, 2018). However, Nikolic *et al*. (2022) suggest more samples of blue shark from these areas will help investigate connectivity between the northeast Atlantic and the Mediterranean Sea.

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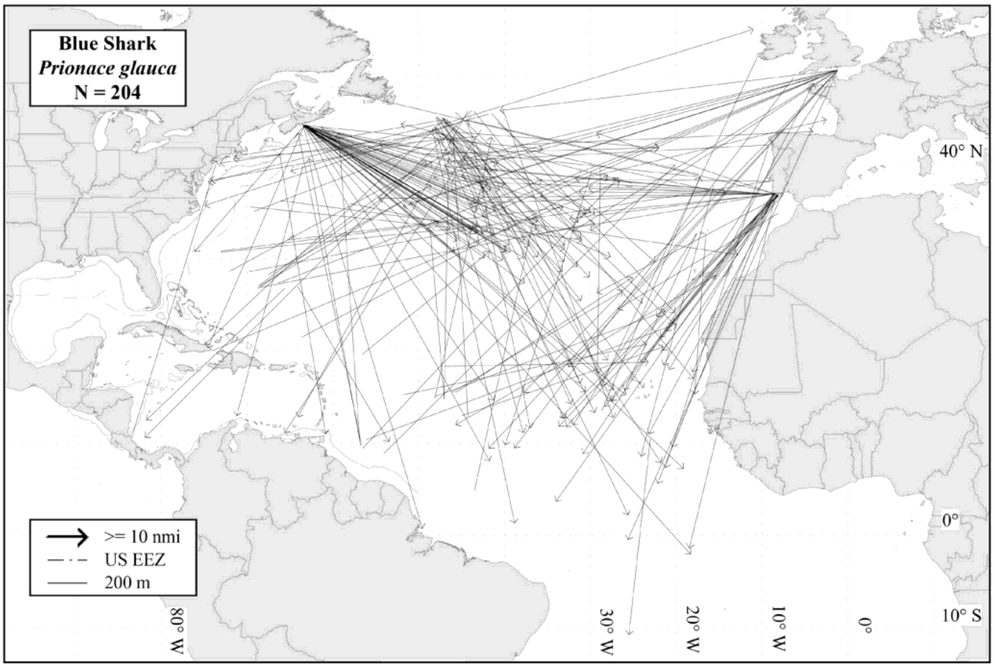

Figure 1. From Kohler and Turner (2019). "Distribution of recapture locations for the blue shark, *Prionace glauca*, tagged outside the U.S. EEZ and distance traveled greater than 1,000 nm, from the NMFS Cooperative Shark Tagging Program (1962-2013)."

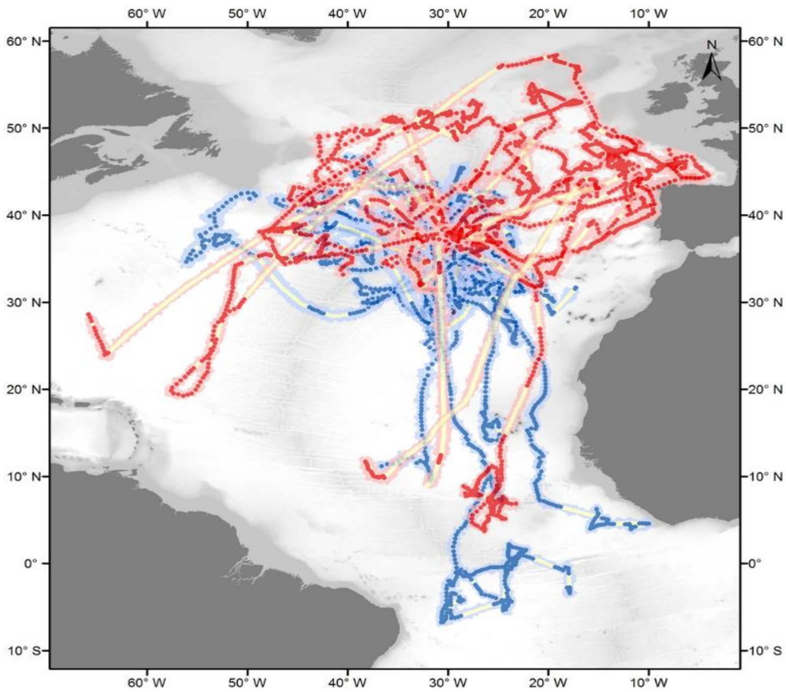

Figure 2. From Vandeperre *et al.* (2014), "Reconstructed migratory pathways of blue sharks tagged in the Azores. Red and blue dots represent the most probable daily position estimates of respectively female and male sharks, with pink and light blue clouds representing the respective errors around the position estimates. Yellow dots indicate data gaps (i.e., days without position information within 72 h intervals)."