RISK ANALYSIS OF SEA TURTLE (*CARETTA CARETTA* & *DERMOCHELYS CORIACEA*) NESTING SEASON BYCATCH IN FLORIDA COASTAL WATERS DUE TO COMMERCIAL FISHING GEAR REGULATIONS

by

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Abstract

Risk Analysis of Sea Turtle (*Caretta caretta & Dermochelys coriacea*)
Nesting Season Bycatch in Florida Coastal Waters Due to
Commercial Fishing Gear Regulations

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Anthropogenic influences have negatively impacted sea turtles on a global scale. In the USA, the commercial fishing industry decimated the population of all five sea turtle species that reside in its waters due to aggressive overfishing that did not end until 1978, when they were listed the United States Endangered Species Act of 1973. The USA commercial fishing industry still poses a significant risk to these recovering sea turtle populations due to bycatch in fishing gear. Bycatch interactions can injure or kill sea turtles due to the turtle being entangled in the gear, which can result in strangulation, drowning, amputation of limbs, as well as both internal and external injuries from fishing hooks. My research analyzes the risk commercial fishing gear regulations pose to loggerheads (*Caretta caretta*) and leatherbacks (*Dermochelys coriacea*), in waters up to 100 nautical miles off the coast of Florida. I used satellite relocation data of loggerhead (n=34) and leatherback (n=11) sea turtles between 2005 to 2017 (provided by the Sea Turtle Conservancy) and maps of 52 federally regulated fishing zones and their commercial fishing gear (longline, trawl, net, dredge, pot and trap) restrictions to assess the association of fishing regulations with hotspots of turtle activity. I used the kernel density function to identify turtle relocation hotspots and overlaid these maps with the regulated fishing zones maps, using the zonal statistics function to determine if any associations between hotspots and gear restrictions emerged. I found that there is an association between higher turtle relocation kernel density values and zones with greater longline and trawl restrictions. My results may help to increase the awareness of commercial fisheries continued impacts on sea turtle populations and lead to the implementation of future gear regulation to help mitigate sea turtle bycatch in Florida waters.

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Introduction

When we think of Florida's white sandy beaches and crystal-clear waters, too few of us remember the creatures that call this region home. Sea turtles are one such group of creatures. Seven species of sea turtles roam the oceans worldwide, five of which are regularly found in the waters of the USA. All seven species of sea turtles are listed as endangered or threatened under the United States Endangered Species Act of 1973 and are all facing a myriad of anthropogenic threats, such as bycatch. Groups such as The National Oceanic and Atmospheric Administration (NOAA), Florida Fish and Wildlife Conservation Commission (FFWCC) and the Sea Turtle Conservancy (STC) are making efforts to better conserve and protect them (Sea Turtle Conservancy, n.d.; NOAA, 2021).

Threats to sea turtles are varied and come in a wide range of different conservation needs. A few of the most prevalent and negatively impactful threats are climate change, habitat degradation, and pollution. Climate change poses risks to turtle due to potential warming causing a shift in the populations sex ratios due to temperature-dependent sex determination, rising sea levels reducing natal nesting beaches, and altered wind and ocean currents impacting migratory patterns, as well as many other risks (Poloczanska *et al*., 2009). Habitat degradation creates risks for turtles due to humans building on nesting beaches and in marine habitats used for foraging, breeding, migration etc., which can result in light pollution disorienting hatchlings, reduced food availability and reduced population interactions for breeding (NOAA, 2021). Pollution poses risk in various ways; however, trash pollution is the most common. For instance, garbage in the water column can turtles to become entrapped or be ingested, which can result in gut blockages, and both can lead to injury or death (Carr, 1987).

While there are many threats to sea turtles, one that stands out the most due to its dark past with the species is fishing. Prior to the Endangered Species Act of 1973, sea turtles were regularly fished commercially in the USA, with landing reports as recently as 1978 (Witzell, 1994). All five of the USA sea turtle's species (green, *Chelonia mydas*; loggerhead, *Caretta caretta*; Kemp's ridley, *Lepidochelys kempi*; hawksbill, *Eretmochelys imbricata*; and leatherback, *Dermochelys coriacea*) were fished, with varying degrees of demand and used for their meat, oil, and shells 1978 (Witzell, 1994). In many states where this fishing was most common, such as Texas and Florida, Canneries were even opened, indicating the size and severity of the sea turtle commercial fishing industry, however by the 1900s the turtle populations had begun to decline and thus the industry with it (Witzell, 1994). The population pressures that sea turtles faced were caused by overfishing, and these affects are still seen in present day. Today, sea turtles are only caught via bycatch when fishing for their other species such as shrimp or yellow finned tuna (Epperly *et al*., 2002; Kot *et al*., 2010). Bycatch is when a non-targeted species is caught accidently by fishermen, in this case the accidental catch of loggerhead and/or leatherback sea turtles (Gardner *et al*., 2008; Evans *et al*., 2021; Ceriani *et al*., 2017). Bycatch interactions can result in the injury and mortality of turtles due to entanglement in gear. As of 2007, there was an estimated 137,800 interactions through bycatch and estimated 4,600 deaths annually of sea turtles caught in USA fisheries (Finkbein *et al*., 2011). Though protections are now placed preventing the intentional landing of sea turtles in the USA, bycatch still poses a significant threat to these recovering populations. Longlines, trawls, nets, dredges and pot and traps are the most commonly used commercial fishing gear all of which have been linked to sea turtle bycatch (USFWS & DOI, 2013; Ripple, 1996; Finkbeiner, *et al*., 2011; Gilman *et al*., 2017).

To help mitigate the impact of bycatch, commercial fishers must abide by strict restrictions and regulations to help conserve the sea turtle populations. Federal and state regulations have been placed in various regions across the USA Coastal water which regulated gear uses and fishing methods allowed (USFWS & DOI, 2013; FAC & FAR, 2023; Florida Legislature, 2023). Not all regulations were put in places for the protection of sea turtles, however they still indirectly benefit them by reducing fishing pressures. Additional regulations, such as the use of Turtle Excluder Devices (TEDS), gangion length, hook type and size, soak times, and mesh sizes, were put in place at both state and federal levels with the aim to reduce bycatch (USFWS & DOI, 2013; FAC & FAR, 2023; Florida Legislature, 2023). These mitigation efforts have proven to substantially reduce bycatch but did not eliminate it and some fishing methods still have higher than preferred sea turtle bycatch rates.

For the purposes of this study, I focused on two species of sea turtles off the coast of Florida, the loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*). Florida and its coastal waters are a region of vital habitat used by sea turtles for nesting, breeding, foraging and migration, where loggerheads are commonly found as well as leatherbacks but to a lesser extent due to their smaller global population size (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). Understanding loggerhead and leatherback sea turtles' movements is another beneficial step to reduce potential bycatch from commercial fishing industries. This leads me to my thesis questions: 1) What risk does the interaction between sea turtle (loggerhead and leatherback) movements and Florida's fishing zones pose to the two sea turtle species during nesting season? 2) How could understanding this interaction, of relocation and regulation, reduce the bycatch of these two species? To answer these questions, I used relocation (movements of individual turtles from one location to another) data of loggerheads and leatherbacks, between

2005 to 2017 during nesting season, to create kernel density hotspots in order to determine where turtle densities were the highest. I then overlayed this with the federal regulated fishing zones up to 100 miles off the coast of Florida, in order to analyze the interaction between these zones and their gear restrictions with the loggerhead and leatherback densities. This allowed me to best analyze the risks that these two species are facing from commercial fisheries and make recommendations accordingly. I hypothesized that 1) regulated fishing zones with higher gear restrictions will be associated with higher turtle relocation densities, 2) regulated fishing zones with higher longlines and trawl restrictions will be associated with higher turtle relocation densities. My null hypothesizes are 1) regulated fishing zones with higher gear restrictions will not have any different turtle relocation densities, 2) regulated fishing zones with higher longlines and trawl restrictions will not affect turtle relocation densities.

Literature Review

This review will first focus on the sea turtle species (loggerhead and leatherback) themselves by looking into the background of each, consisting of morphology, diet, range, U.S. Endangered Species Act listing, and reproduction. Then I will analyze the current commercial fishing industry, fishing zones, fishing gear (longline, trawl, pot and trap, net and dredge), bycatch history and regulations. After this I will further investigate the geographical distribution of sea turtles along the coasts of Florida. Lastly, I will discuss the relationship between the bycatch and geological distribution of sea turtles in Florida. This pathway will guide the understanding of how to reduce future sea turtle bycatch in the future.

Background

This section focuses on the two sea turtle species, loggerheads, and leatherbacks, in the coastal waters of Florida. This will allow for a better understanding of the study outcomes and provide context to the species and regulations in place.

Sea Turtles

Every species of sea turtle has a specialized morphology, diet, and reproductive ranges and behaviors that have evolved to best thrive in the marine ecosystem. Considering these factors can provide insight into their movements and why they are in a specific area. For example, understanding their diet and range helps identify foraging grounds, which is key to the needs for their movements. Similarly, their reproductive habits help us understand why they make migrations and when these migrations may be more likely. Below, these species traits for both loggerhead and leatherbacks are explored.

Loggerhead

Loggerheads are a highly migratory species, found globally in both temperate and tropical regions of the Gulf of Mexico, Mediterranean and the 3 major oceans Atlantic, Indian, and Pacific (Lohe & Possardt, 2021; NOAA, 2022, National Park Service, 2023). This species has 9 distinct population segments (DPS), which are North Pacific Ocean DPS, Mediterranean Sea DPS, Northeast Atlantic Ocean DPS, North Indian Ocean DPS, South Pacific Ocean DPS, Northwest Atlantic Ocean DPS, South Atlantic Ocean DPS, Southeast Indo-Pacific Ocean DPS, and Southwest Indian Ocean DPS (Figure 1; Lohe & Possardt, 2021; Valverde & Holzwart 2017). Each DPS is determined by the nesting beach fidelity, genetic discontinuity, and physical isolation of each population (Lohe & Possardt, 2021). With an estimated global population count of between 40,000 and 50,000 nesting females (males are not counted in population as they do not surface on beaches causing counts to be unreliable), each of these DPS are listed under the Endangered Species Act of 1973 as either threatened or endangered (Sea Turtle Conservancy, n.d.; United states, 1973). This study is examining the population that is found in the Western mid-Atlantic and Gulf of Mexico, which would be the Northwest Atlantic Ocean (NWA) DPS (Lohe & Possardt, 2021; NOAA, 2022; United states, 1973). The Northwest Atlantic Ocean DPS is listed as threatened (United States, 1973). This population of loggerheads mainly nests in South Florida, USA and Oman (NOAA, 2022a). The majority of the estimated 100,000 loggerhead nests found in the USA annually are in Florida (NOAA, 2022a). The abundance of loggerheads inhabiting the Gulf of Mexico and Atlantic Ocean waters surrounding Florida makes it an excellent study area.

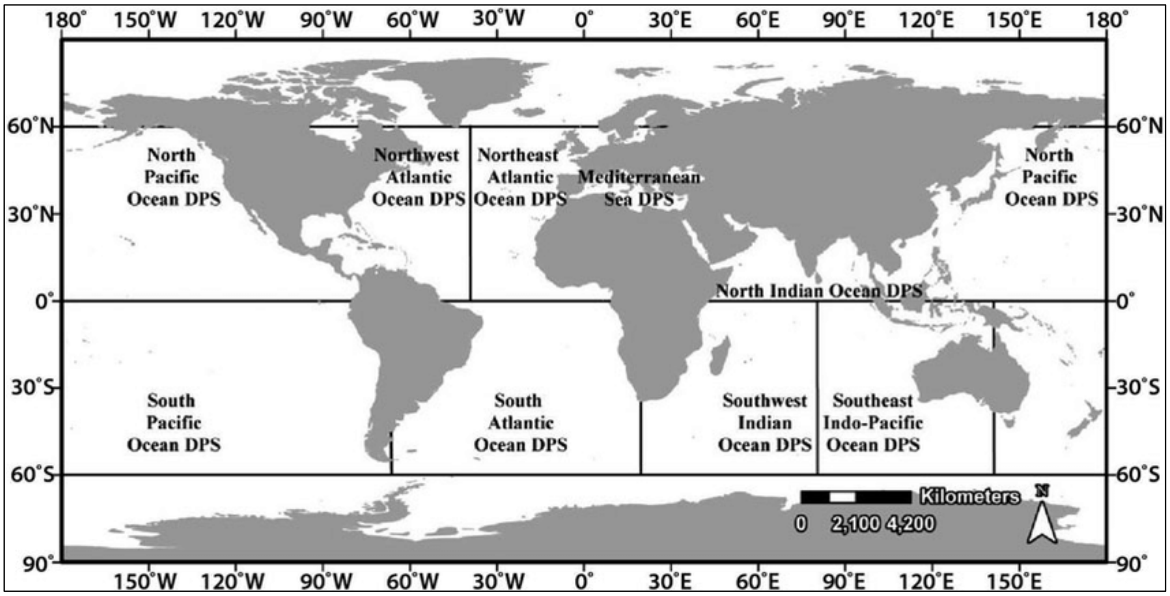


***Figure 1**. Loggerhead DPS boundary map (Valverde & Holzwart, 2017).*

Loggerhead morphology, diet and reproduction is relatively simple, and consistent with other members of the sea turtle family. The average loggerhead has a carapace length of 36 inches and a total weight of 250 pounds (National Park Service, 2023; NOAA, 2022). The coloration of loggerheads varies throughout their body, with the top of their body being darker colored than the bottom, to best blend in with the water column. Their carapace is reddish-brown while the plastron is pale-yellow, and the top of flippers are brown while the bottom of flippers are pale yellow. Named for its distinctive large head, the loggerhead has strong jaws used to feed on crustaceans, mollusks and other prey such as crabs, fish and conches (Plotkin *et al*., 1993; National Park Service, 2023). While they are preferred carnivores, loggerhead are known to eat other plant matter as well, especially in early stages of life (NOAA, 2022a). They have three main life stages, hatchling, juvenile and adult. Hatching and juveniles remain in oceanic habitats where they rely of food sources such as *Sargassum* (a pelagic sea grass) and gelatinous zooplankton, whereas in adulthood they return to neritic habitats which allows for a primarily carnivorous diet (Lohe & Possardt, 2021). Adult loggerheads make frequent migrations and will often forage in oceanic as well as neritic habitats (Plotkin *et al*., 1993). Breeding is one reason turtles migrate; at roughly 30 years of age female loggerheads reach sexual maturity and will return to their natal beaches to nest every 2-4 years (Lohe & Possardt, 2021; NOAA, 2022a).

Leatherback

Similar to loggerheads, leatherbacks are also a highly migratory species, found globally in temperate and tropical regions of the Atlantic, Pacific, and Indian Oceans (NOAA, 2022b). This species has 7 DPS, which are The Northwest Atlantic DPS, Southwest Atlantic DPS, Southeast Atlantic DPS, Southwest Indian DPS, Northeast Indian DPS, West Pacific DPS and East Pacific DPS (Figure 2; National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). The population of leatherbacks is estimated to be 34,500 nesting females globally (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). Due to their low global population numbers, the leatherback's protection status from the ESA is endangered in every DPS (National Marine Fisheries

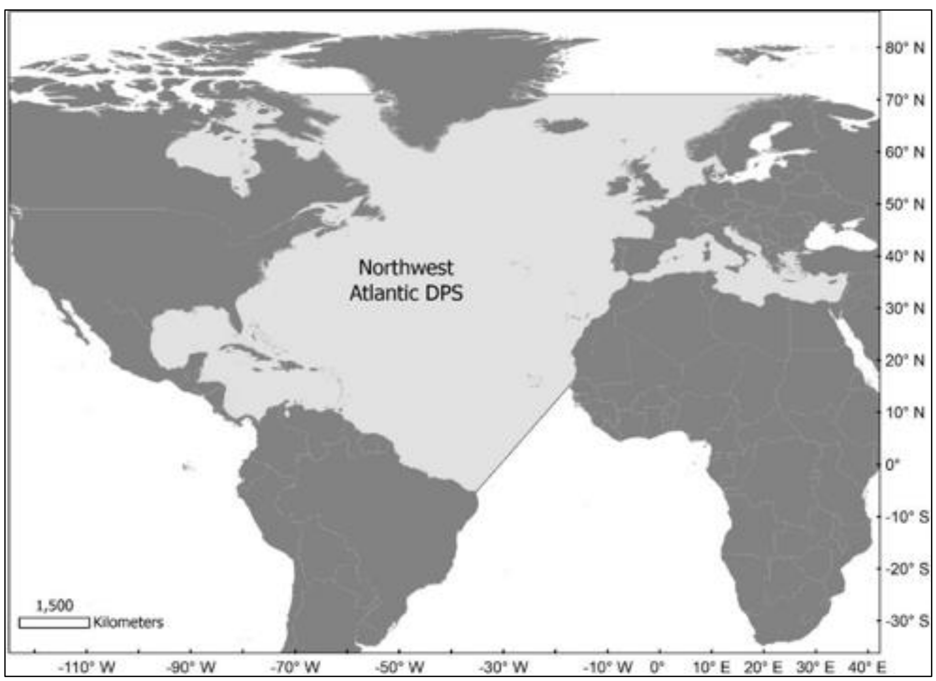


Figure 2. *Leatherback NWA DPS bounary map (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020).*

Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b; U.S. Fish and Wildlife Service, n.d.). This study used data from the largest DPS, the Northwest Atlantic (NWA) DPS, with an estimated population of 20,659. Turtles from this DPS nest in the southeast United States and Caribbean Region DPS (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020), and the abundance of leatherbacks nesting in Florida make it a good study area for this species as well.

The diet and morphology of leatherbacks are unique among the sea turtles. They are the largest sea turtle in the world, at 5 to 6 feet in length and an average weight of 1,000 pounds (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b; U.S. Fish and Wildlife Service, n.d.). The leatherback carapace has seven ridges that are black with white/pink spots and comprised of fatty connective tissue over dermal bones instead of the keratinized scutes, which all other sea turtle species have (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b). Their jaws are sharp and pointed tooth-like cusps with backward-pointing spines down their mouth and throat to assist with consuming their prey (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b). The prey of choice for leatherbacks of all life stages are gelatinous creatures such as jellyfish (Cnidaria), tunicates (Tunicata/Urochordata), and ctenophores (Ctenophora) (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b). As this diet has a low nutrient and calorie density, they must consume large quantities of prey, which leads to the leatherback’s wide foraging distribution. The NWA DPS forage in the waters of the Gulf of Mexico, Atlantic Ocean and Mediterranean Sea, with high-use regions in central and eastern Atlantic waters and seasonally along the eastern U.S. coast (April to June and October to

December), northeast Gulf of Mexico (August- September) and off Canada (July to December) (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020).

The leatherbacks have 3 main life stages post hatching, which consist of hatchling, juvenile and adult. There is little known about leatherback hatchlings and juveniles, they are generally found in warm tropical waters, grow much more rapidly than the other sea turtles species and are believed to consume gelatinous prey (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). Adult leatherbacks migrate from foraging areas to the waters off nesting beaches (natal beach region) every 2- 4 years once they hit sexual maturity between 9 to 20 years of age (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b).

Florida

Florida coastal waters are part of both the Gulf of Mexico (western Florida) and the Atlantic Ocean (eastern Florida). State waters extend off the coastline, three nautical miles into the Atlantic and nine nautical miles into the Gulf of Mexico, and federal waters extend 200 nautical miles off of the end of the state waters (Figure 3; Nalley, 2019). Extending 200 nautical miles of the

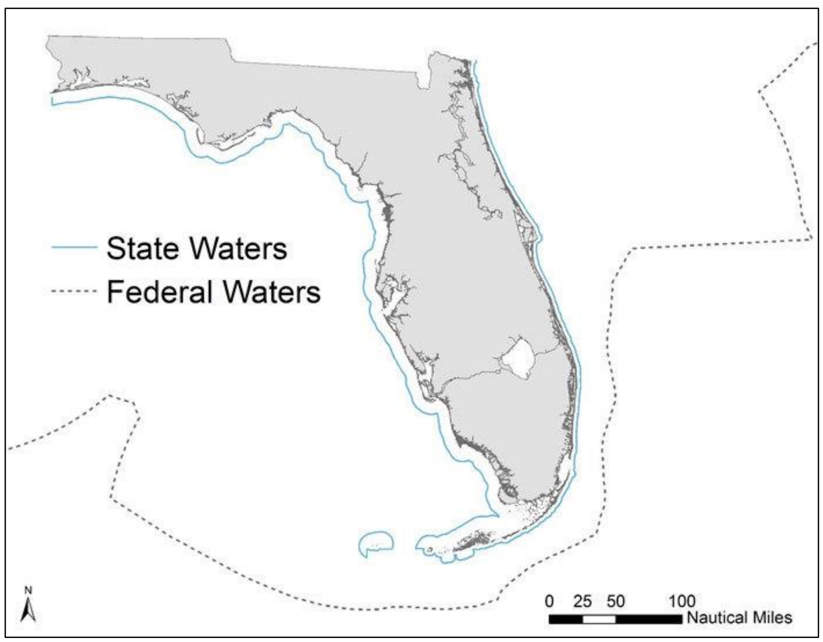


Figure 3. *Florida's state and federal waters (Nalley, 2019).*

coastline of the United States (U.S.) is the U.S. Exclusive Economic Zone (EEZ), where the U.S. has control over the marine resources (NOAA, 2023a).

Florida's ecology and geography determine the productive marine ecosystem that allows sea turtles to thrive there. Coastal water zones throughout the world make up 30% of the ocean's net primary productivity (Alongi, 2020). Upwelling, freshwater inputs (estuaries), and interactions with the continental shelf provide high levels of nutrients into Florida's coastal waters (Alongi, 2020). Wind stress along the West coast of Florida creates coastal upwelling in the Gulf of Mexico, and the boundary current response of the Gulf stream to the continental shelf, on the Eastern coast of Florida, creates coastal upwelling in the Atlantic (Smith, 1982). In the western Gulf of Mexico upwelling varies based on seasons, with summer having the highest rates of upwelling (Zavala-Hidalgo, 2014). *Sargassum* (brown macroalgae) is common in the surface waters on both sides of Florida (Gulf of Mexico and Atlantic) and commonly forms in large groups created raft-like structures (SAFMC, 2002). The *Sargassum* plays host to a diverse planktonic community, creating a draw for a myriad of species that feed on them - over one hundred species of vertebrates, invertebrates, micro- and macro-epiphytes and fungi (United States & National Marine Fisheries Service, 2013; Richardson & McGillivary, 1991). In regions in the western North Atlantic, such as the Gulf Stream and the Sargasso Sea, where Sargassum production is the highest, the *Sargassum* accounts for 60% of all primary production in the surface waters and is more productive than the core of the Gulf stream (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; Richardson & McGillivary, 1991). Peak *Sargassum* production occurs in July or early August in the southeastern U.S (United States & National Marine Fisheries Service, 2013).

Geographical Distribution of Sea Turtles

Nesting Grounds

Florida is heavily used as nesting grounds for many sea turtles. In 2022, there was a total of 155,641 nests found, with 116,765 loggerhead and 1,848 leatherback found over 27 counties in Florida (Table 3) (Florida Fish And Wildlife Conservation Commission [FFWCC], 2023). In Florida nesting season occurs May to September for leatherbacks, while loggerheads nest from June to September (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). The NWA DPS of both loggerhead and leatherback are the sea turtle populations typically nesting in the Florida region (TEWG, 2007; Dodd, 1988). Both turtles' species have similar nesting preferences that are supported by the Florida beach environment; steeply sloped, coarse-grained sandy beaches backed by dunes and/or vegetation that have limited obstacles (coral, rock etc.) and are easily accessible from the sea (Hendrickson & Balasingham, 1966; Provancha & Ehrhart 1987; TEWG, 2007; Kelly *et al*., 2017; Miller *et al*., 2023). Florida's ecology supports these nesting requirements, has 825 miles of beach throughout the state, sandy beaches with dunes and vegetation (grasses, [*Schizachyrium maritimum*], subshrubs [*Chrysoma pauciflosculosa*], shrubs, [*Ceratiola ericoides*] etc.) (Clark, 1993; Johnson, 1997). 80% of all loggerhead nesting activity in the USA occurs along the Florida east coast (Ceriani *et al*., 2012). leatherbacks in the NWA DPS nest throughout the NW Atlantic Ocean and Wider Caribbean Region, including the U.S. mainland where Florida is the primary nesting ground (NMFS, NOAA, & USFWS, 2020). Leatherback nesting in Florida is advantageous due to the easier access for hatchlings to reach the Gulf Stream, which allows them easy transport to northern oceanic foraging grounds (NMFS, NOAA, & USFWS, 2020). Overall, Florida is a vital nesting ground for the leatherbacks and loggerhead sea turtles.

Table 1. *Florida nesting counts by county (FFWCC, 2023).*

East Coast			**West Coast**		
Florida County	**Loggerhead**	**Leatherback**	**Florida County**	**Loggerhead**	**Leatherback**
Nassau	284	0	Collier	1,983	1
Duval	278	4	Lee	2,732	0
St Johns	1,154	15	Charlotte	2,031	0
Flagler	1,008	8	Sarasota	7,771	0
Volusia	4,626	23	Manatee	1,165	1
Brevard	31,623	143	Hillsborough	120	0
Indian River	7,547	106	Pinellas	488	0
St Lucie	7,163	251	Franklin	686	0
Martin	11,779	720	Gulf	507	0
Palm Beach	28,922	536	Bay	152	0
Broward	3,225	28	Walton	59	0
Miami-Dade	863	11	Okaloosa	28	0
Monroe	457	0	Santa Rosa	15	0
---	---	---	Escambia	99	1
TOTALS	**98,929**	**1,845**	**TOTALS**	**17,836**	**3**

<u>Breeding Habitat</u>

Breeding habitat occurs wherever males and females interact during breeding season, this is usually near the shore of nesting beaches (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). Loggerheads have areas two breeding areas in the Florida region that have been identified: (1) 200m offshore of Southern Florida between the Marquesas Keys and the Martin County lines and (2) in southern waters offshore of Cape Canaveral, Florida (Figure 4; NMFS Office Of Protected Resources, 2023; FFWCC, 2023). A subgroup of the loggerhead NWA DPS, known as the Peninsular Florida Recovery Unit, found that male turtles prefer eastern Florida as breeding grounds (Pfaller *et al.*, 2020). Leatherbacks currently do not have breeding grounds identified in Florida region, however, due to the large population that nest in this region it is reasonable to assume that breeding takes places in the waters offshore of more prevalent nesting beaches in counties such as Martin, Palm Beach and St Lucie (Table 1;

FFWCC, 2023). These three counties with the highest nesting numbers are all located on the eastern coast of Florida. Breeding habitats for sea turtles are currently the subject of ongoing research, but little is currently known about possible breeding grounds in Florida.

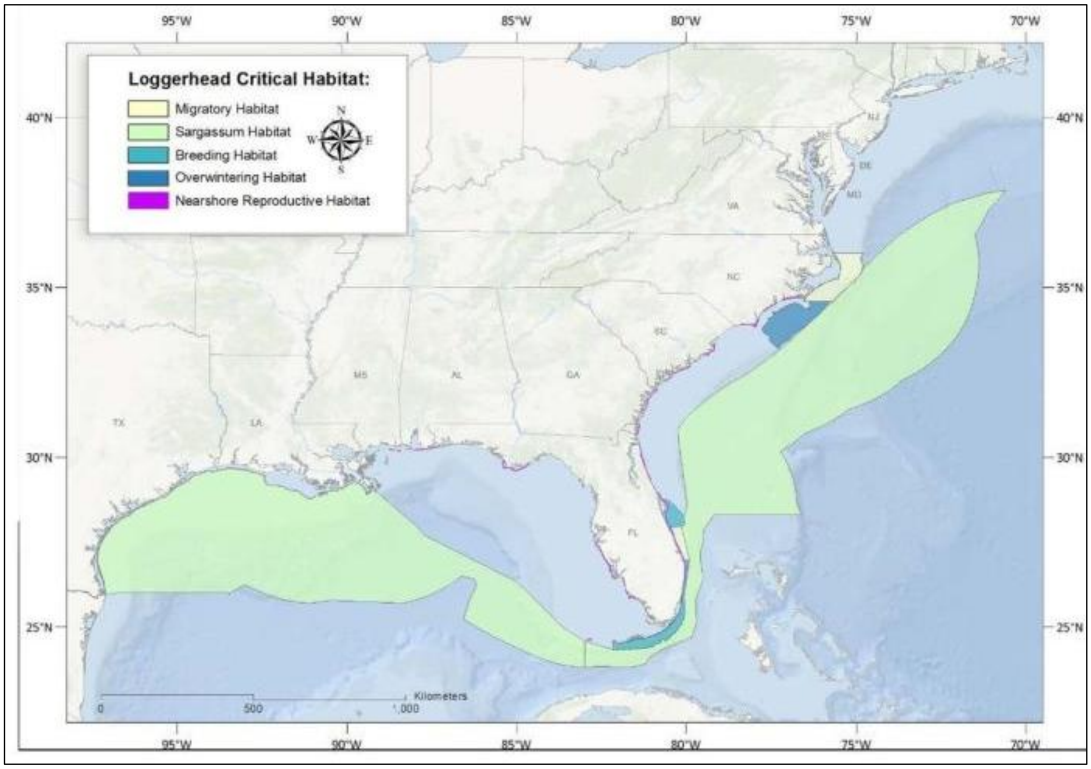


Figure 4. *Loggerhead Critical habitat map (NMFS Office Of Protected Resources, 2023).*

<u>Foraging grounds</u>

Loggerheads and leatherbacks have different diets, and thus have different needs for their foraging grounds. Below, I explore the foraging grounds of each species in the Florida region.

Loggerheads

The NWA DPS loggerheads' foraging habitat is primary made up of neritic (nearshore) environments. Loggerheads have different foraging needs throughout the lifespan and neritic foraging grounds are easily accessible to newly hatched and juvenile turtles (who prefer *Sargassum)*, nesting females, adult resident (turtles remaining in Florida year-round), and seasonal migraters (Griffin *et al*., 2013). Foraging grounds typically do not exceed water depths of 200m and are along the continental shelf, in estuaries, bays, and sounds (Griffin *et al*., 2013, United States & National Marine Fisheries Service, 2013). One study found that 63 out of 65 loggerheads tracked used foraging habitat along the continental shelf (Griffin *et al*., 2013). These neritic environments are highly productive, particularly in benthic biota, which is vital for loggerheads, considering that their diet primarily consists of crustaceans, (Alongi, 2020; National Park Service, 2023; United States & National Marine Fisheries Service, 2013). Foraging grounds must have sufficient availability and quality of prey as well as waters above 10° C (United States & National Marine Fisheries Service, 2013).

Sargassum is an important foraging location, as well as shelter, for post-hatchling and juvenile loggerheads (Witherington, 2002). Loggerheads in the early life stages are known to be attracted to *Sargassum* and show foraging behavior when found with *Sargassum* (United States & National Marine Fisheries Service, 2013). High densities of post-hatchling loggerheads have been found in *Sargassum* off the coast of Florida (Witherington, 2002). Due to the importance of *Sargassum* zones to early life stages of loggerheads, it has been labeled as critical loggerhead habitat (Figure 4).

Foraging grounds in Florida expand along the continental shelf in the Atlantic and Gulf of Mexico, with much foraging also occurring outside of the Florida region. Multiple studies found that the South Atlantic Blight (SAB), Subtropical Northwest Atlantic (SNWA), Eastern Gulf of Mexico (EGoM) and Northern Gulf of Mexico (NGoM) were all used by loggerheads as foraging grounds (Figures 5&6) (Griffin *et al*., 2013; Pfaller *et al*., 2020; Ceriani et al., 2017; Ceriani *et al*., 2012). These regions all have areas that intersect with the 100 nautical mile study radius off Florida, and thus will be a focus of discussion. The Mid Atlantic Blight (MAB), South Gulf of Mexico (SGoM) and North Atlantic have been found to be home to much loggerhead foraging habitat, however as it is out of the study radius they will not be discussed (Griffin *et al*., 2013; Pfaller *et al*., 2020; Ceriani *et al*., 2017; Ceriani *et al*., 2012). A 2013 study of 68 adult female loggerhead tracked between 1998 to 2008 fund the 13 % foraged in the SAB from April to October, and 21% foraged year-round in between the EGoM and the SNWA (Griffin *et al*., 2013). A 2017 study of 749 loggerheads nesting along the EGoM, SAB and SNWA coasts of Florida identified seven foraging hotspots, three of which are within the 100-mile radius of this study off Florida; the three hotspots are (1) SAB, east central coast of Florida, (2) SNWA, Florida Keys and (3) EGoM, west coast of Florida (Figure 6; Ceriani *et al*., 2017). The east central Florida foraging hotspot consistently had the highest usage (mean=0.31). This 2017 study also found that Northern foraging loggerheads had less successful reproductive nesting, as those from the southern foraging grounds,

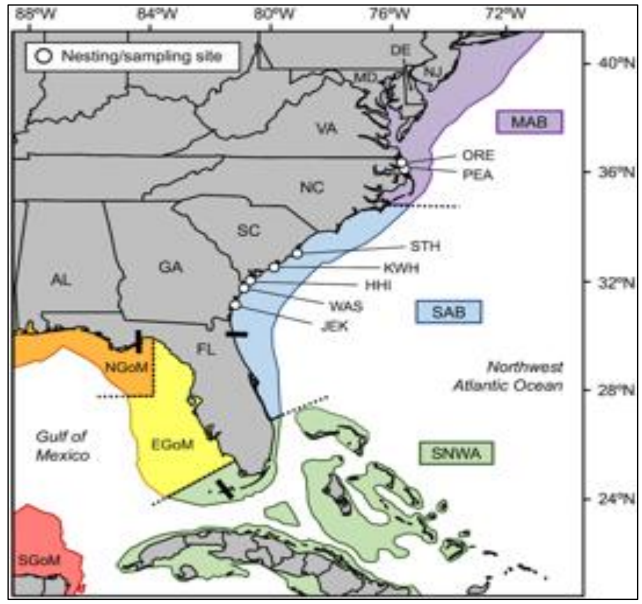


Figure 5. *Map of Florida coastal regions. Mid Atlantic Blight (MAB), South Atlantic Blight (SAB), Subtropical Northwest Atlantic (SNWA), Eastern Gulf of Mexico (EGoM) Northern Gulf of Mexico (NGoM) and South Gulf of Mexico (SGoM) (Pfaller et al., 2020).*

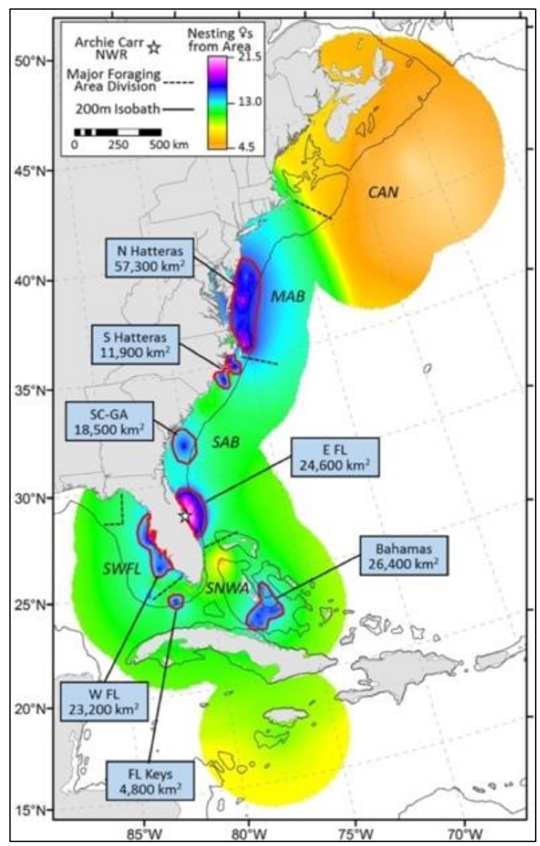


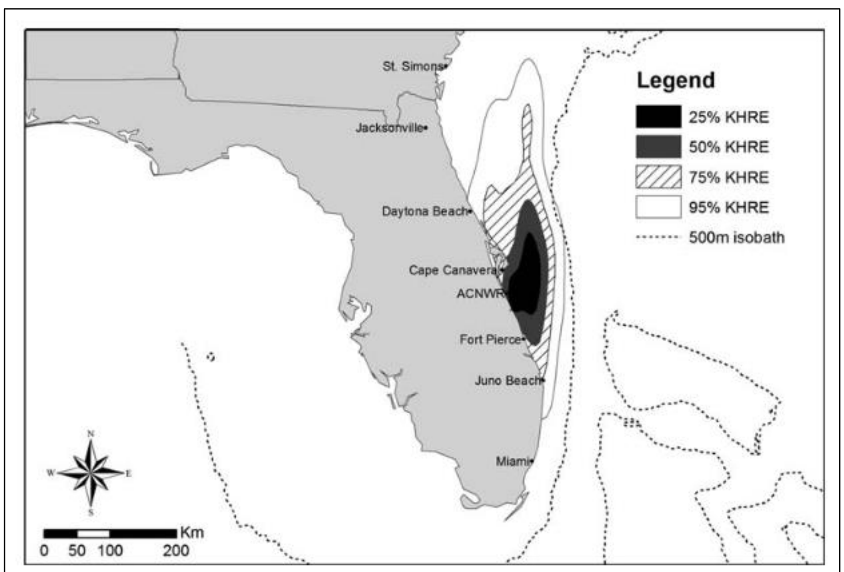
Figure 6. *Foraging Hotspot map of individual NWA DPS loggerheads nesting in east central Florida coast (Ceriani et al., 2017).*

with the two hotspots from the SNWA (Florida Keys and Bahamas) having higher annual reproductive success (Ceriani *et al*., 2017). Between 2008 and 2010, 14 female loggerheads were tracked post-nesting and it was found that 61% foraged in the Mid Atlantic Blight (MAB) and SAB, with 4 turtles remaining year-round in eastern central Florida waters of Cape Canaveral (Ceriani *et al*., 2012). Four other loggerheads remained year-round in the SNWA for foraging (Ceriani *et al.*, 2012). A 2020 study of loggerheads in two subgroups of the NWA DPS, Northern Recovery Unit (NRU) and Peninsular Florida Recovery Unit (PFRU), found that 13.4% foraged in the SAB and 2.2% in the SNWA (Pfaller *et al*., 2020). The PFRU was broken further into two more groups, the eastern Florida PFRU and the western Florida PFRU. The PFRU foraging hotspot breakdown within the Florida region was 50% in SNWA with 18% in SAB and 16% EGoM for the eastern Florida PFRU and 47% in EGoM w29% in SNWA, and 14% in NGoM (Pfaller *et al.,* 2020). The NRU foraging hotspots within the Florida region were 14% in SAB and 3% in SNWA (Pfaller *et al*., 2020). Foraging in the Florida region is vital to loggerhead population survival.

Leatherbacks

Leatherbacks have a very wide range of foraging, with the species found globally. They are known to forage in tropical to temperate waters and dive to depths of more than on one kilometer (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020; NOAA, 2022b). The NWA DPS leatherbacks in particular, have a unique foraging range as they have been sighted as far north as Norway and Iceland (NMFS, NOAA, & USFWS, 2020). This DPS prefers foraging in coastal (along the continental shelfs) and pelagic waters of Gulf of Mexico, and North to central Atlantic Ocean with the eastern and southeastern U.S. coast being a common foraging region (TEWG, 2007). Inter-nesting females forage within 100 km of nesting regions, and as Florida is a common nesting region for leatherbacks, foraging here is vital (NMFS, NOAA, & USFWS, 2020; FFWCC, 2023). Leatherbacks must forage in such a far-ranging migratory fashion as they must maximize their caloric intake due to the low caloric density of their diet of gelatinous organisms (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020).

When looking at the region of study (Florida), most of the foraging is along the continental shelf and seasonal, however there is evidence of some resident leatherbacks (TEWG 2007; Fossette *et al*., 2014; Eckert *et al.*, 2006; Sasso *et al*., 2021; Evans *et al.*, 2021). For the purpose of consistency, the same regional break down of Florida coastal waters as used in the 2020 Pfaller *et al*. study will be used. The regional breakdown is as follows, MAB, SAB, EGoM, NGoM, SGoM, and SNWA (Figure 5). In 2014, Fossette *et al*. found foraging ground throughout the Atlantic Ocean by Satellite tracking of 106 leatherback turtles. Seasonal high-use foraging grounds along eastern U.S. continental shelf (MAB and SAB) from April to June (start of nesting season) and October to December, whereas the northeast Gulf of Mexico (EGoM and NGoM) seasonal high-use was between August to September (end of nesting season) (Fossette *et al.*, 2014; NOAA, & USFWS, 2020). A study between 2000 to 2002 of 10 satellite tracked female leatherbacks off the eastern Florida coast (SAB) has similar findings as Fossette et al. (Eckert *et al*., 2006). This study found high-use 'internesting'



distributions of leatherbacks in the SAB (Eckert et al, 2006).

(between nesting emergences) foraging grounds 2 to 60 km offshore SE of Cape Canaveral, Florida and up to 215 km along the eastern Florida coast from Cape Canaveral (Figure 7) as well as post nesting (after all nesting has finished) seasonal high-use foraging in the SAB in spring, fall and summer months (Figure 8) (Eckert *et al*., 2006). A 2021 study by Sasso *et al*. (2021) found that the western Florida (NGoM and EGoM) were high-use foraging grounds for postnesting leatherbacks (Figure 9). The NGoM and EGoM foraging zones prove to be advantages due to prey abundance and proximity to nesting regions (Sasso *et al.*, 2021). Overall, the coastal waters in Florida prove to be a

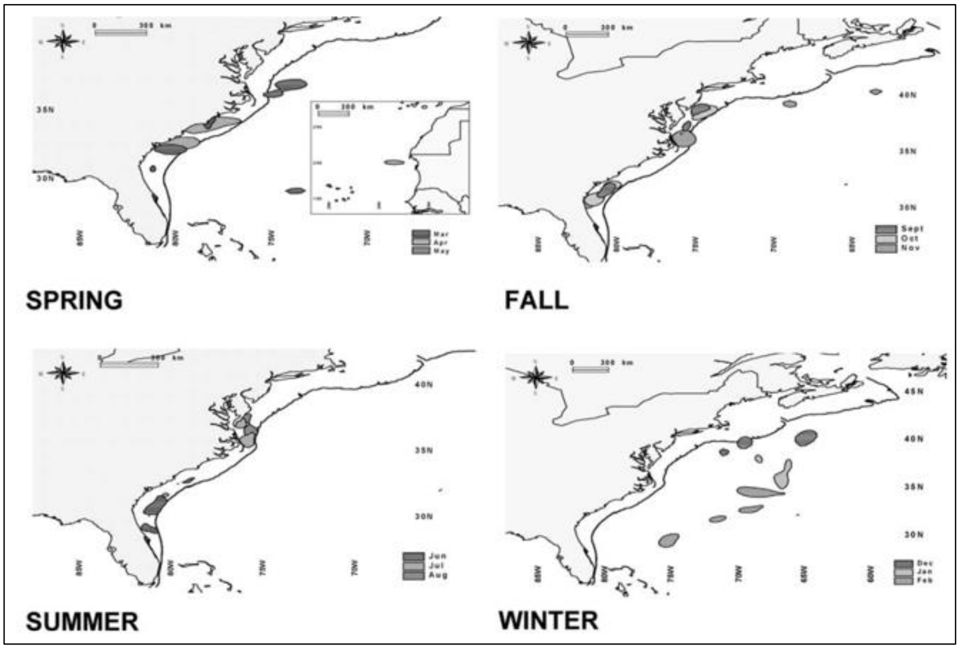


Figure 8. *Seasonal leatherback postnesting high-use area kernel home-range utilization distributions (Eckert et al, 2006).*

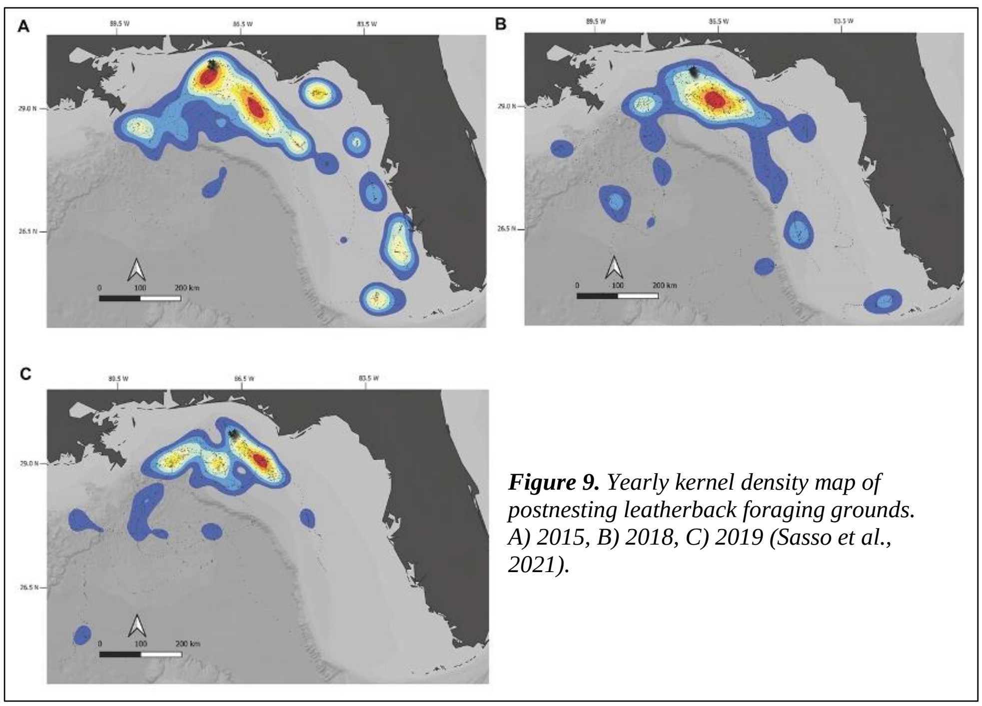


Figure 9. *Yearly kernel density map of postnesting leatherback foraging grounds. A) 2015, B) 2018, C) 2019 (Sasso et al., 2021).*

highly used foraging grounds for leatherbacks.

Migratory Corridors

Migratory corridors are the movement pathways of animals between seasons. Both loggerhead and leatherback are highly migratory species, migrating between regions for different seasonal needs breeding, nesting, and foraging (Sasso *et al.*, 2021; Ceriani *et al.*, 2012; United States & National Marine Fisheries Service, 2013). Having a strong understanding of the migratory corridors in the Florida coastal waters allows better understanding of the turtle's re-locations and how fisheries could impact them. The regional breakdown of Florida coastal waters (MAB, SAB, EGoM, NGoM, SGoM, and SNWA) from Pfaller *et al.* (2020) will be used. Only adult turtle migratory corridors will be discussed.

Loggerheads

Migratory corridors of loggerheads in Florida constantly stayed along the continental shelf; some turtles do migrate into oceanic environments however those are outside the range of this study (Griffin *et al*., 2013; Foley *et al*., 2013). Loggerheads constantly showed three migratory strategies when moving between foraging grounds or to/from nesting grounds, large-scale (migrated between two or more regions), small scale (migrated short distances with in one region) and resident (does not migrate, same area year-round) (Ceriani *et al.,* 2017). In 2013 study by Foley *et al*., identified four migratory corridors from three Florida rookeries (northwestern rookery, central western rookery and eastern rookery), (1) along the northern coast of Cuba (Figure 10B&C), (2) southeastern Florida coast to central Atlantic Ocean (Figure 10C), (3) eastern Florida Panhandle southwest to Yucatán Peninsula, Mexico (Figure 10A) and (4) eastern Florida panhandle southeast down coast (Figure 10A). Corridors 1, 2, 3 and 4 are all large-scale migratory corridors as 1's migration path is between three regions (NGoM, EGoM and SGoM), 2's path is between three regions (EGoM, SNWA and SAB), 3's path is between three regions (NGoM, EGoM and SGoM) and 4's 3's path is between three regions (NGoM, EGoM and SNWA) (Foley *et al*., 2013; Ceriani *et al*., 2017). The 2012 study by Ceriani *et al*., found postnesting two migration corridors of 14 loggerhead nesting in eastern central Florida, referred to as "north" (seasonal migrations, SAB in winter and MAB in summers for foraging) and "south" (migrate south to EGoM or SNWA; Figure 11). Both "north" and "south" are large-scale migratory corridors (Ceriani *et al*., 2012). A resident migratory strategy was also found and is known as "central" (Figure 11, SAB, central Florida coast; Ceriani *et al.*, 2012). Migration corridors in Florida allow loggerheads efficient movement between essential nesting and foraging habitats.

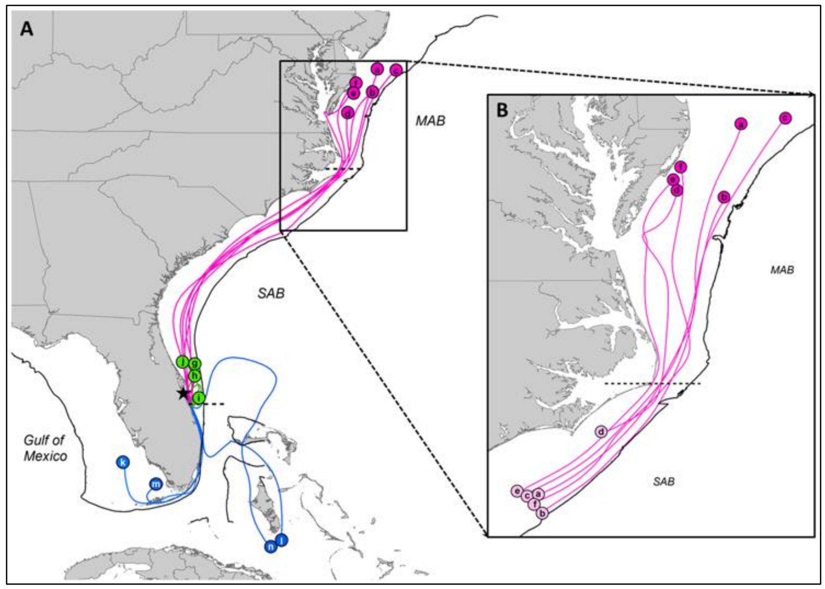


Figure 10. *Map of the migration corridors of 14 loggerhead nesting in eastern central Florida. (A) Pink=north, blue= south and green=resident. (B) dark pink= summer migration and light pink=winter migrations (Ceriani et al., 2012).*

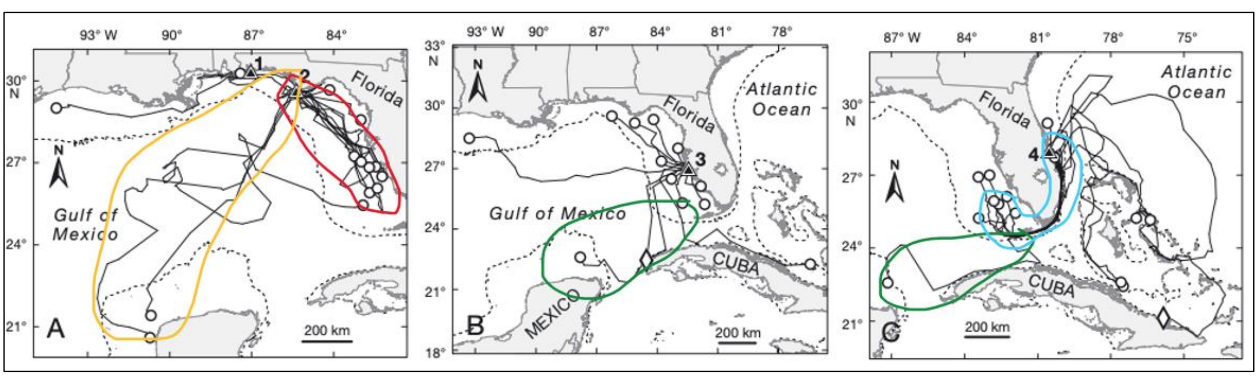


Figure 11. *Postnesting migratory corridors of three from three Florida rookeries, (A) northwestern rookery, (B) central western rookery and (C) eastern rookery, PTT tracked between 1998 to 2001. Migratory corridors: yellow= eastern Florida Panhandle southwest to Yucatán Peninsula, Mexico, red= eastern Florida panhandle southeast down coast, green= along northern coast of Cuba, blue= southeastern Florida coast to central Atlantic Ocean (Foley et al., 2013).*

Leatherback

Leatherbacks are the most highly migratory species of sea turtle, and due to this they have limited migratory corridors within the area of study. Leatherbacks in the NWA DPS often migrate though the Gulf of Mexico to the Northern Atlantic and back, cross the North Atlantic to western Europe and Africa, and take up residence between northern and equatorial waters (Fossette *et al*., 2014). Sasso *et al*., (2021) found some seasonal foraging in the Gulf of Mexico along the west Florida continental shelf (NGoM and EGoM) in autumn and winter. Leatherbacks migrate from the wider Caribbean though the Yucatan Channel to west Florida continental shelf at the end of summer and return back to the wider Caribbean at the start of spring (Figure 12). This migratory corridor is primary used by leatherbacks nesting in

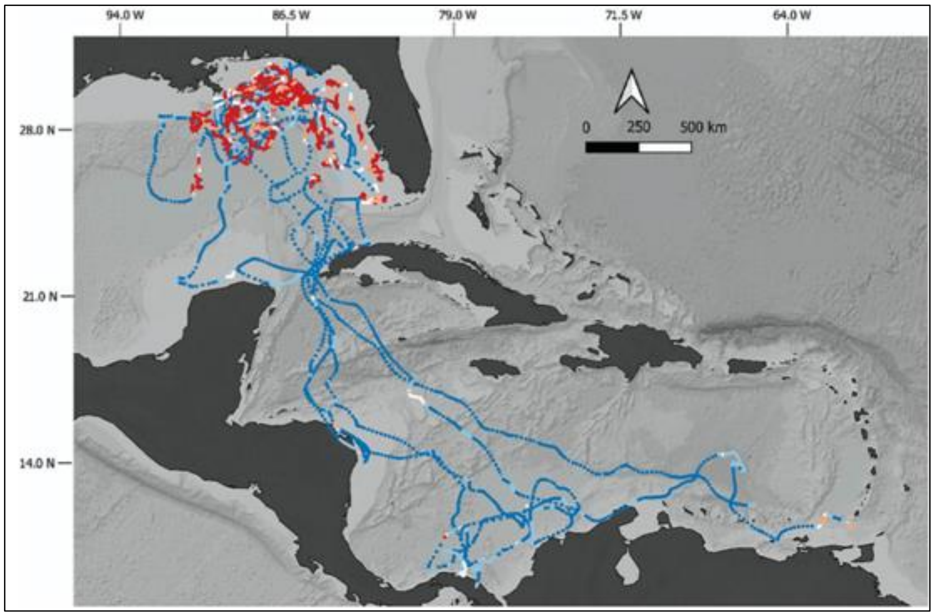


Figure 12. *Leatherback movements throughout Caribbean and Gulf of Mexico from 2015, 2018 and 2019. Red=foraging, blue= migration, and orange/white/light blue=searching/foraging (Sasso et al., 2021).*

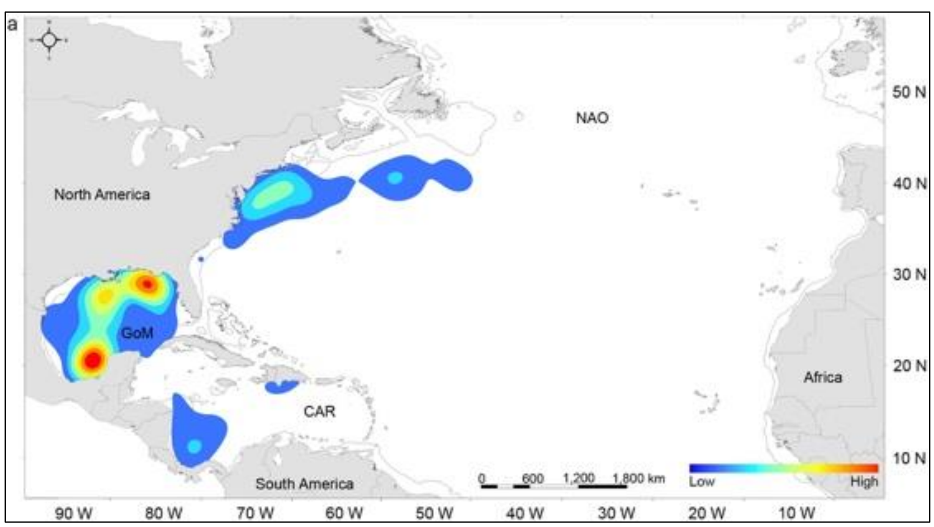


Figure 13. *Kernel density map of leatherback post nesting high-areas of Gulf of Mexico, Caribbean and Northwest Atlantic (Evans et al., 2021).*

Colombia, Honduras, Panama, and Trinidad. Another study satellite-tracked 33 leatherbacks between 2004 to 2018 from the southwest Caribbean coast found that they used the same migratory corridor as leatherbacks from Sasso *et al.* during fall and winter months (Figure 13&14; Evans *et al.*, 2021). The Panhandle of Florida and western Florida were the primary destinations and 55% of turtles used the migratory corridor between the wider Caribbean through the Yucatan Channel to the Gulf of Mexico and west Florida (Evans *et al*., 2021). Migration corridors in Florida allow leatherbacks efficient movement between crucial nesting and foraging habitats.

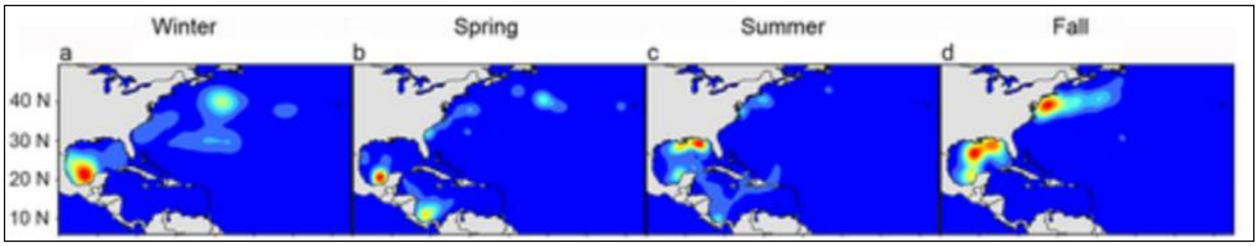


Figure 14. *Seasonal kernel density map of leatherback high-areas of Gulf of Mexico, Caribbean and Northwest Atlantic (Evans et al., 2021).*

Commercial Fishing

Commercial fishing, both current and historically, creates pressures on marine ecosystems, with the potential for negative impacts on sea turtles. In this section the gear used by commercial fisheries, impacts of the fishing gear, federal fishing regulations and the regulated fishing zones within the Florida waters will be described.

Fishing Gear

There are seven main methods of fishing used by commercial fisheries (Marine Stewardship Council [MSC], 2023). This study will be looking at five of the seven gear types, that commonly used by the fishing industry operating within the waters of Florida that are known to impact sea turtles. The five gear types are longline (pelagic and bottom), trawl (pelagic and bottom), net, pot and trap, and dredge.

Longline

Longlining is a fishing method using lines with more than ten baited hooks that trail behind a fishing vessel to which it is attached (MSC, 2023; FAC & FAR, 2023). Longlines can be set at different depths of the water column, either pelagic (midwater) or bottom (near seafloor) (MSC, 2023). Bottom longlines will have modifications to allow the line to sink to the lower depths (MSC, 2023). Within the Atlantic Ocean, Gulf of Mexico, and Caribbean an estimated 6,444 longlines vessels were operating as of 2023 (NOAA, 2023b).

Trawling

Trawling is a fishing method using long cone-shaped nets with a closed end and open mouth that are towed by one or two fishing vessels (MSC, 2023; FAC & FAR, 2023). Much like longlines, trawls can also be set at different depths of the water column, either pelagic or bottom, and net mesh size is variable depending on the target species (United States Fish and Wildlife Service [USFWS] & Department of Interior [DOI], 2013MSC, 2023). Bottom trawls are dragged on the seabed and due to this have alterations to increase structural support and reduce environmental influences (USFWS & DOI, 2023; MSC, 2023; FAC & FAR, 2023). Within the Atlantic Ocean, Gulf of Mexico, and Caribbean an estimated 13,368 trawling vessels were operating as of 2023 (NOAA, 2023b).

Net

Netting is a fishing method in which a mesh or webbed material is deployed into the water from a fishing vessel to catch fish (FAC & FAR, 2023). There are many different types of nets designed to target specific species which can be set at different depths (FAC & FAR, 2023).

A few of the more commonly used nets are gillnets and seines. Gillnets are a “wall” of netting hanging in the water from one or more fishing vessels and can be used in both a stationary and moving manner (MSC, 2023; FAC & FAR, 2023). Seine nets are used to surround dense schools of fish in a vertical “curtain-like” fashion and then either haul them onto a beach (beach seines), or pulled closed at the bottom and hauled into vessel (purse seines) (MSC, 2023). Beach seines are used in nearshore environments whereas purse seines are used in pelagic open ocean environments (NOAA, 2023b; MSC, 2023; FAC & FAR, 2023). Within the Atlantic Ocean, Gulf of Mexico, and Caribbean an estimated 16,739 netting vessels (13,590 gillnets and 3,128 seines) were operating as of 2023 (NOAA, 2023b).

Pot and Trap

Pot and trap is a fishing method in which a stationary device, made of wood, wire netting or plastic, is baited and deployed on the seabed attached to a rope for roughly 24 hours (FAC & FAR, 2023; MSC, 2023). Pots and traps have a cone-shaped tunnel at the mouth to prevent target species, various species of crustaceans, from escaping (FAC & FAR, 2023; MSC, 2023). They are typically deployed in groups (FAC & FAR, 2023). Within the Atlantic Ocean, Gulf of Mexico, and Caribbean an estimated 26,583 pot and trap vessels were operating as of 2023 (NOAA, 2023b).

Dredge

Dredging is a fishing method in which a net is attached a reinforced frame that drags along the seabed while towed behind a fishing vessel (MSC, 2023). Dredges are used primarily to harvest benthic biota, as they are designed to drag along the seabed. Due to the harsh interactions with the seabed dredges are heavily regulated and can only be used in permitted areas (MSC, 2023). Within the Atlantic Ocean, Gulf of Mexico, and Caribbean an estimated dredge 7,403 vessels were operating as of 2023 (NOAA, 2023b).

<u>Bycatch Impacts</u>

Historically and presently, commercial fishing is extremely harmful to the marine environment and its inhabitants. When looking at how fisheries have specifically impacted sea turtles, there are multiple negative impacts, such as injury (from entanglement and/or hooks) and mortality (from drowning and/or from severe injury). A turtle being stuck underwater for any length of time can be lethal, as they can only hold their breath up to two hours; less if they are active (Ripple, 1996; NOAA, 2022c). A trapped turtle is unlikely to rest, and instead be thrashing, moving and otherwise active in an attempt to escape, decreasing its air supply and likely causing further injury. Between 1986 to 2008 various gear regulations were put in place for longlines, trawls, nets, pot and traps and dredges to mitigate sea turtle bycatch (Finkbeiner *et al*., 2011). Prior to by bycatch mitigation methods the U.S. fisheries had an annual mean of 346,500 turtle interactions, that resulted in an estimated 71,000 annual deaths across various species of sea turtle (Finkbeiner *et al.*, 2011). The impact of fishing gear on sea turtles, indicates that bycatch poses a serious threat to the health and population sustainability of loggerheads and leatherbacks that nest, forage and migrate through Florida waters.

Longline

Longlines are a common fishing method used globally, due to their widespread presences and ability to set in multiple depths they pose a serious threat to loggerheads and leatherbacks (MSC, 2023; FAC & FAR, 2023). Turtles can become entangled in the line and/or gangion, or hooked with a varying severity (Kot *et al*., 2010; Donoso, *et al*., 2010; Lewison *et al.*, 2007; USFWS & DOI, 2013, Ripple, 1996). Hooks severity ranges from less severe external hooking (hooked on outside of body or just inside of mouth) to deep hooking (hook swallowed and is residing internally within in throat or digestive system) (Parga, *et al*., 2015). It is worth noting that external hooking often leads to the turtle entanglement in fishing line (Parga, *et al*., 2015; Ripple, 1996). In the year 2000, an estimated 1.4 billion hooks were in the water daily and thus resulting in the bycatch of an estimated 200,000 loggerheads and 50,000 leatherbacks, with 37% of the bycatch from fisheries operating in the Atlantic Ocean (Lewison *et al*. 2004). A study of a longline fishery in Chile, between 2001 and 2005, reported bycatch of 284 and 59 leatherbacks and loggerhead, respectively, from over 10 million hooks (Donoso *et al*., 2010). Lastly, a study of Atlantic longline fisheries sea turtle bycatch between 1986 to 2009 found a total of 6,832 sea turtles caught in longline gear between the regions on Figure 15, with a total annual bycatch of 297 turtles (Kot *et al*., 2010). Of those 6,832, 51% (n=3,514) were loggerheads and 41% (n=2,844) were leatherbacks, the results in an estimated average annual bycatch of 152.9 and 123.6 respectively (Kot *et al*., 2010). Prior to regulations, the Atlantic and Gulf of Mexico pelagic longline fishery had an estimated annual mean of 1800 and 150 sea turtle interactions

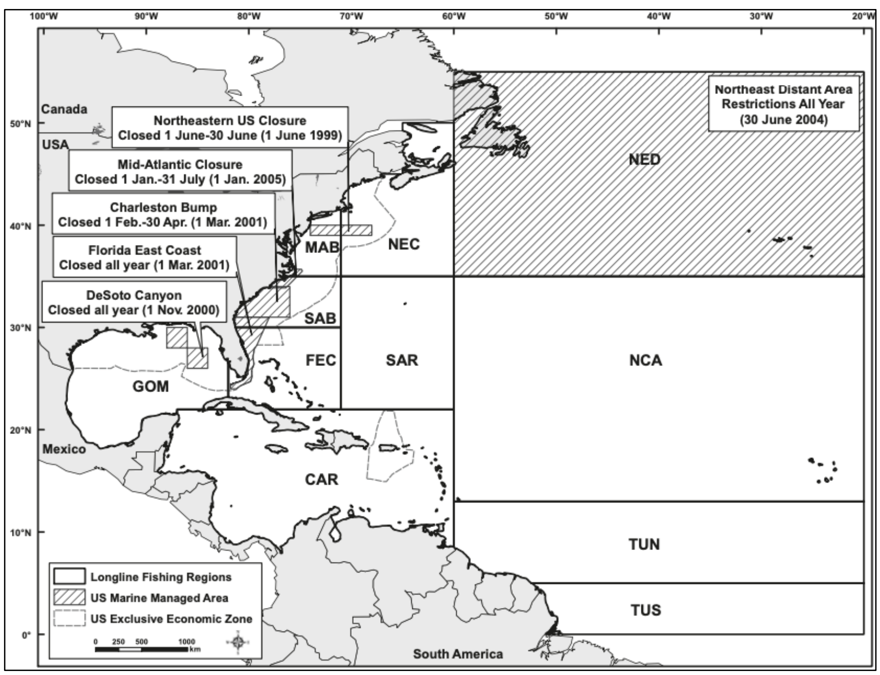


Figure 15. *NOAA SEFSC Atlantic longline fishing regions and NOAA longline marine managed areas between 1986 to 2009 (Kot et al., 2010). Caribbean (CAR), Gulf of Mexico (GOM), Florida East Coast (FEC), South Atlantic Blight (SAB), Mid Atlantic Blight (MAB), Northeast Coastal (NEC), Northeast Distant (NED, North Central Atlantic, (NCA) Tuna North (TUN) and Tuna South (TUS).*

and deaths, respectively (Finkbeiner *et al*., 2011). Longlines therefore pose threats to sea turtles as they account for a sizable amount of bycatch.

Trawl

Like longlines, trawls also pose a threat to loggerheads and leatherbacks due to their widespread presence and ability to be set at multiple depths (Finkbeiner *et al*., 2011; FAC & FAR, 2023; MSC, 2023). Trawls can catch turtles within their nets leading to entrapment and engagement, which can, and often does, result in injury or mortality (Robins, 1995; Epperly, *et al*., 2002). In a study of the Queensland East Coast Otter Trawl Fisheries penaeid prawn trawlers, done between 1991 to 1992, the annual sea turtle bycatch rate was 325.5 turtles with a 1.1% (n=3.5) mortality rate, with 50.4% (n=164) being loggerheads (Robins, 1995). A 2004 to 2005 study on Mid-Atlantic scallop trawl fisheries (4,433 vessel trips) had an estimated annual bycatch range of between 81 to 191 turtles per year (Murray, 2007). A 1987 study of U. S. shrimp trawl fishers reported a bycatch total of 534 sea turtles (loggerhead, Kemp's ridley [*Lepidochelys kempii*], and green [*Chelonia mydas*] turtles), 482 from the Atlantic and 52 from the Gulf of Mexico, with a 20% mortality rate (Henwood *et al*., 1987). Using this data and population estimates from the time, Henwood, *et al*. estimated that 9874 loggerheads died annually due to U. S. shrimp trawl fishers (Henwood *et al.*, 1987). Prior to regulations on trawls, 98% of sea turtle bycatch was from the Southeast Atlantic and Gulf of Mexico Shrimp Trawl fisheries, with an estimated 340,500 and 69,300 sea turtle interactions and deaths, respectively (Finkbeiner *et al*., 2011). These studies all show that trawls have high rates of bycatch and mortality.

Pot and Trap

Pot and Trap bycatch of sea turtles is a relatively unresearched area. Much like longlines, the vertical lines on each trap and pot are a source of entanglement for the sea turtles, which could result in the turtle's injury or death (Zollett, 2009). It is uncertain whether loggerheads or leatherbacks are more commonly entangled with these vertical trap lines (Zollett, 2009). Loggerheads diet of benthic biota such as crustaceans, which is the target species of pots and traps, lead some researchers to believe they would more easily be caught in pot and trap lines (Zollett, 2009; Avissar, 2006; Hamelin *et al*., 2017). A 2005 study on pot and trap damage, conducted on North Carolina's blue crab fishery, showed that 82% of pots/traps (100 pots/day over 41 days) had evidence of loggerhead damage (Avissar, 2006). On the other hand, leatherbacks could become entangled in the lines while foraging in their pelagic environment (Zollett, 2009). One study found that between 1998 to 2004, there were 205 leatherback interactions with pot and trap gear, with an 89.9% survival rate (Hamelin *et al*., 2017). This limited research does not allow for a conclusion to be drawn on the severity of the pot and trap bycatch. With evidence of some turtle bycatch, and as the pot and trap is the largest fishery within the Gulf of Mexico and Atlantic, pot and trap were included as a gear of study.

Net

Net gear from fishers are known to entangle sea turtles which can lead to injury and death (Finkbeiner *et al*., 2011; Murray, 2009b). Although many types of nets are used in fishing, I focused on gillnets and seine nets as they are the most commonly used nets in the waters around Florida (NOAA, 2023). A study of US mid-Atlantic gillnet fisheries, between 1995 to 2006, demonstrated an estimated annual mean bycatch of 350 loggerheads, in which there was a 40% mortality rate (Murray, 2009b). Gillnets with shorter mean soak times (the time that the nets are left in the water, in this study) (29.6 hours), and smaller mesh (<17.8cm) had lower mortality rates then gillnets with longer mean soak times of (80 hours) and larger mesh. (Murray, 2009b). Prior to regulations, net fisheries in the Atlantic and Gulf of Mexico had an estimated annual mean of 1,310 and 250 sea turtle interactions and deaths, respectively, with gillnets accounting for 510 and 240 of those interactions and deaths (Finkbeiner *et al*., 2011).

A 16-year study on the European purse seine fisheries of the Atlantic and Indian oceans found that they had lower impacts on sea turtles. Over the course of the study the total bycatch was 597 turtles, which is 37.3 turtles annually between both the Atlantic and Indian oceans (Bourjea *et al*., 2014). Of these 597 turtles, 92 were loggerheads (6 dead and 6 unknown) and 69 leatherbacks (4 dead and 3 unknown) combined count from both oceans (Bourjea *et al*., 2014). This means that the annual bycatch and mortalities counts are 5.75 and 0.375, respectively, for loggerheads; and for leatherbacks are 4.31 and 0.25, respectively (Bourjea *et al*., 2014). These studies show that the impacts of nets on sea turtles are highly variable, and depended upon the net and its use, with gillnets having significantly higher amounts of bycatch than purse seine.

Dredge

Dredging is not as common the other fishing types, but despite the reduction in use, dredges still pose a threat to sea turtles as they risk entrapment and engagement within the dredge net, which can lead to injury or death. The limited use of dredging in the commercial fishing industry has resulted in limited research on this gear type. One study in the Mid-Atlantic estimated an annual mean of 90 and 68 sea turtle interactions and deaths and serious injuries due to dredges, respectively (Finkbeiner *et al*., 2011). This resulted in dredges having the fifth highest mean annual loggerhead mortality and serious injuries according to that study (Finkbeiner *et al*., 2011). Another study between 1980 and 2003 reported the bycatch of 508 sea turtles within the Atlantic and Gulf of Mexico, 115 being loggerhead sea turtles (Dickerson *et* *al*., 2004). These studies show that dredges do threaten sea turtles, with a disproportionately high risk of bycatch causing death or serious injury.

<u>Regulations</u>

In order to protect the marine environment and ensure longevity of the fishing industry, fishing regulations have been created. Regulations requiring bycatch mitigation methods allowed for an estimated 60% (from 346,500 to 137,800) and a 94% (from 71,000 to 4,600) reduction in sea turtle interactions and mortality, respectively (Finkbeiner *et al*., 2011). These regulations are extensive; thus, I will only cover regulations put in place to protect the sea turtle within the Gulf of Mexico, Caribbean, and/or South Atlantic regions.

Federal

Title 50, part 622 created by the U.S. Fish and Wildlife Service & Department of Interior and updated in 2013, outlines the federal fishing regions of for the Gulf of Mexico, Caribbean, and/or South Atlantic regions. Herein I shall discuss the general prohibited fishing practices. Fishing has seasons and/or area closures that strictly prohibit or limit fishing, and this includes areas with seasonal/permanent gear closures as well. Catching protected species, such as sea turtles, is also prohibited. Various fishing gear and methods have been found to have heath and/or environmental impacts and thus have been banned as well. Prohibited gear includes explosives, certain fish traps, an absence of weak links in the tickler chains, and using Gulf reef fish as bait (USFWS &DOI, 2013) These general regulations protect the marine environment as a whole.

Three main regulations are sea turtle specific, according to Title 50. These regulations regard turtle excluder devices (TED) for trawlers, sea turtle bycatch mitigation for longlines and lastly, checks and in water durations of gillnets (USFWS & DOI, 2013).

Trawlers within the Atlantic area or Gulf area must have an approved TED. A TED is a device made of metal bars and mesh placed inside of a fishing trawl's neck; this allows the target species to pass through the bags into the net while allowing turtles or other larger species to be kept out of the net, thus reducing bycatch in trawling industries (NOAA, 2021; USFWS & DOI, 2013). A study conducted on beaches in South Carolina between 1980 to 1993 on loggerheads found that prior to the use of TEDs there was a 5.3% per year population decline (Crowder *et al*., 1995). Before TEDs were required, 70% to 80% stranding mortalities were attributed to shrimp trawls (Crowder *et al*., 1995). As of April 1, 2021, a new rule regarding TEDs was enacted by the National Marine Fisheries Service (NMFS): "all skimmer trawl vessels 40 feet and greater in length to use TEDs designed to exclude small sea turtles in their net" (NOAA, 2021). After the implementation of TEDs, the SE Atlantic and Gulf of Mexico Shrimp Trawl experienced an estimated reduction of 207,100 and 65,600 turtle interactions and deaths annually, from 340,500 to 133,400 interactions and 69,300 to 3700 deaths annually (Finkbeiner *et al*., 2011). The uses of TEDs allow the turtles to escape the trawl net, thus reducing bycatch and turtle injury/mortality.

Longlines, both pelagic and bottom, within the Atlantic area or Gulf area are required to use sea turtle bycatch mitigation gear and keep the NMFS document "Careful Release Protocols for Sea Turtle Release with Minimal Injury," on board the vessel, as well as have gear modifications designed to protect turtles (USFWS & DOI, 2013). Bycatch mitigation gear is gear used to unhook/detangle turtles from the longlines. This gear consists of long-handled line clipper/cutter (for cutting line), long-handled dehooker (for removal of ingested or external hooks), dipnet (a net used to bring a turtle onboard the vessel), tire (for keeping turtle in upright orientation), short-handled dehooker (for removal of ingested or external hooks), long-handled device (for "inverted V."- dehooking technique), long-nose or needle-nose pliers (for embedded hook removal, bolt cutters (to cut hooks to help with removal), monofilament line cutters (to cut lines of swallowed/unremovable hooks), turtle control devices (tether or T&G ninja sticks used to keep turtle still and at side of vessel to allow for hook removal/entanglement) and mouth openers (to open turtles mouth for hook removal) (USFWS & DOI, 2013). Requiring gear for unhooking and detangling turtles will reduce injury severity and allow for higher post catch survival rates.

The NMFS document provides a protocol on how to care for and release sea turtles caught in longlines. This document goes over the when/when not to bring turtles onboard a longlining vessel for hook removal; turtle are to be “boated” (brought on board using a dipnet) if they are of a size and/or are hooked in a manner in which would cause minimum injury, where as “non-boated” turtles would be those that are too large and/or boarding cannot be done without further injuring the turtle (USFWS & DOI, 2013). Having protocols for how to handle the turtle further ensures their proper treatment and reduces possible injury and mortality.

Lastly gear modifications that are required to be made for all longlines are Gangion (short line off longline holding hooks) length, bait and hook size/type. Gangion are a contributor to turtle entanglement in longlines fisheries (Lewison *et al*., 2007; USFWS & DOI, 2013). Only whole finfish and/or squid bait is allowed to be used on longlines, unless a green-gear stick (line with 10 hooks/ gangions attached suspended above the surface of the water) is used and then artificial bait may be used (USFWS & DOI, 2013). Studies have found reduced hard-shelled turtles (such as loggerheads) and leatherback bycatch when fish and/or squid was used, and this also reduced the amount of deep hooking (Gilman *et al*., 2017). Circle hooks are to be used on all longlines; these hooks can be offset or non-offset. Non-offset circle hooks utilize a size a minimum of 16/0 with the widest point of hook no smaller than 1.74 inches. Offset hook size utilizes a minimum of 18/0 with the widest point of hook no smaller than 2.16 inches, and the offset can be no larger than 10° (USFWS & DOI, 2013). In the 2019 and 2020 nesting season fishing hooks accounted for 7% of all injuries sustained by loggerheads in southwestern Florida (Ataman, *et al*., 2021). Hard-shelled turtles (such as loggerheads) and leatherback bycatch rates are lower using wide circle hooks rather than other hooks, such as J-shaped hooks, and reduced the number of deep/ingested hooks of hard-shelled turtled (Gilman *et al*., 2017). A study conducted between 2000 and 2004 in the western North Atlantic, the Azores, the Gulf of Mexico, and Ecuador found that use of circle hooks reduced sea turtle mortality due to their shape and size (Read, 2007). Using gear proven to reduce bycatch further reduces bycatch in longlines, thus showing the bycatch mitigation regulations benefits.

Drift gillnets must be checked at minimum every two hours and sink gillnets soak time (time in water) cannot exceed 24 hours. A 2009 study found that 285 loggerheads are caught in the Mid-Atlantic sink gillnet fishery, with engagement in the anchor gear being the most common (Murray, 2009a; Murray, 2009b). Between 1990 to 2017, a total of 302 turtles were caught by drift gillnets, with n=100 loggerhead and n=169 leatherbacks (Carretta *et al*., 2019). Sea turtles require air to breath and can only go without for 2 hours while in rest and a few minutes while active (NOAA, 2022c; Ripple, 1996). As turtles will drown if unable to get to the surface for extended periods of time, requiring check time for gillnets will prevent sea turtle bycatch morality (Ripple, 1996). After the implementation of these regulations on gillnets, the Atlantic and Gulf of Mexico experienced an estimated reduction of 100 and 100 sea turtle interactions and deaths annually, from 510 to 410 interactions, and 240 to 140 deaths annually, respectively (Finkbeiner *et al*., 2011).

State

States must follow federal fishing regulations, however, they may also add additional regulations. In Florida four fishing regulations were added and are enforced within the range of the state waters, according to Florida Regulations (FAC & FAR, 2023; Florida Legislature, 2023). These regulations regard monofilament line and netting, longlines, and net gear specifications (FAC & FAR, 2023). The intentional discard of monofilament line and netting within state waters is prohibited (FAC & FAR, 2023). Monofilament line and netting must be disposed of on land. The recovery of monofilament line and netting from state waters is also prohibited if the Division of Law Enforcement has not been notified and is not present (FAC & FAR, 2023). As of January 1, 1993, the use of longline within state waters is prohibited, except for when they are in transit to or from the EEZ (FAC & FAR, 2023). The use of gillnet, entangling nets, nets larger then 500 square feet are prohibited within state waters and only one net can be placed at once, with soak times no longer than one hour (Florida Legislature, 2023; FAC & FAR, 2023). Additionally, within nearshore/inshore areas cast nets cannot exceed 14 feet stretched length (FAC & FAR, 2023). State regulations protect sea turtles in the Atlantic and Gulf of Mexico and help reduce bycatch of these endangered species.

Regulated Fishing Zones

The coastal waters of Florida of consist of two different bodies of water, the Gulf of Mexico and the Atlantic Ocean. Within a 100 nautical mile radius of Florida coast (area of study) there are 51 separate regulated fishing zones: The Atlantic Ocean has 34 zones (Table 2), and the Gulf of Mexico has 17 zones (Table 3). Of the 51 zones, 45 allow commercial fishing, and 6 do not allow any fishing. The names and details of the fishing regulations (fishing allowances, gear restrictions and fishing/gear seasons), along with a count of the number of gear restrictions, is detailed in Tables 2 and 3 (U.S. Fish and Wildlife Service & Department of Interior, 2013).

Conclusion

Sea turtles face threats to survival in the waters off the Florida coast, and the prevalence of commercial fishing further raises these risks. Gear from the widespread commercial fishing industry in Florida impacts the turtle's ability to thrive and is a large part the cause of why these species are still struggling. Trawls and longlines are among the most prevalent gear used in this region and has been shown to negatively harm or kill the sea turtles. Federal regulations regarding bycatch mitigation methods can only protect sea turtles after they have interacted with fishing gear. As loggerheads and leatherbacks use Florida as foraging, nesting, and breeding grounds as well as a migratory corridor, the use of commercial fishing gear disrupts the turtles and can result in their death. Understanding the movements of sea turtles with the Gulf of Mexico and Atlantic waters surrounding Florida would allow for these interactions to be further mitigated.

Table 2. *Fishing zones and their regulations within 100 nautical mile radius of Florida coast in the Atlantic Ocean. Yes= allowed, No= not allowed and Never= zone is not open to any fishing/gear ever. (U.S. Fish and Wildlife Service & Department of Interior, 2013).*

Atlantic											
Fishing Zones	**Fishing Allowed**	**Fishing Months Open**	**Longline**		**Trawl**		**Net**	**Dredge**	**Pot & Trap**	**Gear Months Allowed**	**Counts Gear Restrict.**
			Pelagic	Bottom	Pelagic	Bottom					
Stetson-Miami Terrace HAPC	Yes	Year-round	Yes	No	No	No	Yes	No	No	Year-round	5
Artificial Reef-A	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-ALT	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-C	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-CAT	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-CCA	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-DRH	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-DUA	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-F	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-G	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-J	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-KBY	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-KC	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-KTK	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-L	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-MRY	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-SAV	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Artificial Reef-SFC	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Eagles Nest Reef	Yes	Year-round	Yes	No	Yes	Yes	Yes	Yes	Yes	Year-round	1
Ft. Pierce Inshore Reef	Yes	Year-round	Yes	No	Yes	Yes	Yes	Yes	Yes	Year-round	1
Ft. Pierce Offshore Reef	Yes	Year-round	Yes	No	Yes	Yes	Yes	Yes	Yes	Year-round	1
Key Biscayne/Artificial Reef-H	Yes	Year-round	Yes	No	Yes	Yes	Yes	Yes	Yes	Year-round	1
Florida Keys National Marine Sanctuary	No	Never	No	No	No	No	No	No	No	Never	7
Pourtales Terrace HAPC	Yes	Year-round	Yes	No	No	No	Yes	No	No	Year-round	5
Oculina Bank HAPC	Yes	Year-round	Yes	No	Yes	No	Yes	No	No	Year-round	4
Oculina Bank Experimental Closed Area	Yes	Year-round	Yes	No	Yes	No	Yes	No	No	Year-round	4
Allowable Octocoral Closed Area	Yes	Year-round	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Year-round	0

Table 2 continued on next page

Table 2 continued.

Atlantic											
Fishing Zones	**Fishing Allowed**	**Fishing Months Open**	**Longline**		**Trawl**		**Net**	**Dredge**	**Pot & Trap**	**Gear Months Allowed**	**Counts Gear Restrict.**
			Pelagic	Bottom	Pelagic	Bottom					
East Hump	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
North Florida	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
St. Lucie Hump	Yes	Year-round	No	No	No	No	No	No	No	Year-round	7
Longline Prohibited North of 27 10'N	Yes	Year-round	No	No	Yes	Yes	Yes	Yes	Yes	Year-round	2
Longline Prohibited South of 27 10'N	Yes	Year-round	No	No	Yes	Yes	Yes	Yes	Yes	Year-round	2
East Florida Coast	Yes	Year-round	No	Yes	Yes	Yes	Yes	Yes	Yes	Year-round	1
Charleston Bump closed area	Yes	Year-round	No	Yes	Yes	Yes	Yes	Yes	Yes	Feb- Apr	1
Atlantic Unregulated	Yes	Year-round	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Year-Round	0

Table 3. Fishing zones and their regulations within 100 nautical mile radius of Florida coast in the Gulf of Mexico. Yes= allowed, No= not allowed and Never= zone is not open to any fishing/gear ever (U.S. Fish and Wildlife Service & Department of Interior, 2013).

Gulf of Mexico											
Fishing Zones	**Fishing Allowed**	**Fishing Open Season**	**Longline**		**Trawl**		**Net**	**Dredge**	**Pot & Trap**	**Gear Allowed Seasons**	**Counts Gear Restrict**
			Pelagic	Bottom	Pelagic	Bottom					
The Edges	No	Never	No	No	No	No	No	No	No	Never	7
Madison and Swanson Marine Reserve	No	Never	No	No	No	No	No	No	No	Never	7
Steamboat Lumps Marine Reserve	No	Never	No	No	No	No	No	No	No	Never	7
Middle Grounds HAPC	Yes	Year-round	Yes	No	Yes	No	Yes	No	No	Year-round	4
Pully Ridge HAPC	Yes	Year-round	Yes	No	Yes	No	Yes	No	No	Year-round	7
Reef Fish Longline Restriction	Yes	Year-round	No	No	Yes	Yes	Yes	Yes	Yes	Year-round	2
Reef Fish Stressed Areas, FL, AL and MS	Yes	Year-round	Yes	Yes	Yes	No	Yes	Yes	Yes	Year-round	1
Reef Fish Stressed Areas, FL West Coast	Yes	Year-round	Yes	Yes	Yes	No	Yes	Yes	Yes	Year-round	1
Bottom Longline Prohibited	Yes	Year-round	Yes	No	Yes	Yes	Yes	Yes	Yes	Jun-Sept	1
SW Florida Trawl Closure	Yes	Year-round	Yes	Yes	No	No	Yes	Yes	Yes	Year-round	2
Tortugas Shrimp Sanctuary South	Yes	Year-round	Yes	Yes	No	No	Yes	Yes	Yes	Year-round	2
Tortugas Shrimp Sanctuary North	Yes	Year-round	Yes	Yes	No	No	Yes	Yes	Yes	Year-round	2
Tortugas Shrimp Sanctuary Zone FQUT	Yes	Year-round	Yes	Yes	No	No	Yes	Yes	Yes	Aug-Mar	2
Tortugas Shrimp Sanctuary Zone TUVW	Yes	Year-round	Yes	Yes	No	No	Yes	Yes	Yes	Oct- Apr	2
Tortugas Shrimp Sanctuary Zone GVW	Yes	Year-round	Yes	Yes	No	No	Yes	Yes	Yes	Aug-Apr	2
Tortugas Marine Reserve South	No	Never	No	No	No	No	No	No	No	Never	7
Tortugas Marine Reserve North	No	Never	No	No	No	No	No	No	No	Never	7
Gulf of Mexico Unregulated	Yes	Year-round	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Year-round	0

Methods

Data Collection

Study Area

For this study, fishing regions and turtle relocations within 100 nautical miles of the coast of Florida were examined. Florida's coastal waters are split between two separate water bodies, the Gulf of Mexico on the West side of the peninsula and the Atlantic Ocean on the East side (Figure 16). The border of Atlantic and Gulf of Mexico is located at the southern tip of Florida and extending South. Florida state waters in the Atlantic and Gulf of Mexico are from the shore to 3 nautical miles on the Atlantic and from shore to 9 nautical miles in the Gulf of Mexico, with the federal waters extending 200 nautical miles from the ends of the state waters (NOAA, 2023b).

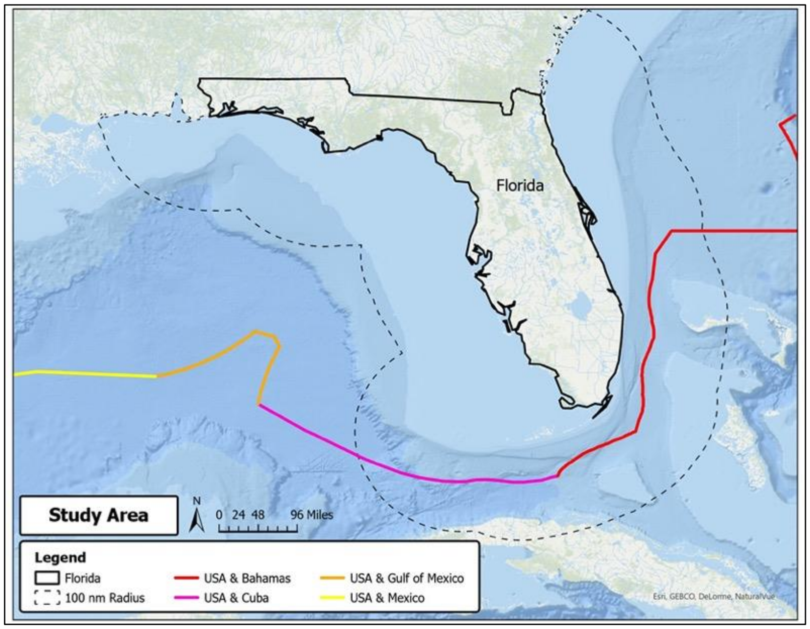


Figure 16. *Study area and USA EEZ, 100 nautical miles of Florida Coast.*

Species of Study

Satellite movement (known as relocations) of loggerhead (Caretta caretta) and leatherback (Dermochelys coriacea) sea turtles were provided by The Sea Turtle Conservancy. A total of 45 female individuals were tracked, 34 loggerheads 2009 to 2017 and 11 leatherbacks from 2005 to 2017. Location in which relocation tracking began was not provided by The Sea Turtle Conservancy, only relocations within 100 nautical miles of the coast of Florida were provided.

Individual relocations were tracked using Platform Terminal Transmitters (PTT) that are attached to the turtle carapace and transmit location data to the satellite when the turtle surfaces (Sea Turtle Conservancy, n.d.). The satellites make on average 8 rotations around the planet per day giving a 10-minute window per day for the data to be collected. This must also coincide with the turtle surfacing which can allow for high location variations upon each location transmission (Sea Turtle Conservancy, n.d.). The accuracy of the PTT has an average error variation between 50 meters to 2.5 kilometers depending on the number of satellites in the area (Sea Turtle Conservancy, n.d.).

Regulated Fishing Zones and Commercial Fishing Gear Regulations

There were 52 regulated fishing zones between the Atlantic (35) and Gulf of Mexico (17), all zone data was pulled from 50 CFR Part 622 -- Fisheries of the Caribbean, Gulf of Mexico, and South Atlantic (Figure 17; Tables 2&3; U.S. Fish and Wildlife Service & Department of Interior, 2013). Only fishing zones with an area of $\geq 450 mi^2$ and 3 or more kernel density (mean, median, maximum, and standard deviation) and results ≥ 0. Of the 52 zones, a total of 19 zones met these criteria and were considered

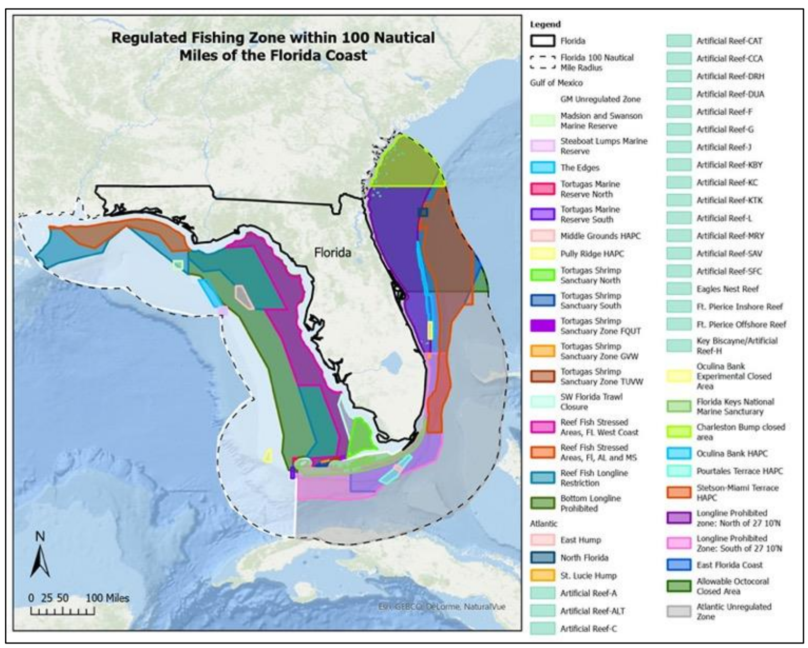


Figure 17. *Regulated fishing zones in the Atlantic and Gulf of Mexico up to 100 nautical miles off Florida coastline.*

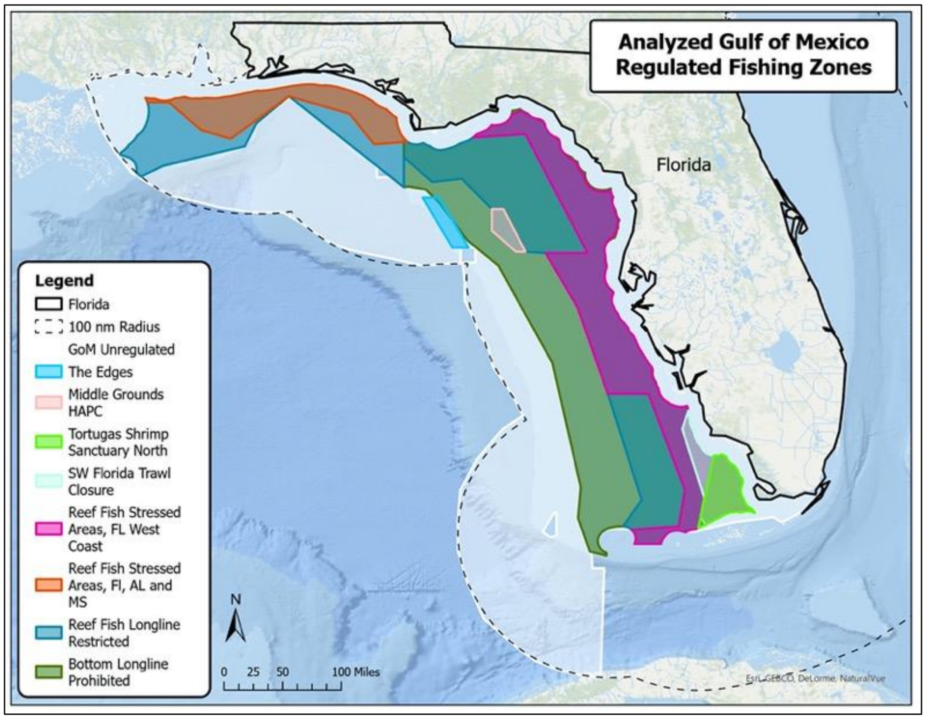
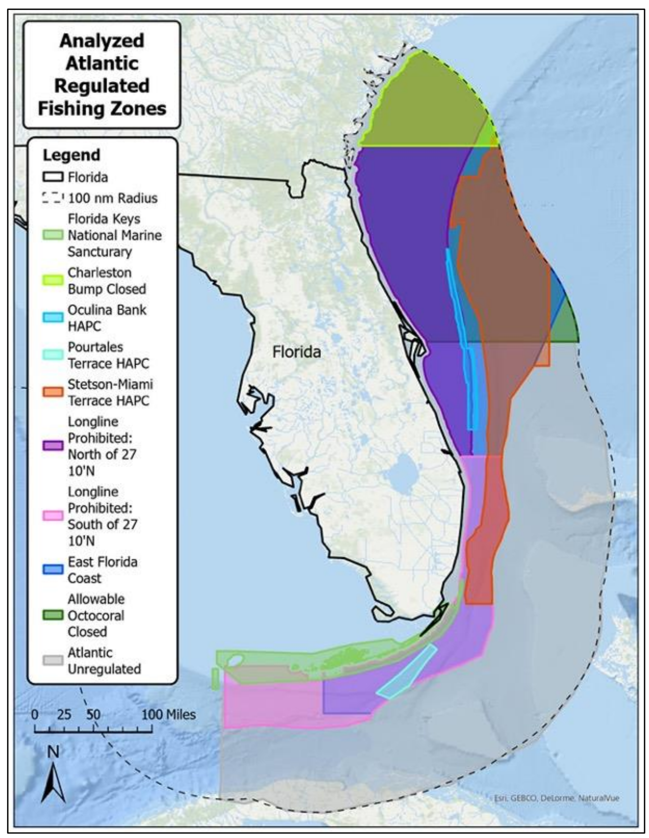


Figure 18. *Analyzed Gulf of Mexico Zones.*

as potential bycatch risk, 10 in the Atlantic and 9 in the Gulf of Mexico (Figure 18&19). An area minimum was established to reduce the results being leveraged into smaller zones (see discussion for more information). Within the regulated fishing zones 7 commercial fishing gear regulations were analyzed, longline (pelagic and bottom), trawl (pelagic and bottom), pot and trap, net, and dredge. See literature



view for further background on each of the gear types. Each of the gear types were checked for usage regulations in each of the zones (Tables 4&5).

Table 4. *Gear restrictions of Atlantic regulated fishing zones. Yes= allowed, No= not allowed.*

Figure 19*. Analyzed Atlantic regulated fishing zones.*

Zone	Longline		Trawl		Net	Dredge	Pot & Trap
	Pelagic	Bottom	Pelagic	Bottom			
Unregulated Atlantic	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stetson-Miami Terrace HAPC	Yes	No	No	No	Yes	No	No
Charleston Bump closed area	No	Yes	Yes	Yes	Yes	Yes	Yes
Allowable Octocoral Closed Area	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pourtales Terrace HAPC	Yes	No	No	No	Yes	No	No
East Florida Coast	No	Yes	Yes	Yes	Yes	Yes	Yes
Longline Prohibited South of 27 10'N	No	No	Yes	Yes	Yes	Yes	Yes
Longline Prohibited North of 27 10'N	No	No	Yes	Yes	Yes	Yes	Yes
FKNMS	No	No	No	No	No	No	No
Oculina Bank HAPC	Yes	No	Yes	No	Yes	No	No

Table 5. *Gear restrictions of Gulf of Mexico regulated fishing zones. Yes= allowed, No= not allowed.*

Gulf of Mexico							
Zone	**Longline**		**Trawl**		**Net**	**Dredge**	**Pot & Trap**
	Pelagic	Bottom	Pelagic	Bottom			
Unregulated-Gulf of Mexico	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reef Fish Longline Restriction	No	No	Yes	Yes	Yes	Yes	Yes
Bottom Longline Prohibited	Yes	No	Yes	Yes	Yes	Yes	Yes
Reef Fish Stressed Areas, FL West Coast	Yes	Yes	Yes	No	Yes	Yes	Yes
SW Florida Trawl Closure	Yes	Yes	No	No	Yes	Yes	Yes
Tortugas Shrimp Sanctuary North	No	No	No	No	No	No	No
Middle Grounds HAPC	Yes	No	Yes	No	Yes	No	No
Reef Fish Stressed Areas, FL, AL and MS	Yes	Yes	Yes	No	Yes	Yes	Yes
The Edges	No	No	No	No	No	No	No

Geospatial Analysis

ArcGIS software by ESRI was used to create a series of maps both detailing the movements of turtles during the duration of the study period and in regulated zones. The relative density of turtle relocations in the study area was then calculated using the Kernel Density function. This allowed me to see where the turtles were more likely to be (and when), and the regulations in each of these zones

Fishing Zone Maps

The zone maps were created on ArcGIS using outline the regulated and unregulated fishery zones up to 100 nautical miles off the Florida coast, in both the Atlantic Ocean and Gulf of Mexico. The regulated zone maps used pre-created shape files pulled from NOAA (NOAA, 2023b). Each of the regulated zone's attribute tables contain information regarding gear regulations, fishing allowances, and yearly timelines of open fishing and gear seasons. The unregulated zones were created by making a 100 nautical mile radius off the coastline of Florida and then using the clipping tool to remove all the regulated zone polygons and areas that overlap with land. All Zone maps were split into 2 groups based on what ocean they reside in, Atlantic or Gulf of Mexico. This is due to general regulations that govern each of the bodies of water.

Sea Turtle Maps

The sea turtle relocation maps consist of two separate maps for each species (leatherback and loggerhead) created on ArcGIS using coordinate, timestamp and PTT number data provided by the Sea Turtle Conservancy. The coordinates where of each location the in which the PTT tag had been detected when the turtle surfaced as the satellites where overhead, which meant the coordinate data of the turtles' movements were not fully encompassing, but rather a snapshot of their movement during the period of observation. Every turtle had a unique PTT tag number associated with it. Using the coordinates of each turtle's points were established on the map at each relocation, then a pattern of movement was found by connecting each re-location point to the next re-location point with the next chronological timestamped point for each individual turtle. This was repeated for each turtle for both the loggerheads (n= 34) and leatherbacks (n= 11) for the duration of tracking.

Sea turtles tend to be a highly migratory species, thus no single turtle stayed in the area of study (100 nautical miles off the coast of Florida) all of the time. The time of year with the most relocations for both leatherbacks and loggerheads coincided with their nesting season (Figures 20&21. Florida is a vital nesting ground for both species and these data corroborate the increase in activity during this timeframe (NOAA, 2023a). Loggerheads' nesting season is June to September while leatherbacks' is May to September (United States &

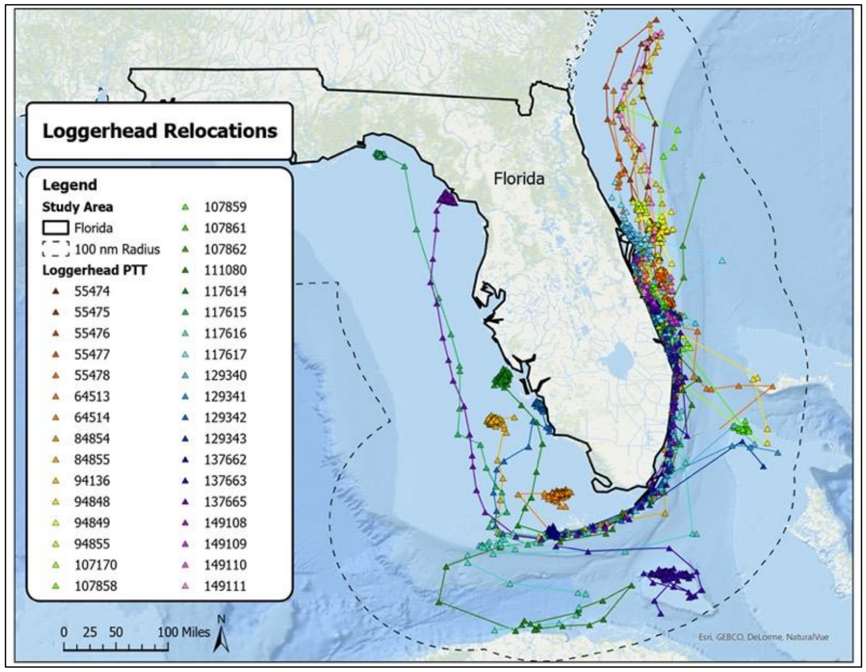


Figure 21. *Loggerhead relocations between 2009 to 2017 (n=34 individual turtles).*

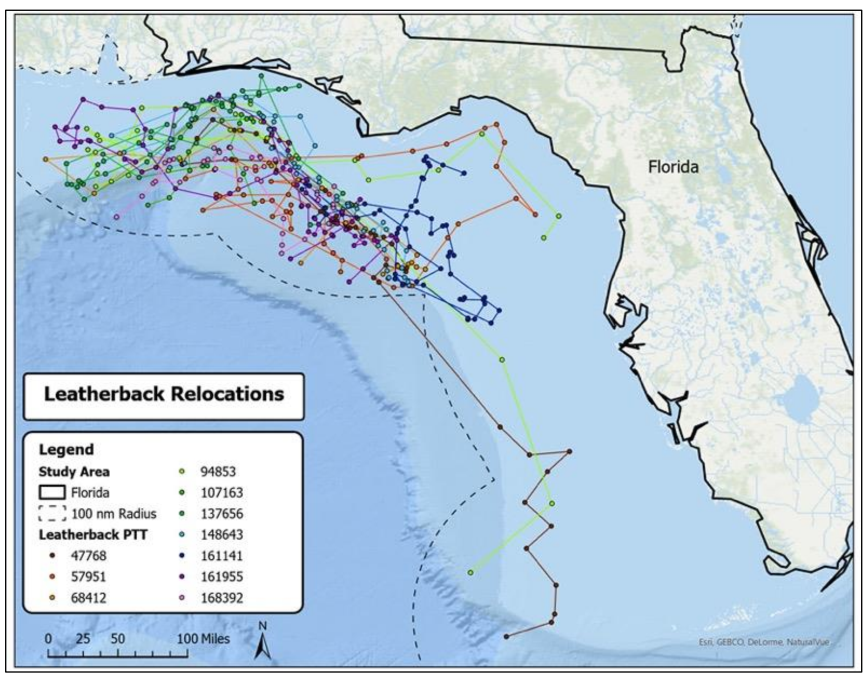


Figure 20. *Leatherback relocations between 2005 to 2017 (n=11 individual turtles).*

National Marine Fisheries Service, 2013; TEWG; 2007). To account for the increased activity of turtles migrating into and out of this region for nesting season, a 1-month buffer was added to the start and end of both species nesting season. For the purpose of this study, the nesting season for loggerheads and leatherbacks were reported as May to October and July to October, respectively. These seasons were then combined for the duration of tracking, 9 years for loggerheads (2009 to 2017) and 12 years for leatherbacks (2005 to 2017), on the maps reflecting each species.

<u>Kernel Density</u>

Once the nesting season maps for both leatherback and loggerhead turtles were created, the Kernel density (KD) tool on ArcGIS was used to determine the relative density of each species in the coastal waters of Florida (ESRI, n.d.) (Figure 21). To determine the KD of each species, the cell output was set to 0.1, area units in SQ KM and land features were removed by using the barrier tool in order to create a more realistic distribution of KD values. This allowed for hotspots of the loggerhead and leatherback densities to be identified.

$$Density = \frac{1}{(radius)^2} \sum_{i=1}^{n} \left[\frac{3}{\pi} \cdot pop_i \left(1 - \left(\frac{dist_i}{radius} \right)^2 \right)^2 \right]$$

$$\text{For } dist_i < radius$$

Figure 22. *Expanded kernel density (ESRI, n.d.).*

Statistical Analysis

<u>Zonal Statistics</u>

The Zonal Statistics as Table (Spatial Analyst) was used to create the mean, median, maximum and standard deviation (SD) from the KD raster in each of the fishing zones as well as the unregulated Gulf of Mexico and South Atlantic zones. Although these statistics were calculated for all fishing zones, in the results only those for zones > 450mi^2 are presented to avoid spurious findings by chance alone for small zones that might overlap KD hotspots.

Analysis

The risks of commercial fishing gear on sea turtles were analyzed at four main points, 1) prevalence of gear restrictions (total and gear type) from all regulated zones, 2) turtle relocation KD of each zone 3) the relationship between count of gear regulations and zone turtle relocation KD, 4) the relationship gear type regulations and zone turtle relocation KD. These points allow me to analyze the risk for loggerheads and leatherbacks that reside in the Florida coastal waters during their nesting seasons.

The prevalence of gear restrictions from all zones was looked at in two parts: the total number of gear restrictions, and the types of gear restrictions. Simple counts of total gear and gear type were taken from each of the 50 regulated fishing zones. Counts of total gear restrictions were compared by zone to determine which zones had the highest/lowest restrictions. Similarly types of gear restrictions were compared to determine which gear types had the highest/lowest gear restrictions. This created a baseline for points 2 and 3 to allow a better understanding of all the gear restrictions in the Atlantic and Gulf of Mexico that can impact loggerheads and leatherbacks.

Turtle relocation KD of each zone was determined by the zonal statistics (mean median, maximum, and SD) as well as considering zone area (mi^2). These statistics were examined and compared with the hotspot maps to determine which zones are more commonly used by turtles than others. Median and mean were used to find the overall KD of the zone. Determination of the maximum found the highest KD values in each zone, which allowed for the higher value KD hotspots residing in the zones to be identified. Standard deviations were used to determine the variation of KD throughout the zone, which helped determine the prevalence of hotspots within the zones. Area was considered with SD as larger zones typically had higher SD than smaller zones. Together these results allowed me to determine where turtles are most prevalent in the Florida coastal waters. This was repeated for both sea turtle species.

` The relationship between count of gear regulations and zone turtle relocation KD was found by comparing each zone's gear counts with the median KD. Linear regressions and R^2 were used to determine if there were a positive, negative or null relationship between the zone turtle relocation KD of loggerheads and leatherbacks with the count of gear restrictions (Figure 23 &24).

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n(\sum x^2 - (\sum x)^2)][n(\sum y^2 - (\sum y)^2)]}}$$

Figure 23. *Expanded R 2 equation.*

$$Y_i = f(X_i, \beta) + e_i$$

Figure 24*. Linear regression equation.*

The relationship gear type regulations and zone turtle relocation KD was concluded by examining the zones with higher (≥0) KD with lower (<0) KD. Here, bar charts were created to visually view which zones with higher KD were associated with higher gear restrictions of any of the gear types. T-tests were used to determine if there was an association between higher gear types and higher KD.

Results

Gear Restrictions

Between the Atlantic and Gulf of Mexico, 51 zones have commercial fishing gear restrictions of the five gear types (longline, pot and trap, net, dredge, and trawl) that have been found to be the detrimental to loggerhead and leatherback sea turtles. Analyzing the regulations of each of these zones allowed determination of the gear allowances in each zone (and what gear types have more allowances), in each region of the Florida coastal waters.

<u>Zonal Gear Restrictions</u>

Atlantic

In the Atlantic, 2 zones (5%), the Allowable Octocoral Closed Area and the Unregulated Atlantic, have the least amount of gear restrictions, with no (types=0) gear restrictions (Table 2). 21 zones (60%) have the most gear restrictions, with all 7 gear types restricted (Table 2). The Allowable Octocoral Closed Area and the Unregulated Atlantic zones both have allowances for all five gear types, and no restrictions on where the longlines or trawls can be used in the water column (pelagic or bottom). The 21 zones with the most restrictions had regulations on all 7 gear types. Out of the 35 regulated fishing zones in the Atlantic, there only 14 zones (40%) with gear allowances of one or more of the 7 fishing gear types, and 9 zones (25.7%) have gear allowances counts of ≥ 3.5 or half of all gear types (Table 2).

Gulf of Mexico

In the Gulf of Mexico, the Gulf of Mexico Unregulated zone has the lowest count of gear regulations (type=0), whereas 5 zones (27%) (The Edges, Madison and Swanson Marine Reserve, Steamboat Lumps Marine Reserve, and Tortugas Marine Reserve North and South) are share the most restrictions (type=7) (Table 3). The Gulf of Mexico Unregulated zone has no gear restrictions for all five gear types, and no resections on where the longlines or trawls can be used in the water column (pelagic or bottom). Out of the 18 regulated fishing zones, 13 zones (72%) have allowances for gear usages, were 11 zones (61%) have gear allowances counts of ≥ 3.5 or half of all gear types (Table 3).

<u>Gear Type Restrictions</u>

Between both the Atlantic and Gulf of Mexico, Trawl and longline restrictions were the most common, together making up 62% of all gear restrictions (Figure 25). Trawls had the most restrictions, a total of 31% of all gear restrictions between both pelagic (14%) and bottom (17%) (counts: pelagic=34, bottom=40 and total= 74). Longlines had the second most gear restrictions, a total of 31% of all gear restrictions between both pelagic (13%) and bottom (17%) (counts: pelagic=31, bottom=40 and total= 71). Trawls and longlines' pelagic and bottom breakdown had higher gear counts then dredges 14% (count= 32), nets 11% (count=26) and pot and traps 14% (counts=32) (Figure 25). The exception to this is the pelagic longlines, which have the second lowest number of restrictions. Nets have the lowest number of restrictions between both the Atlantic and Gulf of Mexico (Figure 25).

Figure 25. *Counts of restrictions in both the Gulf of Mexico and Atlantic Ocean by gear type.*

Atlantic

In the Atlantic there is a total of 175 gear restrictions between all 35 regulated fishing zones. The most restricted gear type throughout all the zones was longlining making up 32% of all gear restrictions between both pelagic and bottom longlining, pelagic=25 (14%), bottom=31 (18%) and total=56 (32%), whereas the least restricted gear type was netting, net=21 (12%) (Figure 26). Trawls were the second most restricted gear making up 27% (counts: pelagic=23 (13%), bottom=35 (14%) and total=48 (27%)). Pot and trapping and dredging were tied for third with each having 25 (14%) gear restrictions. Longlines were used over 2 times more than pot and traps, dredges, and nets. Looking at just pelagic and bottom breakdown longline and trawls amount of gear restrictions, Pelagic trawls have the second lowest, bottom trawls and pelagic longlines are tied for third with pot and traps and dredges, and bottom longlines have the most gear restrictions (Figure 26). Overall, longlines and trawls were the most commonly restricted gear types.

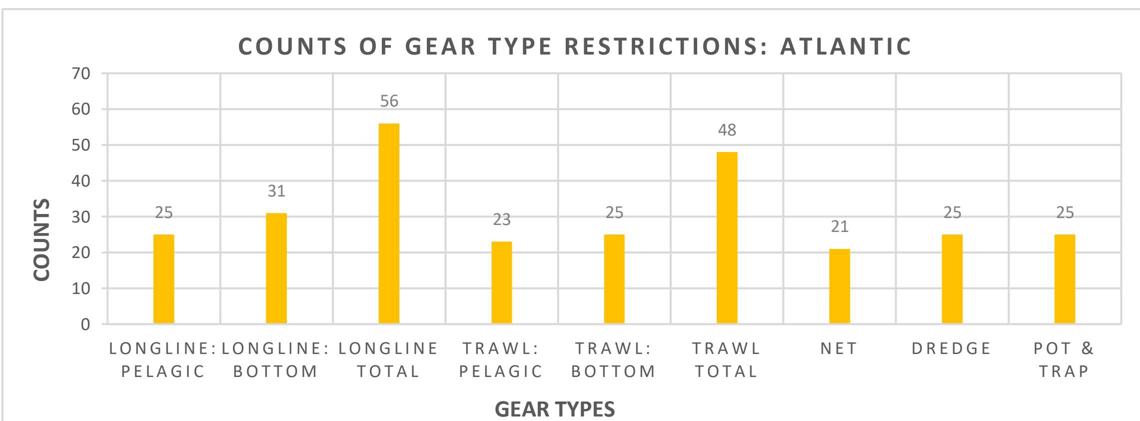


Figure 26. *Counts of restrictions in the Atlantic by gear type.*

Gulf of Mexico

In the Gulf of Mexico there is a total of 101 gear restrictions between all 18 regulated fishing zones. The most restricted gear type throughout all the zones were trawling, making up 43% of all gear restrictions between both pelagic and bottom trawls (counts: pelagic= 11 (18%), bottom=15 (25%) and total=26 (43%)), whereas netting had the least gear restrictions making up

8% (count=5) (Figure 27).Longlines have the second most restrictions (counts: pelagic=6 (10%), bottom=9 (15%) and total=15 (27%)) and pot and trapping and dredging were tied for third with each having 7 (12%) gear restrictions. Looking at just pelagic and bottom breakdown longline and trawls amount of gear restrictions, pelagic longlines have the second least, bottom longlines have the third most (above dredges and pot and trap), pelagic trawls have the second most and bottom trawls have the most restrictions. In the Gulf of Mexico, trawls and longlines are the most commonly restricted gear type (Figure 27).

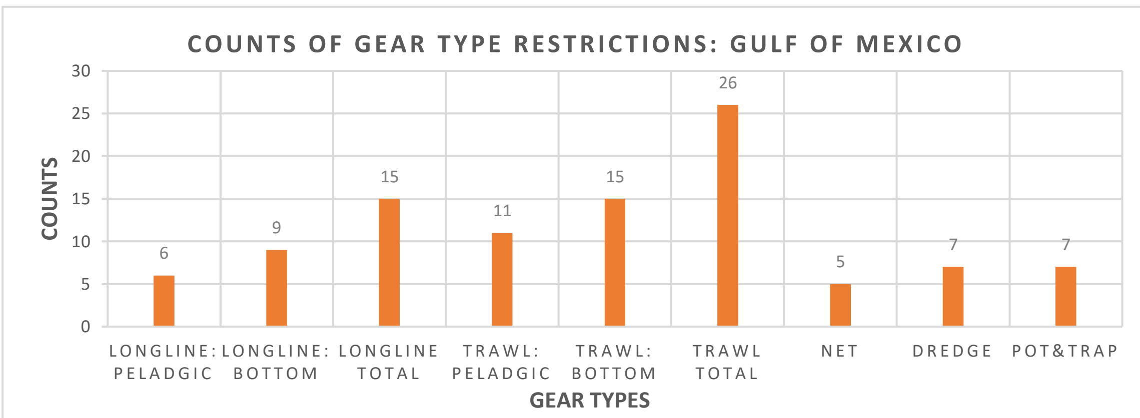


Figure 27. *Counts of restrictions in the Gulf of Mexico by gear type.*

Zonal Sea Turtle Kernel Density

Atlantic

The loggerhead is the only species of this study with relocations in the Atlantic zones. Within the Atlantic waters 100 nautical miles off the coast of Florida there were ten regulated zones where loggerheads KD values were found, and the zones were ≥ 450mi^2 and had KD values (Table 6).

The Florida Keys National Marine Sanctuary (FKNMS) had the highest mean kernel density (KD) (24.6) and the second highest median (7.7) for zones in the Atlantic (Figures 28A&B). The maximum (197.3) and standard deviation (SD) (43.9) represents the high level of variability of KD values within the zone, which suggests that there is a loggerhead hotspot within the zone (Figure 28C&D). This is confirmed by the FKNMS KD map that shows a loggerhead hotspot and its epicenter within the zone (Figures 29).

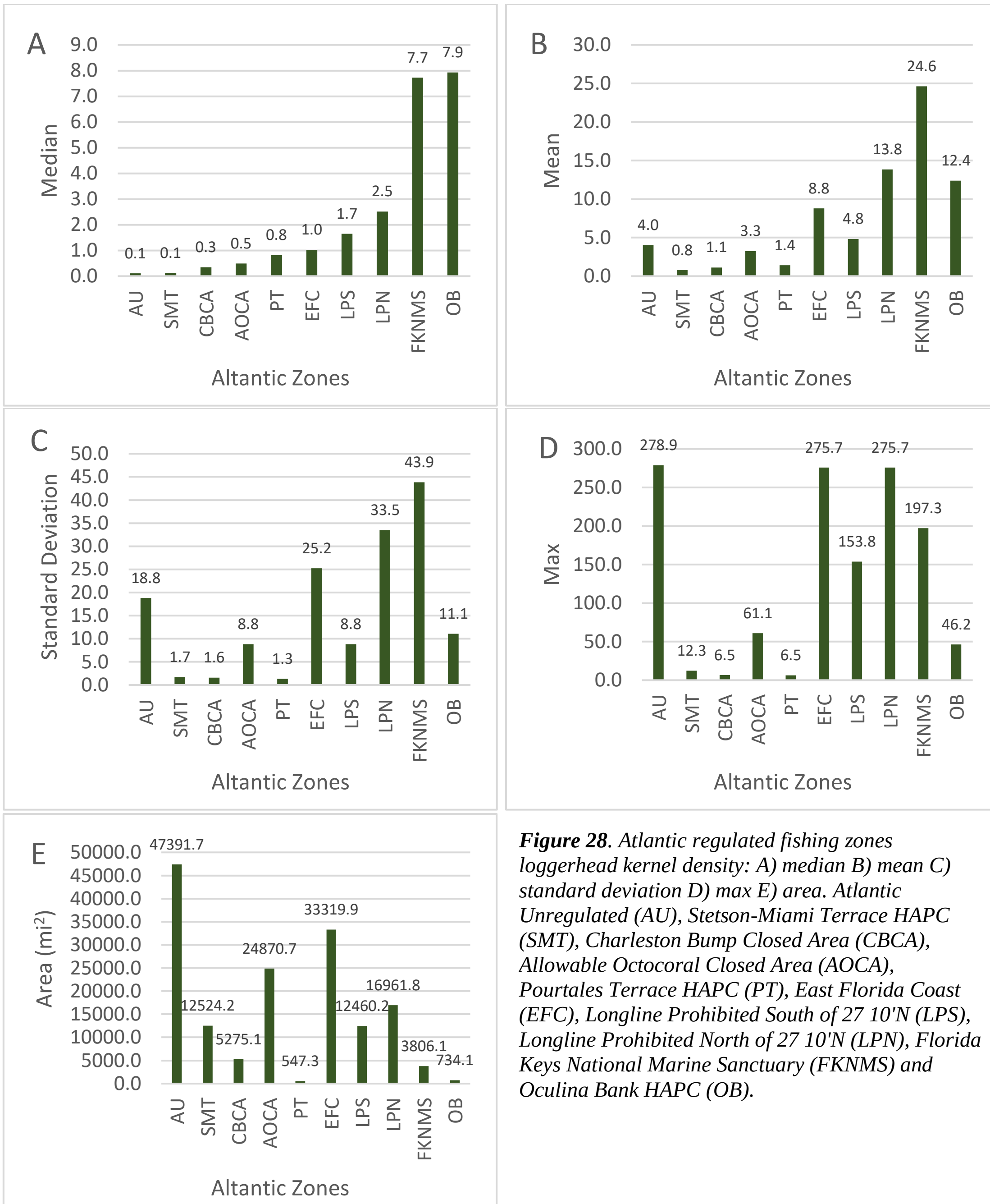


Figure 28*. Atlantic regulated fishing zones loggerhead kernel density: A) median B) mean C) standard deviation D) max E) area. Atlantic Unregulated (AU), Stetson-Miami Terrace HAPC (SMT), Charleston Bump Closed Area (CBCA), Allowable Octocoral Closed Area (AOCA), Pourtales Terrace HAPC (PT), East Florida Coast (EFC), Longline Prohibited South of 27 10'N (LPS), Longline Prohibited North of 27 10'N (LPN), Florida Keys National Marine Sanctuary (FKNMS) and Oculina Bank HAPC (OB).*

Loggerheads

Table 6. *Atlantic regulated fishing zones loggerhead kernel density for median, mean, standard deviation, max and area. All raw data except area was x1000.*

Loggerhead Sea Turtles					
Atlantic Zones	**Median**	**Mean**	**Standard Deviation**	**Maximum**	**Area (mi^2)**
Stetson-Miami Terrace HAPC (SMT)	0.1	0.8	1.7	12.3	12524.2
Atlantic Unregulated (AU)	0.1	4	18.8	278.9	47391.7
Charleston Bump Closed Area (CBCA)	0.3	1.1	1.6	6.5	5275.1
Allowable Octocoral Closed Area (AOCA)	0.5	3.3	8.8	61.1	24870.7
Pourtales Terrace HAPC (PT)	0.8	1.4	1.3	6.5	547.3
East Florida Coast (EFC)	1	8.8	25.2	275.7	33319.9
Longline Prohibited South of 27 10'N (LPS)	1.7	4.8	8.8	153.8	12460.2
Longline Prohibited North of 27 10'N (LPN)	2.5	13.8	33.5	275.7	16961.8
Florida Keys National Marine Sanctuary (FKNMS)	7.7	24.6	43.9	197.3	3806.1
Oculina Bank HAPC (OB)	7.9	12.4	11.1	46.2	734.1

The Oculina Bank HAPC has the third highest mean (12.4) and the highest median (7.9) out of all Atlantic zones (Figures 28A&B). The SD (11.1) for this zone shows that the variability of KD points in this region was significantly lower than the previous zone, FKNMS (Figure 28C). The max (=46.2) is noticeably lower than the FKNMS maximum, (Figure 28D) reflecting the fact that while a hotspot overlaps with the Oculina Bank HAPC, it is only partially intersecting the zone (Figure 30). This zone has the second smallest area (734.1mi2) out of all Atlantic zones which contributes to the median and mean KD results as the Oculina Bank HAPC’s loggerhead hotspot interactions are limited.

The Longline Prohibited North of 27 10'N zone is the fourth largest zone (12460.2mi2) and is tied for the second highest maximum (275.7) in the Atlantic zones (Figures 28D&E). The median (2.5) and mean (13.8) are both the third highest out of the Atlantic zones (Figure 28A&B). The between the max and SD (33.5) this represents that there is significate KD variation within the zone (Figure 28C). These results suggest a loggerhead hotspot, and its epicenter, are interacting with the Longline Prohibited North of 27 10'N zone, and this is confirmed by the loggerhead kernel density map (Figure 31). The size of this zone contributes to the median and mean KD results as the Longline Prohibited North of 27 10'N zone has noteworthy interactions with loggerhead hotspots.

The Longline Prohibited South of 27 10'N zone has a max of 153.8 and SD of 8.8 demonstrating there is some variation within this zone (Figures 28C&D). The large area (12460.2 mi2) of the zone, median (1.7) and mean (4.8) suggest there is limited interactions with the hotspots in this zone (Figures 28A, B, & E). The loggerhead kernel density map of the Longline Prohibited South of 27 10'N zone confirms these results; there is one hotspot interaction, in which the hotspot is only partially intersected by the zone (Figure 31).

The East Florida Coast zone is the 2nd largest zone in the Atlantic (33319.9mi2) (Figure 28E). The mean (8.8) and median (1) indicate that this zone has limited interactions with loggerhead hotspots (Figure 28A&B). The maximum (275.7) and SD (25.2) show significant variation in KD further indicating interactions with loggerhead hotspots (Figures 28C&D). These results are confirmed by the loggerhead kernel density map of the East Florida Coast Zone. The zone interacts with 2 hotspots, both are partially intersected by the zone boundaries, and one hotspot’s epicenter is within the zone (Figure 32). The large size of the zone contributes to the lower median and mean despite the significant hotspot interactions.

The Allowable Octocoral Closed Area zone is the third largest zone in the Atlantic waters (area=734.1mi2) (Figure 28E). The mean (3.3) and median (0.5) indicate that this zone has limited interactions with loggerhead hotspots (Figures 28A&B). The max (61.1) and SD (=8.8) suggest that the zone intersects with a loggerhead hotspot with a low value epicenter (Figures 28C&D). This is confirmed by the loggerhead KD map as the zone partially intersects a loggerhead hotspot with a low value epicenter (Figure 33).

The Pourtales Terrace HAPC is the smallest zone in that analyzed in the Atlantic waters (547.3mi2) (Figure 28E). The mean (1.4) and median (0.8) indicate that this zone has limited interactions with loggerhead hotspots (Figures 29A&B). The SD (1.3) and max (6.5) suggest that this zone does not overlap with a hotspot, but instead have KD Values that are too low to be visually indicated by the KD raster (Figures 28 C&D). The loggerhead KD map of Pourtales Terrace HAPC zone shows no hotspots (Figure 34). The small size of this zone contributes to the median and mean KD results as there are no visible loggerhead hotspot interactions.

The Charleston Bump Closed Area has limited hotspot interactions due to the mean (1.1) and median (0.3) (Figures 29A&B). The max (6.5) and SD (1.6) do not demonstrate variation in the KD, thus suggesting there are no hotspots that interact with this zone (Figures 28C&D). This is also confirmed by the loggerhead KD map, as it shows visible loggerhead hotspot interactions (Figure 35).

The Stetson-Miami Terrace HAPC zone has limited hotspot interactions due to low mean (0.8) and median (0.1) data (Figures 28A&B). The max (12.3) and SD (1.7) do not demonstrate any variation in KD, further indicating the limited hotspot interactions (Figures 28C&D). The loggerhead KD map of the Stetson-Miami Terrace HAPC zone shows no visual interactions with hotspots, confirming the results found (Figure 36).

The Atlantic Unregulated zone is the largest zone in the Atlantic waters (47391.7mi2) (Figure 28E). This zone indicates limited hotspot interactions due to the mean (4) and median (0.1) (Figures 28A&B). The max (278.9) and SD (18.8) demonstrate significant KD variation within the zone, suggesting there is notable loggerhead hotspot interactions (Figures 28C&D). The loggerhead KD map of the Atlantic Unregulated zone shows that that the zone interacts with three hotspots, one completely within the zone and 2 partially intersecting (Figure 37). One of the intersecting zones epicenters is within the zone boundaries. The large size of the zone contributes to the lower median and mean despite the significant hotspot interactions.

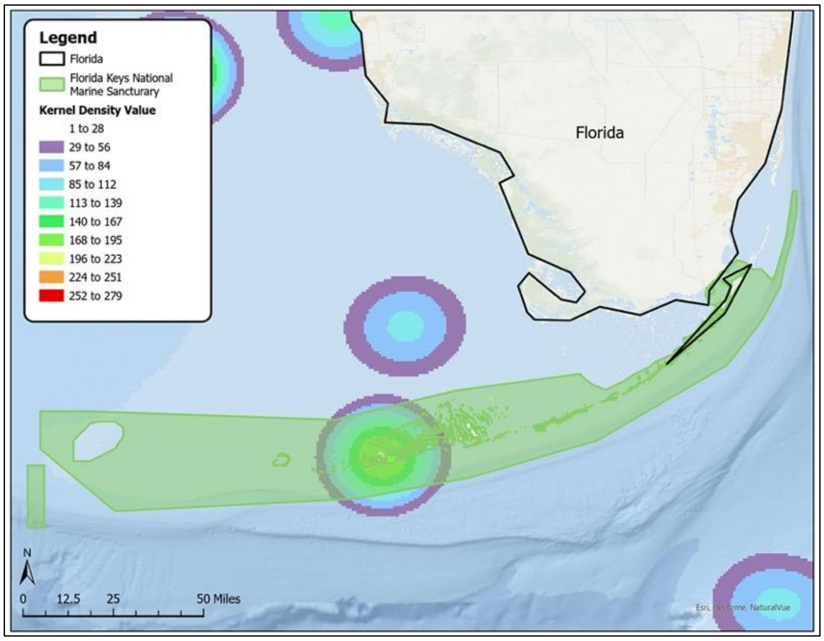


Figure 29. *Florida Keys National Marine Sanctuary loggerhead KD hotspot map.*

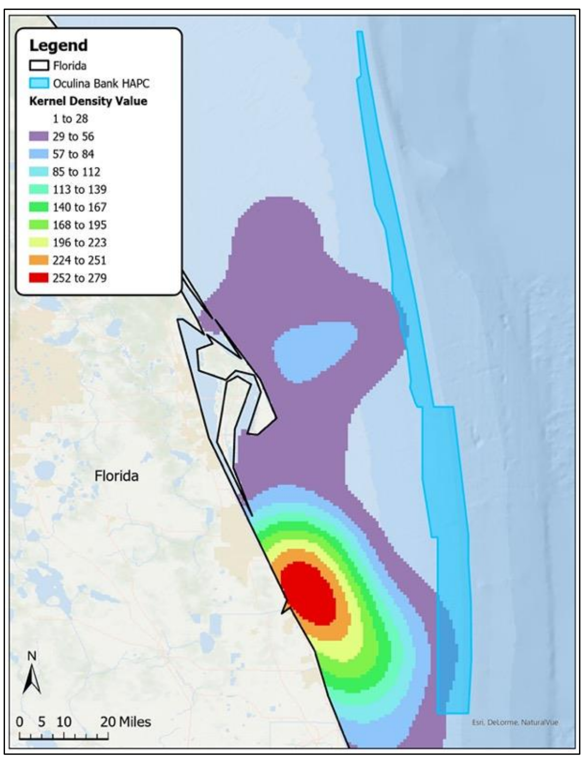


Figure 30. *Oculina Bank HAPC loggerhead KD hotspot map.*

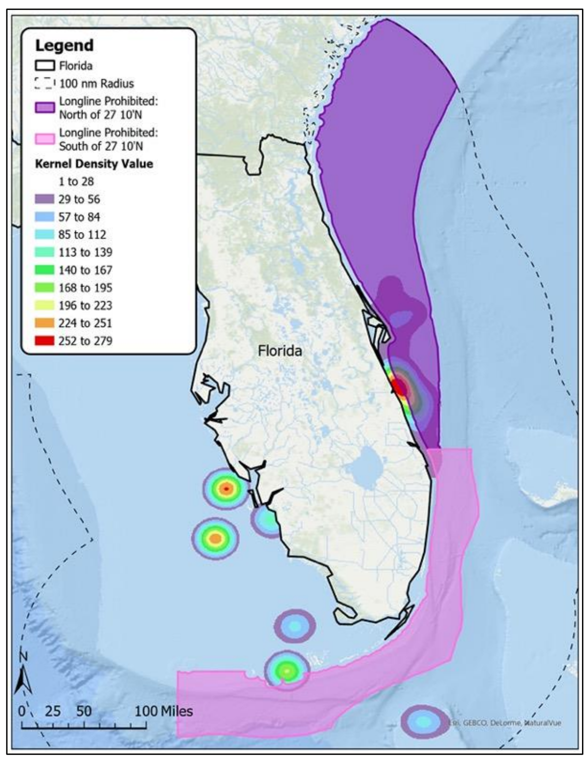


Figure 31. *Longline Prohibited: North of 27 10'N (purple) and South of 27 10' loggerhead KD hotspot map.*

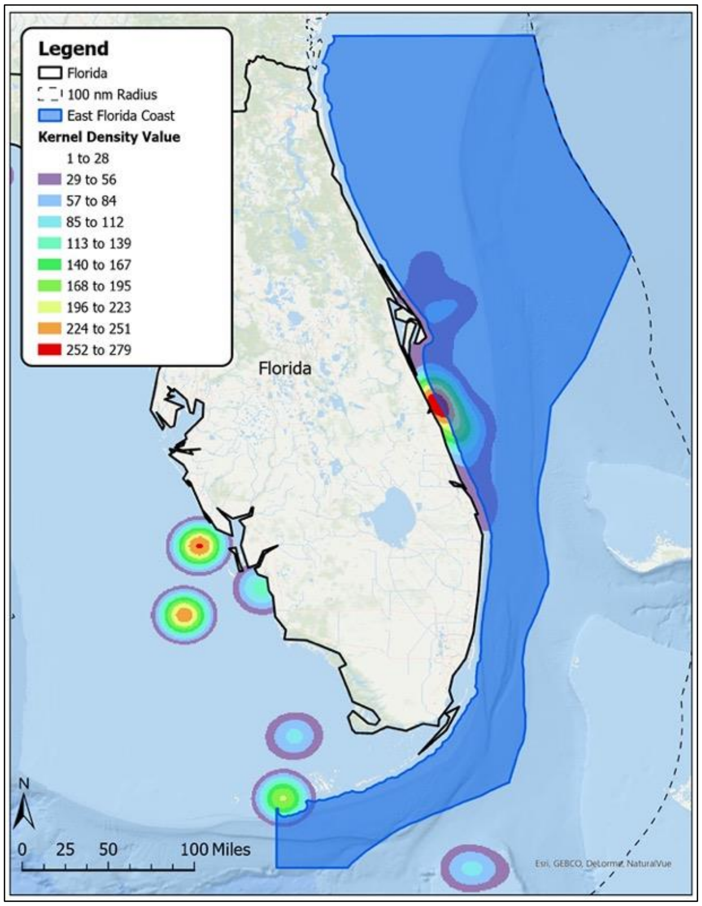


Figure 32. *East Florida Coast loggerhead KD hotspot map.*

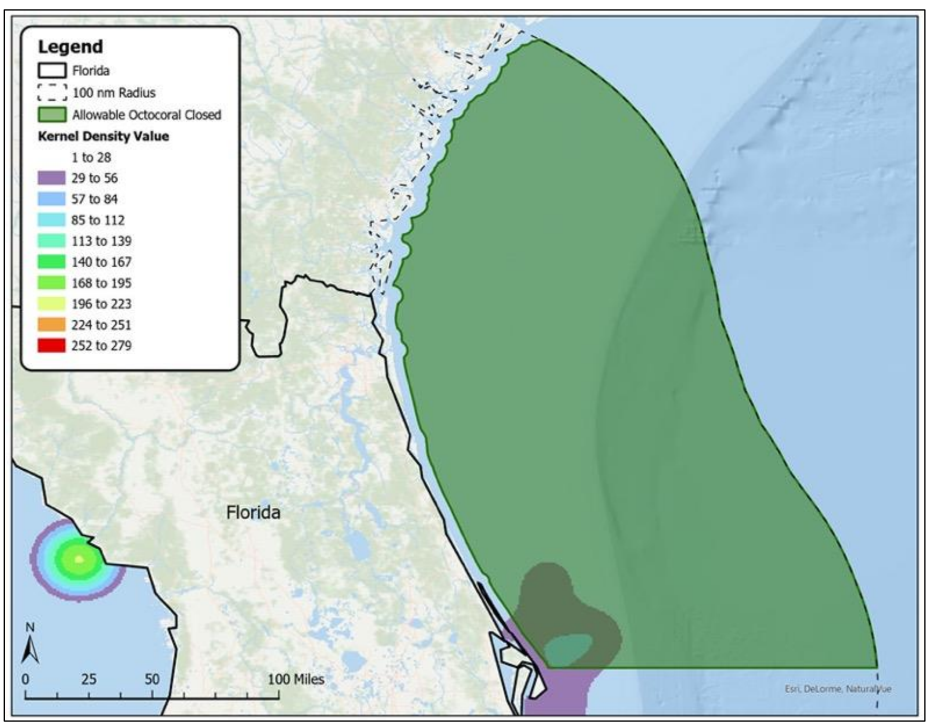


Figure 33. *Allowable Octocoral Closed Area loggerhead KD hotspot map.*

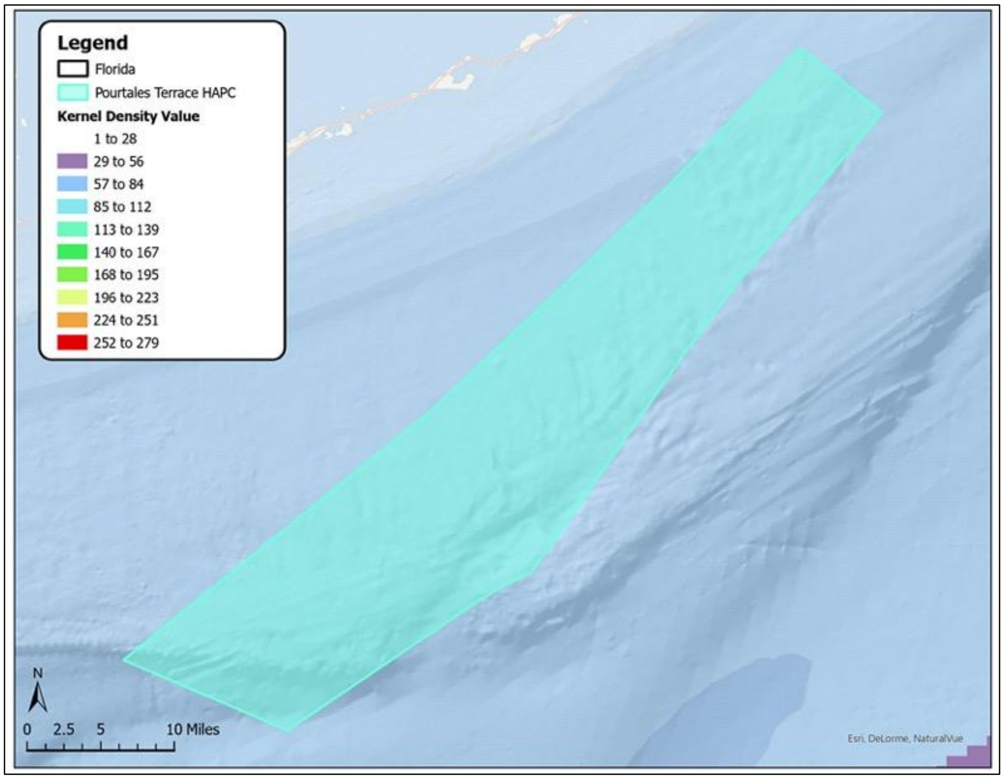


***Figure 34**. Pourtales Terrace HAPC loggerhead KD hotspot map.*

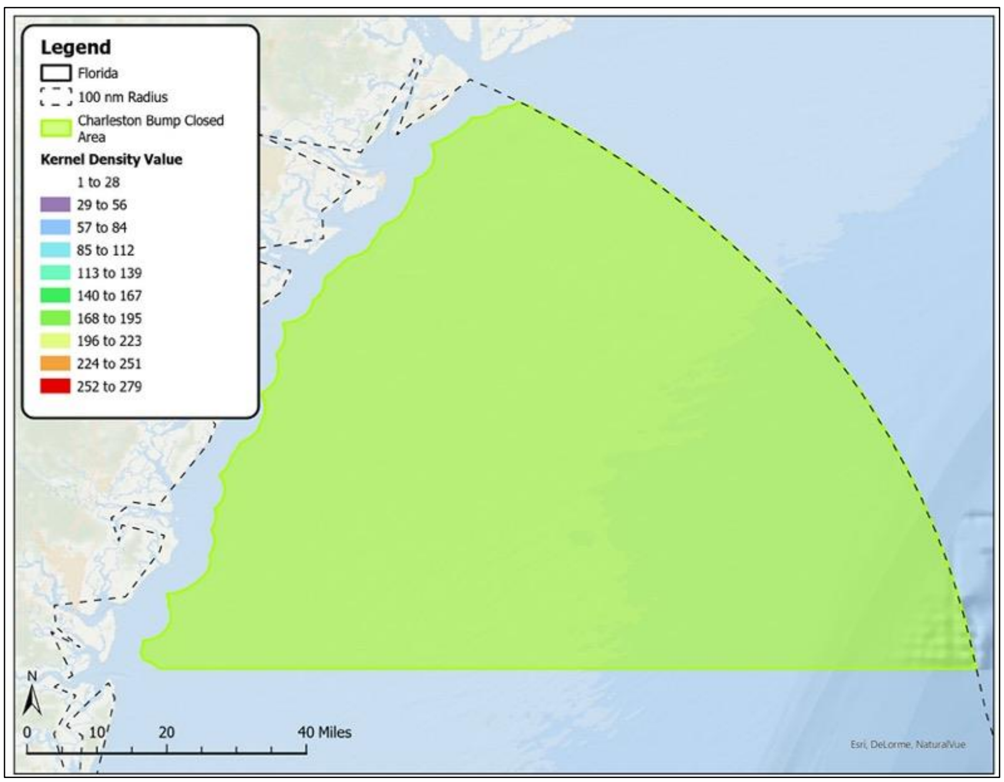


***Figure 35.** Charleston Bump Closed Area loggerhead KD hotspot map.*

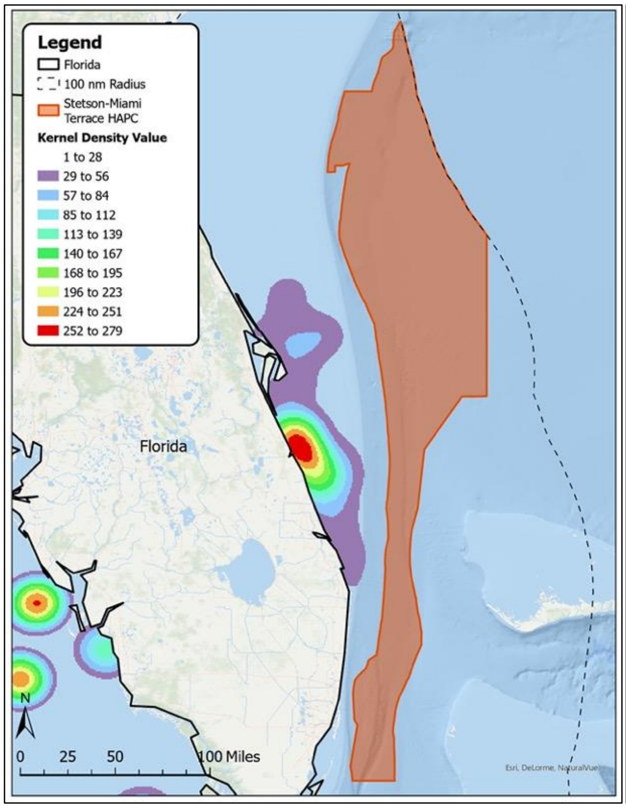


Figure 36. *Stetson-Miami Terrace HAPC loggerhead KD hotspot map.*

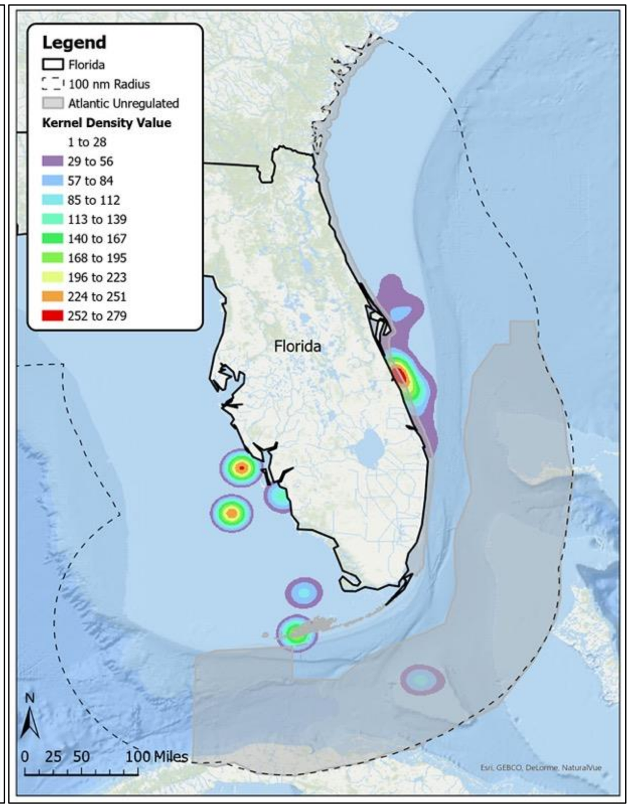


Figure 37. *Atlantic Unregulated loggerhead KD hotspot map.*

Gulf of Mexico

Both loggerhead and leatherback turtles were relocated within 100 nautical miles of the coast of Florida in the Gulf of Mexico. Turtle KD values were found in a total of 9 regulated fishing zones found in the Gulf of Mexico, which the zones were ≥ 450mi^2 and had KD values. Using these perimeters loggerheads were found in 6 zones and leatherbacks were found in 7 zones (Table 7&8).

The Tortugas Shrimp Sanctuary North zone is the smallest zone where loggerheads KD values were found in the Gulf of Mexico (1352.1mi^2) and has the highest mean (29.1) and median (20.5) (Figures 38A&B). The maximum (91.4) and SD (8.8) show variation within the Tortugas Shrimp Sanctuary North zone, indicating loggerhead hotspot interactions (Figures 38C&D). The loggerhead KD map of this zone shows this zone is interacting with 2 loggerhead hotspots, both are partially intersected within the zone (Figure 39). One hotspot is primarily in the Tortugas Shrimp Sanctuary North zone and with its epicenter inside the zone, which

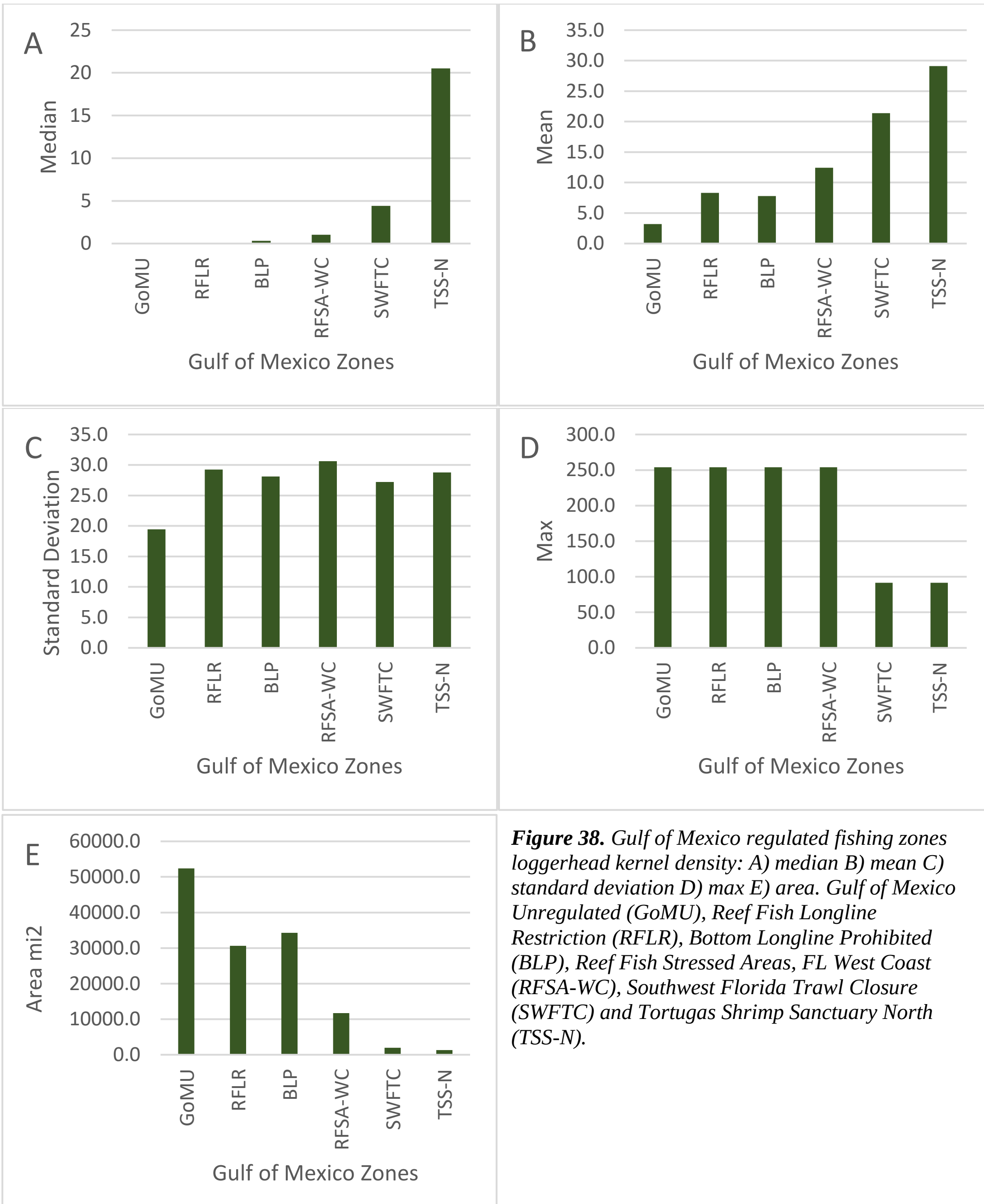


Figure 38. *Gulf of Mexico regulated fishing zones loggerhead kernel density: A) median B) mean C) standard deviation D) max E) area. Gulf of Mexico Unregulated (GoMU), Reef Fish Longline Restriction (RFLR), Bottom Longline Prohibited (BLP), Reef Fish Stressed Areas, FL West Coast (RFSA-WC), Southwest Florida Trawl Closure (SWFTC) and Tortugas Shrimp Sanctuary North (TSS-N).*

confirms the maximum. The other hotspot is only partially within the zone, with the lowest value edge (29 to 56 KD) of the hotspot intersecting within the zone for ≈.8 miles. The small size of the zone and majority enveloped hotspot would contribute to the high mean, median and the lower SD KD values.

Loggerheads

Table 7. *Gulf of Mexico regulated fishing zones loggerhead kernel density for median, mean, standard deviation, maximum and area. All raw data, except area, is x1000.*

Loggerhead Sea Turtle Kernel Density					
Gulf of Mexico Zones	**Median**	**Mean**	**Standard Deviation**	**Maximum**	**Area (mi^2)**
Gulf of Mexico Unregulated (GoMU)	0	3.2	19.5	253.9	52390.5
Reef Fish Longline Restricted (RFLR)	0	8.3	29.3	254	30605.4
Bottom Longline Prohibited (BLP)	0.3	7.8	28.1	254	34322.5
Reef Fish Stressed Areas, FL West Coast (RFSA-WC)	1	12.4	30.6	254	11703.9
Southwest Florida Trawl Closure (SWFTC)	4.4	21.4	27.2	91.4	1925.4
Tortugas Shrimp Sanctuary North (TSS-N)	20.5	29.1	28.8	91.4	1352.1

The Southwest Florida Trawl Closure zone is the second smallest zone (1925.4 mi^2) that loggerheads KD values were found in the Gulf of Mexico (Figure 38E). The mean (21.4) and median (4.4) indicate loggerhead hotspot interaction, which is further corroborated by the significant variation in KD seen by the maximum (91.4) and SD (27.2) (Figures 38A, B, C&D). The loggerhead KD map of the Southwest Florida Trawl Closure zone display interactions with 3 different hotspots (Figure 40). Two hotspots have very mild interactions with the zone, only intersecting a max of ≈7.5 miles into the into the zone with the lowest value edge (29 to 56 KD) of the hotspot. The third hotspot has most of its area enveloped within the zone, which confirms the maximum. The small size of the zone and majority enveloped hotspot would contribute to the high mean and median KD values found within this zone.

The Bottom Longline Prohibited zone is the second largest zone that loggerheads are found the Gulf of Mexico (34322.5mi^2) (Figure 38E). The mean (7.8), median (0), maximum (254) and SD (28.1) show significant variation in limited KD, this indicates that there is hotspot interaction, with high value hotspots, but it is limited (Figures 38A, B, C&D). This is confirmed by the Loggerhead KD map of the Bottom Longline Prohibited zone as it shows 7 hotspot interactions: 4 epicenters (2 of which are completely within and 2 partially intersecting the zone) and 3 partial hotspot interactions (Figure 41). The 4 hotspot epicenters within the zone had KD values ranging between 29 to 254 (maximum). The 3 hotspots partially intersecting with the Bottom Longline Prohibited zone have KD values ranging between 29 to 195. The large size of the zone contributes to the lower mean and median KD despite the high maximum and SD due to the hotspot interactions.

The Reef Fish Stressed Areas, Florida West Coast zone's mean (12.4), median (1), maximum (254) and SD (30.6) represent significant KD variation within the zone, indicating loggerhead hotspot interactions (Figures 38A, B, C&D). The loggerhead KD map of the Reef Fish Stressed Areas, FL West Coast zone shows that seven different hotspots interact partially with the zone (Figure 42). Three hotspots have over half the hotspot area within zone, including their epicenters which range in KD value between 29 to 254 KD (maximum). The remaining four hotspots interacting with the Reef Fish Stressed Areas, FL West Coast zone do not have epicenters within the zone and intersect the zone up to ≈ 6.25miles, and the KD values range between 29 to 167. The larger size of this zone (11703.9 mi^2) contributes to the lower mean and median KD despite the higher maximum and SD KD (Figure 38E).

The Reef fish Longline Restricted zone is second largest zone (30605.4mi^2) in the Gulf of Mexico in which loggerhead KD values area found (Figure 38E). The mean (8.3), median (0), maximum (254) and SD (29.3) demonstrate KD variation, which indicates the zone has interactions with loggerhead hotspots (Figures 38A, B, C&D). The loggerhead KD map of Reef fish Longline Restricted zone so this zone is interacting with 7 hotspots (Figure 43). Four of the 7 hotspots are fully, or majority enveloped in the zone and have epicenter KD values ranging between 29 to 254 (maximum). The remain 3 zones partially intersect up to ≈3miles, with KD values between 29 to 167. The large size of this zone contributes to the lower mean and median KD despite the higher maximum and SD KD.

The Unregulated Gulf of Mexico zone is the largest zone (52390.5mi^2) in the Gulf of Mexico in which loggerhead KD values area found (Figure 38E). The mean (3.2), median (0), maximum (253.9) and SD (19.5) exhibit variation in the KD, indicating there is loggerhead hotspot interactions within this zone (Figures 38A, B, C&D). The loggerhead KD map of the Unregulated Gulf of Mexico zone shows 6 hotspot interactions, all partially interesting with the zone (Figure 44). 2 hotspots have their epicenters within the zone, with KD values ranging between 29 to 223. The remaining 4 hotspots intersect up to ≈7miles into the zone and have KD values ranging between 29 to 253.9 (maximum). The hotspots that do not have the epicenter within the zone have higher KD values than the hotspots with their epicenter within the zone. The large size of this zone contributes to the lower mean and median KD despite the higher maximum and SD KD.

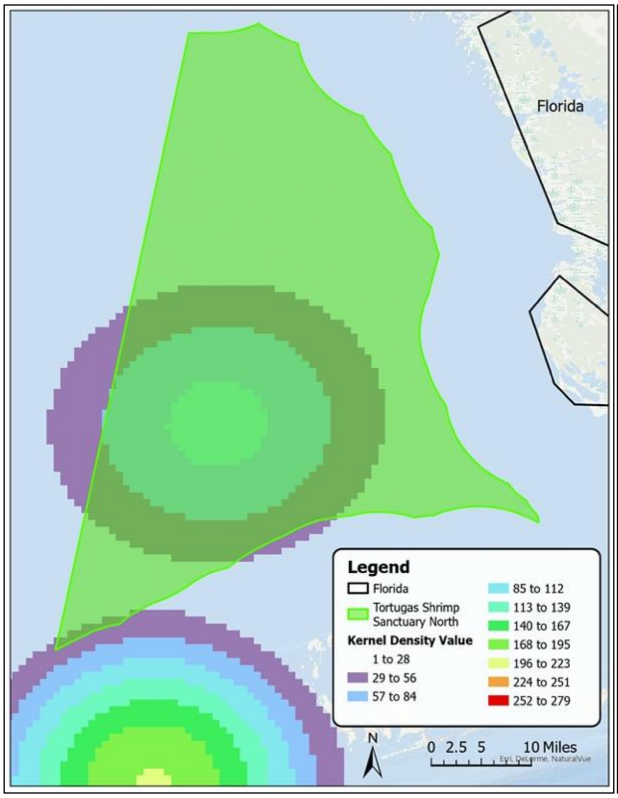


Figure 40. *Tortugas Shrimp Sanctuary North loggerhead KD hotspot map.*

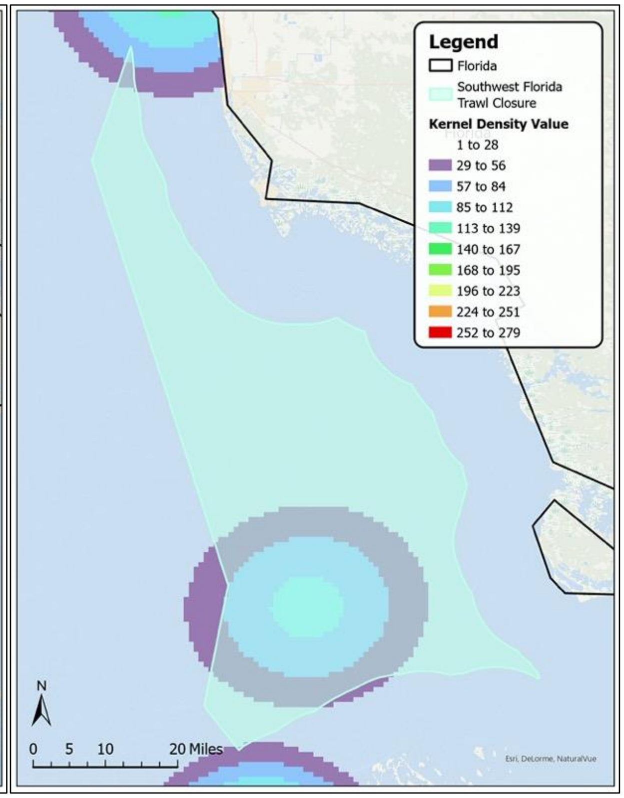


Figure 39. *Southwest Florida Trawl Closure loggerhead KD hotspot map.*

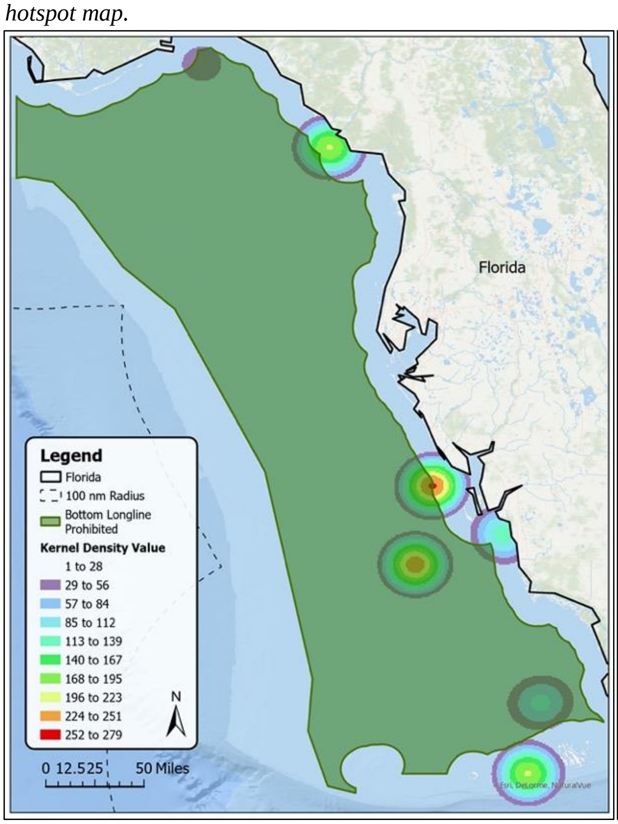


Figure 42.*Bottom Longline Prohibited loggerhead KD hotspot map.*

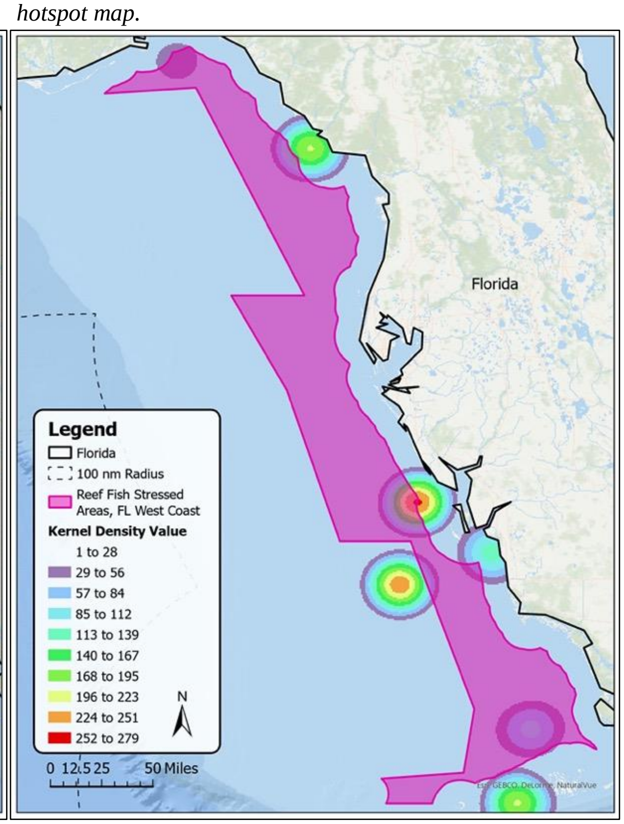


Figure 41. *Reef Fish Stressed Area, FL West Coast loggerhead KD hotspot map.*

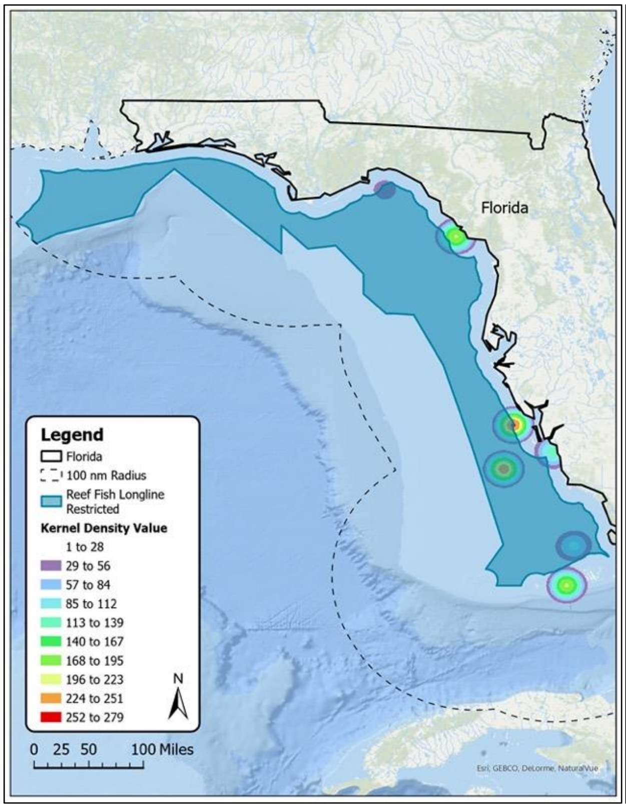


Figure 43. Reef Fish Longline Restricted loggerhead KD hotspot map.

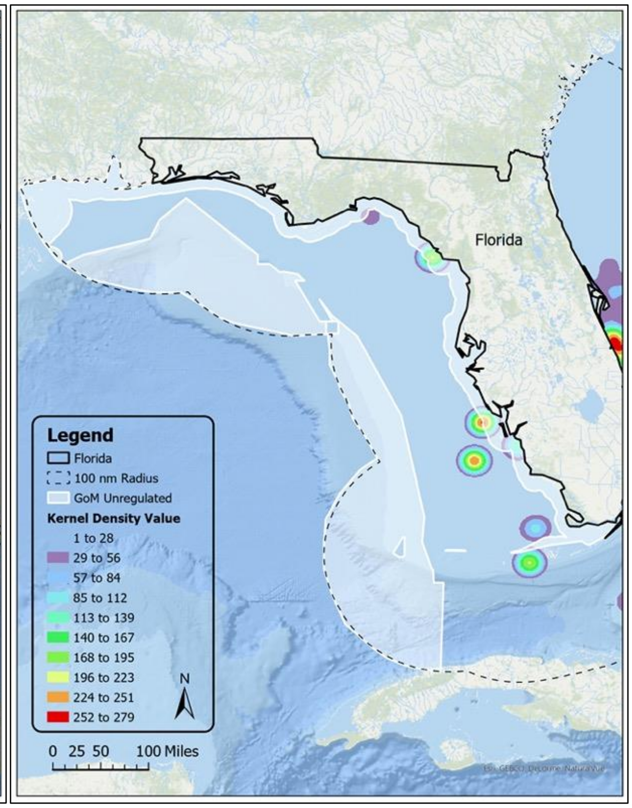


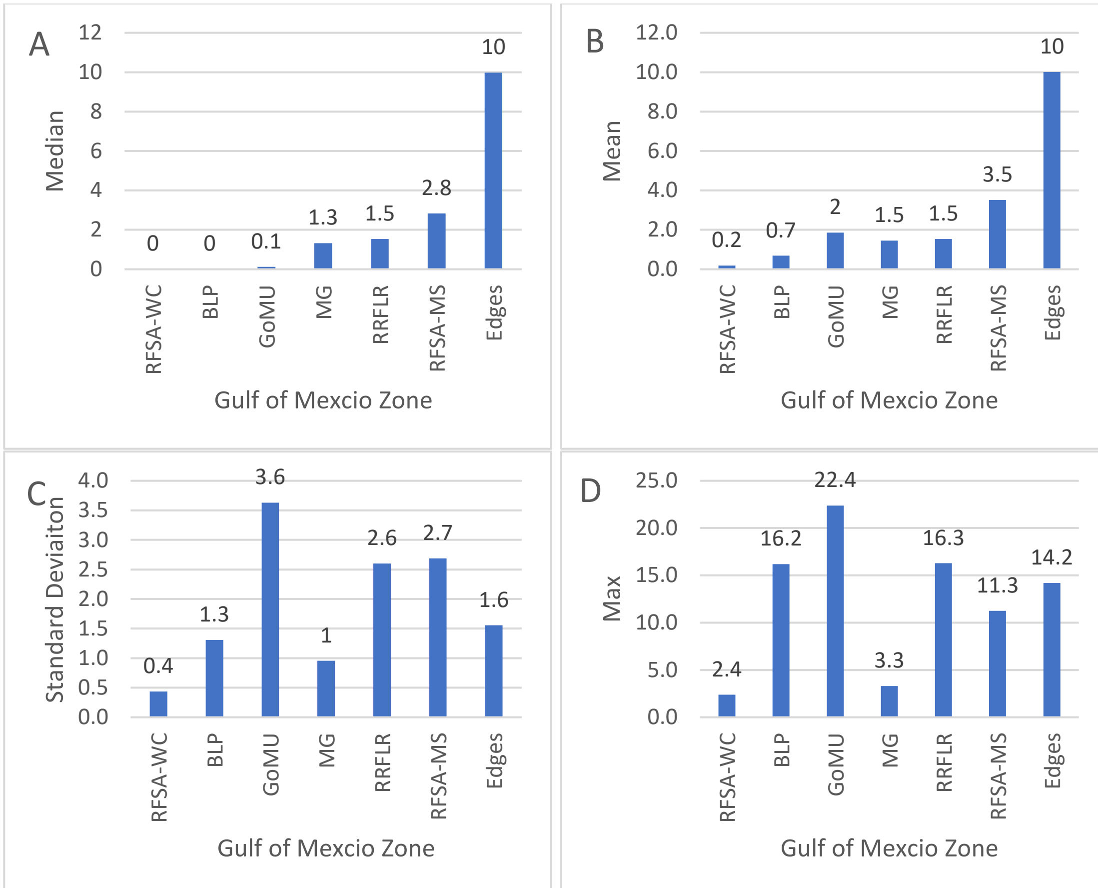
Figure 44. Gulf of Mexico Unregulated loggerhead KD hotspot map.

Leatherbacks

There was a limited leatherback relocation data available for this study. Due to this limitation the KD values of the leatherbacks are much lower than what was seen in the loggerhead data.

Table 8. *Gulf of Mexico regulated fishing zones leatherback kernel density for median, mean, standard deviation, max and area. All raw data except area was x1000.*

Leatherback Sea Turtles Kernel Density					
Gulf of Mexico Zones	**Median**	**Mean**	**Standard Deviation**	**Max**	**Area (mi^2)**
Reef Fish Stressed Areas, FL West Coast (RFSA-WC)	0	0.2	0.4	2.4	11703.9
Bottom Longline Prohibited (BLP)	0	0.7	1.3	16.2	34322.5
Gulf of Mexico Unregulated (GoMU)	0.1	2	3.6	22.4	52390.5
Middle Grounds HAPC (MG)	1.3	1.5	1	3.3	450.0
Reef Fish Longline Restricted (RFLR)	1.5	1.5	2.6	16.3	30605.4
Reef Fish Stressed Areas, FL, AL and MS (RFSA-MS)	2.8	3.5	2.7	11.3	3810.5
The Edges (Edges)	10	10	1.6	14.2	516.5



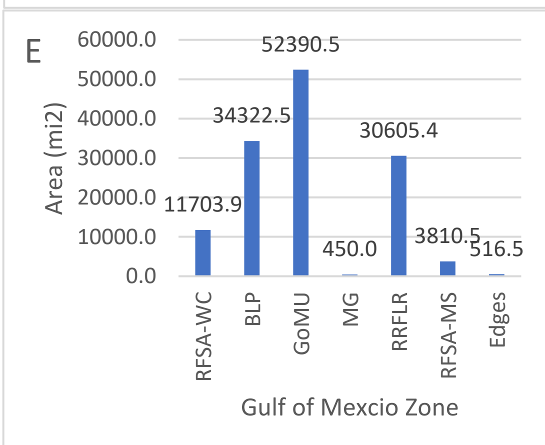


Figure 45. *Gulf of Mexico regulated fishing zones leatherback kernel density: A) median B) mean C) standard deviation D) max E) area. Gulf of Mexico Unregulated (GoMU), Reef Fish Longline Restriction (RFLR), Bottom Longline Prohibited (BLP), Reef Fish Stressed Areas, FL West Coast (RFSA-WC), Reef Fish Stressed Areas, FL, AL and MS (RFSA-MS), Middle Grounds HAPC (MG) and The Edges (Edges)*

The Edges zone is the second smallest zone (516.5mi^2) in the Gulf of Mexico in which leatherback KD values area found (Figure 45E). The mean (10.0), median (10.0), max (14.2) and SD (1.6) exhibit variation in KD, indicating that this zone interacts with a leatherback hotspot (Figures 45A, B, C&D). The Leatherback KD map of the Edges zone confirms this as the whole zone is within a region of a single large hotspot (Figure 46). The Edges Zone is within a region of this hotspot that has KD values ranging between 5 to 16.

The Reef Fish Longline Restricted zone is the third largest zone (30605.4mi^2) in the Gulf of Mexico in which leatherback KD values are found (Figure 45E). The mean (1.5), median (1.5) (figures maximum (16.3) and SD (2.6) exhibit variation in KD, indicating that this zone interacts with a leatherback hotspot (Figures 45A, B, C&D). The Leatherback KD map of the Reef Fish Longline Restricted zone confirms this as the zone that intersects with one large hotspot along its northern end (Figure 47). The region this Reef Fish Longline Restricted zone intersects with is the hotspot that is not on an epicenter but instead the outer edges of the zone; the KD values it intersects range between 3 to 16.3 (maximum). The large size of the zone contributes to the lower KD mean and median values, despite the significant max and SD values.

The Middle Grounds HAPC zone is the smallest zone (450.0mi^2) in the Gulf of Mexico were leatherback KD values area found (Figure 45E). The mean (1.5), median (1.3), maximum (3.3) and SD (1) exhibit little variability in KD, indicating limited leatherback hotspot interactions (Figures 45A, B, C&D). The Leatherback KD map of the Middle Grounds HAPC zone confirms this, as the zone only interacts with a low KD value (3 to 4 KD) edge of a hotspot, intersecting up to ≈6.8miles into the zone (Figure 48). The small size of the zone contributes to the higher overall median and mean KD values.

The Unregulated Gulf of Mexico zone is the largest zone (52390.5mi^2) in the Gulf of Mexico where leatherback KD values area found (Figure 45E). The mean (1.9), median (0.1), maximum (22.4) and SD (3.6) show there is significant variation in KD throughout this zone, indicating there are prevalent interactions with leatherback hotspots (Figures 45A, B, C&D). The leatherback KD map of the Unregulated Gulf of Mexico zone confirms this, as the majority of the hotspot intersects with the zone, including the epicenter (Figure 49). The KD Values of the hotspot that interest with the zone range between 3 to 22.4 (maximum). The large size of the zone contributes to the lower median and mean KD values, despite having the highest SD and max out of all the other zones in the Gulf of Mexico.

The Bottom Longline Prohibited zone is the second largest zone (34322.5mi^2) in the Gulf of Mexico where leatherback KD values are found (Figure 45E). The mean (0.7), median (0), maximum (16.2) and SD (1.3) shows that the Bottom Longline Prohibited zone has limited variation in KD, indicating limited hotspot interactions (Figures 45A, B, C&D). This is confirmed by the leatherback KD map of the Bottom Longline Prohibited zone, as only the north easter edge of the zone interacts partially with 2 hotspots (Figure 50). These hotspots intersect up to ≈68miles within the zone. One hotspot's epicenter is within the zone, with KD values ranging between 8 to 9. The KD value range for the hotspot without the epicenter inside the zone is 3 to 16.2 (maximum). The large size of this zone contributes to the lower median and mean KD despite the higher max.

The Reef Fish Stressed Areas, FL West Coast zone is indicated to have extremely limited leatherback hotspot interactions by the minimal KD variation seen by the mean (0.2), median (0), maximum (2.4) and SD (0.4) (Figures 45A, B, C&D). The leatherback KD map of the Reef Fish Stressed Areas, FL West Coast zone confirms this, as the was only one very minor hotspot interaction, with a KD value between 3 to 4, seen in the north easter corner of the zone (Figure 51).

The Reef Fish Stressed Areas, Florida, Alabama and Mississippi zone is shown to have a significant amount of leatherback hotspot interactions due to higher max (11.3), mean (3.5) and median (2.8) but limited variation shown by the SD (2.7) (Figures 45A, B, C&D). The leatherback KD map of the Reef Fish Stressed Areas, FL, AL and MS exhibits one hotspot interaction with a large hotspot throughout the majority of the zone (Figure 51). The hotspot region that is intersecting partially with the zone does not contain the epicenter and has a KD value range between 3 to 11.3 (maximum).

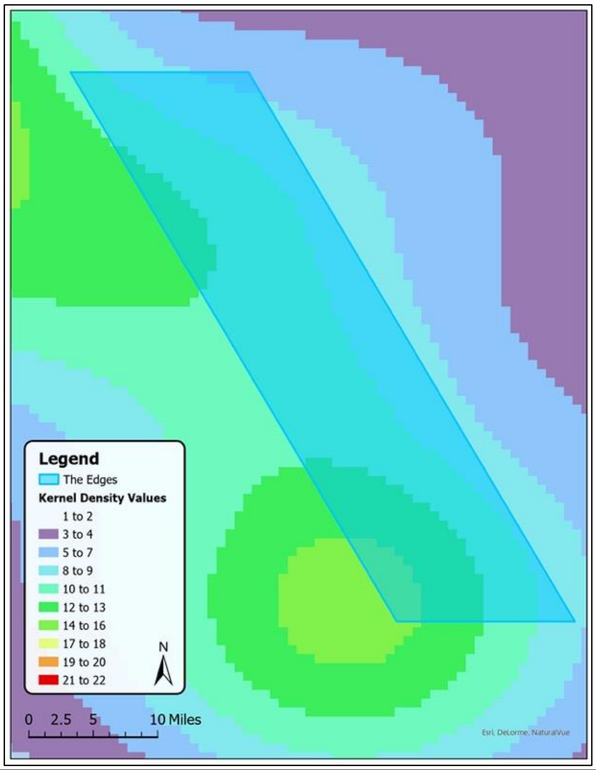


Figure 46. *The Edges leatherback KD hotspot map.*

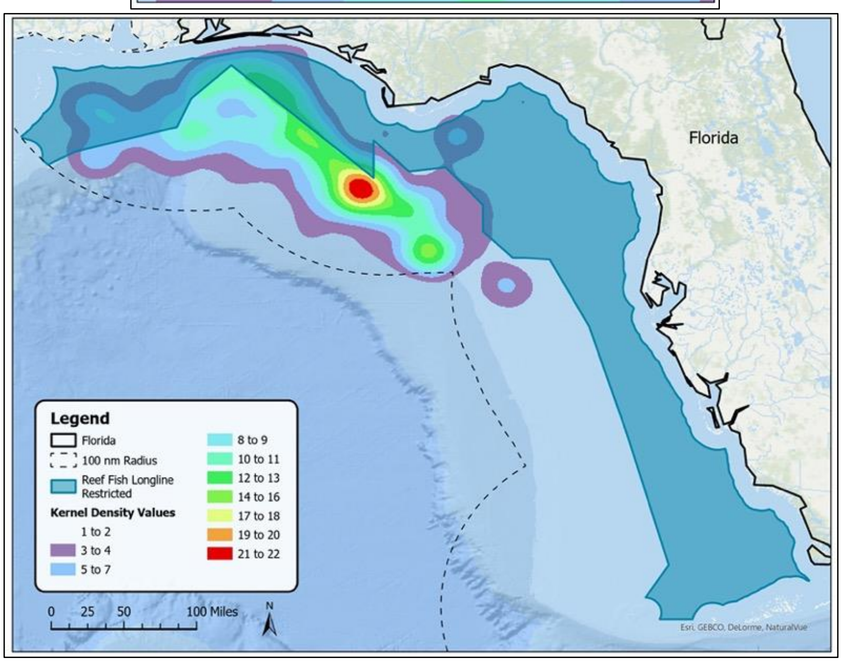


Figure 47. *Reef Fish Longline Restricted leatherback KD hotspot map.*

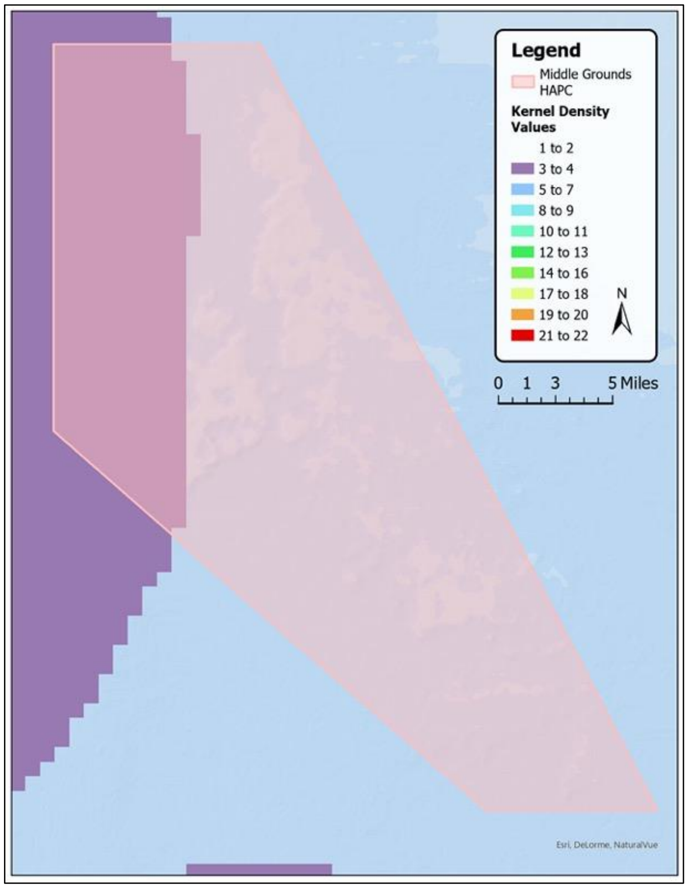


Figure 48. *Middle grounds leatherback KD hotspot map.*

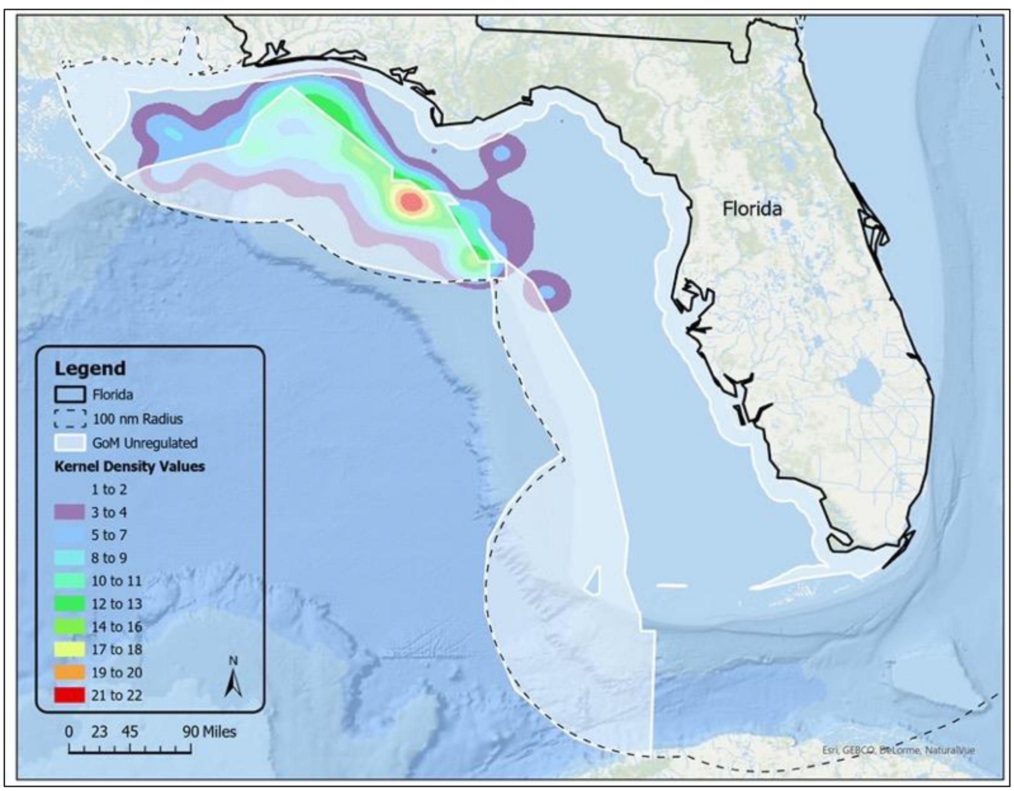


Figure 49. *Gulf of Mexico Unregulated leatherback KD hotspot map.*

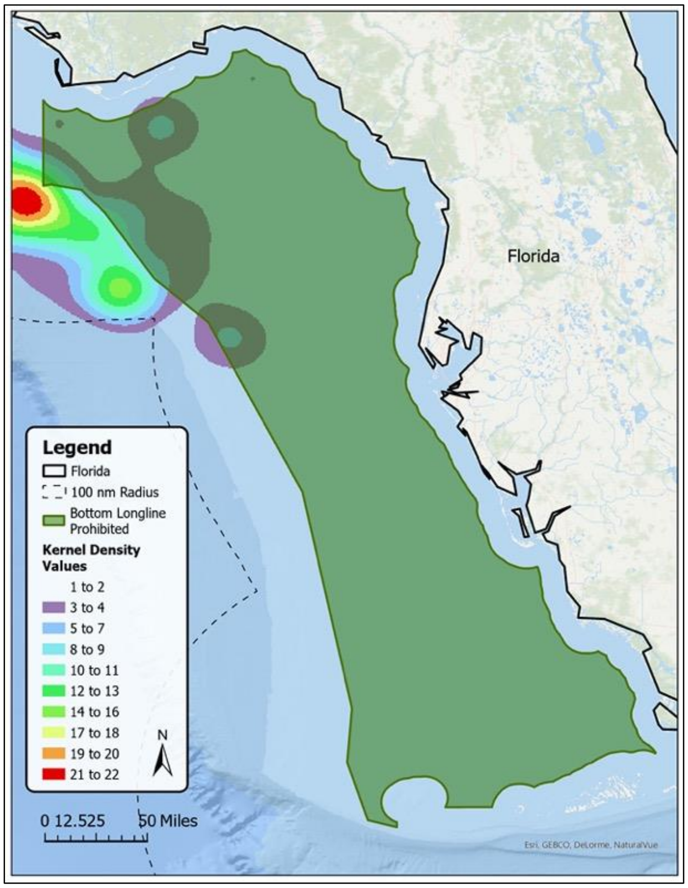


Figure 50. *Bottom Longline Prohibited leatherback KD hotspot map.*

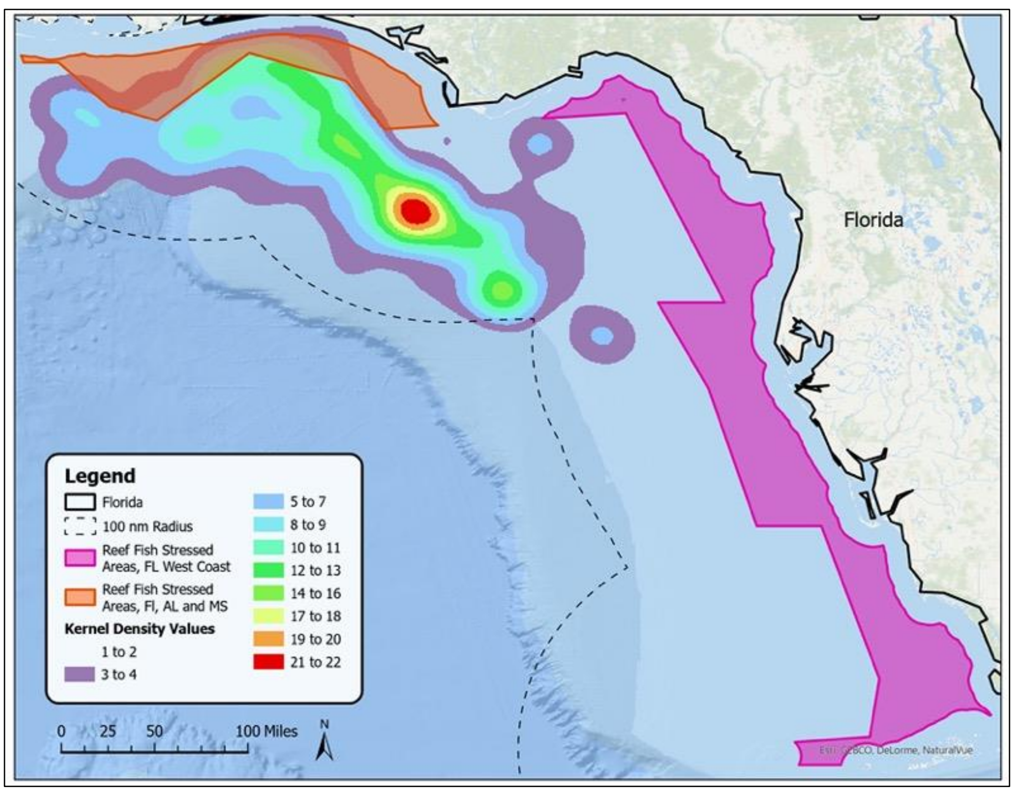


Figure 51. *Reef Fish Stressed Areas: Fl West Coast and Fl, Al and MS leatherback KD hotspot map.*

Gear and Kernel Density Relationships

Regulated Fishing Zone Kernel Density and Gear Restrictions

The median KD of turtle relocations in regulated fishing zones was not significantly related to the number of fishing gear restrictions in those zones, for both loggerheads and leatherbacks in the Atlantic and Gulf of Mexico (Figures 30, 31 & 32) Values of median KD were quite variable and so each plot had substantial scatter. For loggerheads in the Atlantic, the two zones with the highest medians (Florida Keys National Marine Sanctuary (FKNMS) and Oculina Bank HAPC zones) were also the two smaller fishing zones with very different gear restriction counts (Figure 30). For loggerheads in the Gulf of Mexico, variation in gear restriction counts were very limited (0-2, Figure 31). For leatherbacks in the Gulf of Mexico, the Reef Fish Longline Restriction zone had high leverage on the nonsignificant results since it was at the maximum in gear restriction count (7) and had a low median KD, in part due to its large size (30605.4mi^2).

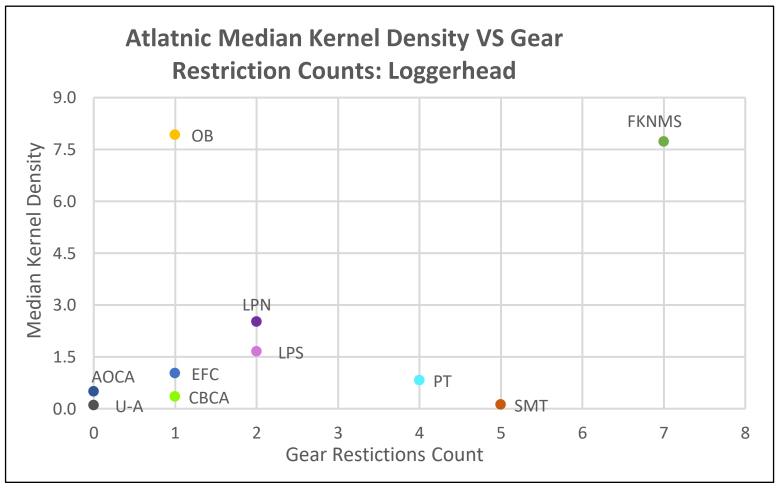


Figure 52. Atlantic Ocean loggerhead regulated fishing zones gear counts and median kernel density do not have a significant relationship (F1,8 = 1.28, p = 0.29, R2 = 0.14).

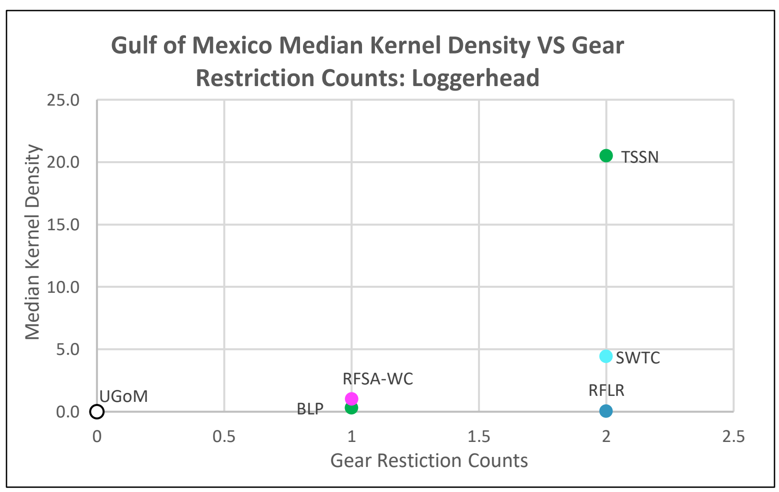


Figure 53. Gulf of Mexico loggerhead regulated fishing zones gear counts and median kernel density do not have a significant relationship (F1,4 = 1.28, p = 0.32, R2 = 0.24).

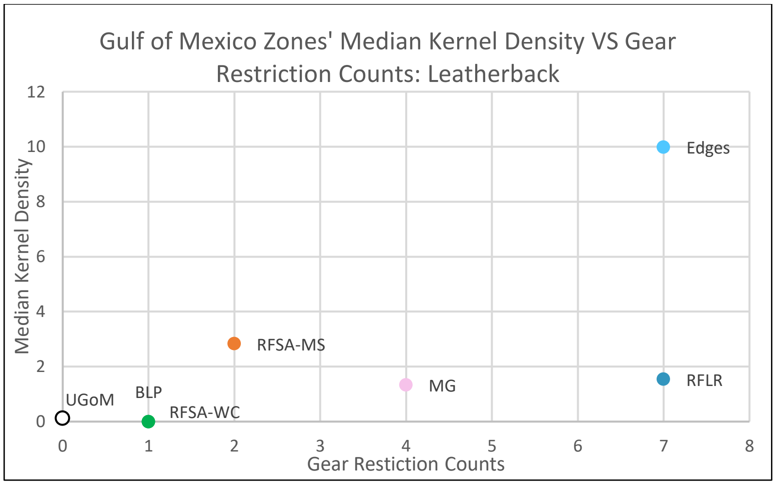


Figure 54. *Gulf of Mexico leatherback regulated fishing zones gear counts and median kernel density do not have a significant relationship (F1,5 = 3.57, p = 0.12, R2 = 0.42).*

Relationship Between Zone Density and Restricted Gear Type

Across all the regulated fishing zones and both species there was constantly more restricted gear types (longline [pelagic, bottom, and total], trawl [pelagic, bottom, and total], net, dredge and pot and trap) for higher median KD (≥1) zones than low median KD (>1) zones (Figure 55A, B&C). This indicates that higher median KD of turtle relocations in regulated fishing zones were associated with higher restrictions of each gear type.

Atlantic

Loggerhead

In the Atlantic, zones with a loggerhead relocation median KD of ≥1 (the top 50%, Table 7) had more gear restrictions in two out of the seven gear types (42%) than the zones with median KD <1 (Figure 55A). The two gear types are longline, which accounted for 30% (pelagic and bottom=15%), and net, which accounted for 4% of all restrictions. This shows that in the Atlantic, higher restrictions of longlines and nets are associated with higher median KD of loggerhead relocations. However, across all gear types, there was not a significant difference in gear restrictions in zones with higher median KD than zones with lower KD (paired t_8 = -1.5, p = 0.172).

Gulf of Mexico

Loggerhead

In the Gulf of Mexico, zones with a loggerhead relocation median KD of ≥1 (the top 50%, Table 8), had more gear restrictions in 5 out of 7 gear types (71%) than the zones with <1 (Figure 55B). These gear types are trawls, which accounted for 33% (pelagic and bottom=17%) of all gear restrictions, and nets, dredges and pot and traps, which each accounted for 8% of restrictions. This shows that in the Gulf of Mexico higher restrictions of trawls, nets, dredges and pot and traps are associated with higher median KD of loggerhead relocations. However, across all gear types, there was not a significant difference in gear restrictions in zones with higher median KD than zones with lower KD (paired t_8 = -1.87, p = 0.09435).

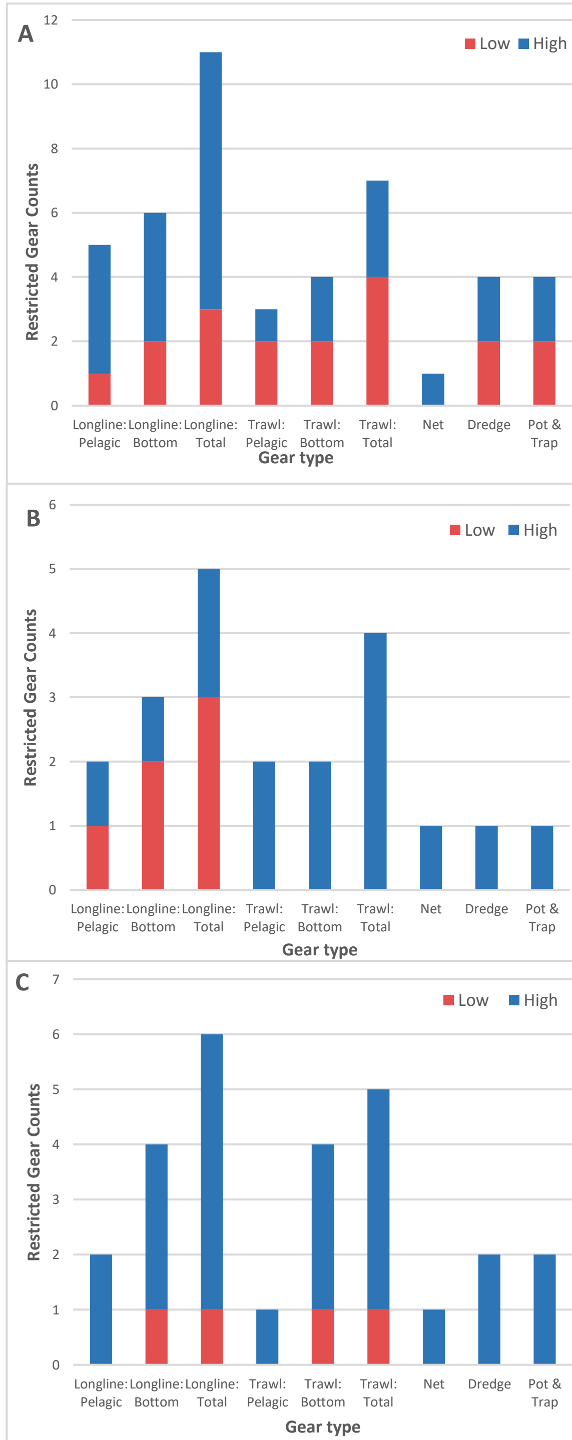


Figure 55. *Zone median kernel density and its relationship with gear type restrictions. A) Atlantic zones with Loggerhead Median KD B) Gulf of Mexico zones with loggerhead median KD C) Gulf of Mexico zones with loggerhead median KD.*

Leatherbacks

In the Gulf of Mexico, zones with a leatherback relocation median KD of ≥1 (the top 57%, Table 9), had higher numbers of gear restrictions across all gear types than the zones with median KD <1 (the bottom 50%, Figure 55C). Across all gear types, in the Gulf of Mexico, there tended to be more gear restrictions in zones with higher median KD than zones with lower KD (paired $t_8 = -6.825$, $p < 0.001$).

Discussion

Hotspots Usage

Based on the relocations of individuals within 100 nm of Florida's coastline there are nine loggerhead hotspots (Figure 56) and three leatherback hotspots (Figure 57). Three of the loggerhead hotspots are in the Atlantic, with the remaining 6 and all 3 leatherback hotspots in the Gulf of Mexico (Figures 56 & 57). These hotspots were created from relocations between all the years of the study; thus, the hotspots do not reflect accurate yearly regional uses, but instead identify regions of common use by turtles along the Florida coast between 2005 to 2017.

<u>Loggerheads</u>

Nine loggerhead relocation hotspots were found within the study area and fell into 4 usage areas around Florida: 1) eastern central Florida coast, 2) Florida Keys 3) western central Florida coast and 4) the Florida panhandle. Eastern central Florida coast was the most commonly used area, second to western central Florida coast, then Florida Keys and lastly Florida panhandle region. High use areas are areas were KD values between 113 to 279. There is a strong possibility that these regions are used for various different needs during nesting season such as foraging, nesting, and breeding.

There is only one hotspot found in the along the eastern central Florida coast, hotspot 1 (Figure 56). It is the largest loggerhead relocation hotspot found in both the Atlantic and Gulf of Mexico, measuring ≈165 miles in length. Hotspot 1 along the continental shelf and has a depth of <200m, which are both foraging preferances of loggerheads (GEBCO, 2021; Griffin *et al*., 2013, United States & National Marine Fisheries Service, 2013). This hotspot is located in the South Atlantic Blight SAB, which is a known foraging ground, both seasonal (summers) and year-round (Figures 5&6; Ceriani *et al*., 2012; Ceriani *et al*., 2017). High use areas are roughly between Brevard, Indian River and St. Lucie counties, which hold 47% (46,333) of nesting in the eastern Florida and 40% of all nesting statewide (FFWCC, 2023).The epicenter alone is ≈15miles in length, north to south, and maximum KD is 278.9, indicating the eastern central Florida coast to be the highest used area by loggerheads, most commonly used as a nesting and foraging ground (Figure 56).

There are 3 loggerhead relocation hotspots (hotspots 2, 3 and 4) in the second usage area, the Florida Keys (Figure 56). Both hotspot 3 (east of Key West, Fl) and 4 (northeast of Key West, Fl) area located along the USA continental shelf at depts of <200m (GEBCO, 2021). Fifty percent of foraging from a loggerhead Northwest Atlantic District Population Subgroup (NWA DPS) subgroup, the Peninsular Florida Recovery Unit (PFPU), is in the Subtropical Northwest Atlantic (SNWA), in which the Florida Keys are located (Pfaller *et al*., 2020). Nesting in Monroe

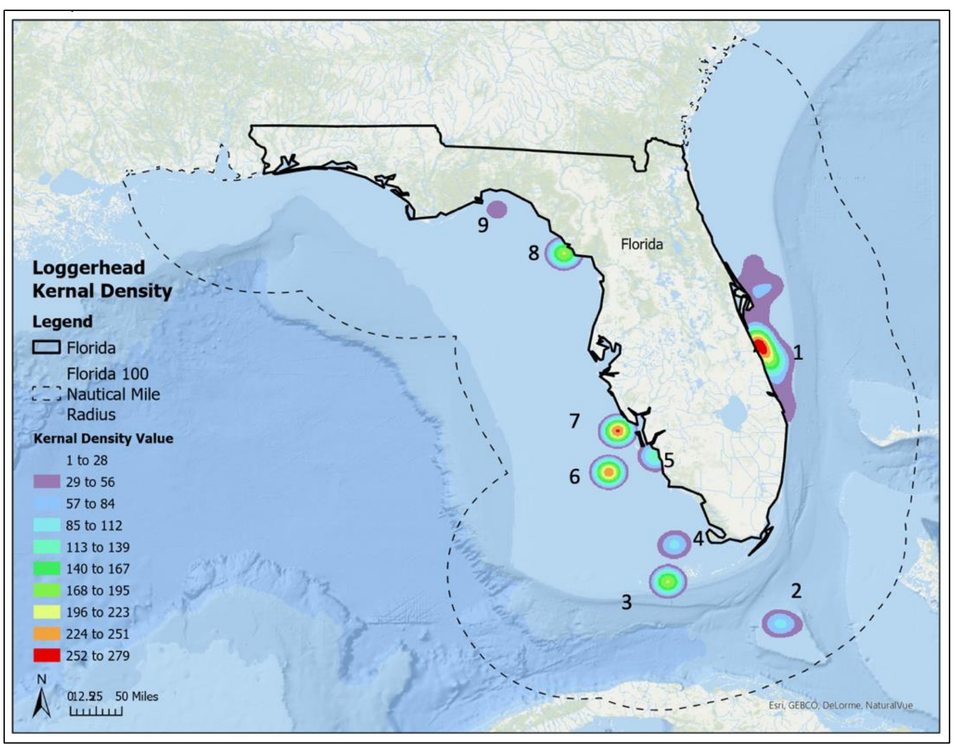


Figure 56. *Loggerhead Relocation kernel density hotspots. 9 hotspots between 4 usage areas: eastern central Florida coast (hotspot 1) Florida Keys (hotspots 2, 3 and 4) western central Florida coast (hotspots 5, 6 and 7) and Florida panhandle (hotspots 8 and 9).*

County (where the Florida Keys are) is only 0.5% (457) of nesting in the eastern Florida and 0.4% statewide; however, this area is a known breeding habitat for the PFPU (NMFS Office Of Protected Resources, 2023; FFWCC, 2023). Hotspot 2 is the only area where a hotspot is located off the USA continental shelf instead it is across the Florida strait on the north edge of the Cay Sal Bank in the Bahamas but is still within the SNWA (Figure 56; Figure 5). The Cay Sal Bank has depths between 7 to 30m, with coral reefs, sea grasses and macroalgae that could sustain benthic biota, all known loggerhead foraging preferances (Purkis *et al*., 2014; Griffin *et al*., 2013). Despite this both hotspots 2 and 4 are lower use hotspots with KD values ranging between 29 to 84. The only hotspot within the Florida Keys area that is a high usage area is hotspot 3, measuring ≈40 miles in length and has a KD maximum of 197.3 (Figure 56). This suggests that these hotspots are used for most commonly as breeding and foraging grounds with limited nesting.

The western central Florida coast usage area has 3 loggerhead relocation hotspots, hotspots 5, 6 and 7 (Figure 56). Each of these hotspots are along the USA continental shelf at depts of <200m (GEBCO, 2021). The Gulf of Mexico is a very productive environment and is home to many of the food sources loggerheads prefer such as crustations and fish (Alongi, 2020; Smith, 1982; Richardson & McGillivary, 1991) A 2017 study, by Ceriani *et al*., identified west coast of Florida as a foraging hotspot for loggerheads, with 16% of the easter PFRU and 47% of western PFRU forage in the region (Pfaller *et al*., 2020; Ceriani *et al*., 2017; Figure 6). Counties in western central Florida coast area are Collier, Lee, Charlotte and Sarasota, which together account for 81% (14,517) of western Florida nesting and 15% of nesting statewide (FFWCC, 2023). This suggests that the western central Florida coast is used primarily as a nesting and foraging grounds. All 3 hotspots in this have high use areas, hotspot 5 is ≈22 miles in length, with KD value maximum of 122.5, hotspot 6 is ≈32 miles in length, with KD value maximum of 242.3 and hotspot 7 is ≈37 miles in length, with KD value maximum of 253.9. The western central Florida coast is the second most used region within the area of study.

The Florida panhandle usage area has only 2 loggerhead relocation hotspots, hotspot 8 and 9 (Figure 56). Each of these hotspots are along the USA continental shelf at depts of <200m (GEBCO, 2021). As the Florida panhandle usage area is also in the Gulf of Mexico, this area is also home to many of loggerheads preferred food sources (Alongi, 2020; Smith, 1982; Richardson & McGillivary, 1991). A 2020 study, by Pfaller *et al*., found that 14% of the western PFRU and 14% of the western PFRU forage in the NGoM, where the Florida panhandle usage area is located. There is limited data on nesting in the counties along the panhandle, only counties east of the high usage hotspots had nesting data. These counties are Pinellas, Franklin, Gulf, Bay, Walton, Okaloosa, Santa Rosa and Escambia, which all together accounted for 11% of nesting along the west Florida coast but only 2% of statewide nesting (FFWCC, 2023). This suggests that the Florida panhandle usage area is used primarily for foraging and has some limited nesting as well. Hotspot 8 is the only hotspot in this usage area that has high use, and it is ≈33 miles in length, with KD value maximum of 197.1 (Figure 56).

Leatherbacks

There are 3 leatherback relocation kernel density hotspots found within the study area and fell into only one usage area, the Florida panhandle (Figure 57). There is also a strong possibility that these regions are used for various different needs during nesting season such as foraging, nesting, and breeding, as is suggested for the loggerheads. High use areas are areas were KD values between 12 to 22. The difference between maximum KD values for loggerheads and leatherbacks reflects the number of relocations of each species (n = 34 for loggerheads, n = 11 for leatherbacks) used in this analysis.

The Hotspots along the USA continental shelf are found between two depth ranges. Hotspots 2, 3 and the northeastern half of 1 were at depts of <200m, however the southwestern half of 1 has a depth range between 200m to 2,000m, both of which are depth ranges that leatherbacks to forage within (GEBCO, 2021; NOAA, 2022b). Leatherback nesting data along the Florida panhandle is nearly nonexistent with only one nest found in that region in 2022 (FFWCC, 2023). This shows that the Florida panhandle is likely used as a foraging ground, as inter-nesting females forgare within 100 km of nesting regions and leatherbacks are migratory foragers (NMFS, NOAA, & USFWS, 2020; FFWCC, 2023; National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2020). This is further conferemd as a 2021 study by Sasso *et al.*, found that the Florida panhandle region was a high use foraging ground used by post nesting females (Figure 14) as well as a 2014 study found there was high seasonal use between August

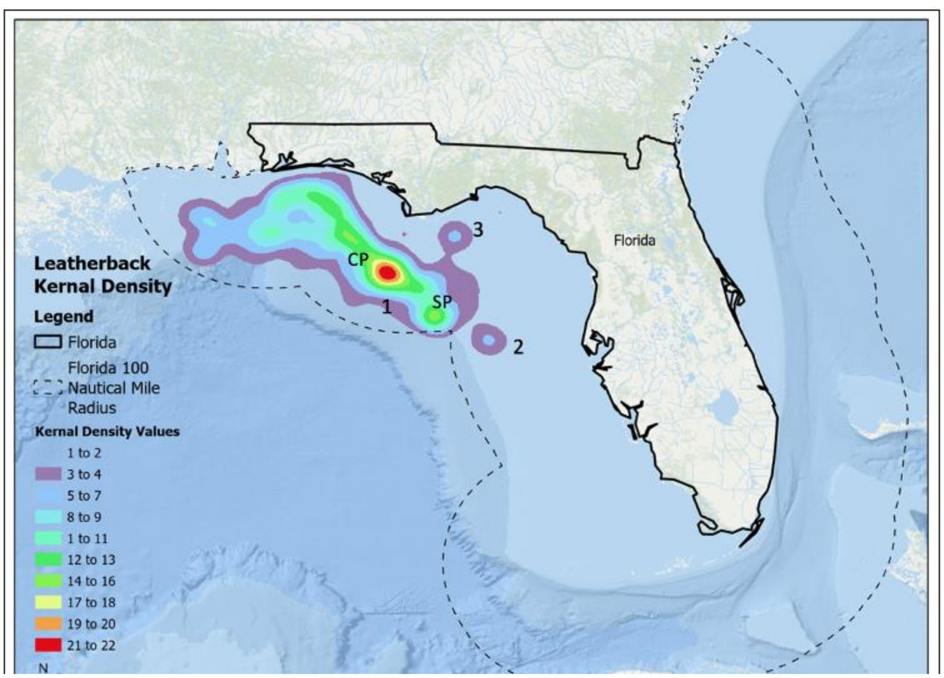


Figure 57. *Leatherback relocation kernel density hotspots. 3 hotspots in the Florida panhandle (hotspots 1, 2 and 3). High use areas are: Central Panhandle (CP) and South Panhandle (SP).*

to September (Fossette *et al*., 2014; NOAA, & USFWS, 2020). Within the Florida panhandle usage area only hotspot 1 is consisted high use, and it is ≈293 miles in length. This hotspot is unique as it has 2 high use areas within it, due to its large size. The first high use area Central Panhandle (CP) and is ≈137miles in length with a KD value maximum of 22.3. The second high use area is South Panhandle (SP) and is ≈21 miles in length and with a maximum KD value of 9.6, with KD value maximum of 14.4. The CP high use area is very long, however its width ranges between is ≈6 to 32miles.

Migratory Corridors

Both loggerheads and leatherbacks in this study show evidence of migratory corridors (Figures 20, 21, 56 and 57). The relocation maps (figures 20 and 21) show similarities between the relocation movements of the turtles in this study and those in other studies. Further research is needed to identify the movements of the loggerheads and leatherbacks in this study; however, some indicators are present on the relocation and hotspot maps.

Figures 10 and 11 highlight migration five corridors used by loggerheads during and after nesting season off the Florida Coast, 1) central east Florida moving to norther Atlantic Coast, 2) southwestern Florida to Bahamas/Cuba, 3) eastern Florida Panhandle southwest to Yucatán Peninsula, Mexico, 4) eastern Florida panhandle southeast down coast, 5) southeastern Florida coast to central Atlantic Ocean (Foley *et al*., 2013; Ceriani *et al*., 2012). Three out of five of these previous identified migratory corridors (corridors 1, 2 and 5), are seen reflected on the loggerhead relocation map (Figure 20). The hotspots also align with corridors 2 (hotspot 2) and 4 (hotspot 1, 3 and 4) providing stronger evidence as they highlight possible foraging activity along these pathways which is commonly seen during loggerhead migrations (Ceriani *et al*., 2017; Ceriani *et al*., 2012; Foley *et al*., 2013).

Leatherback migrations tend to be on a significantly larger scale then loggerheads, due to this the identification of possible leatherback migratory corridors is more speculative as I only had relocation data for a limited area (up to 100nm off Florida coast). Figures 12, 13 and 14 recognized two migratory corridor, 1) Yucatan Channel to western Florida continental shelf in summer, 2) western Florida to north Atlantic through the Florida Strait from summer to fall (Evans *et al*., 2021; Sasso *et al*., 2021). the relocation maps show heavy movements of leatherbacks along the western Florida continental shelf, particularly near the panhandle, as well as two individuals with movements southward (Figure 21 and 57). Due to the limited study area and lack of study on movement timestamps, I am unable to determine if the two southward-moving leatherbacks are migrating towards either the Yucatan Channel or Florida Strait. The presences of leatherbacks along the western Florida continental shelf in the summer aligns with two possible migration corridors but further research is needed in order to identify which corridor, if either, being utilized by the leatherbacks in this study.

Risk Assessment

Commercial fishing gear harms sea turtles whether via interaction, injury or mortality, with longlines and trawls, historically, being the worst offenders (Finkbeiner *et al*., 2011). The result of this study partially supports my hypotheses, regulated fishing zones with higher turtle relocation median KD does not have higher gear restrictions however regulated fishing zones with higher turtle relocation median KD do have higher longlines and trawl restrictions. This shows that commercial fishing gear restrictions on longlines and trawls, allow for more turtles to thrive in areas in which the restrictions are in place.

Given these results, all the loggerhead and leatherback relocation KD hotspots must be reviewed to see where longline and trawl restrictions may be lacking. In order to determine this, I reviewed each of the hotspots (Figures 56 &57) and determine if the high use areas of each of the hotspots have gear restrictions.

7 out of the 9 loggerhead hotspots had longline and trawl restrictions over high use areas (Figure 58). Hotpot 1 has longline (pelagic & bottom) restrictions over a majority of its area but is lacking trawl restrictions in federal waters. The ≈ 1/4 of hotspot 1 not in federal waters had longline, trawl, and net restrictions placed on by the state; all Florida state waters hold these restrictions. Hotspot 2 was the other hotspot unprotected by regulations, this is due to the hotspot being outside out the USA EEZ and instead within the Bahamas EEZ, thus is outside of the USA's jurisdiction. Lastly hotspots 6 though 9 have sufficient longline (pelagic and bottom) and bottom trawl restrictions acroases the majority of the hotspots' areas but are lacking pelagic trawl restrictions. All the loggerhead relocation KD hotspots have at minimum restrictions on either longline or trawls even if it is only in part of the water column.

The three leatherback relocation KD hotspots are lacking gear restrictions on one or both trawls and longlines. Hotspot 1 has ≈ 1/3 of its area protected with longline (pelagic & bottom), and bottom trawl restrictions, however ≈2/3 of hotspot 1 have no restrictions. As this is the largest hotspot between both sea turtle species this is, poses a threat to leatherbacks. Hotspot 2 only have bottom longline restrictions and is lacking pelagic longline and trawl (pelagic and bottom) restrictions. Lastly, hotspot 3 has restrictions for longlines (pelagic and bottom) over the majority of its area but lacks any trawl restrictions. Overall, the leatherback relocation KD hotspots all face significant threats due to the lack of regulations in regions they are most prominent.

Recommendations

Federal and state regulations on commercial fishing such as the regulated zones, gear speciation's, bycatch mitigation gear/particles, and gear check/soak times have all contributed to reduce sea turtle bycatch significantly (USFWS &DOI, 2013; FAC & FAR, 2023; Finkbeiner *et al*., 2011). As the risk assessment in the previous section showed, most of the turtle relocation KD hotspots have limited gear restrictions in place and need further restrictions to allow for sufficient turtle protections. Given the risks that the sea turtles still face by commercial fishing gear in the Florida, further steps should be taken to provide these threatened and endangered species more protections. Limiting commercial fishing high use areas or add gear restrictions for longlines and trawls in high usage areas, are realistic next steps to protect the sea turtles. These recommendations are only for use during the nesting seasons on loggerheads (June to September) and leatherbacks (May to September) (FFWCC, 2023).

Commercial fishing is a prominent part of Florida's economic system and provides livelihood to many Florida citizens. Thus, fishing closures areas could put additional strain on these citizens. For example, in 1994, Amendment Three of the Florida Constitution was enacted which banned the use of entangling nets (e.g., gill and trammel nets) in Florida state waters. This caused a drop of 15% in saltwater product licenses, a requirement for commercial fisheries, showing a substantial drop in the industry as ≈25% of net fishers retired from commercial fishing (Adams *et al*., 2003). This provides context to the impacts of gear restrictions and fishing courses on the people in Florida.

Closing the areas with sea turtle relocation KD hotspots would be ideal to reduce interactions, injuries and mortality, however this is unrealistic as many of these hotspots are quite large and would result in large swaths of waters in which fisheries would have to avoid, resulting undo strain on the livelihoods of those in the fishing industry. To reduce size of closures, I have identified high use areas of loggerheads and leatherbacks within each hotspot (Figure 58). Placing closures between June to September for loggerhead hotspots, Big Bend (BB), Port Charlotte (PC), Cape Coral (CC), Bonita Springs (BS), Key West (KW) and Palm Bay (PB), and May to September for Leatherback hotspots, South Panhandle (SP) and Central Panhandle (CP), should reduce this strain and significantly reduces the areas of closure (from ≈ 29,689 mi^2 to 5,129 mi^2), while still providing sufficient turtle protections. Currently only six regulated fishing zones have full closures to all fishing and gear usage, Tortugas Marine Reserve, The Edges, Madison and Swanson Marine Reserve, Steamboat Lumps Marine Reserve and the Florida Keys National Marine Sanctuary. The combined area of all of these zones is ≈6,134mi^2, and the largest zone closure being Florida Keys National Marine Sanctuary, ≈ 3802mi^2. This would add create a total of ≈11,263mi^2 (some closed zones overlap with recommended high use closures), which could put a strain on the Commercial fishing industry.

Another option would be to place gear restrictions on trawl (pelagic and bottom) and longlines (pelagic and bottom) over each of the high use areas for nesting seasons, on loggerheads (June to September) and leatherbacks (May to September) (Figure 58). Large areas of the coastal waters already have one or both longline and trawl gear restrictions, with a total area of ≈ 85,9841mi^2. Most the high use areas already have trawl and/or longline restrictions provided by the current regulated fishing zones. Only 1 high use area (CP) does not currently have trawl or longline protections over the majority of their area, and 5 high use areas (PB, CC, PC, BS and SP) are lacking pelagic and bottom trawl or longline restrictions. The addition of these restrictions in high use area would only expand the current area of longline and trawl restrictions to ≈ 91,113mi^2. Trawl and longline restrictions on each of the high use areas would have very little impact on the commercial fishermen but provide safe nesting, foraging and breeding habitats for both loggerheads and leatherback sea turtles.

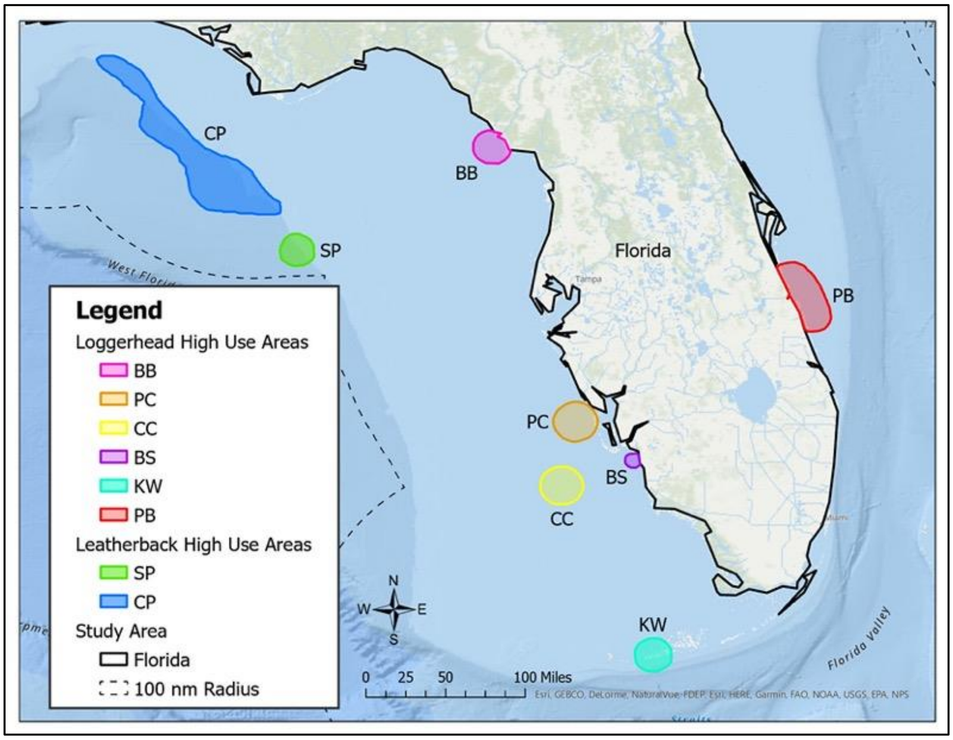


Figure 58. *Sea turtle high use areas. Loggerhead: Big Bend (BB), Port Charlotte (PC), Cape Coral (CC), Bonita Springs (BS), Key West (KW) and Palm Bay (PB). Leatherbacks: South Panhandle (SP) and Central Panhandle (CP).*

Fishing closures over ever high use zone would provide the fullest protection to the turtles that reside in those areas; however, this is not a realistic option given the possible impacts this could have the commercial fishing industry. Enacting pelagic and bottom trawl and longline closures is a far more realistic protection that would limit sea turtles bycatch interactions as trawls and longlines restrictions have been associated with higher turtle relocation KD.

Spatial Considerations

The regulated fishing zones create clean and easy to follow boundaries for commercial fisheries, they are not tailored for research purposes. The varying sizes of the zones and overlap of the zones result in 'on-the-water' complexity that I did account for directly in this study. I will therefore discuss the implications of these spatial factors on my findings.

Zone area can affect the overall mean and median KD values of both large and small zones since hotspots (by definition) are relatively small compared to the study area as a whole. Smaller zones, such as Pourtales Terrace HAPC (547.3mi^2) that overlap with a hotspot (Figure 34) have fewer low KD values within the zone, resulting in a relatively high KD median (0.8) and mean (1.4). Large zones, even with high KD value hotspots within their area, see the opposite of this effect, as a large zone's KD means and medians will be lower by virtue of the areas outside the hotspots with low KD values. For Example, the East Florida Coast (33319.9mi^2) overlapped the majority of the largest loggerhead hotspot (maximum of 275.7) but had a lower mean (8.8) and median (1.0) than many of the smaller zones (Figure 32). The Pourtales Terrace HAPC and East Florida Coast had medians that were very close to one another despite having drastically different levels of hotspot interactions, highlighting how size can leverage the results a more detailed examination was beyond the scope of this study.

Many of the regulated fishing zones overlap with each other which creates an issue when attempting to study the relationship between zone turtle relocation KD and zone gear restrictions. Of the fishing zones that were analyzed, Atlantic zones had 17 distinct overlapping areas, with 15 for the Gulf of Mexico zones (Figures 59&60). Larger zone overlapped the most with other zones. Given that the larger zones typically did not have the same gear restrictions thus when they overlapped the zones would essentially create a separate area subject to both the zones' gear restrictions. Such spatial overlap of gear restrictions from two or more zones was not considered in this analysis but could be an interesting next step. For additional information regarding each zone and their corresponding gear restrictions see tables 2 and 3.

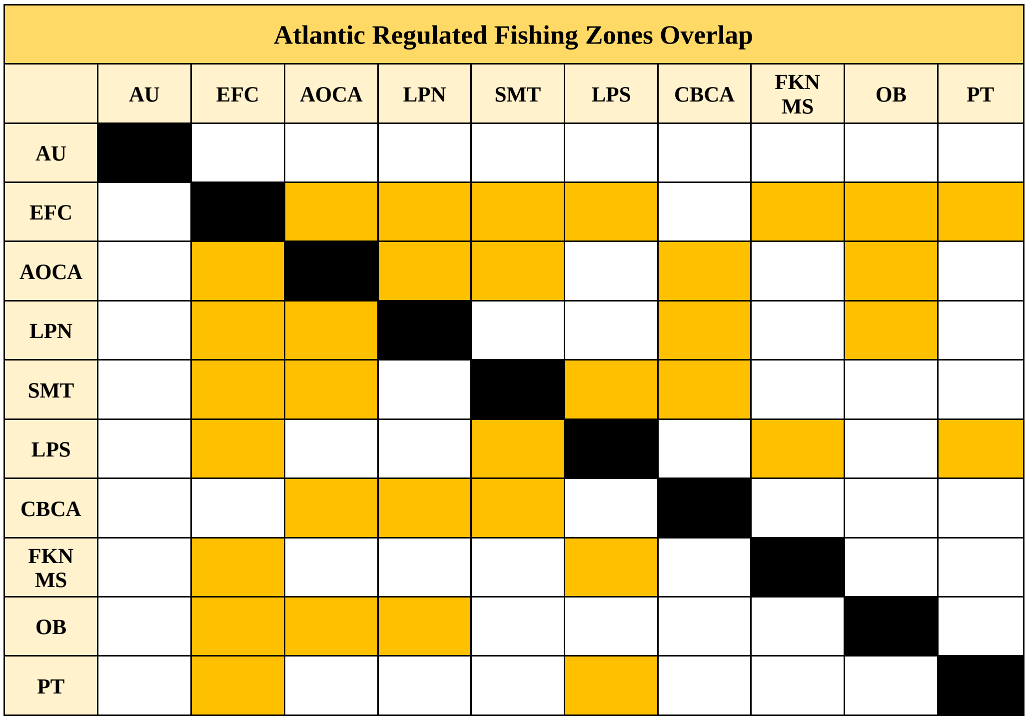


Figure 59. *Atlantic Ocean regulated fishing zone overlaps with other zones. Yellow=overlap, white= no overlap and black= n/a (same zone). Atlantic Unregulated (AU), Stetson-Miami Terrace HAPC (SMT), Charleston Bump Closed Area (CBCA), Allowable Octocoral Closed Area (AOCA), Pourtales Terrace HAPC (PT), East Florida Coast (EFC), Longline Prohibited South of 27 10'N (LPS), Longline Prohibited North of 27 10'N (LPN), Florida Keys National Marine Sanctuary (FKNMS) and Oculina Bank HAPC (OB).*

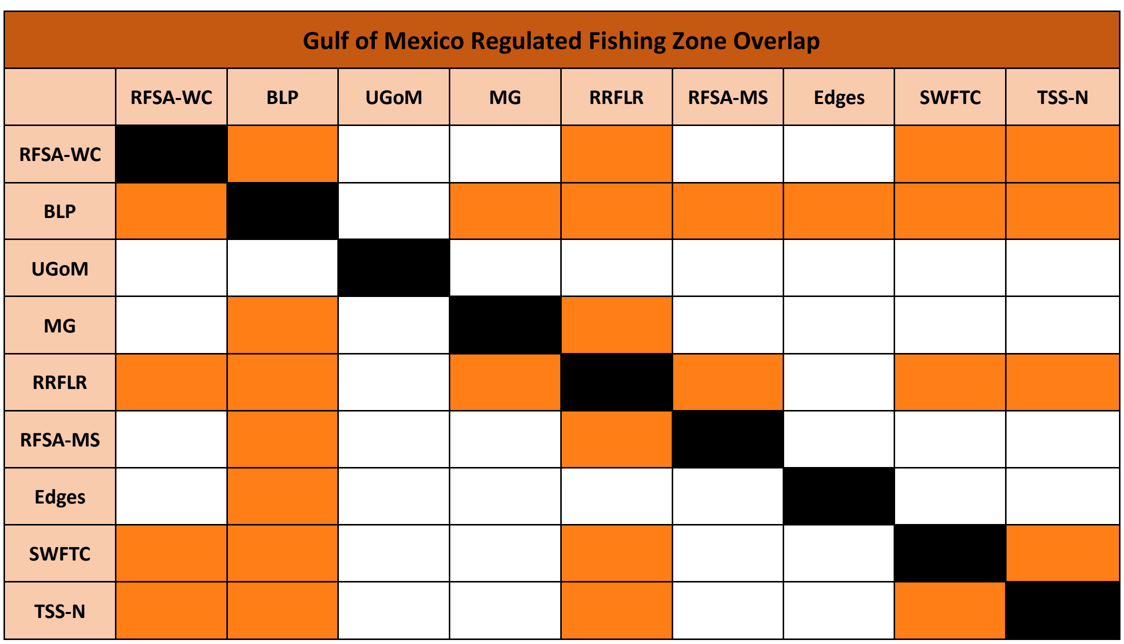


Figure 60. *Gulf of Mexico regulated fishing zone overlaps with other zones. Orange=overlap, white= no overlap and back= n/a (same zone). Unregulated-Gulf of Mexico (UGoM), Reef Fish Longline Restriction (RFLR), Bottom Longline Prohibited (BLP), Reef Fish Stressed Areas, FL West Coast (RFSA-WC), Reef Fish Stressed Areas, FL, AL and MS (RFSA-MS), Middle Grounds HAPC (MG), The Edges (Edges), Southwest Florida Trawl Closure (SWFTC) and Tortugas Shrimp Sanctuary North (TSS-N).*

Conclusion

Overlapped mapping of regulated fishing zones with turtle relocation KD hotspots in the waters off the Florida coast demonstrates that zones with higher KD hotspots are not associated with regulated fishing zones with higher gear restrictions in general. However, higher KD values are associated with more longline and trawl restrictions specifically. 11 hotspots between loggerheads and leatherbacks in both the Atlantic and Gulf of Mexico were identified. Loggerhead relocation hotspots were particularly associated with the Oculina Bank HAPC and Florida Keys National Marine Sanctuary zones in the Atlantic and Tortugas Shrimp Sanctuary North zone in the Gulf of Mexico. Leatherbacks relocation hotspots were particularly associated with the Edges and Reef Fish Stressed Areas, Florida, Alabama and Mississippi zones in the Gulf of Mexico. All of these zones have longline and/or trawl restrictions, further supporting the overall findings of this study stated above. This does not mean that turtles actively avoid areas with lower restrictions of these two types of gear but shows a potential link between how longlines and trawls affect the turtles, and the impacts they could have on the dispersal of habitat usage in Florida.

Longlines and trawls have higher rates of bycatch interactions and mortality then the other commonly used commercial fishing gear such as nets, dredges and pot and traps (Kot *et al*., 2010; Epperly *et al*., 2002; FAC & FAR, 2023; MSC, 2023). This illustrates that higher uses of these two gear types in areas with turtles could create a higher risk of bycatch, than in zones with restrictions. On both a federal and state level gear modifications have been required, such as turtle excluder devices (TED) on trawls as well as gangion length, hook type and size modifications on longlines, to help reduce bycatch (USFWS & DOI, 2013). While these regulations play a role in reducing bycatch it does not eliminate bycatch and longlines and trawls continue to have higher bycatch rates (Finkbeiner *et al*., 2011). Given that many of the relocation hotspots between both loggerheads and leatherbacks have mixed levels of longline and trawl restrictions, it shows that the turtles have an elevated risk of bycatch in the Florida Coastal waters.

Sea turtle conservation is an ever-evolving field of study, with many anthropogenic aspects to address. This study allowed for a closer look to be taken at how commercial fishing gear is associated with sea turtles, the risks they pose and provide possible mitigation methods. The result of this study may only be a small piece of the puzzle of how to reduce sea turtle bycatch, but it does show that gaining a greater understanding of interactions between commercial fishing gear and sea turtle relocations provides a steppingstone to for future research.

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