BRIEF COMMUNICATION

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Is the tiger shark *Galeocerdo cuvier* a coastal species? Expanding its distribution range in the Atlantic Ocean using at-sea observer data

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Running headline: ***GALEOCERDO CUVIER*** DISTRIBUTION IN THE ATLANTIC OCEAN

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The occurrence of tiger shark *Galeocerdo cuvier* in the Atlantic Ocean was assessed using at-sea observer data from multiple pelagic longline fisheries. Geographic positions of 2764 *G. cuvier* recorded between 1992 and 2013 and covering a wide area of the Atlantic Ocean were compared with the currently accepted distribution ranges of the species. Most records fell outside those ranges in both the Southern and Northern hemispheres, which strongly suggests that the distribution range of *G. cuvier* in the open ocean is considerably larger than previously described

Key-words: high seas; distribution; longline fisheries; by-catch; onboard monitoring

The tiger shark *Galeocerdo cuvier* (Peron & LeSueur 1822) is one of the most distinctive species of the family Carcharhinidae. It reaches the largest size among its congeners (up to 5.5 m total length, L_T) and is also the only carcharhinid with aplacental viviparous reproduction (Randall, 1992; Hamlett, 2005; Whitney & Crow, 2007). *Galeocerdo cuvier* is regularly described as a coastal pelagic predator with circumglobal distribution in warm and temperate waters of all oceans (Ebert *et al.*, 2013). Although commonly associated with coastal areas and continental and insular shelves (Holland *et al.*, 1999; Hazin *et al.*, 2013; Afonso & Hazin, 2014), *G. cuvier* is also capable of travelling long distances, even across oceanic waters (Kohler *et al.*, 1998; Heithaus *et al.*, 2007; Hammerschlag *et al.*, 2012). The distribution range of *G. cuvier* in the western Atlantic Ocean comprises coastal and shelf waters from Massachusetts, U.S.A., to Uruguay, including the Gulf of Mexico, the Caribbean and Bermuda. On the eastern Atlantic *G. cuvier* occurs from Angola to Morocco, including the Canary and Azores archipelagos, but has also been occasionally reported close to Iceland and British Isles, possibly advected along with warm waters of the Gulf Stream (Compagno, 1984; Ebert *et al.*, 2013). To date, the presence of *G. cuvier* in the Mediterranean Sea remains uncertain and further confirmation is needed (Serena, 2005). Despite the existence of two records from Spanish and Italian waters (Pinto de la Rosa, 1994; Celona, 2000), at-sea observers of the Spanish longline fishery in the western Mediterranean Sea have not observed this species for over two decades (D. Macias pers. com.) suggesting that its regular occurrence in the Mediterranean Sea is doubtful.

Sub-population structure within the Atlantic Ocean is currently unknown, but long distance migrations inferred from several tagging studies (Kohler *et al.*, 1998; Hammerschlag *et al.*, 2012) suggest that there may be connections between different regions (Mejuto *et al*., 2005).

Galeocerdo cuvier have been regularly captured in some directed commercial shark fisheries (Bonfil, 1997; Simpfendorfer, 2009), recreational fisheries (Stevens, 1984), and shark control programmes (Dudley, 1997; Cliff & Dudley, 2011; Sumpton *et al.*, 2011), but also as by-catch in several fisheries (Bonfil, 1994; Beerkircher *et al.*, 2008; Coelho *et al*., 2012). In the Atlantic Ocean, *G. cuvier* is captured as by-catch in pelagic longline fisheries across its entire distribution range. It is presently ranked as Near Threatened in the global assessment by the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (Simpfendorfer, 2009). Though there is some information on population trends of *G. cuvier* from mostly coastal areas of the north-west Atlantic Ocean (Baum & Blanchard, 2010; Carlson *et al*., 2012) the global trends for this species are currently unknown (Simpfendorfer, 2009). The species' conservation would be important since it is an apex predator considered as a key species in some marine ecosystems, having a considerable influence on community dynamics (Heithaus *et al*., 2009, 2012).

Records from several observer and research programmes were pooled to assess *G. cuvier* distribution. Between 1992 and 2013, scientific observers on board pelagic longline fishing vessels targeting tuna *Thunnus alalunga* (Bonnaterre 1788), *Thunnus obesus* (Lowe 1839), *Thunnus albacares* (Bonnaterre 1788) and *Thunnus thynnus* (L. 1758), and sword fish *Xiphias*

gladius L. 1758 (Fernandez—Carvalho *et al.,* 2015) from Japan, Portugal, Spain, Uruguay and the U.S.A. recorded interactions with *G. cuvier* over a wide geographical area throughout the Atlantic Ocean, including waters over continental and insular shelves and slopes, and especially large expanses of the open ocean.

Galeocerdo cuvier were identified on board fishing vessels by trained observers. Morphologically, *G. cuvier* is easily recognized by its short and blunt head, the presence of long upper labial furrows, low keels on the caudal peduncle, a prominent interdorsal ridge, distinctive strongly combed teeth with heavy serrations and distal cusplets, and a characteristic trunk pigmentation of dark vertical tiger-like stripe markings that become less conspicuous in adults (Compagno, 1984; Ebert *et al.*, 2013).

Data regarding the currently accepted distribution range of *G. cuvier* in the Atlantic Ocean were obtained from the IUCN Red List (IUCN, 2012) and from Ebert *et al*. (2013) (Fig. 1). Observer information collectively covered the period 1992 to 2013. The study was based on data for positive sets (*i.e.* fishing sets where at least one individual of *G. cuvier* was captured). A buffer area of 600 km was created around the positive sets, which was then smoothed using a polynomial approximation with the exponential kernel algorithm (Peters *et al*., 2014). Finally, the outer 200 km of the resulting polygons were clipped out in order to obtain a conservative extension of the distribution range. All spatial analysis and maps were produced using ESRI ArcGis 10.1 (www.esri.com).

In total, 2764 *G. cuvier* were reported during the study period. These were caught throughout the Atlantic Ocean, both over shelf and slope waters and their vicinity, as well as in international waters in the open ocean. Most of the records were reported by the U.S.A. (86.4%, n = 2,387), followed by Japan (8.7%, n = 240), Spain (2.9%, n = 81), Portugal (1.3%, n = 35) and Uruguay (0.7%, n = 21).

Of all observed *G. cuvier*, 86.4% (n = 2,388) and 19.4% (n = 537) were reported outside the distribution ranges currently proposed by the IUCN (2012) and Ebert *et al.*, (2013), respectively (Fig. 1). Furthermore, all *G. cuvier* reported by the Japanese, Spanish, Portuguese and Uruguayan observer programmes occurred outside the IUCN (2012) distribution ranges, as well as every individual captured over the South Atlantic Ocean. Reported catches that fell inside the currently proposed distribution ranges occurred along the U.S. east and south-east coast, the Gulf of Mexico and the Caribbean, respectively. Several reported captures also occurred over oceanic waters in areas located in the middle of the North Atlantic Ocean, over a 1000 km off the nearest coastline (Fig. 1).

Galeocerdo cuvier is infrequently captured by high-seas longline fisheries (Amorim *et al.*, 1998; Miller *et al.,* 2006; Mejuto *et al.*, 2009), probably due to its low abundance there. The observation of several hundred individuals over oceanic waters, however, confirms that this species has a more widespread distribution in the open ocean than previously accounted for. Regional satellite tagging studies in both the Atlantic (Hammerschlag *et al.*, 2012; Lea *et al.,* 2015) and Pacific Oceans (Meyer *et al.*, 2010) support the more general finding. Catches of *G.*

cuvier were recorded over the entire Equatorial area, whereas this does not appear to be the case for higher latitudes (Fig. 1). This suggests that the Equatorial area could be acting as a connecting corridor between the east and west Atlantic, where *G. cuvier* may take advantage of both the North and South Equatorial Current and the North Equatorial Counter Current (Philander, 2001) advection as natural pathways to cross the Atlantic. Advection of *G. cuvier* by oceanic currents has also been proposed by Compagno (1984), who suggested that the isolated records reported form the U. K. could be of vagrant individuals following the Gulf and North Atlantic stream northwards. A recent telemetry study on *G. cuvier* conducted in the north-western Atlantic Ocean (Hammerschlag *et al.*, 2012) provides further evidence of long-distance migrations into the open ocean associated with waters of the Gulf Stream, and hypothesizes that these movements could be related to feeding behaviour.

Based on data provided by several observer programmes and research activities developed on fleets that target large pelagic fishes in the high-seas of the Atlantic Ocean, this paper proposes to expand the distribution range for this species (Fig. 1). This expansion is towards the open ocean, and the proposed area doubles the one previously recognized. Though the extent of observer coverage did not allow full confirmation, due to the absence of data for some fleets, it is highly possible that the apparently isolated areas appearing to the higher north and southern latitudes (question marks in Fig. 1) are also part of the distribution range, at least during certain times of the year as a consequence of migratory cycles. Expanded distribution ranges, as shown here, have direct implications for management and conservation. These findings raise questions about long-distance migrations, population or sub-population

connectivity, and the identification and delimitation of different stocks. Furthermore, expanded distribution ranges also imply potentially larger availability and susceptibility to fisheries, which may result in higher vulnerability in ecological risk assessments (Cortés *et al*., 2010). At the same time the results suggest a potentially higher biomass than previously thought when only considering a coastal distribution. Future evaluations, such as stock and ecological risk assessments, should take this new distributional information into account to provide more realistic and up-to-date results.

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