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British sharks in Sicily: records of long-distance migration of tope shark (*Galeorhinus galeus*) from the north-eastern Atlantic to the Mediterranean Sea

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Abstract

This study presents data of two adult female tope sharks, *Galeorhinus galeus* (Linnaeus 1758) that were tagged in the north-east Atlantic and recaptured in the central Mediterranean Sea. The sharks were tagged in Scotland in 2009 and Ireland in 2015 and were recaptured off the south coast of Sicily in 2014 and 2017, respectively. The specimen captured in Scotland was a female with an initial total body length of 175 cm, which grew 37 cm and gained about 10 kg on recapture (5.4 years later, or 1967 days). The specimen captured in Ireland was a pregnant female that grew 14 cm between captures (spanning 248 days), with an estimated age of 15-17 years. The growth rate of the two specimens was 6.8 and 7.8 cm year⁻¹, respectively. This growth rate was faster than the annual increments previously suggested for adults of this species. Previous tope shark recapture records in the Mediterranean Sea were limited to the Alboran Sea, coast of Valencia, and the coast of Algeria. Thus, the records for the two females in the current study provided the first evidence of long distance entrance of the north-east Atlantic tope shark in the Mediterranean Sea. Genetic data are required to establish the connectivity of the population across the north-east Atlantic and Mediterranean, along with the identification of factors driving the migration of females from the north-east Atlantic to lower latitudes.

Keywords: Shark migrations; Tope shark; *Galeorhinus galeus*; Mediterranean Sea.

Introduction

The Tope shark, *Galeorhinus galeus* (Linnaeus 1758), also known as the School shark, is an oceanodromous species (Riede, 2004) that is distributed worldwide in the temperate waters of the Pacific, Atlantic, and western Indian Ocean (Compagno, 1984; Last & Stevens, 1994). It is a viviparous species that has a unique spherical or globular placenta (Compagno, 1984), producing from six to 52 pups per litter (Cox & Francis, 1997), depending on the size of the female (Capapé & Mellinger, 1988). At birth, pups have a body length of 24–32 cm (Capapé *et al.*, 2005). Females spawn once a year, with ovulation occurring in early summer and parturition occurring in spring and early summer, after about 12 months gestation (Walker *et al.*, 2006; Capapé *et al.*, 2005). Tope sharks are thought to be long-lived and slow to mature. In south-eastern Australia, their longevity has been demonstrated by the recapture of tagged individuals after 36 and 42 years in the wild (Olsen, 1990). This species is mainly benthopelagic, both on the continental shelf and

the upper slopes (Last & Stevens, 1994), although pelagic behavior has been observed in the open-ocean, where this species is frequently caught by tuna longlines (Cox & Francis, 1997; Stevens & West, 1997). Previous tagging experiments have demonstrated that this species is a diurnal descending at dawn to depths of up to 600 m before ascending at dusk (West & Stevens, 2001).

The Tope shark is targeted by fisheries in several areas, often leading to severe overexploitation and depletion (Ripley, 1946; Francis, 1998; Punt *et al.*, 2000). It is listed as Vulnerable Globally and Conservation Dependent in Australasia in the International Union for Conservation of Nature (IUCN) Red Data Book (Stevens, 2000). An updated assessment in 2006 (Walker *et al.*, 2006) retained the original Vulnerable global assessment, and presented new regional assessments of this species as Critically Endangered in the Southwest Atlantic, Vulnerable in Australia and South Africa, Near Threatened in New Zealand, and of Least Concern in the Eastern North Pacific. In North East Atlantic and Mediterranean Sea, *G. galeus* is classified as Vulnerable with declining

populations by the IUCN (McCully *et al.*, 2015; Nieto *et al.*, 2015), like the other Triakidae sharks (Colloca *et al.*, 2017). In the Mediterranean Sea, it is listed in the Barcelona Convention Annex II SPA/BD Protocol. Furthermore, the General Fisheries Commission for the Mediterranean Sea (GFCM) states that tope sharks caught with bottom-set nets, longlines and tuna traps must be promptly released unharmed and alive to the greatest extent possible (Recommendation GFCM/36/2012/3). This species is considered as very rare throughout the Mediterranean basin (Capapè *et al.*, 2000; Ragonese *et al.*, 2013). In Italian waters, *G. galeus* has almost disappeared, with only one specimen being recorded during bottom trawl surveys carried out from 1994 to 2009 (Relini *et al.*, 2010). In the Tyrrhenian Sea, the Tope shark has been locally extinct since the beginning of industrial fishing (Ferretti *et al.*, 2005). Individuals have been detected in the by-catch of the swordfish fishery of the Alboran Sea and the Balearic Sea. It is rarely caught in the Strait of Sicily (Megalofonou *et al.*, 2005). It has not been recorded in the Sea of Marmara (Kabasakal, 2003) or the Black Sea (Branstetter, 1984).

The migratory behavior of the species has been documented in Australia. Juvenile Tope sharks (1-2 years old) tend to make local migrations, whereas adults range more widely, moving offshore or north (towards the tropics) in winter, and nearshore or south (poleward) in spring (Olsen, 1954). In the north-east Atlantic, this species undertakes extensive migrations, crossing deep waters to the Canary Islands, the Azores, and the coast of Algeria (Holden & Horrod, 1979). Tagged specimens have also been recaptured in north-west Iceland (Stevens, 2010). A southerly migration from January to September and a return northerly migration from October to December has been hypothesized, as well as ontogenetic changes in migratory behavior (Holden & Harrod, 1979). From 1970-2002, a total of five individuals tagged in Irish waters were recaptured in the western Mediterranean Sea, off the

coast of Algeria and in the Gulf of Valencia (Fitzmaurice *et al.*, 2003). However, knowledge remains limited about whether the long-distance migration of *G. galeus* from the north-east Atlantic to the Mediterranean Sea reflects occasional dispersion or whether is part of a migratory behavior linked to reproduction or feeding.

This short note reports two records of Tope sharks that were tagged in the north-east Atlantic and were recaptured in the northern part of the Strait of Sicily (central Mediterranean Sea). The information presented here is expected to advance current knowledge on the migratory behavior of this species in the region.

Materials and Methods

The Tope sharks were captured by Sicilian artisanal fishers using trammel nets in 2014 and 2017 (Fig. 1). The specimens were originally tagged by the Scottish Sharks Tagging Programme (<https://www.ssacn.org/>) and the Inland Fisheries Ireland-Marine Sport Fish Tagging Programme, respectively (<https://www.fisheriesireland.ie/Tagging/tope.html#tagging-results>).

The first specimen was not available for laboratory analysis, and only data on body weight was recorded at tagging. The second specimen was brought to the laboratory to collect data on total length, girth length, body weight, and maturity. Maturity was assessed using the Medits maturity scale (AA.VV., 2016). In addition, the second and third vertebrae were extracted and left in ammonia for 2-3 h; a 1 mm section was obtained from each vertebra with an IsoMet low-speed cutting machine equipped with a diamond blade. Finally, the vertebrae were embedded in a two-component epoxy resin (Buehler EpoThin resin and Buehler EpoThin hardener in a 5:2 weight ratio). Growth increments were read using a 0.8x dissection microscope connected to a camera.

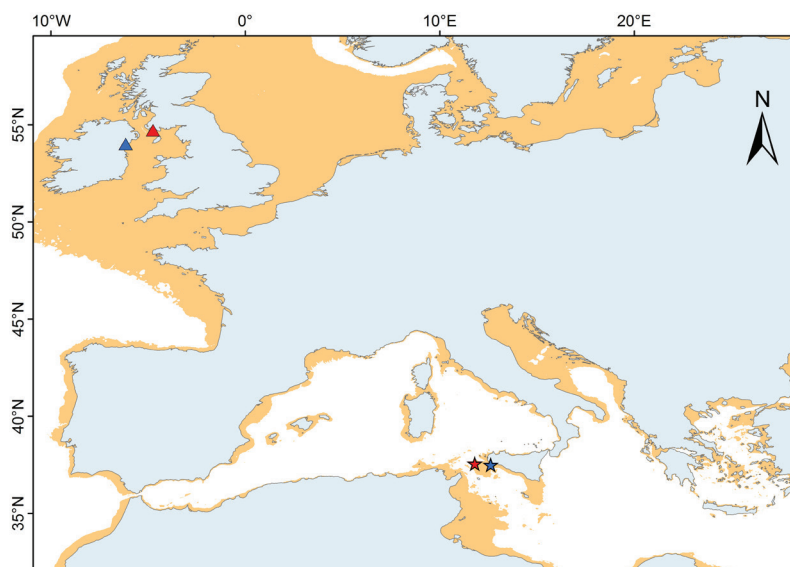


Fig. 1: Map showing the tagging sites (specimen tagged in Scotland, red triangle; specimen tagged in Ireland, blue triangle) and recapture sites (specimen tagged in Scotland, red star; specimen tagged in Ireland, blue star). The orange background represents the continental shelf area (0-200 m depth).

Results and Discussion

Both of the Tope sharks that were recaptured were females that were originally tagged in the Irish Sea. The female tagged in Scotland (tag no. 29351) was captured in Luce Bay (West Scotland: 54.71° N, 4.75° W), on June 14, 2009. It was recaptured offshore from the south-west coast of Sicily on November 4, 2014 (Talbot Bank: 37.33° N, 11.47° E) at a depth of 35 m. Between tagging and recapture, 1967 days passed (5.4 years), with the individual nearly doubling in weight from 11 to 21 kg. Using the length-weight relationship provided by Silva *et al.* (2013), the estimated increase in size was 37 cm, assuming a size of 138 cm total length (TL) at tagging.

The Tope shark (tag no. 45197) from Ireland was tagged in Carlingford Bay (East Ireland: 54.02° N, 0606° W) on June 26, 2015 and was recaptured on April 4, 2017 offshore from Selinunte harbor (South Sicily: 37.32° N, 12.39° W) at about 30 m depth. At tagging, the specimen was 153 cm TL and 21.6 kg in body weight. During its 648 days at sea, its TL increased by 14 cm, whereas its body-weight decreased by 3 kg (Table 1). Gonad analysis showed that the shark was the early stages of pregnancy (stage 3b Medits scale) with 44 eggs in the oviducts, which was higher than the maximum number (41) detected by Capapé & Mellinger (1988). The observed loss in weight of this specimen might be related to the weight being misreported at tagging or the effect of parturition. The female was caught during the season for parturition, and its body size was close to that for first maturity, which is estimated to be between 140 cm TL (Capapé & Mellinger, 1988) and 155 cm (Dureuil, 2013). The south-eastern coast of Ireland, where the female was tagged, is hypothesized as a possible nursery ground for the species, and therefore not far from the corresponding parturition area (Fitzmaurice, 2003). The estimated age from the vertebrae band readings of this female was 15–17 years. Uncertainty in aging was associated with difficulty in identifying the birth ring and the counts of winter rings on the margin (Fig. 2). According to the growth estimates provided by Dureuil & Worm (2015) using tagging data, it should have been about 23 years old; therefore at least 6 years older than our estimate. The younger age of the two tagged females is, however, supported by the tagging data, which indicated that they grew at an annual rate of 6.8–7.8 cm year⁻¹, which was about double the growth rate estimated by Dureuil & Worm (2015) for adult females in the north-east Atlantic.

The two females recaptured in the Strait of Sicily, an area connecting the western and the eastern Mediterranean basins, provided the first evidence of long distance entrance of north-east Atlantic tope shark in the Mediterranean Sea suggesting the possibility for Atlantic individuals to also penetrate the eastern Mediterranean basin. Previously, recapture records of Tope shark in the Mediterranean were limited to the Alboran Sea, coast of Valencia, and the Algerian coasts (Fitzmaurice, 2003). According to Fitzmaurice (2003), *G. galeus* undertakes extensive migrations from the tagging area in the north-east Atlantic. This species has been recaptured as far north

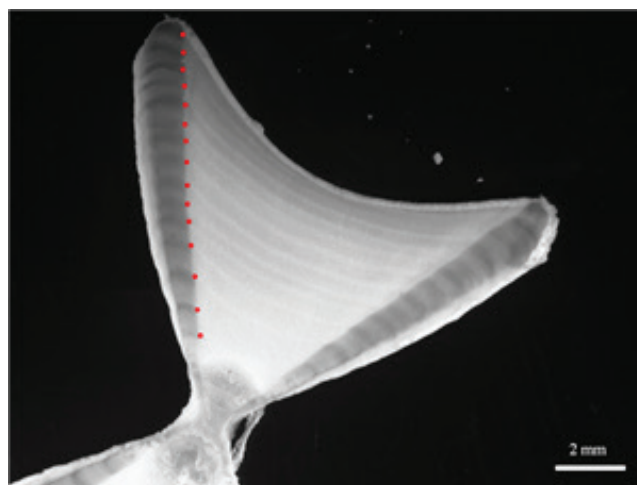


Fig. 2: Transverse section of a vertebral centrum from the Tope shark female tagged in Ireland and recaptured offshore from the south-west coast of Sicily. Red points represent the growth rings.

as Norway and as far south as the Canary Islands and the coast of Morocco, with a maximum linear distance of about 3000 km being covered from tagging to recapture. The two specimens recaptured in Sicily demonstrate that Tope shark undertake longer migrations. Several individuals were recaptured up to eight and nine years after initial tagging in the Atlantic, and often within 20 miles of the tagging location. Thus, Tope sharks likely return to the same natal area, at least once during their life cycle (Fitzmaurice, 2003). The occurrence of both gravid females and juveniles along the coast of Tunisia (Capapé & Mellinger, 1988) supports the hypothesis of a distinct breeding and parturition area in the Mediterranean. However, genetic data are needed to determine population connectivity across the north-east Atlantic and Mediterranean. In addition, the factors that drive the migration of females from the north-east Atlantic to lower latitudes still remain unknown.

Genetic studies are necessary to investigate the population structure of the North-East Atlantic-Mediterranean tope shark and understand if the occurrence of a fine genetic structure might support the presence of a distinct Mediterranean population.

Table 1. Biometrics and reproductive data of the Tope shark female originally tagged in Ireland. N.A. = not available.

<i>Irish Tope</i>	Capture	Recapture
Total Length (cm)	153.0	167.0
Fork Length (cm)	142.0	145.0
Girth (cm)	59.0	58.8
Weight (kg)	21.6	18.6
Liver weight (kg)	N.A.	2.63
Eggs weight (kg)	N.A.	1.93
Eggs number	N.A.	44
Maturity	N.A.	stage 3b

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