SCRS/2016/125 Collect. Vol. Sci. Pap. ICCAT, 73(9): 3128-3151 (2017)

PRELIMINARY ESTIMATES OF THE NUMBER OF SEA TURTLE INTERACTIONS WITH PELAGIC LONGLINE GEAR IN THE ICCAT CONVENTION AREA

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SUMMARY

In 2010, the International Commission for the Conservation of Atlantic Tunas (ICCAT) requested its Standing Committee on Research and Statistics to conduct an assessment of the impact of ICCAT fisheries on sea turtles. Information on the area of operation and reported fishing effort of 16 longline fleets fishing in the Atlantic in 2014 was obtained from the ICCAT EFFDIS (effort distribution) database. Sea turtle bycatch rates were identified for 6 fleets operating within the ICCAT convention area through a comprehensive literature review. For the remaining 9 fleets for which data were not available, bycatch rates were assigned based on spatial overlap of fleets with published rates. The total number of sea turtle interactions was estimated using the reported and assigned sea turtle bycatch rates per fleet and multiplied by reported total fishing effort deployed by the fleets. The total number of sea turtle interactions (all species combined) ranged from 18,708-25,731 for all ICCAT fleets fishing in 2014. However, this estimate should be considered an underestimation, as not all the pelagic longline effort was taken into consideration in the present study.

RÉSUMÉ

En 2010, la Commission internationale pour la conservation des thonidés de l'Atlantique (ICCAT) avait demandé à son Comité permanent sur la recherche et les statistiques d'effectuer une évaluation de l'impact des pêcheries de l'ICCAT sur les tortues de mer. Des informations sur la zone d'activité et l'effort de pêche déclaré de 16 flottilles palangrières pêchant dans l'Atlantique en 2014 ont été extraites de la base de données de l'ICCAT EFFDIS. Les taux de prise accessoire des tortues marines ont été identifiés pour six flottilles opérant dans la zone de la Convention ICCAT grâce à un examen exhaustif de la bibliographie. Pour les neuf flottilles restantes pour lesquelles les données n'étaient pas disponibles, des taux de prise accessoire ont été assignés sur la base du chevauchement spatial des flottilles avec des taux publiés. Le nombre total d'interactions avec les tortues marines a été estimé en utilisant les taux de prise accessoire de tortues marines déclarés et assignés par flottille et multipliés par l'effort de pêche total déclaré déployé par les flottilles. Le nombre total d'interactions avec les tortues marines (toutes espèces confondues) a varié de 18.708 à 25.731 pour toutes les flottilles de l'ICCAT pêchant en 2014. Toutefois, cette estimation devrait être considérée comme une sous-estimation, étant donné que tout l'effort palangrier pélagique n'a pas été pris en compte dans la présente étude.

RESUMEN

En 2010, la Comisión Internacional para la Conservación del Atún Atlántico (ICCAT) solicitó a su Comité Permanente de Investigaciones y Estadísticas (SCRS) que realizara una evaluación del impacto de las pesquerías de ICCAT en las tortugas marinas. A partir de la base de datos EFFDIS (distribución del esfuerzo) de ICCAT se obtuvo información correspondiente a las zonas de operación y esfuerzo pesquero declarado de 16 flotas de palangre que faenaron en el Atlántico en 2014. Se identificaron las tasas de captura fortuita de tortugas marinas para seis flotas que operaron en la zona del Convenio de ICCAT mediante un examen exhaustivo de la bibliografía. Para las nueve flotas restantes para las que no se disponía de datos, las tasas de captura fortuita se asignaron basándose en el solapamiento espacial de las flotas con tasas publicadas. El número total de interacciones con tortugas marinas se estimó utilizando las

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tasas de captura fortuita de tortugas marinas por flota declaradas y asignadas, y se multiplicó por el esfuerzo pesquero total declarado desplegado por las flotas. El número total de interacciones con tortugas marinas (todas las especies combinadas) oscilaba entre 18.708-25.731 para todas las flotas de ICCAT que pescaron en 2014. Sin embargo, este valor debe considerarse una subestimación, ya que en el presente estudio no se tomó en consideración todo el esfuerzo de palangre pelágico.

KEYWORDS

By catch, catch/effort, geographical distribution, long lining, temporal distribution

1. Introduction

Bycatch, the unintended capture of non-target species by a fishery, is a major anthropogenic threat facing marine ecosystems at a global scale. If the species caught as bycatch are endangered or protected, as in the case of sea turtles, even low overall levels of bycatch may be of concern (National Marine Fisheries Service, 2011). The number of sea turtles incidentally caught in coastal and pelagic fisheries is a cause for concern that requires holistic management. Similar to other marine megafauna, the biological characteristics of sea turtles such as their longevity, low reproductive success, and delayed maturity could increase the vulnerability of the species to extinction as the result of unsustainable levels of incidental mortality (Sales *et al.,* 2010).

Sea turtles face a wide range of threats ranging from the direct harvest of turtles and their eggs, egg predation, loss and degradation of suitable nesting habitat, pollution, bycatch, and changing oceanographic conditions and nutrient availability (Coelho *et al.,* 2015). Of these threats, fisheries bycatch is considered one of the major causes of decline for sea turtle species. Sea turtles are susceptible to incidental capture in a wide range of fisheries and fishing gear including coastal types of gear such as trawls, gillnets, and pound nets and gear used in the open ocean such as longlines, purse seines, and driftnets. There is significant concern over the ecological effects of pelagic longline fishing, which extends globally throughout temperate and tropical waters.

The International Commission for the Conservation of Atlantic Tunas (ICCAT) is the Regional Fishery Management Organization (RFMO) that manages fisheries for tunas and 'tuna-like' species in the Atlantic Ocean including the adjacent seas (i.e., Mediterranean Sea, Caribbean Sea, and the Gulf of Mexico). While the main goal of ICCAT is to manage tuna and tuna-like species, the Commission also compiles data on incidentally captured species such as sea turtles, which can be used to assess the impacts of ICCAT fisheries on non-target species (ICCAT 2009). Sea turtles are known to interact with fishing pelagic longline fleets in the Atlantic Ocean (Camiñas *et al*. 2006, Fairfield-Walsh and Garrison 2006, Honig *et al.* 2008). The five species of sea turtles that interact with pelagic longline fleets in the ICCAT convention area are loggerhead (*Caretta caretta*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), hawksbill (*Eretmochelys imbricata*), and olive ridley (*Lepidochelys olivacea*). Of these five species, Angel *et al.* (2014) estimated that loggerheads and leatherbacks are the species most likely to encounter longlines. Given that sea turtles spend a majority of their lives at sea and are exposed to growing levels of anthropogenic impacts, accurate estimates of sea turtle interactions with different fishing gears and the sea turtles post-interaction fate are essential elements to assess population viability.

In an effort to decrease the number of sea turtles incidentally caught in commercial fisheries, several bycatch reduction measures have been proposed and implemented in some fisheries. Management measures such as time/area closures, fishery bans and limitations on fishing effort have been implemented (Coelho *et al.,* 2015). Modifications to gear in the form of turtle excluder devices (TEDs), deterrents (sonic pingers, lights or chemical repellents), circle hooks, and changes in bait all have shown to reduce sea turtle bycatch.

Overall bycatch values can only be estimated if reliable quantitative information is available. To ensure the most effective conservation and management strategies can be adopted and successfully implemented, it is important to consider and assess the impact of the different commercial fisheries on sea turtles. To successfully conduct an impact assessment of a fishery on sea turtles, the first step is to estimate sea turtle bycatch rates.

In the present study, we estimated the number of sea turtle interactions with pelagic longline gear with a methodology similar to one used to estimate the number of seabird interactions with pelagic longlines in ICCAT fisheries (Klaer *et al.* 2009). This study estimated the total number of sea turtles caught by pelagic longline fisheries in the ICCAT convention area by using a combination of published and assigned sea turtle bycatch rates as a function of the estimated longline fleet fishing effort.

2. Methods and Materials

Spatial and temporal distribution and fishing effort for pelagic longline fleets were obtained from the ICCAT EFFDIS (effort distribution) database for year 2014. The EFFDIS database corresponds to the reported number of hooks fished by each fleet in each 5º X 5º quadrants and month since 1991 (Beare *et al.* 2016). The reported effort for each fleet in EFFDIS was compiled from the catch and effort information submitted to ICCAT by its members.

Coelho *et al*. (2013) completed a thorough review of scientific literature related to sea turtle interactions with ICCAT fisheries. The present study conducted a new literature review to identify new research on this issue published after or not included in the Coelho *et al.* (2013) review. All bycatch rates in this document correspond to number of sea turtle interactions per 1,000 hooks.

For each of the ICCAT longline fleets for which sea turtle bycatch rates were available, a careful review of the area of operations and the reported number of hooks deployed in the EFFDIS database was conducted. Using ArcGIS 10.2.2 (ESRI, Inc.), the area of operation of each of these fleets was mapped using 5ºx5º grids and each cell in the grid was assigned the number of hooks deployed by each fleet by month. For these fleets, if the available bycatch rate(s) were only estimated for a particular time period of the year, it was assumed that the bycatch rate remained constant through the entire year. For those fleets for which sea turtle bycatch rates have not been estimated or were not available, we assigned bycatch rates from fleets with known sea turtle bycatch. When a range of bycatch rates were determined through the literature review, the total number of sea turtle interactions were calculated using the lowest bycatch rate and the highest rate. The assignment of bycatch rates was done by carefully matching those bycatch rates from fleets that operated in the same temporal/spatial stratum and fished similarly to the fleets with unknown bycatch rates. The number of sea turtle interactions was estimated for each month-quadrant stratum by multiplying the bycatch rate assigned through the literature review to the EFFDIS reported fishing effort data for each fleet then divided by a thousand.

Estimated total turtle interactions = bycatch rate x effort/1000

The estimated number of interactions was then used to identify and map hotspots of sea turtle interactions with longline gear in the ICCAT Convention Area. Areas of potential conservation concern for each species were determined through the use of hotspot and kernel density statistical analysis tools in ArcGIS. In this study, hotspot analysis was used to determine statistically significant areas of high and low sea turtle interactions with pelagic longline gear. The kernel density tool calculated the number of sea turtles interacting with pelagic longline gear per square kilometer. According to Esri, hotspot analysis identifies ‘statistically significant spatial clusters of high values (hot spots) and low values (cold spots)’ while kernel density calculates a ‘magnitude per unit area from point features using a kernel function to fit a smoothly tapered surface to each point’ (Esri, 2014).

3. Results

Fifteen pelagic longline fleets were identified as actively fishing in the ICCAT convention area in 2014. In addition, EFFDIS also defined an additional fleet named ‘OTHER’, which corresponded to a combination of fleets from different nations that did not operate or report data consistently since 1991.

The literature review identified only 7 published studies with sea turtle bycatch rates from 6 pelagic longline fisheries operating in the ICCAT convention (**Table 1**). Of these 7 studies, all of them provided included bycatch rates for loggerheads, 6 studies for leatherbacks, 3 studies for olive ridley, 2 studies for greens, and 1 study for hawksbill sea turtles (**Table 1**). Bycatch rates from the 7 studies were then assigned to the remaining 9 longline fleets for which bycatch rates were not available (**Table 2**).

The total reported number of pelagic longline hooks fished in 2014 in EFFDIS was 178,525,515 (including the effort of the fleet ‘OTHER’). Details of the bycatch rates assigned to the different fleets, and the estimated effort and number of interactions are provided in **Table 2**.

3.1 Brazil

Sea turtle bycatch rates for Brazilian longline fleets in the southwest Atlantic were estimated by Pons *et al.* (2010) and Sales *et al.* (2008). The Pons *et al.* (2010) study examined bycatch data collected by observer programs from the Brazilian and Uruguayan longline fleets between April 1998 and November 2007. The bycatch rate of loggerheads in the Brazilian longline fleets fluctuated throughout the study, but showed a general declining trend during the period 1998-2005 before increasing in the last two years of the study (2006-2007). Standardized bycatch rates values ranged from the lowest in 2003 at 0.39 to the highest at 1.78 in 2007. Between the years of 2001-2005 a total of 11,348,069 observed hooks were deployed resulting in the incidental capture of 1,386 turtles. Reported bycatch rates for this time period were 0.07 for loggerheads, 0.03 for leatherbacks, 0.00 for green, 0.01 for olive ridley. In the Brazilian EEZ and adjacent international waters, Brazilian pelagic longline vessels target swordfish, tuna, and sharks Sales *et al.* (2008). Between 2001 and 2005 a total of 11,348,069 hooks were observed and 1,386 sea turtles were recorded as incidentally caught. Reported bycatch rates for this time period were 0.07 for loggerheads, 0.03 for leatherbacks, 0.01 for olive ridley, and 0.0 for green. The reported fishing effort of the Brazilian pelagic longline fleet in 2014 was 4.4 million hooks. **Figure 1** shows the reported area of operation of the Brazilian longline fleet during 2014.

3.2 Chinese-Taipei

The Chinese-Taipei fleet is one of the largest distant-water longline fleets operating in the Atlantic Ocean (**Figure 2**), fishing in both tropical and temperate waters (Huang 2015). In the tropics between 15°N and 15°S, the fleet targets bigeye (*Thunnus obesus*) at fishing depths of more than 100 meters. In the higher latitudes of the northern and southern Atlantic, the fleet targets albacore (*T. alalunga*). Huang (2015) analyzed bycatch observations from June 2002 to December 2013 to estimate bycatch rates for sea turtles in the deep-set longline fleet. The 18,142 observed sets and 47.1 million hooks analyzed in this study resulted in the capture of 767 sea turtles. Leatherbacks were the most commonly captured species (59.8%) followed by olive ridley (27.1%), and loggerhead (8.7%). A majority of the turtles were caught in the bigeye fishery in the tropical Atlantic. The highest bycatch rate corresponded to leatherbacks in the tropical Atlantic at 0.030. Olive ridley bycatch rates ranged from 0 to 0.010; while loggerhead bycatch rates varied from 0.000 to 0.0239. Total reported number of hooks deployed by the Chinese-Taipei fleet in 2014 was on the order of 59.3 million. For those fleets that were assigned the bycatch rates of the Chinese-Taipei fleet, we estimated the number of interactions using the maximum and minimum bycatch rate values provided by Huang (2015).

3.3 Portugal

Bycatch rates for the Portuguese pelagic longline fleet operating in the equatorial waters of the Atlantic were estimated by Santos *et al.* (2012). A total of 221 longline sets were deployed by the Portuguese fleet operating in tropical waters between January 2009 and March 2011 resulting in the incidental capture of 231 sea turtles. Olive ridley and leatherbacks accounted for the 2 highest species caught with mean bycatch rates at 1.2 and 0.45 respectively. Santos *et al.* (2013) also examined data from 310 longline sets deployed by the Portuguese longline fleet in the south Atlantic between October 2008 and February 2012. Over the course of the study, 148,800 hooks of each type (J-hook, GT offset circle hook, and non-offset circle hook) were deployed resulting in the incidental capture of 286 sea turtles. Loggerheads accounted for the most frequently caught sea turtle species with a bycatch rate of 1.505 (J-style hooks with squid bait) while leatherbacks had a bycatch rate of 0.188 (J-style hooks with squid bait. Bycatch rates for both species were lower for circle hooks baited with mackerel compared to the bycatch rate for the traditional J-style hook baited with. Due to both the spatial and temporal overlap between the Spanish and Portuguese pelagic longline fleets in the northeast Atlantic, bycatch rates for sea turtles caught in the Spanish fleet (Mejuto *et al.* 2008) were assigned to the Portuguese fleet. The Portuguese pelagic longline fleet deployed a total reported 263,487 hooks. The reported area of operation of the Portuguese longline fleet in 2014 is shown in **Figure 3**.

3.4 South Africa

Petersen *et al.* (2009) estimated sea turtle bycatch rates for the South African fishery (**Figure 2**). Petersen *et al.* (2009) conducted the first assessment of sea turtle bycatch in the South African tuna and swordfish longline fisheries using observer data collected from 1998 to 2005. A total of 181 turtles comprising four different species were caught resulting in an overall sea turtle bycatch rate of 0.04. Loggerheads bycatch rate was 0.02, which accounted for 60% of all sea turtles captured in the study. Leatherbacks were the second most frequently caught sea turtle species with a bycatch rate of 0.01; while hawksbill and green turtles both had bycatch rates of 0.001. The fishing effort reported by the South African fleet for 2014 was in the order of 149,000 hooks. The reported area of operation for 2014 is shown in Figure 4.

3.5 Spain

Bycatch rates for the Spanish longline fleet in the North and tropical Atlantic (**Figure 3**) were estimated by Mejuto *et al.* (2008). The study examined the effect of hook type (circle and J hooks) and baits (mackerel and squid) on the incidental capture of sea turtles and other non-target species in the Spanish pelagic longline swordfish fishery between October 2005 and August 2006 in the North and South Atlantic between 47ºN–23º S latitude. A total of 162,289 hooks were deployed resulting in the incidental capture of 171 loggerheads and 69 leatherbacks. Nominal bycatch rates for loggerheads were 1.758 for the northwest, 0.104 for the northeast, and 0.421 for the eastern tropical area. Nominal bycatch rates for leatherbacks were 0.349, 0.391, and 0.631 for the northwest, northeast, and eastern tropical areas, respectively. In the south Atlantic, the longline fleets of Spain and Chinese-Taipei overlap extensively both spatially and temporally. Due to these similarities, bycatch rates from the Chinese-Taipei fleet (Huang 2015) were assigned to the Spanish fleet operating in the South Atlantic. In 2014, the Spanish fleet reported that it deployed 15.5 million hooks. **Figure 5** shows the reported area of operation of the Spanish fleet in 2014.

3.6 United States of America

United States bycatch rates values reported by Garrison and Stokes (2014) were used to estimate total sea turtle interactions during the 2014 season. The U.S. pelagic longline fleet operates in waters from New England to the Caribbean (including the Gulf of Mexico), as well as international waters of the North Atlantic (Garrison and Stokes, 2014) (**Figure 4**). The U.S.' area of operation was divided into six smaller regions; Northeast Central, Mid Atlantic Bight, South Atlantic Bight, Florida East Coast, and Gulf of Mexico and Garrison and Stokes estimated quarterly bycatch rates for each of these regions (**Table 2**). The reported number of hooks fished by the U.S. in 2014 was 6,391,871.

3.7 Belize

In 2014, the Belizean longline fishery operated in both the North and South Atlantic (**Figure 4**) and deployed an estimated 6.3 million hooks. The areas fished by this longline fleet overlapped with some of the fishing areas of the Chinese-Taipei longline fleet. Therefore, the bycatch rates of the Chinese-Taipei fleet were assigned to the pelagic longline fleet from Belize. The fishing effort reported by Belize in 2014 was 6,306,504 hooks.

3.8 Canada

The main fishing ground of the Canadian pelagic longline fleet is the northwest Atlantic (**Figure 1**), an area also fished by the U.S. pelagic longline fleet. The reported number of hooks for the Canadian fleet in 2014 was 1.46 million. Bycatch rates from the U.S. pelagic longline fleet operating the northwest Atlantic were assigned to the Canadian fleet.

3.9 China

While the Chinese pelagic longline fleet fishes in the northeast Atlantic, the largest area fished is the equatorial waters of the Atlantic (**Figure 4**). There are no sea turtle bycatch rates available for this fleet. Therefore, bycatch rates from the Chinese-Taipei fleet were assigned to this fleet. The total estimated effort for the Chinese fleet in 2014 was estimated to be 6.2 million hooks.

3.10 Japan

The Japanese longline fishery covers a wide geographical distribution within the Atlantic Ocean from as far south as the waters off South Africa, to north of the United Kingdom (**Figure 6**). Similarly to the Chinese longline fleet, the bycatch rates of the Chinese-Taipei fleet (Huang 2015) were assigned to the portion of the Japanese longline fleet operating in the North and South Atlantic, and the Tropics. For the portion of the effort of the Japanese fleet deployed in the Southeast Atlantic, bycatch rates estimated for the South African longline fleet (Peterson *et al*., 2009) were assigned. The reported effort of the Japanese longline fleet in 2014 was 46 million hooks.

3.11 Korea

The area fished by the Korean longline fleet overlaps with that of the Chinese-Taipei fleet throughout the Atlantic, particularly in the tropics (**Figure 6**). Therefore, bycatch rates estimated for the Chinese-Taipei fleet (Huang *et al.* 2015) were assigned to the Korean fleet. In 2014, the Korean longline fleet deployed an estimated 1.4 million hooks.

3.12 Namibia

Along the southwestern coast of Africa, Namibian and South African longline fisheries overlap in the area they fish (**Figure 1**). Without available estimates of sea turtle bycatch rates for the Namibian longline fishery, the estimated bycatch rates for the South African fleet (Petersen *et al.*, 2009) were assigned to the Namibian fleet. The reported effort deployed by the Namibian longline fleet in 2014 was 1.2 million hooks.

3.13 St. Vincent and the Grenadines

Throughout the Atlantic, the pelagic longline fleet of St. Vincent and the Grenadines experienced spatial and temporal overlap with the longline fleet of Chinese-Taipei, particularly in the North Atlantic (**Figure 3**). Due to similarities in the spatial/temporal fishing operations of these two nations' fleets throughout the Atlantic, sea turtle bycatch rates from the Chinese-Taipei fleet (Huang 2015) were assigned to most of the effort deployed by the longline fleet St. Vincent and the Grenadines. In addition, a portion of the fleet from St. Vincent and the Grenadines also fishes in the same region as Brazilian flagged vessels. For this portion of the St. Vincent and the Grenadines fleet, the bycatch rates estimated by Sales *et al.* (2008) were applied. In 2014, the St. Vincent and the Grenadines longline fleet reported a fishing effort of 12.9 million hooks.

3.14 Vanuatu

In 2014, the longline fleet of Vanuatu fished predominately in the North Atlantic with some fishing also occurring in equatorial and southern Atlantic waters (**Figure 5**) and deployed 1.2 million hooks (reported fishing effort). In the North Atlantic, the Vanuatu and Chinese-Taipei fleets experience spatial and temporal overlap. The greatest overlap between the two fleets occurs in the northwest Atlantic. Due to these similarities the bycatch rates described by Huang (2015) for the Chinese-Taipei fleet were assigned. For the portion of the effort deployed by the fleet from Vanuatu off of the northern coast of Brazil we assigned the bycatch rates estimated by Sales *et al.* (2008).

3.15 Venezuela

Venezuelan longline vessels operate in the Venezuelan Exclusive Economic Zone and in adjacent international waters (**Figure 1**). The Venezuelan fleet overlaps in part with Chinese-Taipei longline vessels fishing in the central Atlantic off of the northern coast of South America. Therefore, the bycatch rates described by Huang (2015) for the Chinese-Taipei fleet were assigned to the Venezuelan fleet.

3.16 OTHER

The fleet 'OTHER' operated primarily in equatorial waters between 20º N and 14º S with additional locations in the Gulf of Mexico and the northeast Atlantic (**Figure 7**). The reported number of hooks of this fleet in 2014 was 18,696,525 (10.4% of the total reported hooks). Because there was no information associated to this fleet besides area of operating and reported effort, no attempt was made to assign a bycatch rate from another fleet to this group.

3.17 Hotspot and kernel density analysis

As expected, the estimated number of sea turtles interacting with pelagic longline gear in the ICCAT Convention Area varied greatly for each fleet and among fleets depending on the sea turtle species considered, bycatch rates, and reported fishing effort. For example, in 2014 the reported effort of the longline fleet of South Africa was only 149,216 hooks in the South Atlantic with a bycatch rate of 0.02 for loggerheads. The resulting estimated total number of loggerheads interacting with this fleet in the South Atlantic in 2014 was 3. On the other hand, in 2014, the reported fishing effort of the Chinese-Taipei longline fleet was approximately 50.8 million hooks and the estimated number of loggerhead interactions was 487. The complete list of the total number of estimated interactions by region and species for each fleet is listed in **Table 2**.

The total estimated number of sea turtle interactions (all species combined) with pelagic longline gear in the ICCAT convention area in 2014 ranged from 18,078 to 25,731. Of these interactions, estimated interactions range from 11,030 to 14,338 for individual loggerhead turtles, from 6,901 to 9,412 for leatherback turtles, from 97 to 1,826 for olive ridley turtles, from 31 to 138 for green turtles, and a single estimate of 19 hawksbill turtles.

Sea turtle bycatch rates varied for each species throughout the ICCAT Convention Area. Loggerhead bycatch rates were highest in the Northwest Atlantic. Through the use of hotspot analysis in ArcGIS this region was determined to be a hotspot with a 99% confidence (**Figure 8**). Areas with low loggerhead bycatch rates were found in parts of the tropical and South Atlantic. Similar low bycatch rates were located off of southern Africa. The areas with the highest densities of loggerhead interactions with longline gear (number of individuals per square kilometer) reflected the areas of high confidence determined in the hotspot analysis (**Figure 9**).

Interactions with leatherback sea turtles were located in eastern Atlantic waters primarily in the northeast and tropics (**Figure 10**). The highest bycatch rates (greater than 99% confidence) were located in the northeast Atlantic while low values were found in the northwest and south Atlantic. High values were also located in the eastern tropics. High densities of leatherbacks interacting with longline gear were found in the central North Atlantic and equatorial waters (**Figure 11**). Low densities were found primarily in coastal regions and in the south Atlantic.

The highest bycatch rates for both olive ridley and green sea turtles were found entirely in the tropical waters of the Atlantic (**Figures 12 and 13**). The North and Southeastern Atlantic were found to have low bycatch rates for both species. During 2014, high densities of olive ridleys interacting with longline gear were estimated to be in the tropical Atlantic (**Figure 14**) while the lowest number of interactions occurred in the North and South Atlantic. Green sea turtles followed similar density trends with a majority of estimated interactions occurring in tropical and southern waters (**Figure 15**). Hawksbill sea turtles were predominately caught in the same region of the Southeastern Atlantic that olive ridley and green sea turtles reported low interaction values (**Figure 16**). Hawksbill turtles in this region were concentrated along the southern coast of Africa with the number of individuals per square kilometer ranging between 0.000000609-0.000009131 (**Figure 17**).

4. Discussion

The approach used in this study was similar to the approach used in an assessment of the impact of ICCAT fisheries on seabirds (Klaer *et al.* 2009). Our method builds on the approach used by Klaer *et al.* (2009) by assigning bycatch rates at a fleet level instead of assigning bycatch rates to different areas in the Atlantic.

There are other variables that affect sea turtle bycatch in addition to time and area of fishing that were not taken into consideration in the present study when assigning bycatch rates to different fleets. Some of these variables include, but are not limited to, species targeted by the fleets, type and size of the hooks, bait type, and gear configuration (Pacheco *et al.*, 2010; Stokes *et al.*, 2012). Detailed information on these variables for the fleets considered in this study was not available to include in our analyses.

Areas identified in this study with estimated high numbers of sea turtle interactions with longline gear are of conservation concern. These bycatch hotspots may be driven by fishing intensity, sea turtle density, or a combination of both. Fishing effort distribution is non-random as greater effort is typically concentrated in areas of high production of the target species. Target species, gear configuration, and fishing strategy are all important components to consider when examining sea turtle bycatch. Fleets that deploy shallow set longlines have sea turtle interaction rates approximately 10 times greater than deep-set gear (Angel *et al.*, 2014). That is because sea turtles are potentially exposed to shallow set gear for the entire soak time whereas deep set gear is usually only in sea turtle habitat (~ upper 100m) during deployment and haulback (Angel *et al.*, 2014). Additionally, the target species and resulting fishing strategy influences the total number of sea turtle interactions. For example, fleets targeting swordfish generally set relatively shallow (20-30m) and at night due to swordfish's nocturnal feeding behavior; fleets targeting bigeye tunas tend to deploy and haulback gear during the daytime and at greater depths (up to 500m) resulting in lower numbers of sea turtle interactions than fleets targeting swordfish (Angel *et al.*, 2014).

Sea turtle density is likely dependent on a variety of oceanographic and physiological factors for each species. Both loggerheads and leatherbacks are widely distributed in the Atlantic Ocean and with fairly large populations, which increases the chance of interactions with pelagic longliners during their trans-Atlantic crossings (Angel *et al.*, 2014). This study found that leatherback and loggerhead interaction rates were highest in the North Atlantic, an important foraging and migrating ground for both of these species (**Figures 8 and 9**). Green, hawksbill, and olive ridley turtles are less likely to interact with pelagic longliners, as these species tend to have more coastal distributions.

While many sea turtles caught in longline gear are released alive, it is assumed that injuries caused by hooks or line entanglement may result in post-release mortality (Chaloupka *et al*., 2004). Hooking location appears to play a major role in the survivability of released sea turtles. Sea turtles that were deep hooked were more likely to suffer post-release mortality during the first 50-60 days after release than lightly hooked turtles. Quevedo *et al*. (2013) indicated that post-release mortality from longline gear after 90 days at large ranged from 0.308 to

0.365 depending on the calculation approach used. Besides hooking location, the presence of long monofilament plays a critical role in a turtle's chances of survival due to the risk of strangulations and tractions in the gastrointestinal track, which are often more lethal than hooks (Quevedo *et al*., 2013). Sea turtles with hooks trailing long line experience the highest probability of death (Parga 2012). Sea turtle survivability can be significantly increased when the line is cut as close as possible to the mouth if hook removal is not possible. When it is possible to board a hook sea turtles using a dip-net, with the correct use of dehooking devices, on visible hooks can reduce the impact to bycaught sea turtles (Parga 2012). Due to the large amount of gear deployed by longline vessels, bycatch levels across the entire fleet could be considerable despite low bycatch rates from individual longline vessels (Lewison and Crowder, 2007). While longlines may not be the largest single source of fisheries-related mortality, high levels of bycatch call for increased conservation and management.

The present study constitutes the first attempt to estimate the number of sea turtle interactions with pelagic longline gear in the ICCAT convention area. There are several potential limitations of the results presented here. Some of the bycatch rates published in the scientific literature were estimated for a particular time of the year. For these cases, that bycatch rate was applied to all the months when the fleet operated with the assumption that the bycatch rates remained constant throughout the year. Similarly, most of the bycatch rates used in this study were estimated from data collected in years prior to 2014 and they were assumed to have remained unchanged for the purpose of our analyses. These assumptions could result in biased estimates. As previously explained, no estimates of sea turtle number of interactions were made for the fleet named OTHER (which constituted 10% of the total effort in 2014) nor for any longline fleet operating in the Mediterranean Sea. In addition, this study used the reported fishing effort by the different fleets. Because some fleets only report a fraction of their total fishing effort, the total fishing effort used in our analysis is an underestimate of the true total effort. Therefore, since not all the pelagic longline fishing effort in the ICCAT convention area was included in this study, the estimated number of interactions should be considered to be an underestimation. In addition, there is the potential that some of the bycatch rates assigned to the fleets for which bycatch rates were not available might not represent those of these fleets.

Despite the limitations of the present study, it provides the first minimum estimates of sea turtle interactions with pelagic longline fleets in the ICCAT convention area. There is a significant amount of scientific literature that supports the finding that the use of circle hooks in longline fisheries reduces sea turtle bycatch rates and/or increases post-release survival (Serafy *et al.,* 2012). The positive effect of circle hooks in reducing the number of sea turtle interactions is enhanced if the hooks are used in combination with finfish bait. We recognized that in some fisheries the use of circle hooks have not shown positive results for all species, but at the present time the use of circle hooks is the most effective bycatch mitigation measure for sea turtles. Sea turtle bycatch mitigation measures should include, but not be restricted to, the mandatory use of circle hooks in longline fisheries, the use of protocols and techniques to board and safely de-hook and release sea turtles, and the mandatory training of all vessel crew members on this techniques.

References

Angel A., Nel, R., Wanless, R.M., Mellet, B., Harris, L., and Wilson, I. 2014. Ecological risk assessment of sea turtles to tuna fishing in the ICCAT region. Col. Vol. Sci. Pap. ICCAT. 70(5):2226-2259.

Beare, D.J., Palma, C., de Bruyn, P., and Kell, L. A modeling approach to estimate overall Atlantic fishing effort by time-area strata (EFFDIS). Collect. Vol. Sci. Pap. ICCAT, 72(8): 2354-2370.

Camiñas, J.A., Baez, X., Valeiras, J.C., Real, R. 2006. Differential loggerhead bycatch and direct mortality due to surface longlines according to boat strata and gear type. Sci. Mar., 70: 661–665.

Chaloupka, M., Parker, D., and Balazs, G. 2004. Modeling post- release mortality of loggerhead sea turtles exposed to the Hawaii-based pelagic longline fishery. Marine Ecological Progress Ser 280:285 – 293.

Coelho, R., Santos, M. N., Fernandez-Carvalho, J., and Amorim, S. 2015. Effects of hook and bait in a tropical northeast Atlantic pelagic longline fishery: Part I-incidental sea turtle bycatch. Fisheries Research (Amsterdam), 164, 302-311. doi:http://dx.doi.org/10.1016/j.fishres.2014.11.008

Coelho, R., Fernandez-Carvalho, J. and Santos, M.N 2013. A review of fisheries within the ICCAT convention area that interact with sea turtles. Collect. Vol. Sci. Pap. ICCAT, 69: 1788-1827.

Esri. 2014. Kernel Density (Spatial Analyst). Retrieved November 23, 2015, from http://resources.arcgis.com/en/help/main/10.2/index.html#//009z0000000s00

Esri. 2014. Hot Spot Analysis (Getis-Ord Gi*) (Spatial Statistics). Retrieved November 23, 2015, from http://resources.arcgis.com/en/help/main/ 10.2/index.html#//005p000000100

Fairfield-Walsh, C. and Garrison, L.P. 2006. Estimated bycatch of marine mammals and turtles in the U.S. Atlantic Pelagic Longline Fleet during 2005. NOAA Tech. Mem. NMFS-SEFSC-539: 52pp.

Garrison, L. P. and Stokes, L. 2014. Estimated Bycatch of Marine Mammals and Turtles in the U.S. Atlantic Pelagic Longline Fleet During 2013. NOAA Technical Memorandum NMFS-SEFSC-667: 61 p.

Honig, M.B., Petersen S.L., Duarte A. 2008. Turtle bycatch in longline fisheries operating within the Benguela current large marine ecosystem. Col. Vol. Sci. Pap. ICCAT, (6): 1757-1769

Huang H-W. 2015. Conservation Hotspots for the Turtles on the High Seas of the Atlantic Ocean. PLoS ONE 10(8): e0133614. doi:10.1371/ journal.pone.0133614

ICCAT 2009. Recommendation by ICCAT on the by-catch of sea turtles in ICCAT fisheries. ICCAT recommendation [10-09] 2p.

Klaer N.L., A. Black, and E. Howgate. 2009. Preliminary estimates of total seabird by-catch by ICCAT fisheries in recent years. Col. Vol. Sci. Pap. ICCAT. 64(7):2405-2414.

Lewison R.L., Crowder LB. 2007. Putting longline bycatch of sea turtles into perspective. Conservation Biology. 21:79–86.

Mejuto, J., García-Cortés B., Ramos-Cartelle, A. 2008. Trials using different hook and bait types in the configuration of the surface longline gear used by the Spanish swordfish (*Xiphias gladius*) fishery in the Atlantic Ocean. Col. Vol. Sci. Pap. ICCAT, 62 (6): 1793-1830.

National Marine Fisheries Service. 2011. U.S. National Bycatch Report [W. A. Karp, L. L. Desfosse, S. G. Brooke, Editors]. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-117C, 508 p.

de Quevedo, I. Á., Cardona, L., De Haro, A., Pubill, E., & Aguilar, A. 2010. Sources of bycatch of loggerhead sea turtles in the western Mediterranean other than drifting longlines. ICES Journal of Marine Science: Journal du Conseil, 67(4), 677-685.

Pacheco J.C., Kerstetter DW, Hazin FH, Hazin H, Segundo RSSL, Graves JE, et al. 2010. A comparison of circle hook and J hook performance in a western equatorial Atlantic Ocean pelagic longline fishery. Fisheries Research. 2011; 107: 39–45.

Parga M.L. 2012. Hooks and sea turtles: a veterinarian's perspective. Bull Mar Sci 88:731−741

Petersen, S.L., Honig, M.B., Ryan, P.G., Nel R. and Underhill, L.G. 2009. Turtle bycatch in the pelagic longline fishery off southern Africa. Afr. J. Mar. Sci. 31(1): 87–96.

Pons, M., Domingo, A., Sales, G., Fiedler, F.N., Miller, P., Giffoni, B., Ortiz, M. 2010. Standardization of bycatch rate of loggerhead sea turtle (*Caretta caretta*) caught by pelagic longliners in the Southwestern Atlantic Ocean. Aquat. Living Resour., 23: 65–75.

Sales, G., Giffoni, B. B., Fiedler, F. N., Azevedo, V. G., Kotas, J. E., Swimmer, Y., & Bugoni, L. 2010. Circle hook effectiveness for the mitigation of sea turtle bycatch and capture of target species in a Brazilian pelagic longline fishery. Aquatic Conservation: Marine and Freshwater Ecosystems, 20(4), 428-436. doi:http://dx.doi.org/10.1002/aqc.1106

Sales, G., Giffoni, B., Barata, P.C.R. 2008. Incidental catch of sea turtles by the Brazilian pelagic longline fishery. Journal of the Marine Biological Association of the UK, 88, pp 853-864. doi:10.1017/S0025315408000441.

Santos, M.N., Coelho, R., Fernandez-Carvalho, J., Amorim, S., 2013. Effects of 17/0 circle hooks and bait on sea turtles bycatch in a Southern Atlantic sword- fish longline fishery. Aquat. Conserv.: Mar. Freshwater Ecosyst. 23, 732– 744.

Santos, M.N., Coelho, R., Fernandez-Carvalho, J., Amorim, S., 2012. Effects of hook and bait on sea turtle catches in an equatorial Atlantic pelagic longline fishery. Bull. Mar. Sci. 88, 683–701.

Serafy, J.E., Diaz, G.A., Shivji M.S, and Swimmer Y. (Guest Editors). 2012. Proceedings of the International Symposium on circle Hooks. Bull. Mar. Sci. 88(3): 365-825.

Stokes L.W., Epperly SP, McCarthy PJ. 2012. Relationship between hook type and hooking location in sea turtles incidentally captured in the United States Atlantic pelagic longline fishery. Bulletin of Marine Science 88: 703–718.

Table 1. List of published literature with pelagic longline bycatch rates for different sea turtle species in the ICCAT convention area.

Reference	***Years***	***Species***	***Area of study***
Garrison and Stokes, 2014	2013	Leatherback, loggerhead	Northwest Atlantic
Huang 2015	2002-2013	Leatherback, loggerhead, olive ridley	North Atlantic, Tropics, South Atlantic
Mejuto et al. 2008	2005-2006	Leatherback, loggerhead, olive ridley	North Atlantic, South Atlantic
Petersen et al. 2009	1998-2005	Leatherback, loggerhead, green, hawksbill	Southeast Atlantic
Pons et al. 2010	1998-2007	Loggerhead	Southwest Atlantic
Sales et al. 2008	2001-2005	Leatherback, loggerhead, olive ridley, green	Brazilian and adjacent international waters
Santos et al. 2012	2008-2012	Leatherback, loggerhead	South Atlantic
Santos et al. 2013	2009-2011	Leatherback, olive ridley	Tropics

Table 2. Bycatch rates (sea turtles /1000 hooks), estimated fishing effort (number of hooks) from EFFDIS, estimated total interactions (number of individuals) by species and area and associated quarter (QTR) in the ICCAT Convention Area for different fleets. 'Reference' indicates the study from which the bycatch rates were assigned to the different fleets.

FLEET	SPECIES	AREA	QTR	BYCATCH RATE	EFFORT	NUMBER INT.	REFERENCE
BELIZE	*C. caretta*	N Atlantic	1-4	0-0.0128	3,692,311	47	Huang 2015
		Tropics	1-4	0-0.003	2,403,650	7	Huang 2015
		S Atlantic	1-4	0-0.0239	210,544	5	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	3,692,311	38	Huang 2015
		Tropics	1-4	0-0.03	2,403,650	72	Huang 2015
		S Atlantic	1-4	0-0.0038	210,544	1	Huang 2015
	L. olivacea	Tropics	1-4	0.0024	2,403,650	6	Sales et al., 2008
	C. mydas	Tropics	1-4	0.0032	2,403,650	8	Sales et al., 2008
BRAZIL	*C. caretta*	SW Atlantic	1-4	0.39-1.78	1,609,178	627-2864	Pons et al., 2010
		Tropics	1-4	0.07	2,828,310	198	Sales et al., 2008
	D. coriacea	Tropics	1-4	0.03	2,828,310	85	Sales et al., 2008
	L. olivacea	Tropics	1-4	0.01	2,828,310	28	Sales et al., 2008
	C. mydas	Tropics	1-4	0	2,828,310	0	Sales et al., 2008
CANADA	*C. caretta*	NW Atlantic	2	0.138	134,869	19	Garrison & Stokes, 2014
		NW Atl. coastal	3	0.313	662,795	207	Garrison & Stokes, 2014
		NW Atl. offshore	3	0.119	327,378	39	Garrison & Stokes, 2014
		NW Atl. coastal	4	0.145	156,175	23	Garrison & Stokes, 2014
		NW Atl. offshore	4	0.262	81,614	21	Garrison & Stokes, 2014
	D. coriacea	NW Atlantic	1	0.179	17,779	3	Garrison & Stokes, 2014
		NW Atlantic	3	0.35	327,378	11	Garrison & Stokes, 2014
		NW Atlantic	4	0.295	156,175	46	Garrison & Stokes, 2014
CHINA	*C. caretta*	N Atlantic	1-4	0-0.0128	60,374	0-1	Huang 2015
		Tropics	1-4	0-0.003	6,153,398	0-18	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	60,374	0-1	Huang 2015
		Tropics	1-4	0.03	6,153,398	0-184	Huang 2015
	L. olivacea	Tropics	1-4	0-0.0232	6,153,398	0-143	Huang 2015

Table 2 (continued)

FLEET	SPECIES	AREA	QTR	BYCATCH RATE	EFFORT	NUMBER INT.	REFERENCE
CHINESE-TAIPEI	*C. caretta*	N Atlantic	1-4	0-0.0128	2,630,935	0-34	Huang 2015
		Tropics	1-4	0-0.003	33,488,024	0-100	Huang 2015
		S Atlantic	1-4	0-0.0239	14,748,208	0-352	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	2,630,935	0-27	Huang 2015
		Tropics	1-4	0-0.03	33,488,024	0-1005	Huang 2015
		S Atlantic	1-4	0-0.0038	14,748,208	0-56	Huang 2015
	E.	SE Atlantic	1-4	0.001	8,473,921	8	Petersen et al., 2009
	L. olivacea	N Atlantic	1-4	0	2,630,935	0	Huang 2015
		Tropics	1-4	0-0.0232	33,488,024	0-777	Huang 2015
		S Atlantic	1-4	0-0.0032	14,748,208	0-47	Huang 2015
	C. mydas	SE Atlantic	1-4	0.001	8,473,921	8	Petersen et al., 2009
		Tropics	1-4	0.0032	33,488,024	0-107	Sales et al., 2008
JAPAN	*C. caretta*	N Atlantic	1-4	0-0.0128	6,323,814	0-81	Huang 2015
		Tropics	1-4	0-0.003	30,323,819	0-91	Huang 2015
		S Atlantic	1-4	0-0.0239	9,438,423	0-226	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	6,323,814	0-66	Huang 2015
		Tropics	1-4	0-0.03	30,323,819	0-910	Huang 2015
		S Atlantic	1-4	0-0.0038	9,438,423	0-36	Huang 2015
	L. olivacea	Tropics	1-4	0-0.0232	30,323,819	0-704	Huang 2015
		S Atlantic	1-4	0-0.0032	9,438,423	0-30	Huang 2015
	C. mydas	SE Atlantic	1-4	0.001	9,433,049	9	Petersen et al., 2009
	E.	SE Atlantic	1-4	0.001	9,433,049	9	Petersen et al., 2009
KOREA	*C. caretta*	N Atlantic	1-4	0-0.0128	244,852	0-3	Huang 2015
		Tropics	1-4	0-0.003	1,179,180	0-3	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	244,852	0-3	Huang 2015
		Tropics	1-4	0-0.03	1,179,180	0-35	Huang 2015
	L. olivacea	N Atlantic	1-4	0	244,852	0	Huang 2015
		Tropics	1-4	0-0.0232	1,179,180	0-27	Huang 2015
	C. mydas	Tropics	1-4	0.0038	1,179,180	4	Sales et al., 2008
	C. caretta	N Atlantic	1-4	0-0.0128	244,852	0-3	Huang 2015
NAMIBIA	*C. caretta*	SE Atlantic	1-4	0.02	1,210,015	24	Petersen et al., 2009
	D. coriacea	SE Atlantic	1-4	0.01	1,210,015	12	Petersen et al., 2009
	C. mydas	SE Atlantic	1-4	0.001	1,210,015	1	Petersen et al., 2009
	E.	SE Atlantic	1-4	0.001	1,210,015	1	Petersen et al., 2009
PORTUGAL	*C. caretta*	NE Atlantic	1-4	0.104	131,870	1	Mejuto et al., 2008
		S Atlantic	1-4	1.505	54,414	82	Santos et al., 2013
	D. coriacea	NE Atlantic	1-4	0.391	131,870	52	Mejuto et al., 2008
		Tropics	1-4	0.45	50,204	23	Santos et al., 2012
		S Atlantic	1-4	0.188	54,414	10	Santos et al., 2013
	L. olivacea	Tropics	1-4	1.2	50,204	60	Santos et al., 2012

Table 2 (continued)

FLEET	SPECIES	AREA	QTR	BYCATCH RATE	EFFORT	NUMBER INT.	REFERENCE
SOUTH AFRICA	*C. caretta*	SE Atlantic	1-4	0.02	149,216	3	Petersen et al., 2009
	D. coriacea	SE Atlantic	1-4	0.01	149,216	1	Petersen et al., 2009
	E. imbricata	SE Atlantic	1-4	0.001	149,216	0	Petersen et al., 2009
	C. mydas	SE Atlantic	1-4	0.001	149,216	0	Petersen et al., 2009
SPAIN	*C. caretta*	NW Atlantic	1-4	1.758	3,860,843	6787	Mejuto et al., 2008
		NE Atlantic	1-4	0.104	3,779,639	393	Mejuto et al., 2008
		Tropics	1-4	0.421	5,081,172	2139	Mejuto et al., 2008
		S Atlantic	1-4	0-0.0239	2,833,280	68	Huang 2015
	D. coriacea	NW Atlantic	1-4	0.349	3,860,843	1347	Mejuto et al., 2008
		NE Atlantic	1-4	0.391	3,779,639	1478	Mejuto et al., 2008
		Tropics	1-4	0.631	5,081,172	3206	Mejuto et al., 2008
		S Atlantic	1-4	0-0.0038	2,833,280	11	Huang 2015
ST. VINCENT AND THE GRENADINES	*C. caretta*	N Atlantic	1-4	0-0.0128	10,647,265	0-136	Huang 2015
		Tropics	1-4	0-0.003	2,127,643	0-6	Huang 2015
		S Atlantic	1-4	0-0.0239	164,344	0-4	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	10,647,265	0-111	Huang 2015
		Tropics	1-4	0.0.03	2,127,643	0-64	Huang 2015
		S Atlantic	1-4	0-0.0038	164,344	0-1	Huang 2015
	C. mydas	S Atlantic	1-4	0	164,344	0	Sales et al., 2008
	L. olivacea	S Atlantic	1-4	0.01	164,344	2	Sales et al., 2008
VANUATU	*C. caretta*	N Atlantic	1-4	0-0.0128	1,027,757	0-13	Huang 2015
		Tropics	1-4	0.0135	202,295	3	Sales et al., 2008
		S Atlantic	1-4	0-0.0239	36,303	0-1	Huang 2015
	D. coriacea	N Atlantic	1-4	0-0.0104	1,027,757	0-11	Huang 2015
		Tropics	1-4	0.035	202,295	7	Sales et al., 2008
		S Atlantic	1-4	0-0.0038	36,303	0-1	Huang 2015
	L. olivacea	N Atlantic	1-4	0	1,027,757	0	Huang 2015
		Tropics	1-4	0.0024	202,295	1	Sales et al., 2008
		S Atlantic	1-4	0-0.0032	36,303	0-1	Huang 2015
VENEZUELA	*C. caretta*	Tropics	1-4	0-0.003	5,282,398	16	Huang 2015
	D. coriacea	Tropics	1-4	0-0.03	5,282,398	158	Huang 2015

Table **2 (continued)**

FLEET	SPECIES	AREA	QTR	BYCATCH RATE	EFFORT	NUMBER INT.	REFERENCE
UNITED STATES	*C. caretta*	Florida E Coast	1	0.027	271,589	7	Garrison & Stokes, 2014
		Florida E Coast	3	0.087	180,957	16	Garrison & Stokes, 2014
		Florida E Coast	4	0.054	196,463	11	Garrison & Stokes, 2014
		Gulf of Mexico	1	0.009	441,554	4	Garrison & Stokes, 2014
		Gulf of Mexico	2	0.008	382,056	3	Garrison & Stokes, 2014
		Gulf of Mexico	4	0.021	283,930	6	Garrison & Stokes, 2014
		Mid Atl. Bight	2	0.038	240,897	9	Garrison & Stokes, 2014
		Mid Atl. Bight	4	0.179	186,193	33	Garrison & Stokes, 2014
		NE Coastal	3	0.313	632,043	198	Garrison & Stokes, 2014
		NE Coastal	4	0.145	173,992	25	Garrison & Stokes, 2014
		S Atl. Bight	2	0.02	414,278	8	Garrison & Stokes, 2014
	D. coriacea	Florida E Coast	1	0.027	271,589	7	Garrison & Stokes, 2014
		Florida E Coast	2	0.057	182,088	10	Garrison & Stokes, 2014
		Florida E Coast	4	0.051	196,463	10	Garrison & Stokes, 2014
		Gulf of Mexico	1	0.09	441,554	40	Garrison & Stokes, 2014
		Gulf of Mexico	2	0.0921	382,056	35	Garrison & Stokes, 2014
		Gulf of Mexico	3	0.021	458,515	10	Garrison & Stokes, 2014
		Gulf of Mexico	4	0.047	283,930	13	Garrison & Stokes, 2014
		Mid Atl. Bight	4	0.108	186,193	20	Garrison & Stokes, 2014
		S Atl. Bight	1	0.044	383,385	17	Garrison & Stokes, 2014
		NE Coastal	2	0.065	167,733	11	Garrison & Stokes, 2014
		NE Coastal	3	0.179	632,043	113	Garrison & Stokes, 2014
		NE Coastal	4	0.295	173,992	51	Garrison & Stokes, 2014

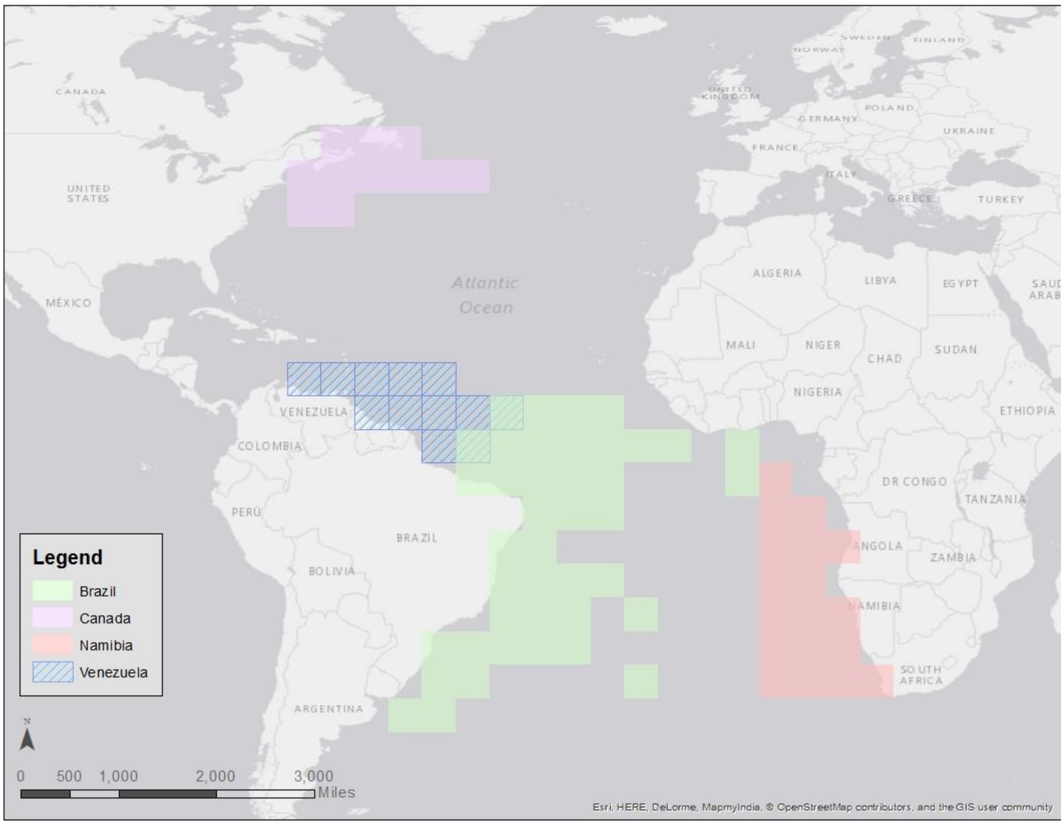

Figure 1. 5X5 quadrants fished by Brazil, Canada, Namibia, and Venezuela for 2014.

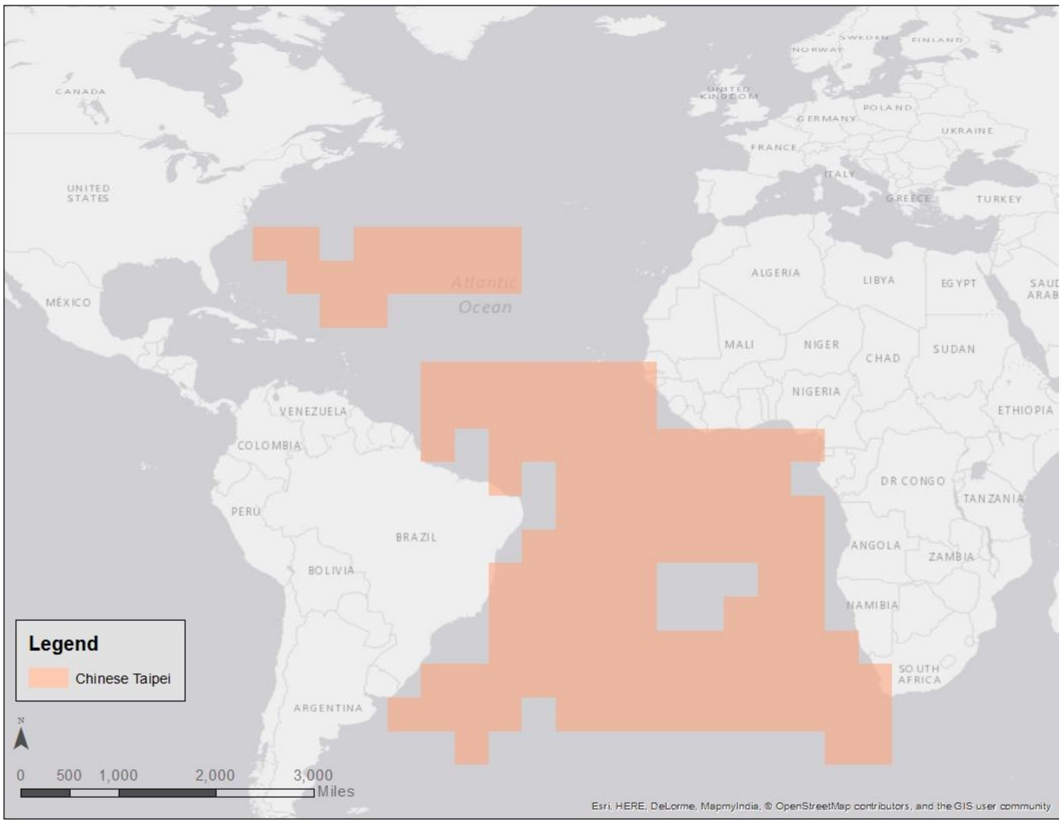

Figure 2. 5X5 quadrants fished by Chinese-Taipei in 2014.

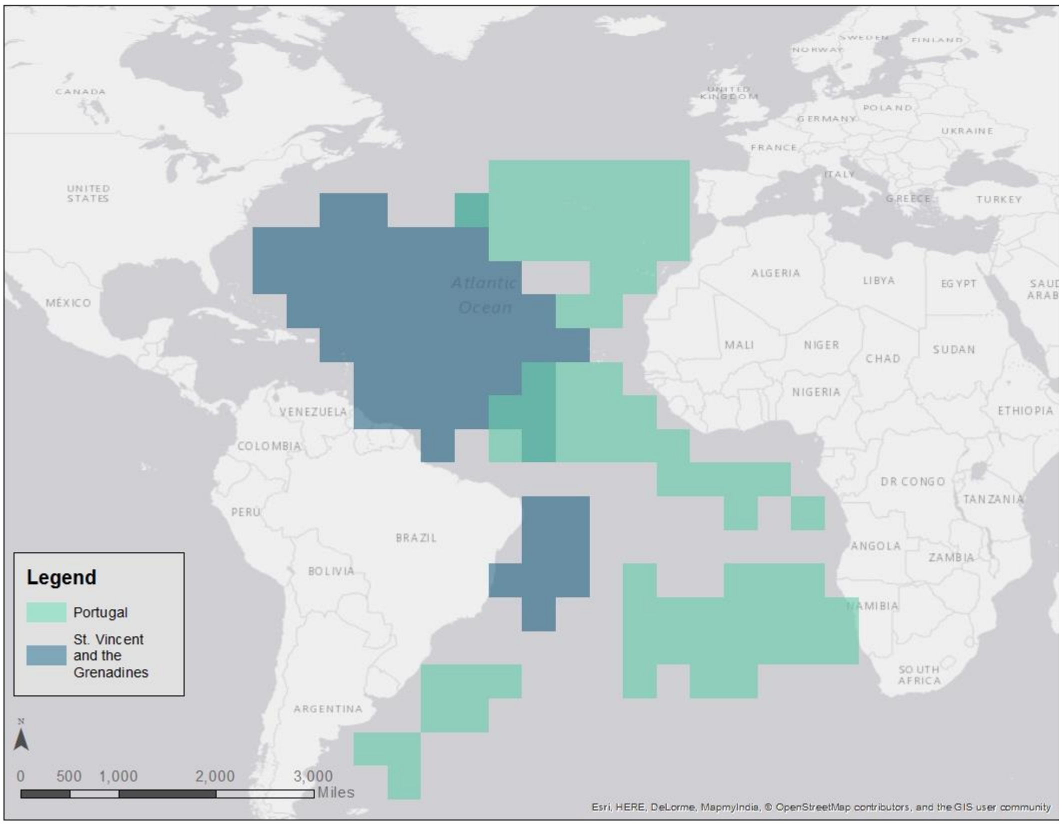

Figure 3. 5X5 quadrants fished by Portugal and St. Vincent and the Grenadines in 2014.

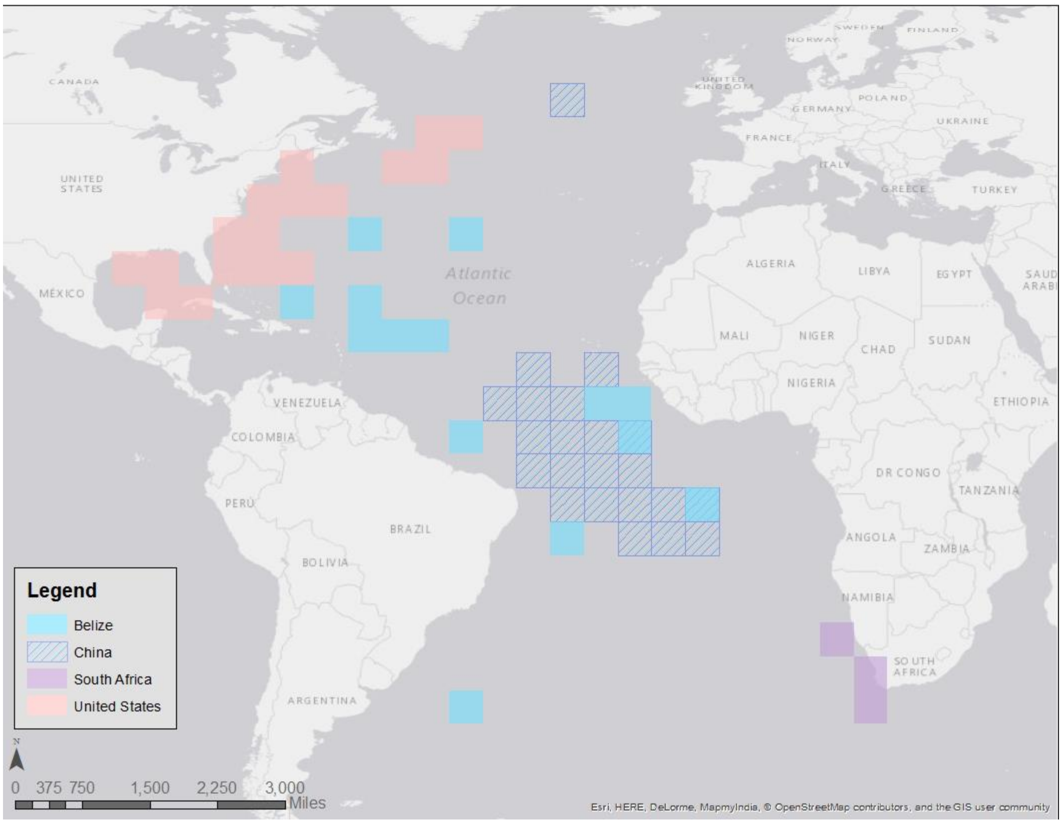

Figure 4. 5X5 quadrants fished by Belize, China, South Africa, and the United States in 2014.

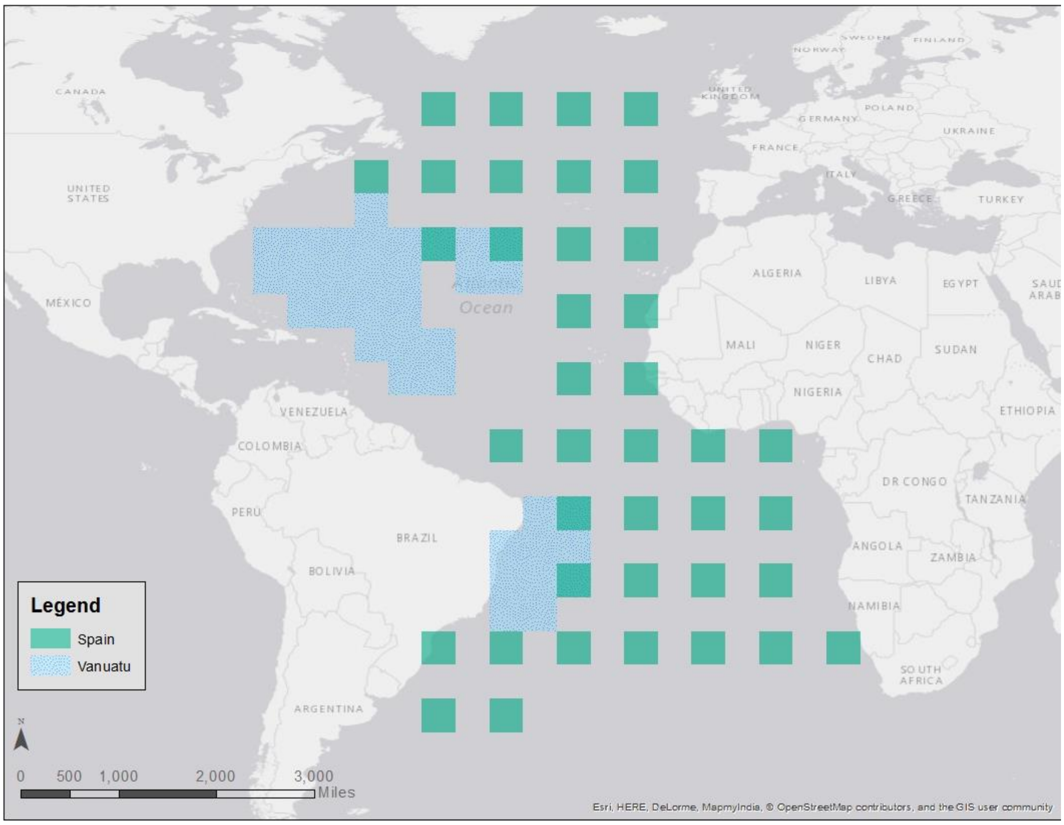

Figure 5. 5X5 quadrants fished by Spain and Vanuatu in 2014.

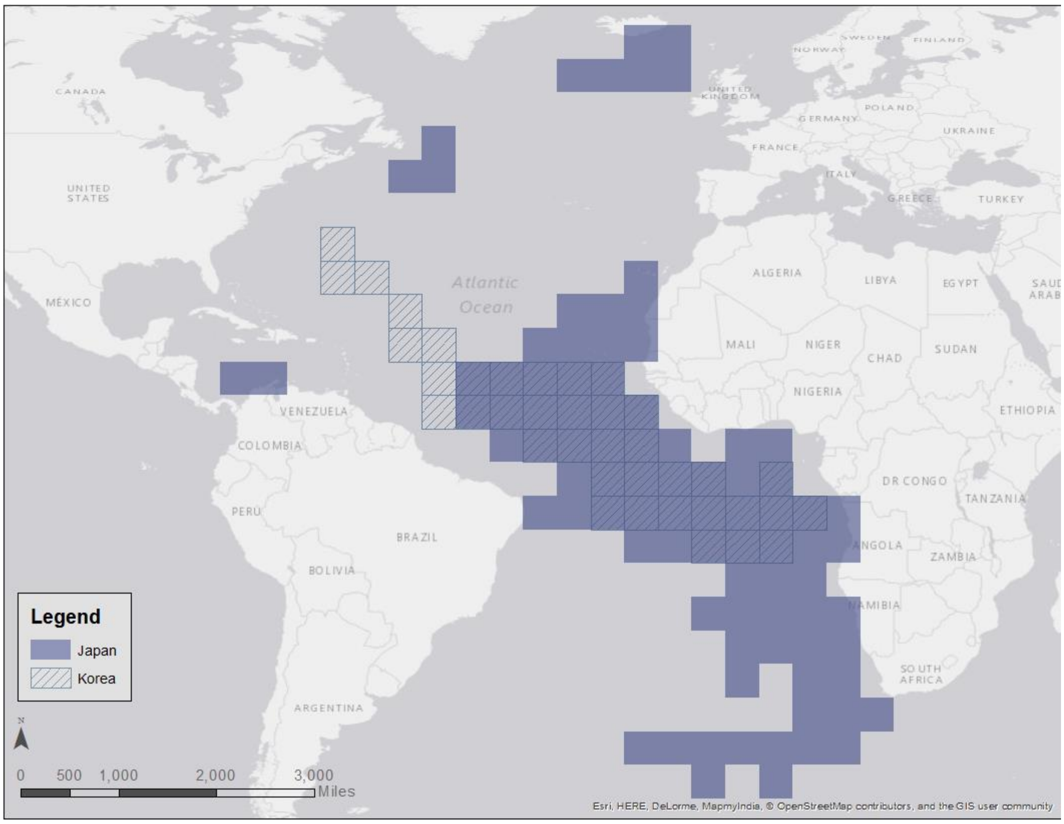

Figure 6. 5X5 quadrants fished by Japan and Korea in 2014.

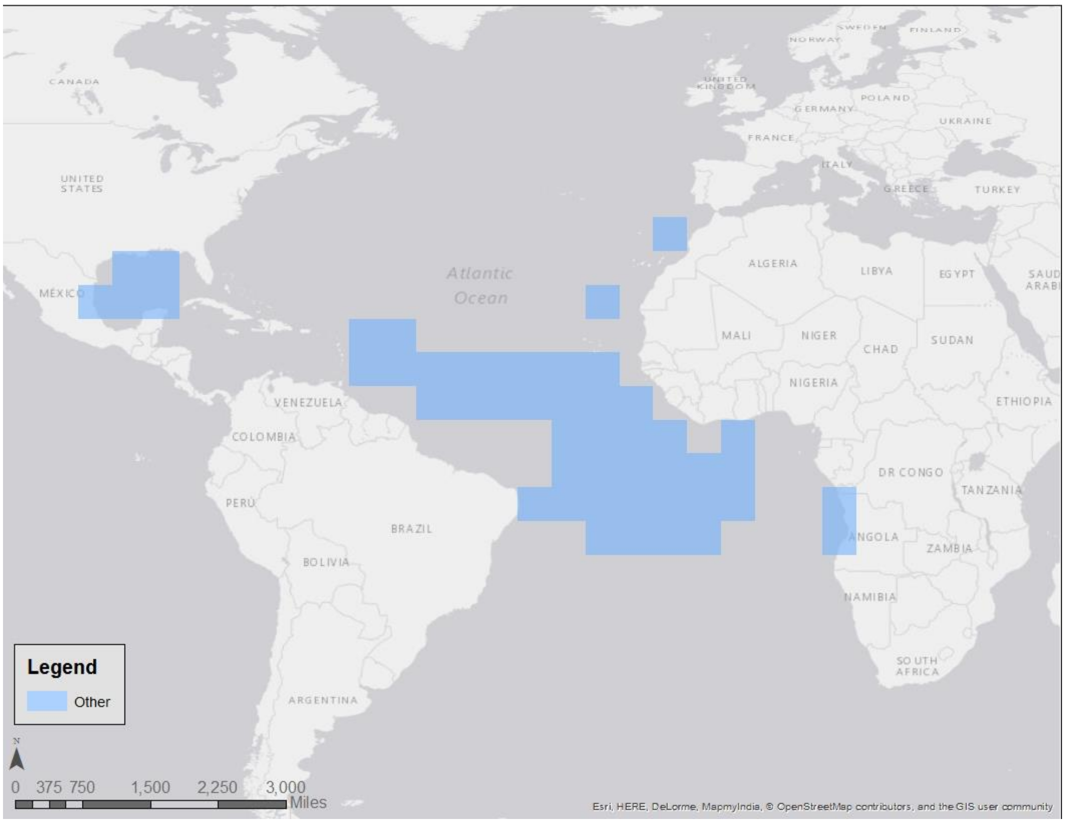

Figure 7. 5X5 quadrants fished by the fleet ‘Other’ in 2014.

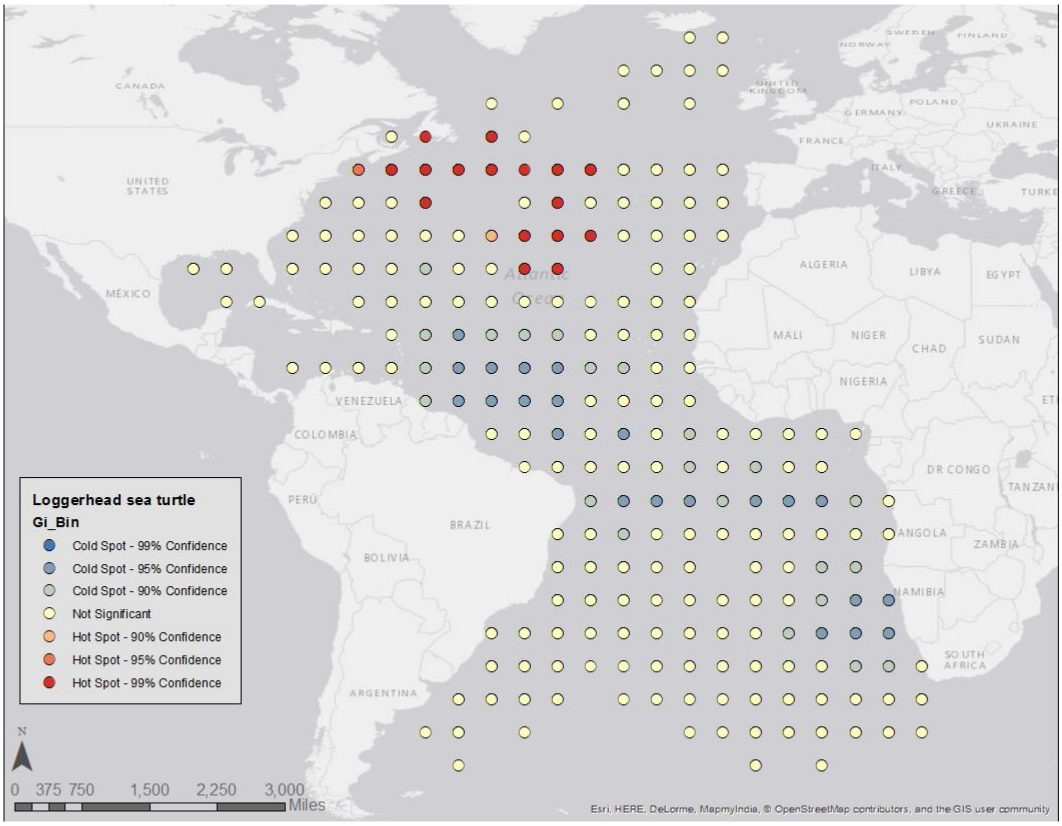

Figure 8. Results of the loggerhead sea turtle (*Caretta caretta*) hotspot analysis. Points in red indicate 99% confidence areas of high loggerhead interactions with longline gear.

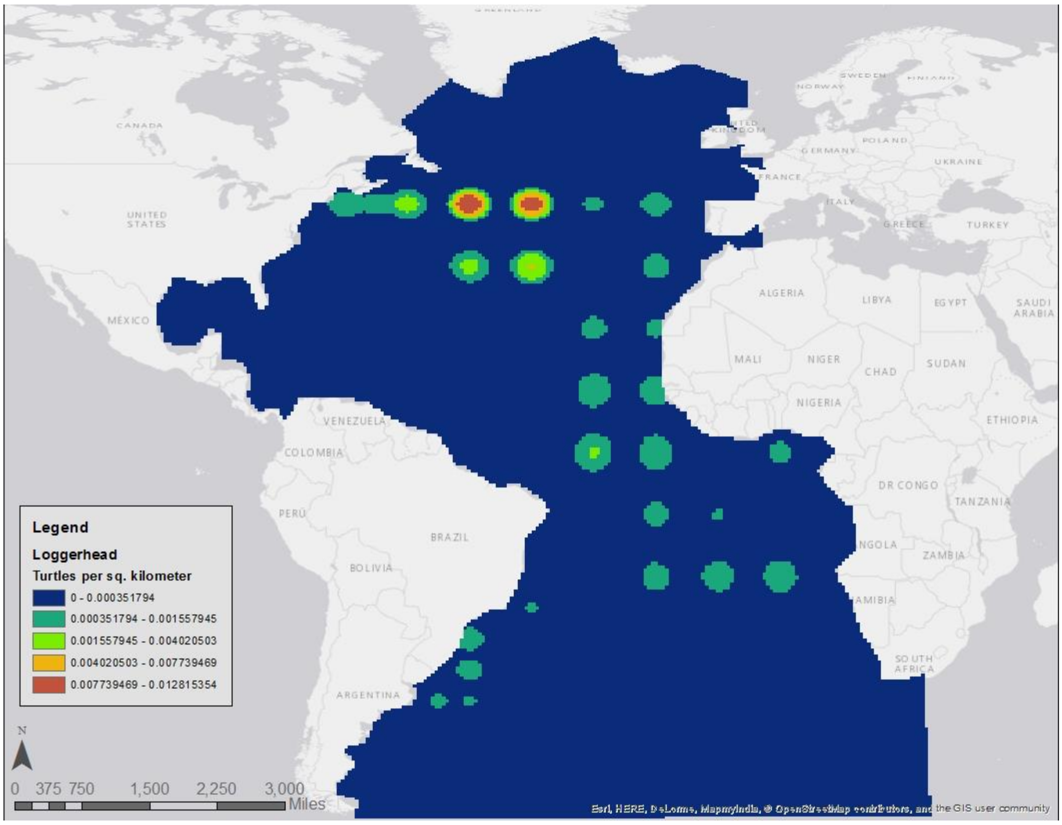

Figure 9. Loggerhead sea turtle density represented as the number of sea turtle interactions per square kilometer. Areas in red correspond to high numbers of loggerhead interactions with longline gear.

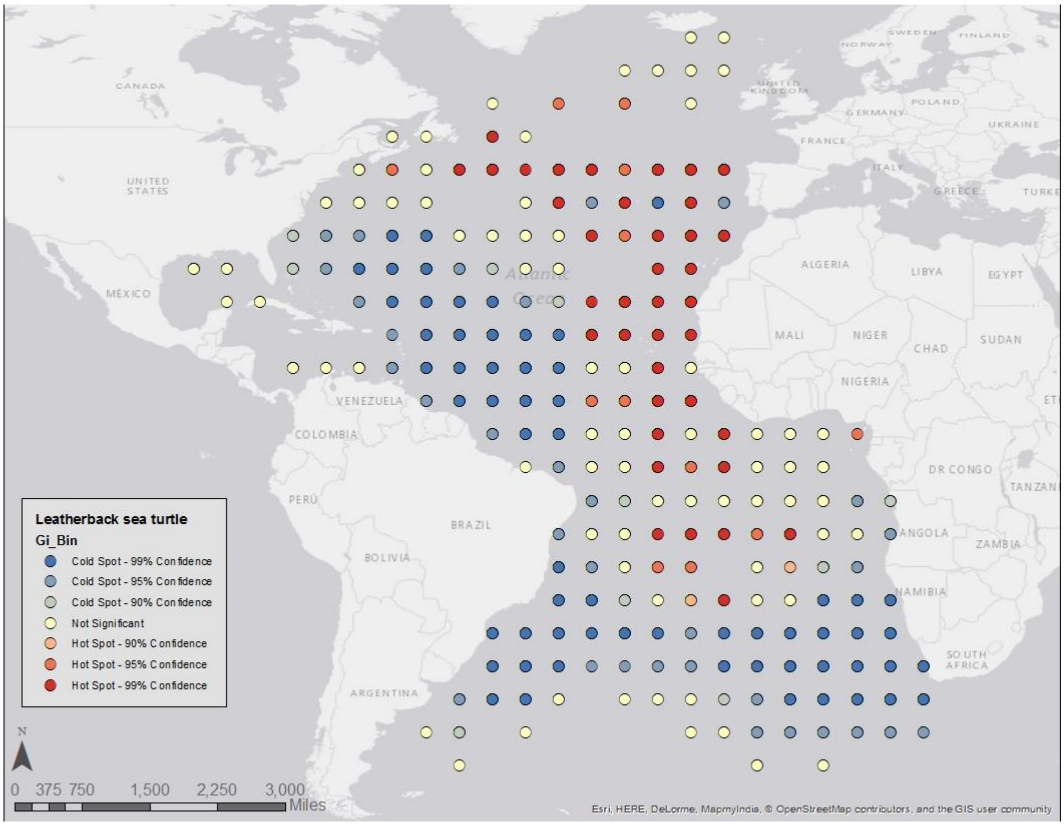

Figure 10. Results of the leatherback sea turtle (*Dermochelys coriacea*) hotspot analysis. Points in red indicate 99% confidence areas of high loggerhead interactions with longline gear.

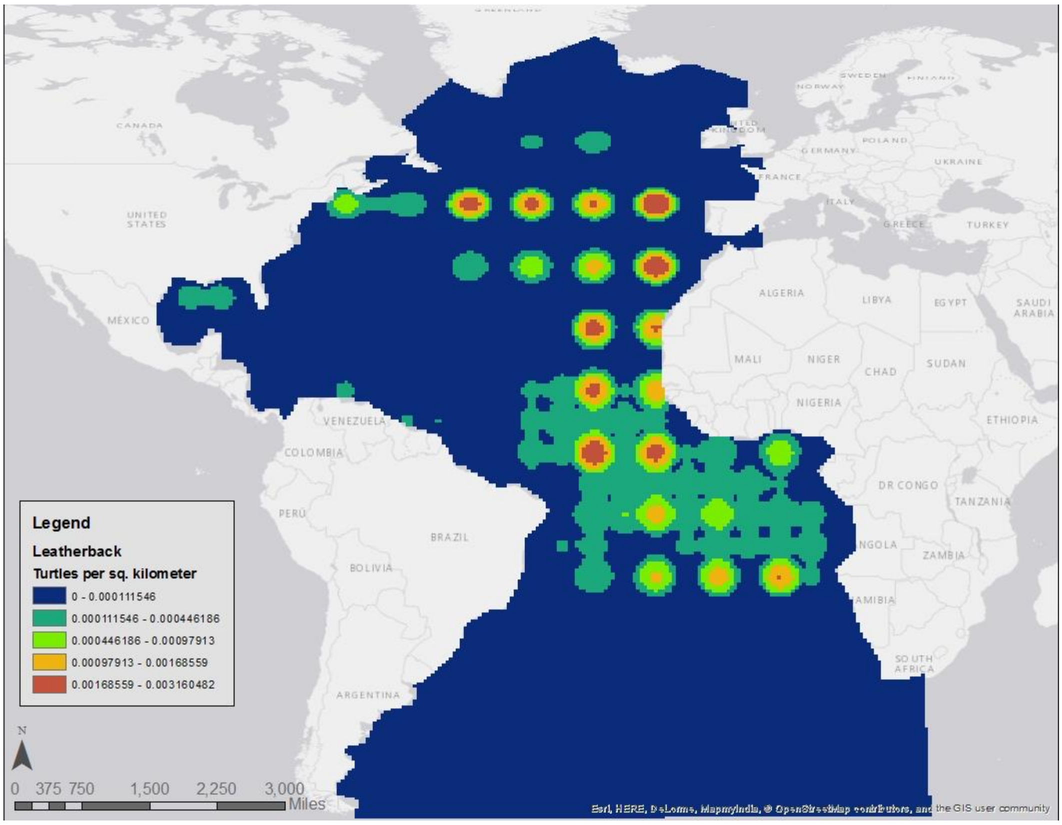

Figure 11. Leatherback sea turtle density represented as the number of sea turtle interactions per square kilometer. Areas in red correspond to high numbers of leatherback interactions with longline gear.

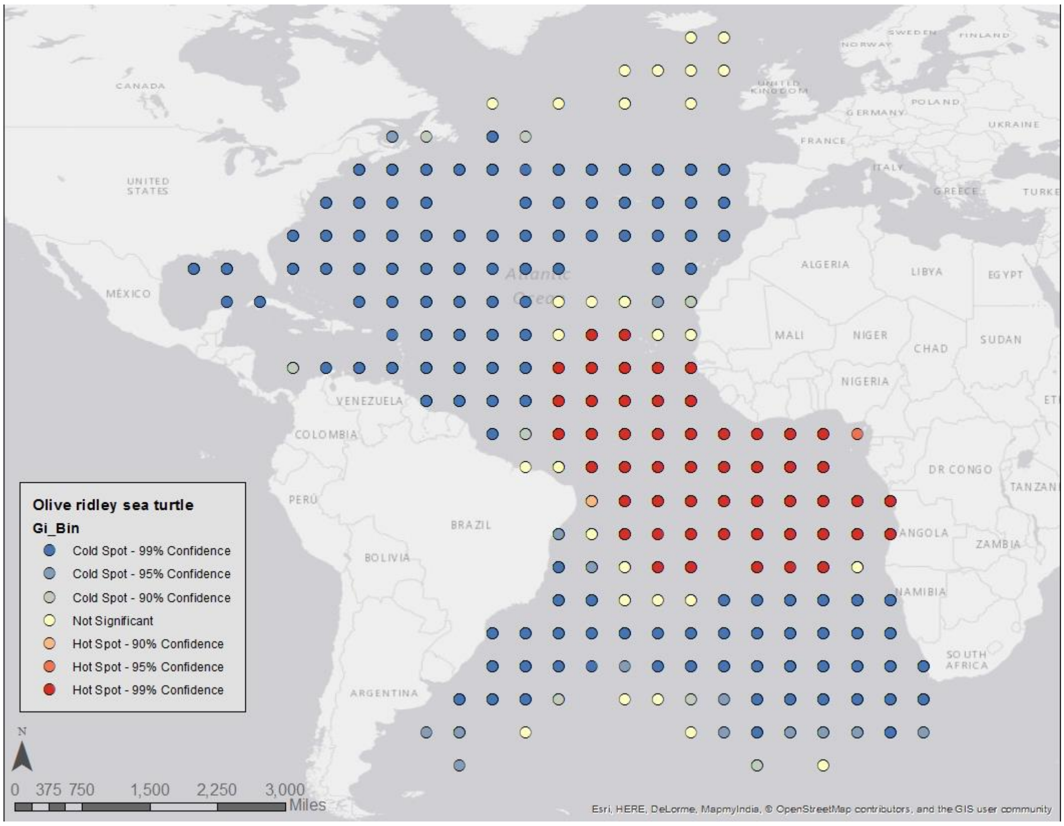

Figure 12. Results of the olive ridley sea turtle (*Lepidochelys olivacea*) hotspot analysis. Points in red indicate 99% confidence areas of high loggerhead interactions with longline gear.

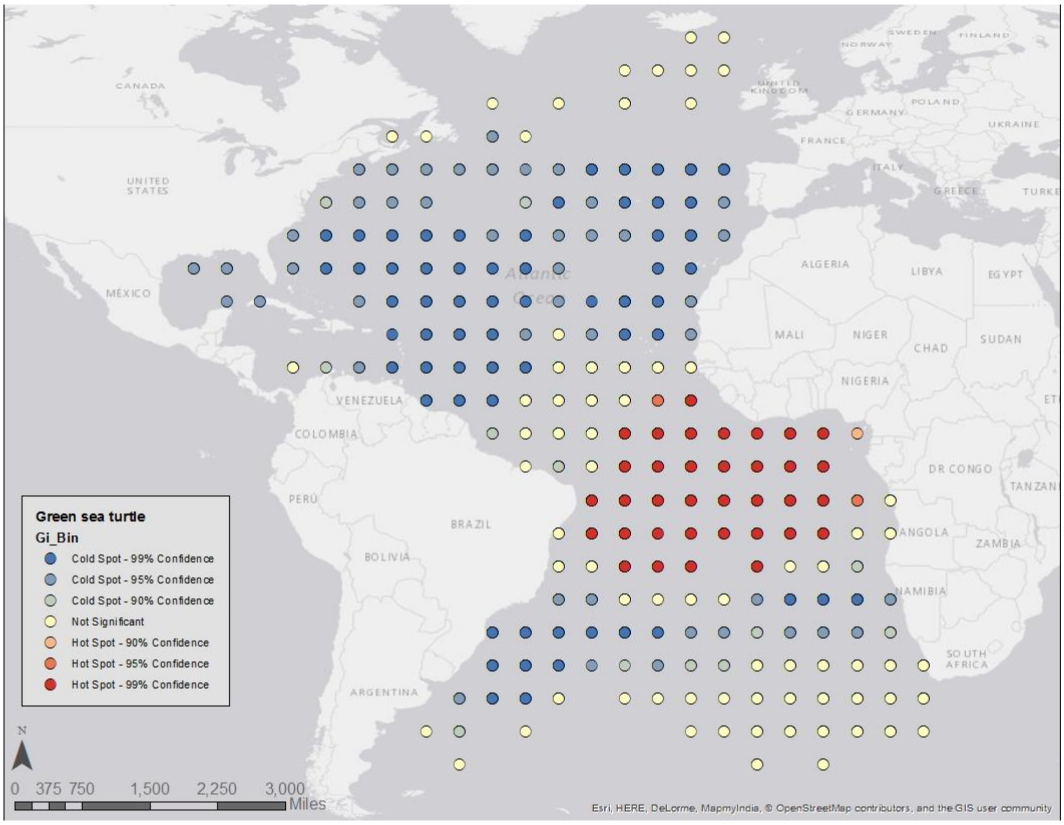

Figure 13. Results of the green sea turtle (*Chelonia mydas*) hotspot analysis. Points in red indicate 99% confidence areas of high loggerhead interactions with longline gear.

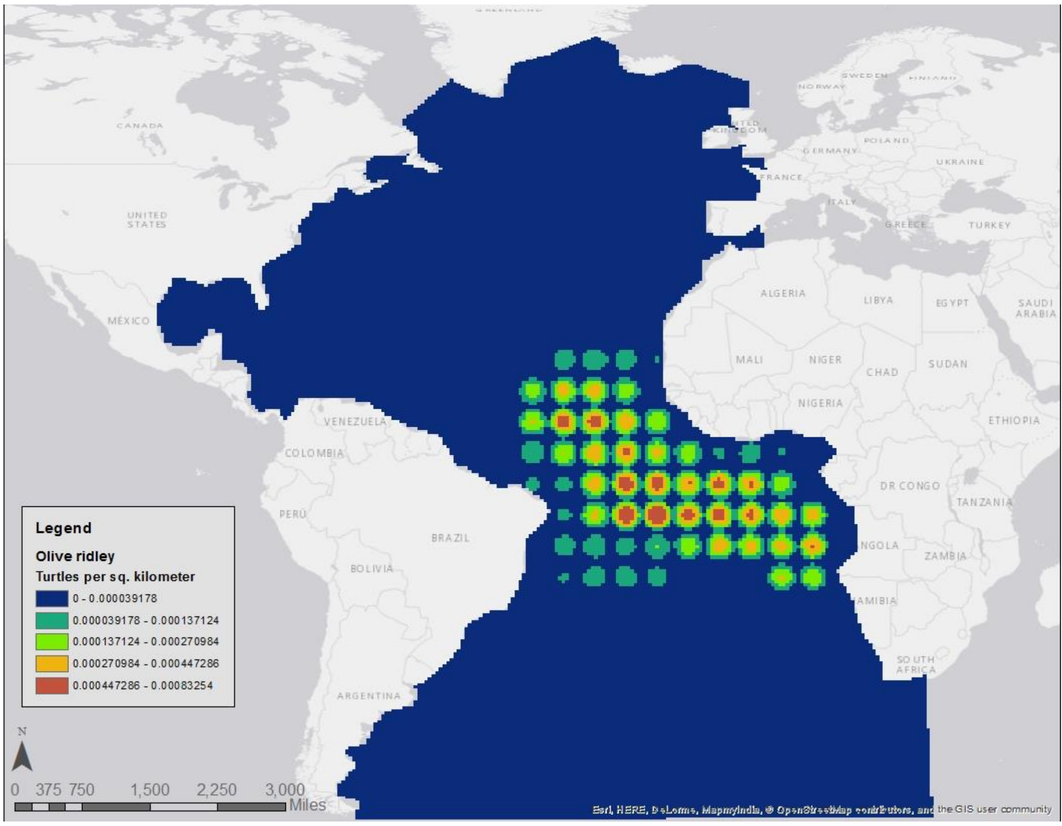

Figure 14. Olive ridley sea turtle density represented as the number of sea turtle interactions per square kilometer. Areas in red correspond to high numbers of olive ridley interactions with longline gear.

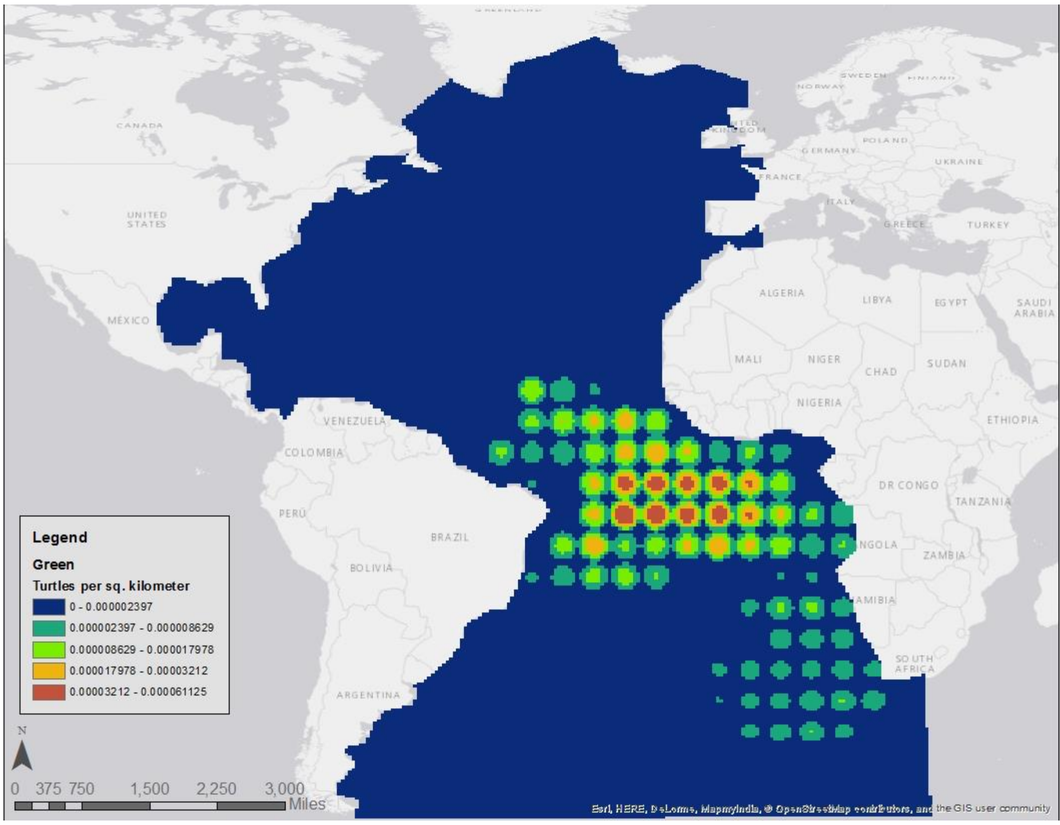

Figure 15. Green sea turtle density represented as the number of sea turtle interactions per square kilometer. Areas in red correspond to high numbers of green interactions with longline gear.

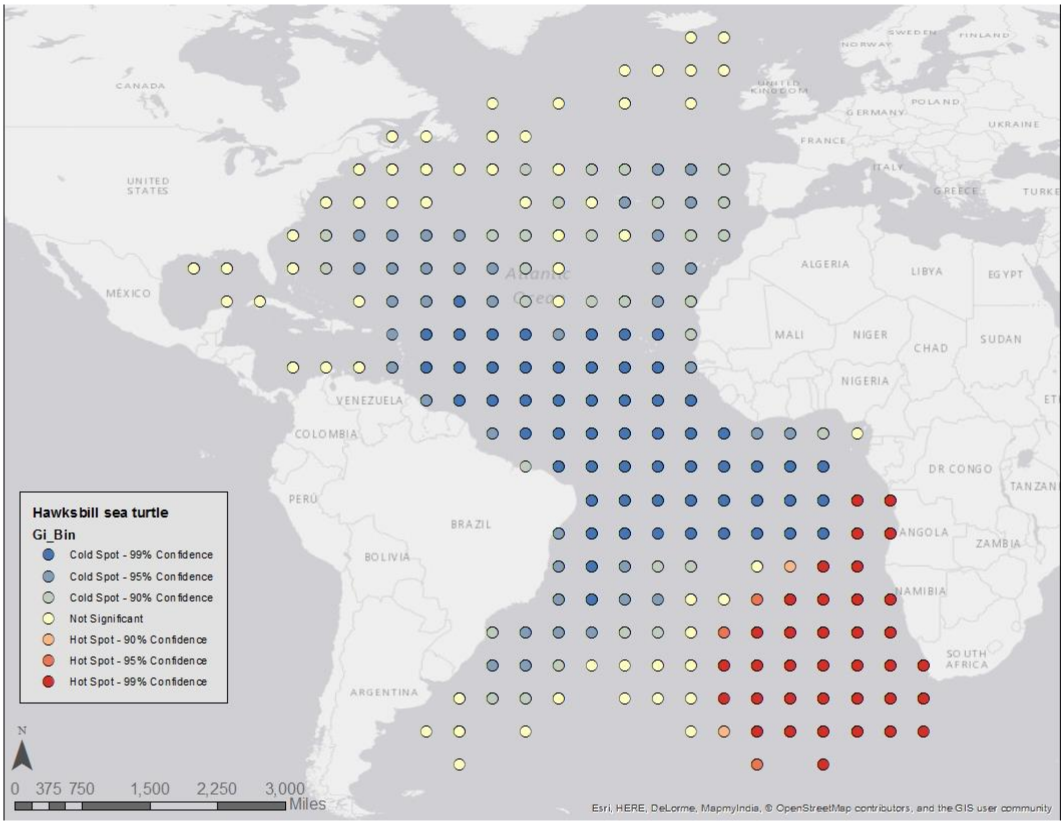

Figure 16. Results of the hawksbill sea turtle (*Eretmochelys imbricata*) hotspot analysis. Points in red indicate 99% confidence areas of high loggerhead interactions with longline gear.

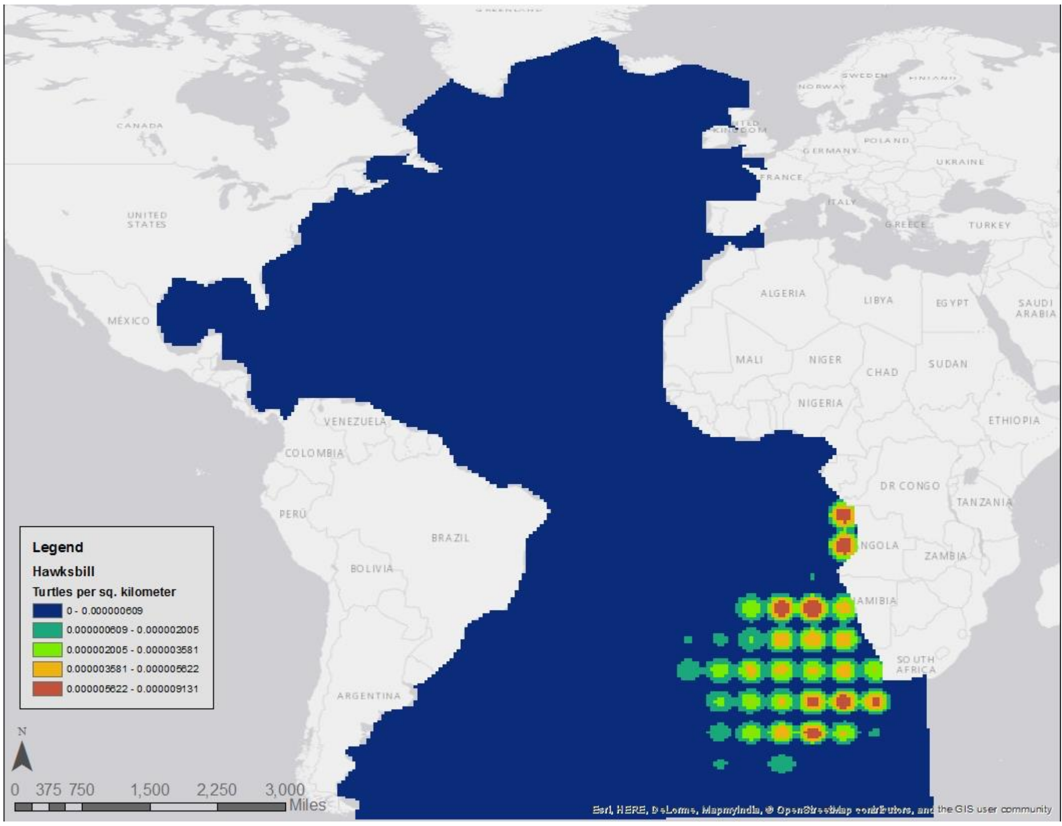

Figure 17. Hawksbill sea turtle density represented as the number of sea turtle interactions per square kilometer. Areas in red correspond to high numbers of hawksbill interactions with longline gear.