Determination of size discrepancies for sailfish (*Istiophorus platypterus)* in varying ocean basins.

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Executive Summary

This paper describes an internship project to fulfill the requirements for a Master of Professional Science from the University of Miami. The internship sought out to determine if sailfish grow to larger asymptotic sizes in different areas of the worlds oceans and hypothesize what factors, both environmental and oceanographic, could lead to differences in the length of sailfish.

This internship project, in cooperation with the International Game Fish Association (IGFA), focused on using the available size (length and weight) data held by the host organization as well as databases held by regional fishery management councils to compare size frequencies and asymptotic length of sailfish around the globe.

A total of 104,949 individual sailfish lengths and locations were used in the analysis of this study. After separating the observations into regions, the largest average sizes of sailfish were determined to be in the eastern Atlantic (n = 199), 204 cm and the eastern Pacific (n = 16,474), 187 cm. Both areas coincide with eastern boundary currents which are known to have some of the most productive ocean systems in the world, holding large accumulations of prey species.

Habitat compression, caused by hypoxic zones, in these areas may also force sailfish prey closer to the surface of the water column and therefore congregate the schools of both predators and prey further. Analysis of variance shows there was a significant difference in the size of sailfish between ocean basins ($p < 2e^{-16}$).

The data acquired from the Indian Ocean had over 75,000 observations and in total had an average size of 180 cm. Out of the total observations, 60% came from three fleets, Japan (n = 830), Taiwan (n = 13,368) and Sri Lanka (n = 31,744). The data set reported that the Sri Lankan fleet used gill nets and the Japanese and Taiwanese fleets used longlines.

The distribution of the fleets throughout the region also varied. The Sri Lankan fleet reported observations in two grids, 6105075 (western part of Sri Lanka) and 6105080 (eastern part of Sri Lanka). The Japanese fleet reported observations in 13 grids, which had a relatively diverse distribution throughout the ocean, and the Taiwanese fleet reported observations in 98 grids, which spanned mostly in the western part of the ocean and off the southeast coast of Sri Lanka.

Introduction

Sailfish

The sailfish, *Istiophorus platypterus*, is a cosmopolitan species that can be found in tropical and temperate waters (Rosas-Alayola et al. 2002). Sailfish follow a similar pattern to other billfish species where they remain in the upper water column most of the time and only dive to depth during the daytime (Holland et al., 1990; Block et al., 1992; Brill et al., 1993; Graves et al., 2002; Gunn et al., 2003; Kraus and Rooker, 2007; Sippel et al., 2007; Chiang et al., 2011; Kerstetter et al. 2011). They frequent coastal waters and have been studied to have large horizontal movements which coincide with the 28°C isotherm (McDowell 2002).

Sailfish consume a wide range of prey items feeding mainly on epipelagic species in coastal and oceanic waters. Throughout their lifetime sailfish occupy a wide range of trophic levels in the pelagic ecosystem. Stable isotopic analysis of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) revealed a clear relationship between body length and trophic level. Fishes with a higher $\delta^{15}N$ signal generally have a higher proportion of fishes in their diets.

They are sexually dimorphic regarding asymptotic length. Males and females have been shown to grow at the same rates for the first two years, then, males typically taper off as females continue to grow and reach larger asymptotic length (Hoolihan 2006). Many researchers report sailfish growth up to 2.5 – 3 m in length (Hedgepeth et al. 1982; Hoolihan 2006; Tsai et al. 2014).

Ocean Productivity

Ocean productivity refers to primary production of organic carbon by phytoplankton. Higher concentrations of chlorophyll, which can be attributed to higher production, can be seen along the equator, along the western coastlines of south America and Africa and eastern margins of the oceans as well as in higher latitudes (Sigman and Hain 2012).

Phytoplankton use phosphates, nitrates, and other nutrients to produce organic matter. Upwelling systems bring these subsurface nutrients up to the euphotic zone where they can be used in primary production. Some of the world's most productive oceans and largest fish populations are associated with coastal upwelling systems (Bakun 1996).

These systems have persistent winds that drive largescale offshore movement of surface waters through Ekman transport where cooler, nutrient rich water from depth is brought to the surface and pushed perpendicular to the coast (Carr, 2001). Large regions of shallow hypoxic waters known as oxygen minimum zones occur in these highly productive areas and, are consistent with eastern boundary upwelling systems (Ehrhardt and Fitchett 2006; Prince and Goodyear 2006). Depth distributions of sailfish in the eastern tropical Pacific and Atlantic have been monitored and shown that this hypoxic environment can establish a lower habitat boundary in these regions.

These areas of hypoxic water can compress the habitat for not only sailfish but their prey. We hypothesize that sailfish grow larger in different ocean basins and that the larger sailfish will be found around eastern boundary currents, where the high production allows for a plethora of prey items, and compression of these prey items towards the surface. We examine size discrepancies of sailfish in different ocean basins, two of which have well known eastern boundary currents, two with no eastern boundary currents and one with a very intricate current system.

Data and Methods

Data Sets

The entirety of this study was conducted using data acquired from Regional Fishery Management Organizations (RFMOSs) and Non-Governmental Organizations (NGOs). The data sets were acquired from, the International Game Fish Association (IGFA), the Inter-American Tropical Tuna Commission (IATTC), the International Commission for the Conservation of Atlantic Tunas (ICCAT), the Indian Ocean Tropical Tuna Commission (IOTC) and the National Oceanic and Atmospheric Administration's (NOAA) Pacific Island Fisheries Science Center (PIFSC). Each data set acquired included, at the minimum, a relative location of capture in decimal degrees, and the length of the sailfish in either centimeters or inches. Any observations made prior to 1990 were excluded from the study.

Data from the IGFA were provided via email as the online database includes only weights of individuals. The IATTC, ICCAT, and IOTC data sets were downloaded off the organization's respective websites (IATTC 2021, ICCAT 2020, IOTC 2018). The PIFSC data was provided upon request via email as their records are not publicly accessible.

The saltwater species world records held by the IGFA are comprised of fish caught using different recreationally caught line classes ranging from 2lb to 130lb for both male and female categories as well as an "All-Tackle" record representing the largest fish of a given species ever weighed by IGFA certified weighing devices and caught under IGFA angling rules. Information for each record catch includes the fish's size (length(cm), and weight(kg)) as well as a relative location of the caught individual. The IATTC data consists of billfish size measurements made by observers aboard purse-seine vessels in the eastern Pacific Ocean. The ICCAT data include individuals caught and released from their conventional tagging program for tuna-like species. The IOTC data were reported by IOTC contracting, co-operating and other parties having fleets that target tuna and billfish. The data provided by the PIFSC incorporated measurements of sailfish caught in the Hawaii-based longline fisheries.

Ocean Basins

This study compared five ocean basins, which were determined by RFMO designations of billfish stocks, data availability, and environmental/oceanographic boundaries. The central

Pacific Ocean (CPO), eastern Pacific Ocean (EPO), western Atlantic Ocean (WAO), eastern Atlantic Ocean (EAO) and the Indian Ocean (IO) (Table 1, Figure 1). The Pacific regions were separated based on the westerly edge of the hypoxia plume caused by the upwelling system defined in Prince *et al* (2006). The Atlantic regions were separated at the 35.00° W line. Due to the intricate currents within the Indian Ocean, no separation was determined in this region.

Data Quality Assurance

After initially plotting the locations from the raw data sets using ArcGIS Pro version 2.9.0, it was observed that quality assurance was needed to move forward with the study. Some points that were reported by ICCAT, an Atlantic-based organization, appeared to be in the Pacific Ocean, as well as out of the temperate and tropical waters where sailfish are known to frequent. Countries that are members of ICCAT may also fish outside of the Atlantic Ocean, but still report their catches to the organization and could be the reason for these points (personal communication, D. Die October 2021). Many data sets included individuals whose points appeared to be far inland and therefore could not be determined on the relative location of capture. All points that were ultimately used, were consistent within the organizations declared regions.

When required, lengths of sailfish were converted from measured units to lower-jaw fork length (LJFL) using the relationship defined by the IOTC for Indo-Pacific sailfish (IOTC 2018) and the relationship for Atlantic sailfish described in Prager *et al* (1995) (Table 5). Any lengths reported but considered to be strong outliers, e.g., size was 500 cm, were removed.

Data sets whose locations were reported as a latitude by longitude grid box were used, only after a set coordinate was determined as the center point of the given matrix. Data sets in which observations were from longline fisheries, whose reported locations were the start and end of the haul. The location was determined to be the center of the given haul. Any observations lacking any relative location were removed.

The IOTC data set locations were reported using Coordinating Working Party on Fishery Statistics (CWP) grid numbers, consistent with the Food and Agricultural Organizations of the United Nations (FAO). The CWP grid numbers consisted of seven digits the first digit determined what size the coordinate rectangle was, the next digit determined which quadrat of the globe the grid occurred in, the last five digits determined the latitude (two digits) and longitude (three digits) of the corner of the rectangle that was closest to 0° latitude and 0° longitude. After determining the corner coordinates and the size of the grid, the center point of the given grid was chosen.

Length Analysis

After compiling the acquired data sets into the five ocean basins, I then analyzed the same descriptive statistics prior to comparing the basins to each other. I determined the range of sizes, the average, and percentiles of each ocean basin. I grouped individuals into six classes according to percentiles, < 50th, 50th, 75th, 80th, 85th, and 90th. The < 50th percentile class contained all individuals whose length was less than the 50th percentile. The 50th percentile class contained all individuals whose length were greater than or equal to the 50th percentile but less than the 75th percentile. The 75th-85th classes follow the same structure, and the 90th percentile class contained all individuals whose size was greater than or equal to the 90th percentile.

In total 104,949 individual sailfish lengths and locations were used in the analysis of this study (Figure 2). In all ocean basins six heat maps were produced to visualize the distribution of sailfish in these regions based on their percentile bracket (Figures 3-7). These heat maps were produced using ArcGIS Pro version 2.9.0, using the percentile classes I separately made map frames using the heat map tool to visualize the distribution of sailfish in the ocean basin based on their size. I then combined all size classes into one map frame to better visualize how the distribution varied among size classes.

To determine if there was a difference in sizes between these ocean basins, an analysis of variance was run to compare the group means and to determine if individual ocean basins were different than one another a Tukey honest significant difference test was used. All statistical tests were run using Rstudio version 4.1.1, the analysis of variance test was ran using the "aov" function and the TukeyHSD test used "TukeyHSD". I used these statistical tests after determining the lengths followed a normal distribution by plotting histograms.

Results

Size Distributions in varying ocean basins

The eastern Atlantic and eastern Pacific had the two highest mean sizes, 204cm and 187cm respectively. The eastern Atlantic had the largest 90th percentile size, 245cm. The Indian Ocean, and western Atlantic had the next two highest 90th percentile range, 224cm and 218cm respectively (Table 2).

In three out of the five ocean basins the largest individual was a record reported by the IGFA, however in the western Atlantic and the Indian Ocean the maximum size reported was larger. The largest fish in the study came from the Western Atlantic, 366 cm.

Central Pacific

The data acquired for the central Pacific region came from fisheries that use longlines and purse seines. Sailfish in the central Pacific were found to have an average size of 160 cm. There were 1,371 individuals in this region. The largest individual was 322 cm, and the region had the lowest 90th percentile value at 191cm. The smaller individuals seem to congregate off Hawaii, where the larger individuals seem to emigrate from the waters around the islands of Hawaii south to the waters that surround Fiji (Figure 3).

Eastern Pacific

The data from the eastern Pacific came from a fishery that uses purse seines. A total of 16,474 individuals were analyzed in this region. The largest being 363 cm, and the region had the second lowest 90th percentile, at 217cm. When separating the eastern Pacific region further, looking at north and south of the equator, the 90th percentile increased to 277cm below the equator and remained at 217cm above the equator. The distribution of smaller sailfish appears to be equal along the central American coastline and into the Gulf of California. Larger sailfish seem to congregate off the coasts of Guatemala and Costa Rica (Table 3 & Figure 4).

Western Atlantic

The data for the western Atlantic used a combination of hook and line. This region included data from 10,678 individuals. The largest reported individual being 366cm, this was the largest out of the entirety of the study. Most of the individuals in this region were reported through ICCATs tagging program which seemed to congregate their study area around the coastline of Florida and the Caribbean. The distribution of smaller individuals appears to be throughout the Caribbean and the Gulf of Mexico as well as a small number caught off the southern coast of Brazil. Larger individuals seem to have a congregation off Venezuela (Figure 5).

The dataset for the western Atlantic had 708 individuals whose reported size measured 213.86 cm. Which can be the cause of two percentiles, the 80th and 85th, having the same value.

Eastern Atlantic

The data for the eastern Atlantic came mostly from hook and line fisheries. This region had 199 individual lengths reported. The largest of which was 299 cm. The sample had the highest average, and 90th percentile, 204 and 245 cm, respectively. There appears to be a large distribution of the smaller individuals in the eastern Atlantic while the larger individuals seem to travel to areas off the southwestern central African coastline near Gabon and Angola as well as northwestern Africa off the coast of Senegal (Figure 6).

Indian Ocean

The data for the Indian Ocean contained a combination of different fisheries including longlines, gill nets and purse seines. The Indian Ocean had the largest sample size, with 76,227 individuals. This ocean had the second highest 90th percentile at 224cm and an average size of 180cm. Smaller individuals appear to be congregated off the southern coast of India and around Sri Lanka. The larger individuals seem to distribute evenly among the entirety of the Indian Ocean (Figure 7). The data in this region were reported by at-sea observers aboard tuna vessels that also targeted billfishes. The dark coloration in all the map frames around the southern coast of India and Sri Lanka, lead to the understanding of a large fishery in this region.

When further analyzing the Indian Ocean data it was apparent that the dark coloration in the map frames is a result of the Sri Lankan fleet. We found that 60% of observations in the Indian Ocean came from three fleets, Sri Lanka, Taiwan, and Japan.

The Sri Lankan fleet accounted for 31,744 observations and had a mean size of 152 cm. The largest induvial observed by this fleet was 298 cm and the 90th percentile value was 196 cm. The smaller individuals seem to be found off the western coast of the country and as they grow larger, they seem to congregate off the eastern coast of the country (Figure 8).

The Taiwanese fleet reported 13,368 individuals that had an average size of 167 cm. The largest individual reported was 283 cm and the 90th percentile was 199 cm. The Taiwanese fleet had reported observations in the most grids out of these three fleets, 98 grids. A majority of the reporting came from the western side of the ocean along the eastern coast of Africa. The smaller sailfish were mainly on this side of the ocean, where larger individuals seemed to move further into the open ocean and there was a hot spot of larger fish around the southeastern coast of Sri Lanka (Figure 9).

The Japanese fleet accounted for 830 observations and had a mean size of 173 cm. The largest individual was 259 cm and the 90th percentile was 208 cm. The smallest individual was 76 cm, which was the largest minimum size out of these three fleets. The distribution of the Japanese fleet covers a large range of the Indian Ocean with smaller individuals being caught in all reported grids, and larger individuals having a higher reporting in the eastern part of the ocean, including a hot spot off northwestern Australia (Figure 10).

Analyses of Length Discrepancies

After running an analysis of variance test, we can conclude that there was a significant difference in the size of sailfish in these ocean basins, ($p < 2e\text{-}16$) as well as a significant difference in ocean basins when compared individually amongst each other, using a Tukey HSD test (Table 4). The result of this analysis confirms the hypothesis that sailfish grow to different lengths in different oceans.

Discussion

This study sought out to determine how the physical, biological, and ecological dynamics of different ocean basins could affect the size of sailfish. Our study confirmed our hypothesis that sailfish do grow to different lengths in different oceans. We found that the largest average sizes occurred in both eastern ocean basins, leading us to believe that larger individuals are in fact found in areas with eastern boundary currents.

When looking further into the eastern Pacific boundary, the equator separates two currents. We determined that individuals south of the equator, where the Humboldt current is found, hold larger individuals than the region north of the equator, where the California current operates. The California current has been shown to be the least productive of all eastern boundary currents (Carr 2001).

When looking further into the Indian Ocean, the difference in fleets may show some insight into how gear types may affect the size frequencies found throughout the rest of the ocean boundaries. Both Taiwan and Japan, reported that the observations were from longlines and the data from the Sri Lankan fleet came from gill nets. The clear distinction between the size of individuals, from the Sri Lankan fleet, between the western and eastern side of the country suggests that some factors are influencing larger fish to be found off the eastern side. It could be possible that spawning may occur on this side of the coast. Furthermore, there may be a difference in allowable mesh size on this side of the country. The Sri Lankan national report from 2021 indicated that only 8% of their fleets used gill nets, and that High Sea gill nets have a maximum 5” or 6” stretched mesh. Mesh size could influence the number of larger individuals observed in this data set where longlines may have a larger range of fish that the gear can catch.

Based on recreational catch records and prevailing opinion among recreational anglers, we know that the largest sailfish frequent areas around eastern boundary currents (personal communication, B. Pohlot, August 2021). We anticipated that commercial data would mimic these observations, however the selectivity of the purse seine may mask the pattern due to the potential of larger sailfish not associating with the purse seines fishery’s targeted tuna species. Smaller sailfish may share the same prey items as the tunas and therefore may be caught disproportionately in purse seines.

We can see the disproportionate lengths when looking at the western Atlantic data set. This data included sailfish caught via recreational anglers using hook and line as well as individuals reported by ICCAT through their tagging program which utilized purse seines to catch sailfish. The individuals reported by recreational fishery were almost never as large as the ones found in the ICCAT dataset.

The analysis seems to reflect what is to be expected in these highly productive ocean basins, a more productive area will be able to maintain more abundant prey populations supporting more and larger predators. The habitat compression in these regions contribute to concentrating the high abundance of the prey items into the surface waters where they are more available to predators although this also makes the predators more available to extraction from fisheries. These regions seem to allow sailfish to hunt more efficiently without having to dive deeper to find prey items, but rather the schools being forced to the upper water column due to the low dissolved oxygen levels.

Our findings add to our understanding of how sailfish are distributed relative to ocean basins with varying levels of productivity. Understanding sailfish growth and asymptotic size is crucial to conservation and assessment of these species in specific regions. Also understanding how sailfish size relates to ecosystem dynamics is helpful to better understand how sailfish will react to climate change as oxygen minimum zones continue to grow further westward and become shallower.

Caveats

This study looked at five ocean basins, however one region, the western Pacific, was left out due to the lack of public data. A request for data was placed with the Western and Central Pacific Tuna Commission, but they were unable to fulfill my request in the timeframe for this internship project.

The data set used for the eastern Atlantic only had 199 individuals sixty-one of which were IGFA world record lengths. This may have caused the statistics to reflect a larger average size in this region where commercial fishery statistics are lacking.

Lastly, this study used data which was collected using a wide range of techniques and could result in gear selectivity issues. The different gears used in this project could reflect different maximum lengths to be present. As mentioned previously purse seine fisheries may catch smaller sailfish as bycatch due to the species they are targeting and the shared prey items. Gill net mesh size can change the selectivity of the gear and therefore the size of fish caught in the nets. Longlines may reflect certain sizes depending on the bait and size of the hooks. Future studies could look at predator/prey interactions in these boundaries to see if they are greater in regions with habitat compression.

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Figures and Tables

Table 1
Study Area

Ocean Basin	Limits	Estimated Area
Central Pacific	180.00° W - 135.00° W 35.00° N - 35.00° S	36,055,183 km^2
Eastern Pacific	135.00° W - 75.00° W 35.00° N - 35.00° S	41,655,047 km^2
Western Atlantic	97.00° W - 35.00° W 45.00° N - 30.00° S	42,893,330 km^2
Eastern Atlantic	35.00° W - 15.00° E 45.00° N - 30.00° S	38,937,449 km^2
Indian Ocean	25.00° E - 130.00° E 23.00° N - 43.00° S	78,407,672 km^2

Table 1: Dimensions of Ocean Basins. The limits of the basins create a box but are contingent on the boundary remaining in the correct ocean.

Table 2
Descriptive
Statistics

	Central Pacific	Eastern Pacific	Western Atlantic	Eastern Atlantic	Indian Ocean
n	1,371	16,474	10,678	199	76,227
Minimum	69	18	100	114	14
Maximum (IGFA Record)	322 (322)	363 (363)	366 (255)	299 (299)	333 (296)
$\bar{X}$	160	187	182	204	180
50^{th} Percentile	163	188	183	200	183
75^{th} Percentile	180	203	208	218	207
80^{th} Percentile	183	206	213	224	211
85^{th} Percentile	187	211	213	230	217
90^{th} Percentile	191	217	218	245	224

Table 2: Descriptive statistics of each ocean basin. Contains the percentiles which coincide with the heat maps created for visualization of different size distribution for each basin.

Table 3
Further separation of
Eastern Pacific Region

	Eastern Pacific	Eastern Pacific (North)	Eastern Pacific (South)
n	16,474	16,355	119
Minimum	18	18	41
Maximum (IGFA Record)	363 (363)	363	329
$\bar{X}$	187	187	199
50th Percentile	188	188	204
75th Percentile	203	203	223
80th Percentile	206	206	233
85th Percentile	211	211	250
90th Percentile	217	217	277

Table 3: Descriptive statistics when further separating the eastern Pacific boundary. The separation occurred at the equator. The southern observations overlap a greater upwelling area.

	diff	lwr	upr	p.adj	Pair
EA-CP	44.942685	37.301478	52.583893	0.000000e+00	EA-CP
EP-CP	27.558866	24.724195	30.393538	0.000000e+00	EP-CP
IO-CP	20.592875	17.844650	23.341100	0.000000e+00	IO-CP
WA-CP	22.863739	19.970721	25.756757	0.000000e+00	WA-CP
EP-EA	-17.383819	-24.566023	-10.201615	4.047113e-10	EP-EA
IO-EA	-24.349810	-31.498337	-17.201284	5.229150e-14	IO-EA
WA-EA	-22.078946	-29.284378	-14.873515	5.295764e-14	WA-EA
IO-EP	-6.965991	-7.831288	-6.100694	0.000000e+00	IO-EP
WA-EP	-4.695128	-5.946347	-3.443909	4.207745e-14	WA-EP
WA-IO	2.270864	1.230225	3.311502	2.637308e-08	WA-IO

Table 4: Results of the Tukey-HSD test comparing each individual basin to each other. All pvalues are below the threshold of 0.05 therefore rejecting the null hypothesis that the group means are equal. Leading us to confirm our hypothesis that sailfish grow to different lengths in varying ocean basins.

Population Group	Equation	Parameters
Indo-Pacific Sailfish	$\lambda_0 = (\lambda_1 + \beta)/\alpha$	$\alpha = 0.8845$ $\beta = -3.7025$
Atlantic Sailfish	$\lambda_{0\,=}\ \alpha + \beta{*}\lambda_1$	$\alpha = 7.719$ $\beta = 1.106$

Table 5: Equations used to convert Eye-Orbital Fork Length to Lower Jaw Fork Length.

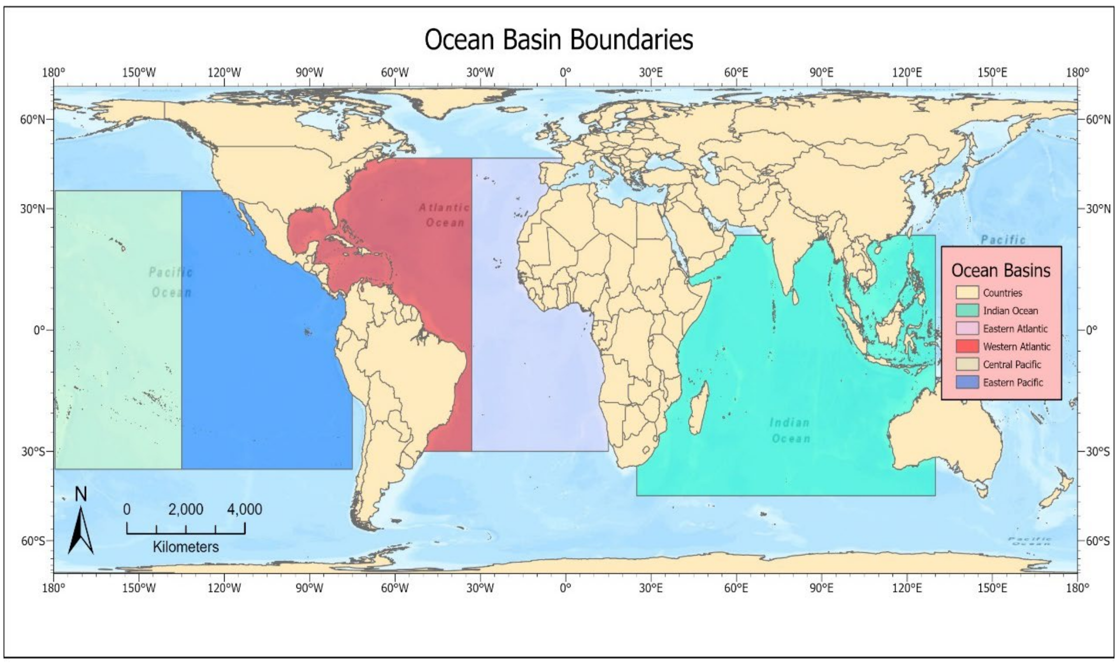


Figure 1: Study areas separated into their respective ocean basins.

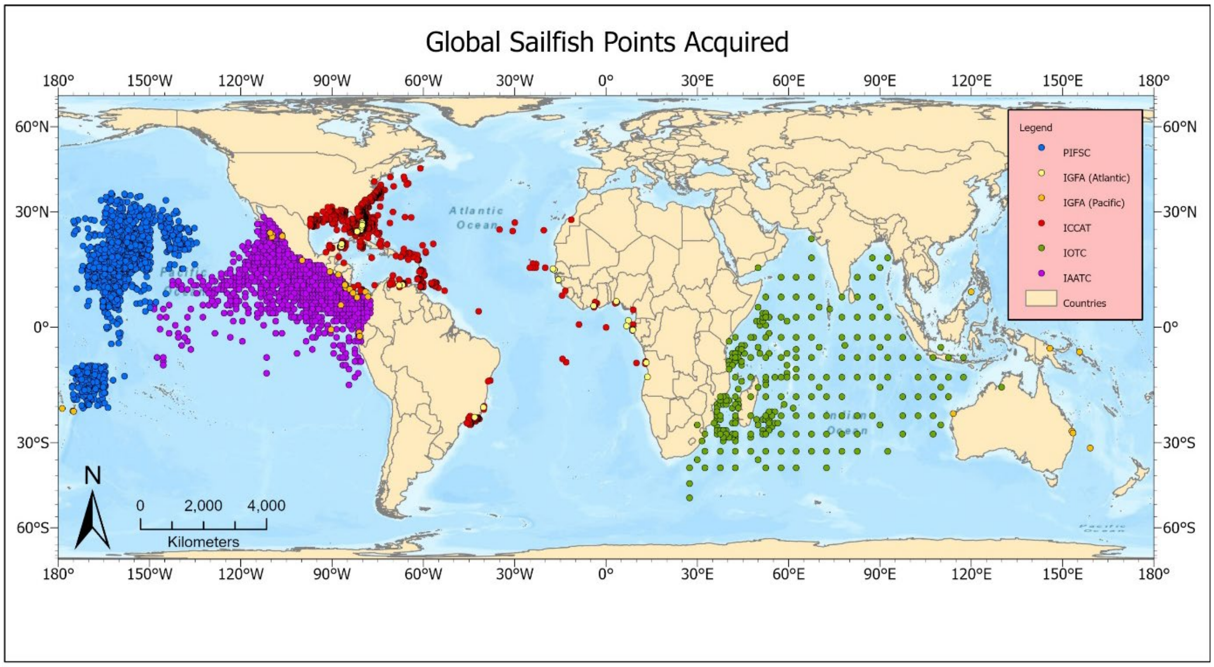


Figure 2: Global sailfish points acquired from Regional Fishery Management Organizations and Non-Governmental Organizations. These points were further separated using the jitter function in Rstudio to avoid points overlapping for the heat maps.

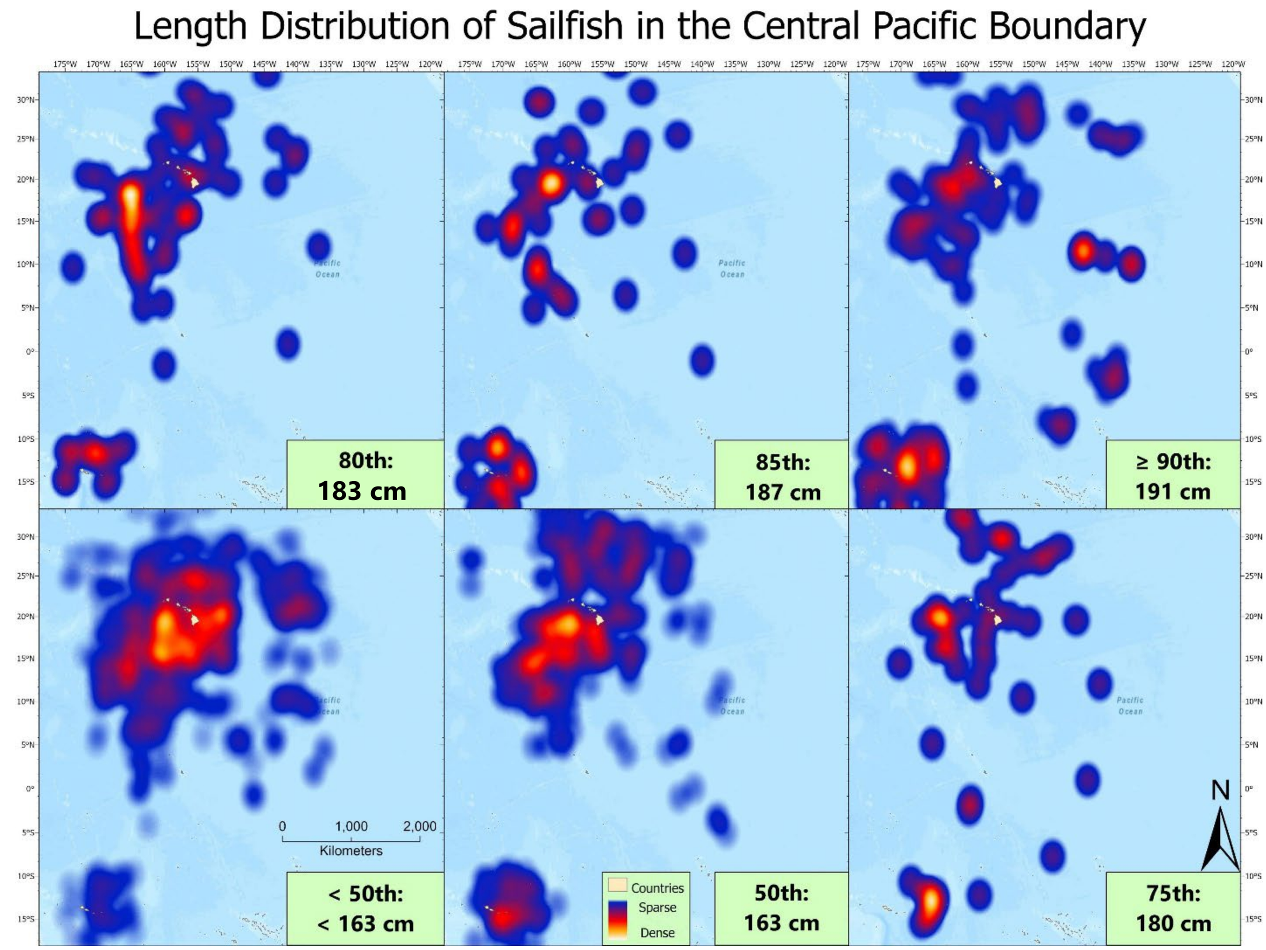


Figure 3: Distribution of different lengths of sailfish in the central Pacific. Smaller sailfish seem to congregate off the waters surrounding Hawaii. As they grow the distribution starts to expand and has a congregation off Fiji.

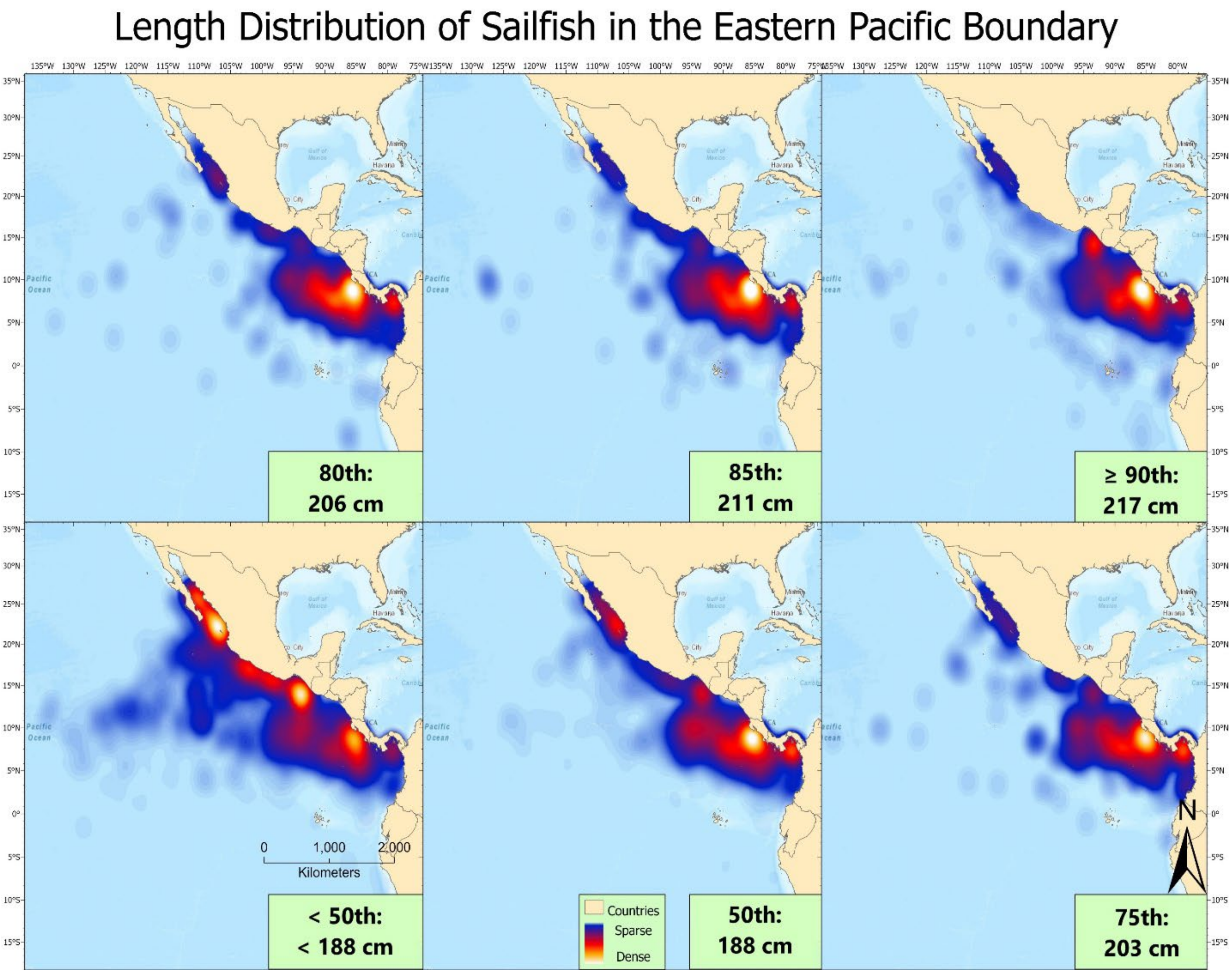


Figure 4: Distribution of different lengths of sailfish in the eastern Pacific. Smaller sailfish have an equal distribution around Mexico and central America, where larger sailfish move further south and congregate off Costa Rica and Guatemala.

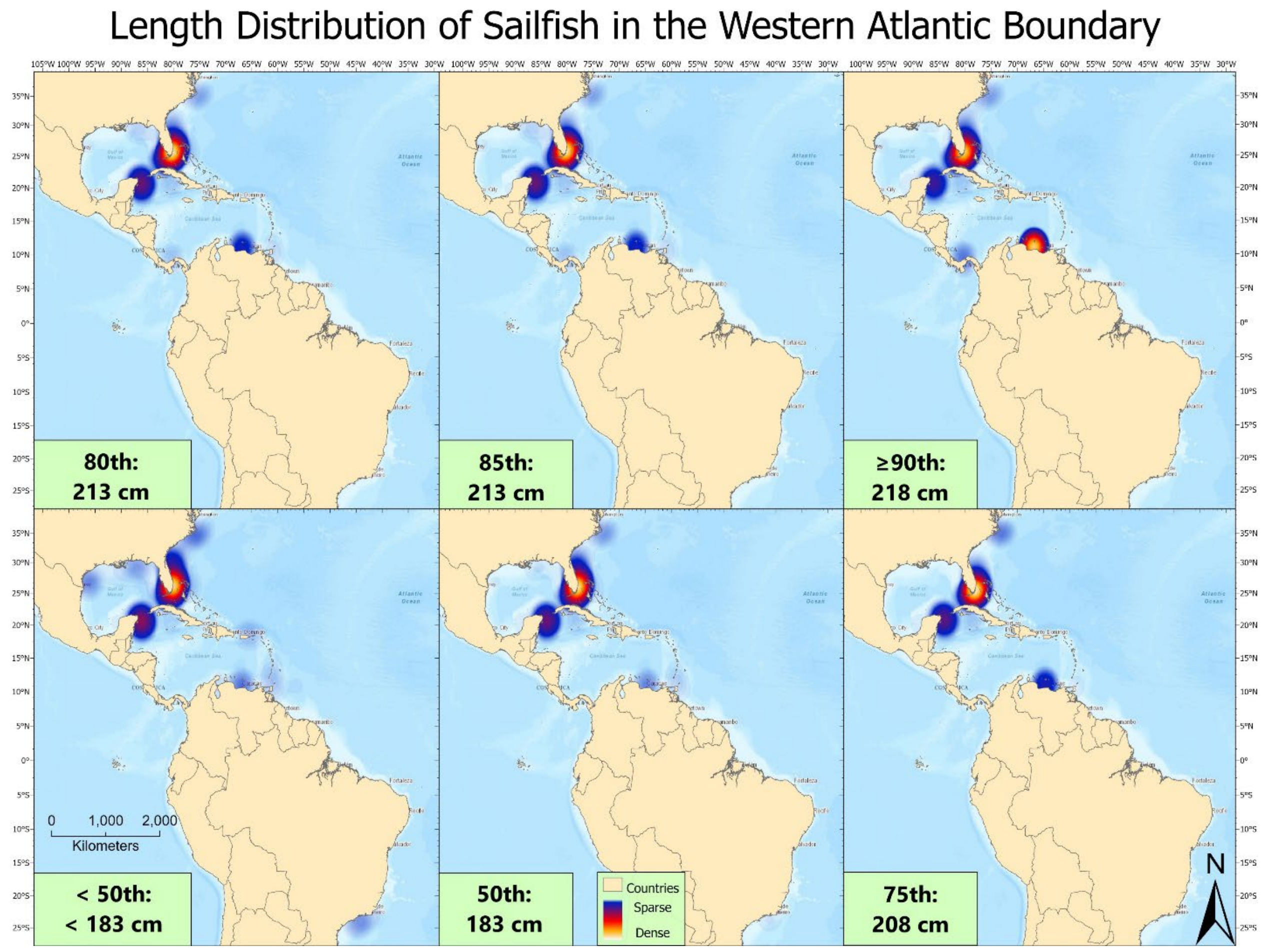


Figure 5: Distribution of different lengths of sailfish in the western Atlantic. Most of the observations in this dataset came from ICCATs tagging efforts and was contained a great number of observations in the Caribbean and off the east coast of the United States.

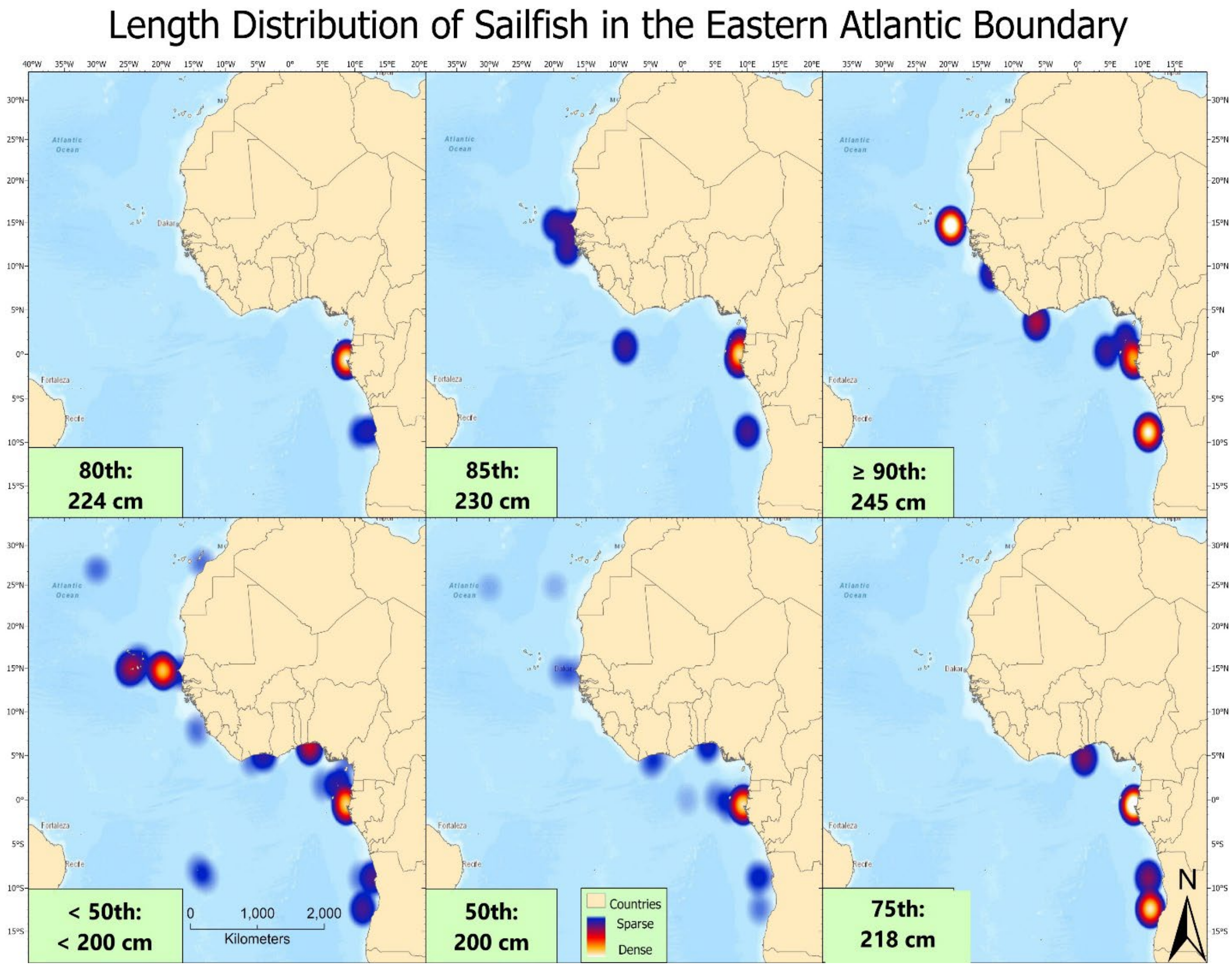


Figure 6: Distribution of different lengths of sailfish in the easter Atlantic. The smallest sample size out of all the data sets, (n = 199). Smaller individuals have an equal distribution along the African coastline where larger individuals seem to congregate off of the central western coastline.

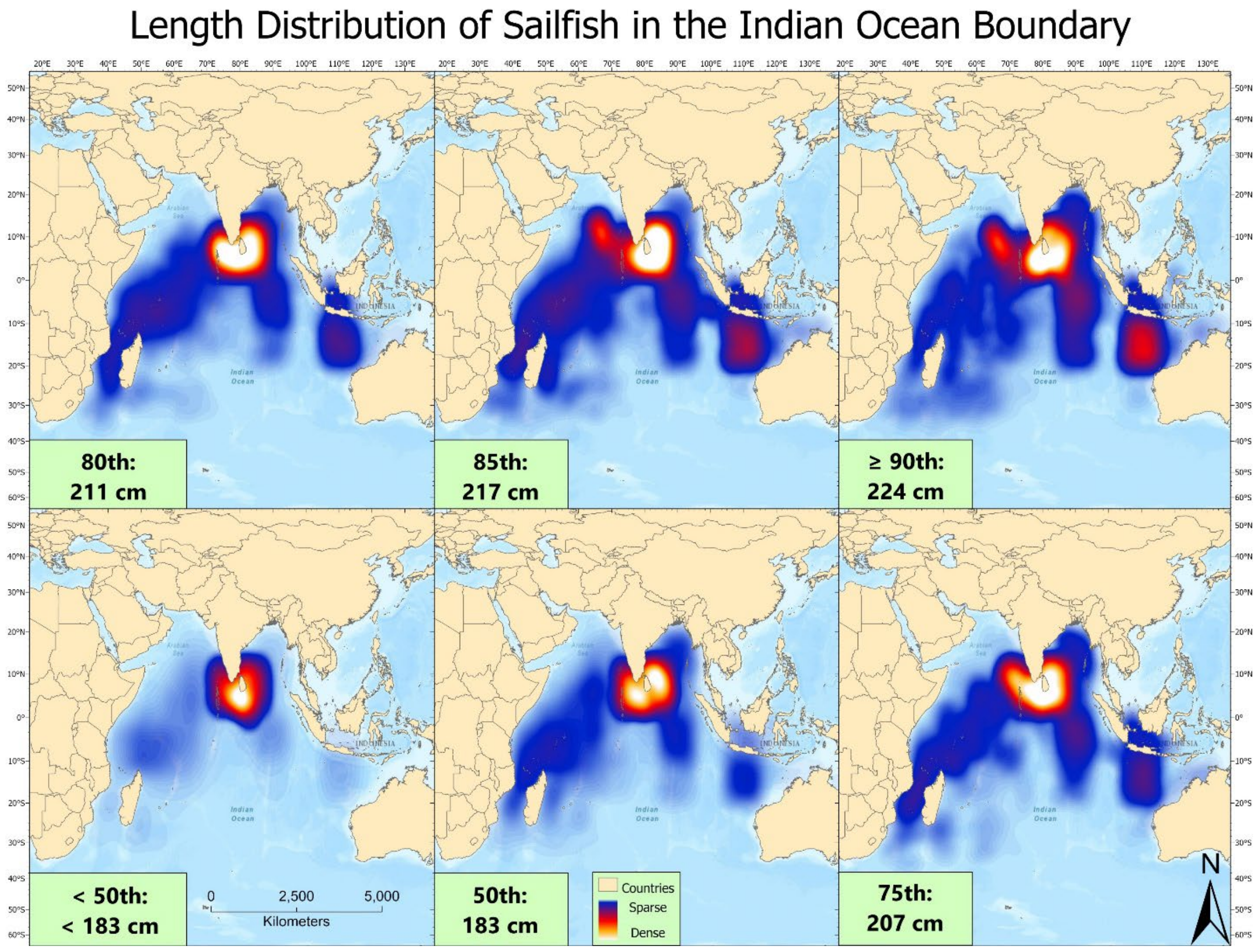
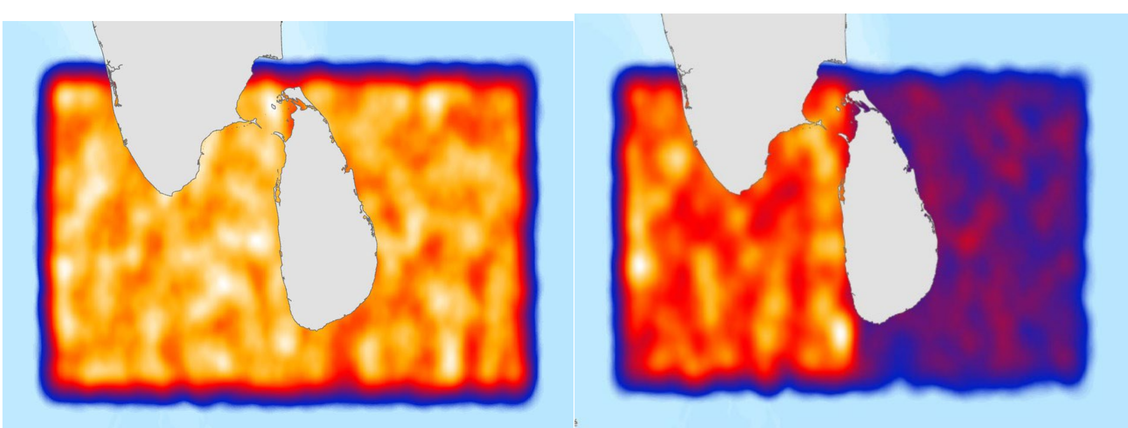
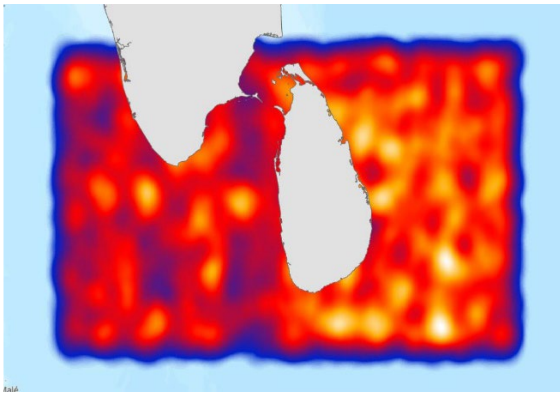


Figure 7: Distribution of different lengths of sailfish in the Indian Ocean. The largest data set, (n = 76,227) smaller individuals are shown to be heavily congregated around the southern tip of India and Sri Lanka, where larger sailfish have an equal distribution among the study area.

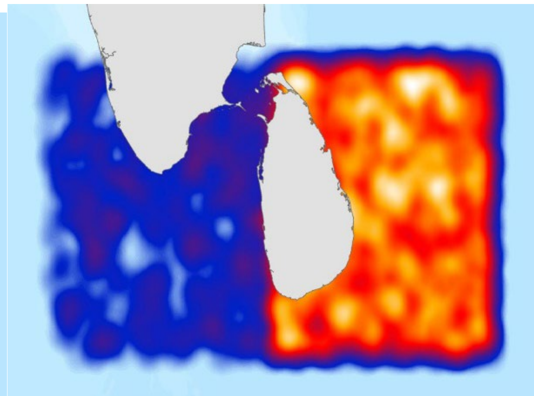


Sri Lankan Fleet All Observations

Sri Lankan Fleet 50th Percentile: 157 cm

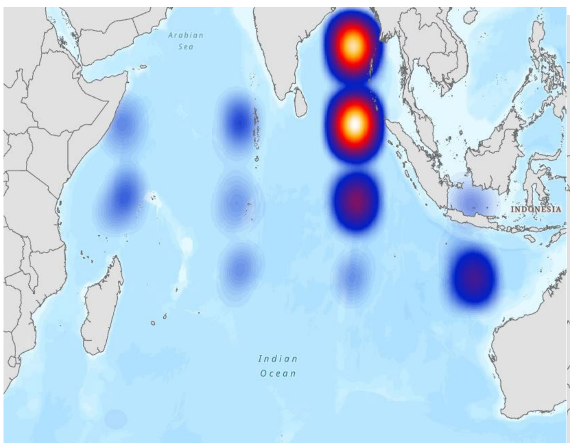


Sri Lankan Fleet 75th Percentile: 178 cm

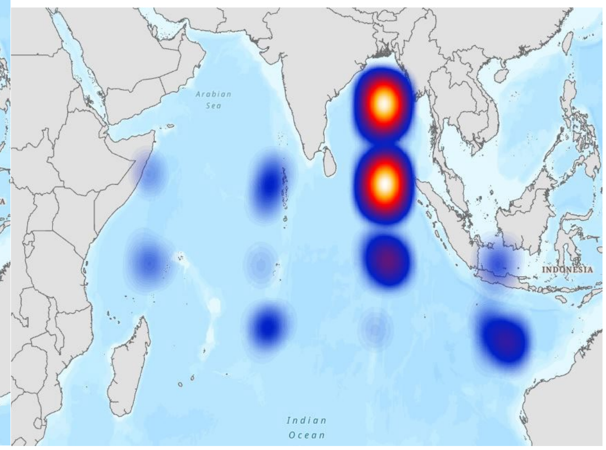


Sri Lankan Fleet 90th Percentile: 196 cm

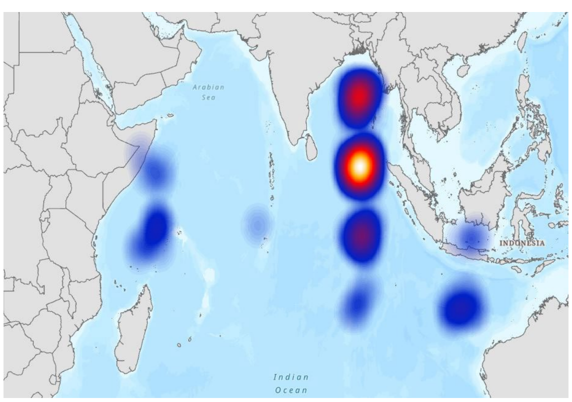
Figure 8: Distribution of different lengths of sailfish from the Sri Lankan fleet in the Indian Ocean. The most observations out of any fleet, (n = 31,744). Smaller individuals are found off the western coast and as they grow larger they seem to congregate off the eastern coastline.



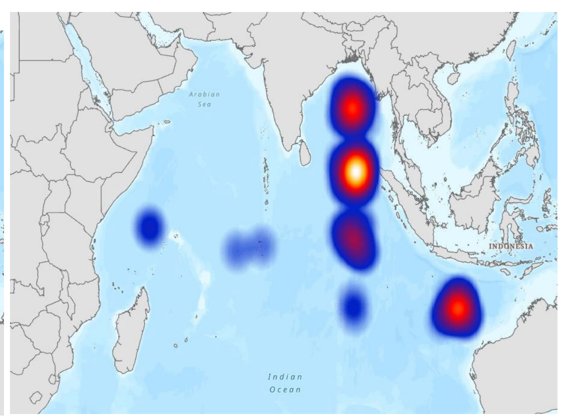
Japanese Fleet All Observations



Japanese Fleet 50th Percentile: 169 cm

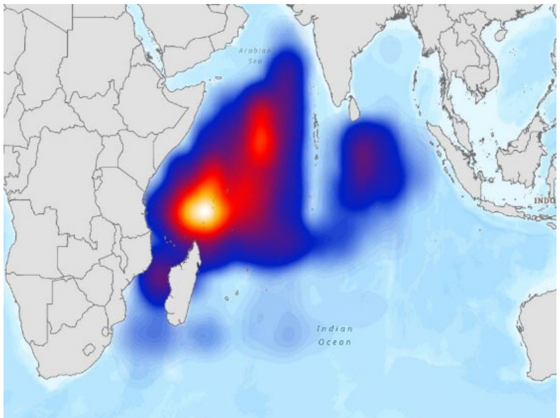


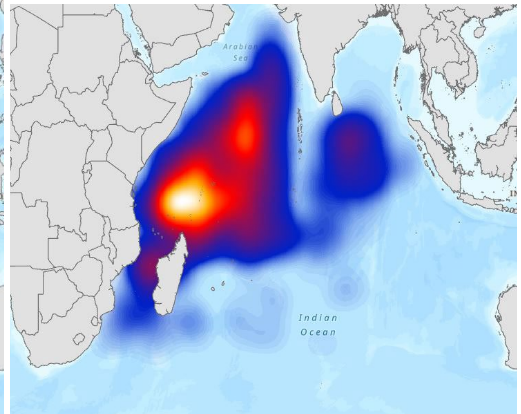
Japanese Fleet 75th Percentile: 184 cm



Japanese Fleet 90th Percentile: 208 cm

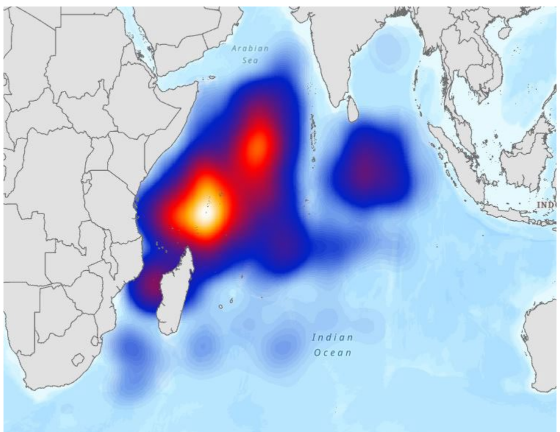
Figure 9: Distribution of different lengths of sailfish from the Japanese fleet in the Indian Ocean. The least observations out of the three fleets, (n = 830). Smaller individuals are found in all reported grids, larger individuals seem to congregate further on the eastern side of the ocean, with a hotspot off northwestern Australia.

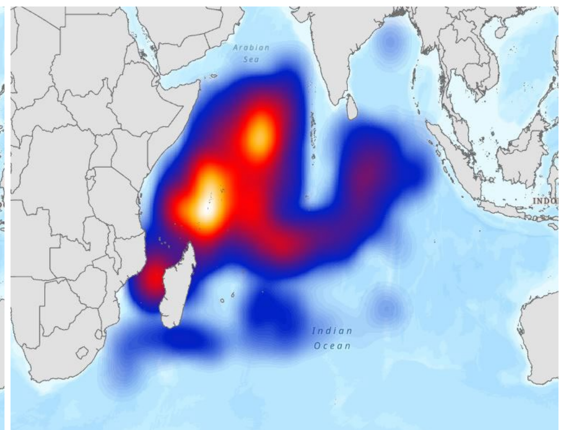




Taiwanese Fleet All Observations

Taiwanese Fleet 50th Percentile: 169 cm





Taiwanese Fleet 75th Percentile: 184 cm

Taiwanese Fleet 90th Percentile: 199 cm

Figure 10: Distribution of different lengths of sailfish from the Taiwanese fleet in the Indian Ocean (n = 13,368). Smaller individuals are found in all reported grids, larger individuals seem to move out into the middle of the ocean, and even work their way towards the southern coast of Sri Lanka.