4-27-2017

Geospatial analysis of Tursiops truncatus, Common Bottlenose Dolphin, from NOAA cetacean stranding data in Florida to explore human fishery impacts

Jamie S. Ahn
ja1402@nova.edu

HALMOS COLLEGE OF NATURAL SCIENCES AND OCEANOGRAPHY

Geospatial analysis of *Tursiops truncatus*, Common Bottlenose Dolphin, from NOAA cetacean stranding data in Florida to explore human fishery impacts.

By
Jamie S Ahn

Submitted to the Faculty of
Halmos College of Natural Sciences and Oceanography
in partial fulfillment of the requirements for
the degree of Master of Science with a specialty in:

Marine Biology &
Marine Environmental Science

Nova Southeastern University

3/27/2017

Table of Contents:

List of Figures

List of tables:

Appendices:

Abstract:

Cetacean strandings provide valuable biological and geographic information, including various human impacts to vulnerable populations. This study utilizes global information systems (GIS) to conduct geospatial analyses of common bottlenose dolphin, *Tursiops truncatus*, strandings impacted by fishery interactions in Florida from 2002 to 2014 along with summary statistics of the types of interaction and gear involved. In addition four human impact factors, average human population, average number of boat licenses, average number of fishing permits, and coastline length, were compared to the stranding densities per county for association and predictability. Four regions of stranding "hotspots" were identified, and all human impact factors were found to have low to moderate association. The fishery interaction summary statistics found entanglement in fishery gear to make up 52.2%, fishery gear ingestion at 29.7%, and vessel collisions at 18.1%. The fishery gear summarization found hook and line gear to make up 52.3% of entanglement events and 80.5% of ingestion events. Vessel strikes were found to be mostly sharp force trauma at 84% with blunt force trauma at 16%. With growing coastal human populations, identifying "hotspot" regions allow conservation managers to maximize resources and create efficient managing policies to minimize negative human impacts to cetacean populations.

Keywords: Common bottlenose dolphin, strandings, entanglements, ingestion, vessel collision, global information systems, hotspots

1. Introduction:

Cetaceans are vital components of marine ecosystems as top predators and important sentinels of the health of marine coastal environments (Wells, 2004). Of these cetaceans, the Common Bottlenose Dolphin, *Turciops truncatus,* serves as a particularly important indicator of marine ecosystem health. The reason for their importance is that this species is long-lived and a long-term resident in tropical-temperate regions worldwide, such as Florida, USA (Wells, 2004). Internationally, cetaceans suffer injuries from many commercial and recreational anthropogenic sources (Wells, 2008). Commercially, marine mammals and fishing vessels often occupy the same marine real-estate, directly competing for the same fish species. Because of this commonality, negative interactions between the commercial fishing industry and dolphins are unavoidable. Further, recreational waters also frequently overlap with the geographic distributions of many marine mammals, especially in coastal areas of high tourism and water sports, for which Florida has particular providence. Quantifying where commercial and recreational fishing gear interact with cetacean populations is crucial to understand the detrimental extent of these impacts (Gomercic, 2008). Many interactions between dolphins and fishing gear result in injuries and mortalities. Entanglement of dolphins in lines or nets, ingestion of fishing gear and debris represent the most typical outcomes (Wells, 2008).

Fishing gear interactions can occur accidently when the gear is not apparent to the animal, indiscriminately when the gear is indistinguishable from natural objects, or deliberately due to curious, foraging, or investigative behaviors of the foreign object (Adimey, 2014). The phenomenon, known as "depredation", is a strategy where cetaceans steals or damages the bait or already captured prey item in order to reduce foraging energy expenditures (Powell, 2011). The upshot of depredation is an increase of interactions between the animal and fishing gear (Gomercic, 2008). Marine mammals are particularly vulnerable to these impacts due to their K-selective characteristics such as low fecundity, slow growth rates and long maturation period (Adimey, 2014). Understanding where these interactions with fishing gear occur is especially important when endangered, endemic or threatened species populations are susceptible to being negatively impacted (Burdett, 2007).

Studies have increasingly utilized Geographical Information System (GIS) for spatial and temporal analysis in marine mammal strandings. As will be employed in this study, GIS provides a quantitative framework for analysis of stranding data and provides a means for the visual display of geographic trends and patterns (Smith, 2013). In 1992, the National Oceanic and Atmospheric Administration (NOAA) created the Marine Mammal Health and Stranding Response Program (MMHSRP). This established NOAA's National Marine Fisheries Service (NMFS) as the lead agency in coordinating stranding related activities (NOAA, 2014), which includes the collection of Marine Mammal Level A Stranding Reports throughout the United States.

Live and dead strandings have historically been a reliable means to study the biology and distribution of marine mammals populations (McLellan, 2002). Understanding the spatial distribution of human and marine mammal interactions with analysis of stranding data allows conservation managers to make informed decisions on policies to reduce negative impacts. By focusing on strandings, and especially those strandings that can unequivocally be related to human fishery activity, it is possible to develop an understanding of where the overlapping zones of interaction are located, alongside quantification of key variables impacting these zones.

1.1 Objective

This study will utilize GIS to conduct various geospatial analyses of stranding data from NOAA over the past 12 years offshore the State of Florida. This analysis will focus on the Common Bottlenose Dolphin, in the database that can unequivocally be found positive for human interactions. The NOAA stranding data spans from 2002 to 2014, organized and sorted to remove data points with impartial data, determine the type of interaction, and determine the type of gear involved in each interaction. A comprehensive summary analysis of the dataset will be performed using basic statistical formulas with Microsoft Excel. This analysis will evaluate interaction frequency (i.e. ingestion, entanglement, or vessel strike), various types of gear within each interaction, and overall trends of human interactions contrasted with human population changes along the coast. Statistical relationships between strandings and data on commercial and recreational fishing permits, boat licenses, length of shorelines, and average human

populations will also be evaluated. In addition, this analysis will illustrate and quantify the changes over time in the number and frequencies of cetacean strandings and how they are associated with human use of the coastal zone.

The human population in Florida has increased by 261.6% from 1960 to 2008, with 75% of those residing in coastal areas (Adimey, 2014). This population increase along with other human coastal impacts may show a statistical correlation with stranding events for the Common Bottlenose Dolphin in Florida. GIS analysis will be used to evaluate trends and pinpoint various "hotspots" in Florida that correspond to increasing human populations and marine activities along the coastline. This geospatial analysis will be used to investigate for correlations between various human fishing activities within these hotspots and stranding events. The motivation of this work is to impart a better understanding of the types of human interactions affecting the vulnerable population of the CBD in Florida.

2. Background

2.1. Stranding Networks in the United States

In the United States regional stranding networks are responsible for responding and reporting marine mammal strandings. The Marine Mammal Protection Act (MMPA) is responsible for authorizing regional stranding networks (NOAA, 2013). NOAA and the regional stranding network organizations facilitates the response to stranding events, monitor stranding rates and anthropogenic caused mortalities, maintain the stranding database, and conduct studies on determining causes of death (NOAA, 2013). Regional stranding programs are responsible for training volunteers to ensure accurate and consistent reporting of events, reporting to the authorities to notify before initial investigations, and how to safely handle animals in live stranding events (Reynolds, 1991). In Florida, the Southeast Region Stranding Program of the Marine Mammal Health and Stranding Response Programs contain 18 main stranding networks covering both the Atlantic and Gulf of Mexico oceans and is responsible for the reported data used in this project.

Marine mammal strandings provide basic biological and ecological information of animal populations such as the geographic range, age, prey types, and disease pathology

(NOAA, 2013). Marine mammal strandings also provides valuable insight and information of human impacts on such vulnerable populations (NOAA, 2013). Strandings of marine mammals provide an insight on mortality rates and their causes and population threats and stressors (Norman, 2011). The majority of stranded marine mammals are found dead and beached. Occasionally, live animals are found stranded and are usually single animals that are either ill, injured, or both (Wilkinson, 1999). Mass strandings of two or more animals are considered uncommon and can be attributed to unusual weather anomalies and meteorological events such as El Nino/La Nina or toxic algal blooms (Wilkinson, 1999). This study will focus on individual marine mammal stranding events related to commercial and recreational fishery interactions.

2.2. Utilization of Geographic Information Systems (GIS)

The role of geographic information systems (GIS) and spatial analyses in the marine sciences has increased, particularly in the sustainable management of coastal zones (Dahdouh-Guebas, 2002). GIS is useful to help analyze spatial data such as examining population trends associated with environmental and anthropogenic factors of endangered species (Dahdouh-Guebas, 2002). The ability to visualize spatial and temporal interaction data in a GIS has proven useful in coastal management, epidemiological studies, and in mapping of stranding events (Norman, 2011). Strandings can be mapped temporally and spatially in order to model future events, therefore augmenting surveillance and monitoring programs for marine mammals (Norman, 2011). With Florida's growing human population along the coastlines, it can be safely assumed that anthropogenic interactions with marine mammals will increase. Utilization of GIS maps to highlight areas inhabited by cetaceans overlapped with high human population and activity can help conservationists and policy makers to mitigate and minimize negative interactions.

2.3. Biology and Distribution of the Common Bottlenose Dolphin in the Southeastern United States and Gulf of Mexico

The bottlenose dolphin genus *Tursiops* has two recognized species: the common bottlenose dolphin (CBD) *T. truncatus* and the Indo-Pacific bottlenose dolphin *T.*

aduncus (Bearzi, 2008). The CBD is both coastal and pelagic and is found globally in tropical and warm-temperate regions such as the marine waters of the southeastern United States (Brownell, 2008). Physical characteristics of the CBD are relatively generic, with moderately sized stocky beaks, varying gray coloration, a slight curved mouth line that resembles a smile, and flippers that curve with pointed tips (Reynolds, 2000). The CBD lifespan ranges from 40 to over 50 years, reaching sexual maturity at 5-14 years (Brownell, 2008). CBDs are generalist feeders with a variable diet consisting of shrimp, crustaceans, squid, and fish. Their foraging behaviors are driven by food item availability, seasonal movements of prey, and geographic location (Bearzi, 2008).

In the southeastern United States, CBDs are commonly found in coastal and pelagic waters south of 45° N latitude in the Gulf of Mexico (GOM), Caribbean Sea, and western Atlantic Ocean (Reynolds, 2000). Coastal populations primarily inhabit water depths of less than 20 meters and are non-migratory, maintaining definable, multi-generational home ranges. Offshore populations are migratory and have larger geographic ranges, though they are often found near the 50-meter isobath flanking the slope of the continental shelf (Waring, 2014). Importantly, both pelagic and coastal CBDs are often found in close proximity to human fishing and shipping activities, potentially exposing them to the threat of negative impacts.

CBDs are segregated, for conservation and management purposes, into management 'stocks'- defined and assessed by photographic identification of individuals, tagging studies, and more recently, genetics utilizing mitochondrial DNA haplotype frequencies (NMFS, 2012). CBD stocks in the southeastern United States are separated into two morphologically and genetically distinct coastal and offshore groups. In Florida, there are a total of 18 stocks (Waring, 2015). In the GOM, stocks there are three coastal stocks, two offshore stocks, and six bay, sound, and estuarine stocks (Waring, 2015). In the Atlantic Ocean, there are two coastal stocks, one offshore stock, and four bay, sound, and estuarine stocks (Waring, 2015).

2.4. Threats to the Common Bottlenose Dolphin

2.4.1. Conservation status of the bottlenose dolphin in the United States

In the United States the CBD is not listed as threatened or endangered under the Endangered Species Act but protected under the Marine Mammal Protection Act (MMPA) of 1972 (NMSF, 2012). The National Marine Fisheries Service (NMFS) maintains records of strandings cetaceans along with any human interactions reported with the stranding event (Wells, 2008). Accurate identification of anthropogenic-induced injuries and areas of high risk such as commercial and recreational human activities are crucial for management and policy-making purposes to protect and preserve cetacean populations (Wells, 2008). In 2010, more than 39% of the United State's population, over 123.3 million people, lived in coastal shoreline counties (Crossett, 2013). The United States Census Bureau has projected an additional 8% increase in population changes in coastal counties from 2010 to 2020 (Crossett, 2013). This increasing trend of human coastal populations will lead to increasing human marine recreational activities and potentially can negatively impact coastal CBD populations.

2.4.2 Conservation status of common bottlenose dolphin in Florida

The state of Florida is bordered by the Atlantic Ocean and the Gulf of Mexico and has over a thousand miles of coastline making it the most marine state in the continental United States (Moore, 1953). According to the U.S. Census Bureau analysis of coastal populations, Florida's share of the national coastline population in 1960 was 8% and by 2008 has doubled to 16% (Wilson, 2010). Though natural increase in coastline population is normal, Florida's net inshore to coastal migration of 1.4 million people accounted for 85 % of its coastline growth (Wilson, 2010). This coastline population growth increases coastal development as well as the rate of habitat degradation, boat traffic, recreational marine activities, and other negative anthropogenic interactions to the local environments (Wilson, 2010).

In Florida, the MMPA has listed the Western North Atlantic Coastal stock as depleted and the NMFS has classified five U.S. stocks as "strategic": Eastern Gulf of Mexico Coastal, Western Gulf of Mexico Coastal, Gulf of Mexico Bay, Sound and Estuarine, Northern Gulf of Mexico Coastal, and Western North Atlantic Coastal

(NOAA, 2015c). Through the MMPA, NMFS determines whether a stock is strategic or non-strategic based on whether the level of direct human-cause mortality surpasses the potential biological removal level (PBR) and if it is declining at a rate to be listed as threatened within the near future (NOAA, 2014b). This determination defines the level of protection and monitoring by the agency.

In Florida, there has been in increase of CBD ingesting and entangling in fishing gear (Powell, 2011). This is a growing trend throughout the state since Florida contains the highest number of saltwater recreational anglers in the United States, unofficially called the "Recreational Fishing Capital of the World" (Adimey, 2014). According to the Florida Fish and Wildlife Conservation Commission (FFWCC), in the 2013 to 2014 fiscal year, there were over 1.6 million saltwater recreational fishing licenses sold (FWC, 2015). Commercial fisheries are also economically significant in Florida. The number of commercial fishery licenses sold in the 2012 to 2013 fiscal year was 12,752 and generated over $925,000 in revenue (FWC, 2015). A large number of cetaceans inhabit or migrate through Florida waters, ranging from small cetaceans such as bottlenose dolphins to large cetaceans such as the Atlantic right whale. With the high diversity of threatened and endangered cetaceans in Florida, it is important to have a comprehensive understanding of the different factors that may attribute to strandings due to human fishery interactions such as growing human populations along the coastline, recreational and commercial fishery permits, boating licenses, and geographical features.

2.4.3 Threats to common bottlenose dolphin from fisheries

The most detrimental threat to CBD populations is fishery related injuries and mortality such as incidental catches in gillnets, trawls, hook-and-line gear and entanglement and ingestions of the gear (Bearzi, 2008). Due to their opportunistic behavior, CBD habitually interact with fisheries where injuries and mortality are being increasingly reported (Reynolds, 2000). Overlap of target species by dolphins and fisheries have caused prey depletion, especially with excessive world wide fishing pressures causing massive declines in fish stocks and an overall loss of marine diversity (Bearzi, 2008). Because there is no estimate of overall abundance it is difficult to classify

some of the populations as endangered even though they are threatened by human activities.

Depredation is defined as the partial or complete removal of fish caught on fishing gear by the cetacean (Friedlaender, 2001). This behavior is a common occurrence in global commercial and recreational fisheries and has become a growing concern due to increasing probability of interactions between the fishing gear and CBD (Read, 2008). Depredation is expected to increase as the world's oceans prey populations decline with increased fishery efforts (Read, 2008). In the United States, there are concerns with increase depredation behavior by CBD with the diminishing food resources. For example, CBD interactions with gear from spot and other sciaenid gillnet fisheries are common since the target fishes are major prey items for both parties (Friedlaender, 2001). There are also increased observed acts of depredation by CBD with other fisheries such as king mackerel, which is not a common prey item of the CBD (Zollett, 2006). This shows that increased fishing pressures by commercial fishing industry not only affect the behavior of the CBD but the diet and prey item as well (Zollett, 2006).

2.4.3.1 Impact of Gear Entanglement

Entanglements in fishing gear are a growing concern and evidently shown through the dataset by making up over 50% of the reported strandings. Marine mammals entangled in fishing gear exhibit scars, impressions, and/or abrasions on their epidermis (Burdett, 2007). Injuries from gear entanglement range depending on the type of gear involved, location of entanglement, and chronicity of the entanglement. Common site of attachments are the mouth/head, tail insertion, and the flipper (Moore, 2013). Entanglement associated injuries in the common sites are linear marks due to forces of drag (Moore, 2013). Signs of acute entanglements can be fresh, uninfected linear marks. Subacute signs include weak or motionless listing at the water surface, appendages or sections of the torso submerged due to weight of attached gear, and restricted range of motion of the flippers (Moore, 2013). Chronic entanglement signs include similar symptoms of subacute entanglement along with infected lesions, abrasions, or incisions, and signs of healing around the wounds (Moore, 2013). Gear that is still attached to the animal may stay on the animal and become embedded in the lacerations leading to

structural damage to the bones (Moore, 2013). Chronicity of gear attachment can lead to impaired locomotion and foraging abilities, leading to starvation (Cassoff, 2011). There are three main clinical signs of entanglement from a stranded animal: (1) signs of prior entanglement unrelated to a stranding event, (2) recent entanglement, leading directly to death, and (3) prior entanglement that has contributed to the stranding due to recurring impairment (Moore, 2013). Evidence of recent entanglement is determined by either the presence of the gear still on the animal or gear impressions such a scars, unhealed injuries around the body, and/or damaged teeth (Moore, 2013).

2.4.3.2. Impact of Gear Ingestion

Strandings linked to gear ingestion in dataset have shown various fishing gear to mainly be free floating in the body, embedded in various internal locations or involved in larynx strangulation. Ingestion of marine debris by marine mammals, unlike entanglement, is not a well-documented cause of mortality because ingested items can only be detected during post-mortem necropsy examinations of the stranded animal (Jacobsen, 2010). The fishing gears commonly ingested by marine mammals are hooks, lures, lines, and nets. Serious cases of gear ingestion can result in fatalities due to obstruction of the normal passage of food through the digestive tract, toxic chemicals leaching into the internal tissues, and the inability to feed properly leading to starvation (Adimey, 2014). Clinical signs of gear ingestions can be difficult to recognize without post-mortem necropsies unless the fishing line extends outside of the mouth.

One of the major concerns of ingesting fishing gear is larynx strangulation (Gomercic, 2008). Larynx strangulation occurs when fishing gear impacts the laryngeal protrusion and the laryngeal spout, which can lead to edema, mucosal injury, hypergranulation, and ultimately death (Gomercic, 2008). This strangulation results from the line wrapping around the goosebeak, forming a slipknot, and preventing regurgitation of the gear (Wells, 2008). The repeated cycle of unsuccessfully swallowing gear, followed by regurgitation around the other side of the goosebeak, can also result in the line wrapping around the protrusion (Wells, 2008). Other common pathological conditions from larynx strangulation are pneumonia and heavy bacterial infestation in the lungs (Gomercic, 2008). Hooks attached to discarded fishing line can also embed in

various locations from the oral cavity down to the intestines. This can lead to secondary infections and abscesses, overall compromising the animal's immune system and eventually death (Wells, 2008). Cetaceans can also experience blockage of the intestinal tracts by the debris (Levy, 2009). Ingestion of fishing gear does not always result in immediate fatalities; most cases are found emaciated and weak (Wells, 2008). Non-fatal cases of gear ingestions are when the hooks are not embedded in the tissue and can be found free floating in the stomachs of stranded dolphins (Wells, 2008).

2.4.3.3. Impact of vessel strikes

Vessel-cetacean collisions, commonly classified as vessel collisions and/or propeller strikes make up the final portion of the dataset. Though many of the vessels involved in collisions are from commercial use (e.g. tanks and cargo ships), other vessels such as whale-watching vessels, high-speed ferries, and sailing vessels are also involved. For the purpose of the study, we are classifying all vessel strikes as commercial and recreational fishery related being that the data does not distinguish the type of vessel involved. There are several factors that can result in a collision between vessels and cetaceans: 1) vessel related factors, 2) cetacean-related factors, and 3) geographical factors (Dolman, 2006). Vessel related factors depend on the speed, type, and size (Dolman, 2006). Larger vessels are found to be more of a hazard to cetaceans since they are less maneuverable, travel at faster speeds, and have lower visibility (Dolman, 2006). Operators are also less likely to detect cetaceans at higher speed and unable to avoid the cetaceans (Dolman, 2006). Despite this, vessels of varying class and size have been implicated in collisions with cetaceans, from cargo ships to jet-skis to non-motorized vessels (i.e. sailboats) (Dolman, 2006). Recently, there have been more reports of Jet Ski colliding with cetaceans. This is because Jet Skis are extremely fast, noisy, and highly maneuverable, they can startle and scare the unaware cetaceans (Dolman, 2006).

Cetacean-related factors depend on the age, health, swimming ability, if the animal is distracted by feeding or mating activities, and/or if the animal is habituated to vessels (Dolman, 2006). Finally, geographical factors include areas the cetacean population geographic habitats are near or overlap with vessel routes, highly urbanized coastal zones, or popular marine recreational areas (Dolman, 2006). For CBD, coastal

populations are exposed to higher levels of human activities in smaller areas, such as recreational fishing boats, than pelagic cetaceans (Nowacek, 2001). There is concern that an increase of recreational activities in coastal areas that will result in higher rates of collision, especially during the summer months when CBD populations tend to shift to more shallow inshore waters and increase of human activities because of tourism (Green, 2010).

Collisions between vessels and cetaceans result in either blunt force trauma or sharp traumatic injuries. Severity of the trauma depends on the proximity of the animal to the vessel, speed of the vessel, the size of the vessel relative to the animal, and the location of impact. Blunt force trauma is defined as a mechanical stress that damages the tissue resulting in bodily deformation (Moore, 2013). There are four types of injuries: 1) contusions, 2) abrasions, 3) lacerations, and 4) bony fractures (Moore, 2013). In a vessel collision, the animal will come into contact with non-rotating features such as the rudder, hull, bow, or skeg (Moore, 2013). Lethal blunt force trauma injuries are commonly characterized by a well-defined central area of subcutaneous edema and hemorrhage, torn muscles and tendons, damage to organ systems, and bone fractures (Moore, 2013). Clinical signs of blunt force trauma are impaired locomotion, lethargy, abnormal body posturing, prolapsed eyes, hemorrhaging from the nares, blowhole, or eyes, unresponsiveness, and anorexia (Moore, 2013). Impact with smooth object may not result in an external sign and can only be revealed in post-mortem necropsy.. Blunt force trauma is not easily recognized unless a complete necropsy is performed or witnessed in real-time. Majority of the strandings involving vessel strikes are found to be sharp force trauma such as propeller wounds.

Sharp traumatic injuries from vessel collisions are easily recognizable and typically caused by rotating propellers resulting in incising and/or chopping wounds (Moore, 2013). Injuries can range from nonfatal nicks to severe amputations and internal wounds. A common characteristic of sharp traumatic injury is single or multiple linear and sinusoidal or parallel equi-distant lacerations (Moore, 2013). Vessel related sharp-force trauma severities also vary based on the radius/size of propeller, propeller speed, and the propeller size relative to the animal's size (Moore, 2013). Clinical signs of sharp-force trauma are impaired locomotion, logging/listing at the surface, shallow to deep

lacerations, exposed red to pink muscles (for more acute damage), and in severe cases, amputations of appendages (Moore, 2013).

2.4.4. Federal response to fisheries threat to common bottlenose dolphin

Conservation efforts for the CBD range from local to federal agencies and organizations. In efforts to reduce incidental mortality and serious injury from bycatch of the North Atlantic coastal bottlenose dolphin stock, the NMFS issued the Bottlenose Dolphin Take Reduction Plan Regulations in 2006 (BDTRP) (NOAA, 2006). The immediate goal was to reduce serious injury or incidental mortality of marine mammals from commercial fisheries below the PBR established for the stock, within six months of implementation (NOAA, 2006). The long-term goal of the plan is to reduce the serious injury and incidental mortality to an insignificant level approaching a zero injury and mortality rate, within five years of implementation (NOAA, 2006). The management measure focuses on the eight coastal fisheries that operate within the CBD's geographic range. The amendment changed the seasonal closure of portions of the mid-Atlantic EES to fishing with gillnet mesh size from 8-inch or larger stretched mesh to 7-inch stretch mesh or larger, restricts in gear proximity requirements, and gear deployment (NOAA, 2006).

The geographic scope of the BDTRP spans seven spatial Management Units, from the New York-New Jersey border to the end of the Florida coast within 6.5 to 14.6 nautical miles off shore (NOAA, 2006). In Florida, the BDTRP regulation measure requires all gillnet fishermen to remain within 0.25 nautical miles of the closest portion of their gear at all times in state and federal waters (14.6 nautical miles from shore) year round (NOAA, 2006). The plan also requires all of the gear to be removed from the water and stowed on board before the vessel returns to port (NOAA, 2006). Non-regulatory elements of the BDTRP require enforcement of regulations, education and outreach to fishermen, and a joint effort by all states to remove derelict crab trap-pot gear (NOAA, 2006). Since the implementation, a study by McDonald et al. (2014) evaluating various Take Reduction Plans in the United States has found the BDTRP has been successful in meeting at least one goal of reducing and maintaining bycatch below the PBR.

3. Material and Methods

3.1. Data collection

Stranding data for the Common Bottlenose Dolphin for Florida was obtained from the NOAA Southeast Regional Marine Mammal Health and Stranding Response Program database provided through email from the NOAA Assistant stranding coordinator. Whereas this database spans 1998 through 2015, the focus of this study was on the strandings that occurred between 2002 and 2014. Each stranding entry in the dataset was from a Level A report submitted by a stranding organization and flagged positive for human interaction. Level A reports are forms for detail documentation of stranding events that organizations are required to use during any stranding event and is provided through the NOAA Marine Mammal Health Stranding Response publication website. To maintain consistency throughout the database, reports that had no or partial GPS coordinates, else no indication for any type of human interactions, were omitted from further analysis. Specifically, the stranding data that reported fishery gear found on or in the body, descriptions of human interactions (such as scars and/or impressions), or positive identification of vessel collisions were used. This filtering excluded stranding data for mutilation (gunshot wounds and knife cuts) and ingestion or entanglement with foreign debris. Factors such as sex, life stage, cause of death and other details (i.e. morphometric measurements), were also omitted due to the lack of available information, consistency, and irrelevance to the analysis. GPS coordinates were converted into decimal degrees forms using the Polar Geospatial Center Coordinate Converter by the University of Minnesota (PGC, 2012).

The Florida Fish and Wildlife Conservation Commission (FWC) commercial and recreational fishing permit data were obtained through an online request to the FWC. The FWC were only able to provide recreational fishing permits from 2002 to 2014, while commercial fishing permits were available since 2000. For the purpose of consistency, recreational and commercial fishing permits by county were only used for the years 2002 to 2014. Boating license data were obtained by the Florida Department of Motor Vehicles Florida vessel owner annual statistics by county. Human population data for 2002 and 2014 was obtained through the United States Census Bureau website population demographics search engine American Fact finder. Each county was organized to average

population, average number of permits, average number of boating permits, and the length of shoreline in kilometers into a single Excel spreadsheet and labeled as "human impact data". Coastal counties (counties with shoreline length < 0) were included in the study.

3.2. Spatial Analysis

Geospatial analysis was performed with ArcGIS (version 10.3). The kernel density tool in ArcGIS was used to examine the spatial density of strandings positive for fishery human interactions. The tool calculates the magnitude-per-unit area from point features using the kernel function to produce a more generalized density raster. This allows a visual representation of the density of strandings in an area by creating "hotspots". The parameters of the kernel density used were designated by the program where the "Population Field" was none, "Output cell size" at 0.02458592 km^2, the "Area units" at square map units, "Output values" at densities, and "Method" at planar. The legend was modified to show a qualitative comparison of the density "Low" to "High" by editing the images on the Apple Preview program (Figure 1). Regions of "hotspots" were defined and color-coded into Table 1, containing each county's number of strandings and the total strandings in each region.

Spatial analysis of the each human impact was conducted by overlaying each impact with Figure 1 (Figure 2-5). This was done by joining the collated county data to the original county shapefile and illustrating the data for each category (e.g. average population by county, etc.) using six equal interval classifications and a graduated color ramp. Stranding density per county was calculated based on the number of strandings and the total length of shoreline for each county. To obtain the total length of shoreline for each county, the county borderline of Florida shapefile from the Southwest Florida Water Management District GIS, Maps, and Survey Shapefile Library was utilized. The county borders in this shapefile were already measured and separated. Therefore the total length of shoreline for each county was calculated by converting length measurement of county polygon to kilometers and adding up the converted polygons values per county into an Excel spreadsheet. Stranding data was imported into ArcGIS as a point shapefile.

Additional spatial analyses were conducted on stranding density per county based on each of the human impacts. The first was a summary statistics of each region and its respective counties by the three different fishery interactions (Table 1). The second was a summary statistics of each region and its respective counties by the four human impact factors as well as the average number of strandings per county in each region (Table 2). Each of the region were ranked one to four for each human impact factor: 1) average human population per county (HP), 2) average length of shoreline per county (SL), 3) average number of boat permits per county (BP), and 4) average number of fishing permits per county (FP). Finally, simple scatter plots on Microsoft Excel were used by plotting the number of strandings per county against each of the human impacts per county (Figure 7-10). Each scatterplot was fitted with a linear trend line and R-squared value. Data points on the scatterplot from each "hotspot" were changed by the color code from Table 1.

3.3. Temporal analysis and fishery gear summary statistics

For the purpose of the study, stranding events were divided in to three main fishery interactions based on the potential cause for the stranding: ingestion, entanglement, and vessel collisions. Fishery gear associated with entanglement and ingestion events were further divided based off the study of fishery gear interactions in Florida by Adimey et al. (2014), namely: 1) hook and line (HL) (i.e. fishing hooks, lures, weights, and fishing line) 2) trap pot gear (TPG), 3) fishing net (FN) and 4) multiple gear (MG) (i.e. any combination of the fore-mentioned gear categories). A fifth category was utilized for entanglement interaction: human interaction scars/impressions (HI) from fishing line and nets found on the animals. Fishery gears in ingestion events were broken down further in the manner to how the gear interacted with the animal: 1) free floating, 2) embedded, and 3) strangulation. Vessel collisions were categorized as either blunt force or sharp force trauma.

Summary statistics of the various fishing gear/impacts for each human interaction was conducted on Excel with pivot tables. Table 3 shows each human interaction was separated by type of gear and impact. Table 4 shows a further break down for ingestion

by the type of gear interaction and the gear's interaction in the animal's body. Finally, Table 5 summarizes the types of gear for each of the regions and its respective counties.

For seasonal trends of strandings, a temporal analysis was conducted by plotting the number of strandings by year and by month. Pivot tables were used in Excel to summarize the number of strandings per fishery interaction by year and by month (Table 3-4). Stacked column graphs of the strandings of each fishery interaction by year and by month (Figure 10 and 11). Marked line graphs were created with the number of boat licenses in the y-axis, the year 2002 to 2014 on the x-axis, and CBD strandings on the z-axis (Figure 12). This was also done for the number of fishing permits on the y-axis (Figure 13).

4. Results

4.1. Spatial Analysis

There are two regions with a high density (n > 63) of CBD strandings, and two regions with a moderate density (13 < n < 62) (Figures 1). The region with the highest density (Region 1) was made up of Brevard, Volusia, Indian River, and St. Lucie County (Table 1). This region had a total of 112 CBD strandings. The region with the second highest density (Region 2) was comprised of Pinellas, Sarasota, Charlotte, Lee, Manatee, and Hillsborough County, and had a total of 71 strandings. The first region of moderate density (Region 3) encompassed Duval and St. Johns County, and had a total of 23 CBD strandings. The second region of moderate density (Region 4) included Escambia, Bay, Okaloosa, Santa Rosa, and Walton County, and had a total of 16 CBD strandings.

The density of CBD strandings was compared to four different human factors: 1) population density, 2) coastline length, 3) average number of boat licenses, and 4) average number of fishing permits. All four regions have moderate association of average human population (n < 82439) with the density of strandings but two counties of highest average human population (Broward and Miami-Dade county) had little to no strandings (Figure 2). When comparing the density of strandings to the length of shoreline, Regions 1 and 2 had moderate association (n > 610) with the length of shoreline (Figure 3). Regions 3 and 4 had a lower association (1 < n < 203) with the length of shoreline. Regions 1-3 were highly associated (n < 28152) with the average number of boat

licenses, while Region 4 had a moderate association (n < 12430), as seen in Figure 4. Regions 1 and 2 had moderate associations (n > 811) with the average number of fishing permits, while Regions 3 and 4 had low associations (n < 169), as seen in Figure 5. Based on the maps alone, all four human impact factors have an average of moderate predictable associations with the stranding densities of each region, in exception to several outlier counties.

The various human interactions documented for each CBD strandings were summarized for each region and its respective counties (Table 1). Region 1 had almost even number of entanglements (n=52) and ingestions (n=45) as well as 15 vessels strikes. For Region 2, entanglements accounted for almost half of the interactions (48%), ingestions a third (30%) and the rest vessel strikes (21%). For Region 3, entanglements made up the majority of the strandings interactions (73%), followed by vessel strikes (17%) and then ingestion (8%). Finally, for Region 4, entanglements made up the majority of the strandings interactions (81%), while vessel strikes accounted for the rest. There were no reported strandings with positive signs of ingestion in this region.

The four human impact factors examined for predictability of CBD strandings were also summarized for each of the regions and its respective counties (Table 2). Region 1 had the highest number of average strandings by county (n=28) and ranked first for shoreline (SL), second in boat licenses (BL) and fishing permits (FP), and third in average human population (HP). Region 2 and Region 3 has the same number of average strandings per county (n = 12). Region 2 ranked first in HP, BL, and FP and then second in SL. Region 3 ranked second in HP, third in FP and BP, and fourth for SL. Region 4 ranks third in SL, and fourth for BL, FP, and HP. Based on the summary statistics alone, none of the human impact factors have conclusive predictability for strandings.

Statistically, no significant correlations were observed between CBD stranding density and any of the human impacts (Figures 6-9). The lowest correlation ($r^2 = 0.0181$) was between CBD stranding density and average human population by county (Figure 6), while the greatest correlation ($r^2 = 0.16404$) was between CBD stranding density and the length of shoreline by county (Figure 7). The correlations between CBD stranding and each human impact are statistically too low to be used to predict CBD strandings by

human impacts but in used to rank the possible predictability amongst each of the human factors.

4. 2. Temporal Analysis

Temporal analysis of CBD strandings between the years 2002 to 2014 revealed a peak in strandings between 2006 and 2008, a decrease in the subsequent three years, and then another peak in 2012 (Figure 10). The highest number strandings due to entanglement was in 2012 (n = 20), the highest number of strandings due to ingestion was in 2006 (n = 13), and the highest number of strandings due to vessel strikes was in 2006 and 2013 (n = 7). In comparison to the number of the different human impacts (Figure 12-13), there are no discernable patterns with the number of strandings by year. The number of boat licenses by year has a unimodal distribution from 2006 to 2008 and is weakly associated with the number of strandings. The number of fishing permits by year has no significant patterns or peaks but has a slight increase from 2011 to 2013, with a slight decrease in 2014, weakly correlating with the number of strandings.

Analyzing CDB strandings by month revealed a peak from July to August, with 25% of the strandings falling within these two months for the 2002 to 2014 timeframe (Figure 11). The highest number of strandings for each interaction was also greatest from July to August. The human impact data was not available by month; therefore, temporal analysis was not conducted on a monthly scale.

4.3. Fishery Gear Summary Statistics

During 2002 to 2014, a total of 2,522 CBD strandings were reported in Florida. From this, 247 (9.79%) were identified to have positive human impact involving fishery gear. Furthermore, of these 247 CBD strandings, entanglements made up 52.2% (n=132) of the interactions, ingestions made up 29.7% (n=72), and vessel collisions made up 18.1% (n=43), as shown in Table 3. There were various causes for entanglement-related strandings including hook and line (52.3% of entanglement strandings), trap pot gear (27.3% of entanglement strandings), HI scars and impressions (15.9% of entanglement strandings), fishing net (3.8% of entanglement strandings) and multiple gears (0.7% of entanglement strandings). Fewer cases were reported for ingestions. Reported ingestion

causes included hook and line made (80.5% of entanglement strandings) and multiple gears (19.5% of entanglement strandings). Ingestion was further classified by the impact of the gear in the animal's body cavity (Table 4). Gear found free floating in the body of the animal made up most of the impact at 53% to 56%, gear embedded in various locations in the body for 25% to 31%, and ingestion of gear resulting in larynx strangulation for 12% to 21%. The vessel interactions results revealed that sharp force trauma made up for 84% of the vessel strikes while 16% of strikes was found to be blunt force trauma.

The type of gears found in entanglement and ingestion strandings varied by each region and their respective counties (Table 5). For Region 1, hook and line make up for the majority of the fishing gear at 65.9%, trap pot gear at 14.4%, multiple gears at 9.3%, and the rest with fishing net and HI scars/impressions at 3-7%. For Region 2, hook and line were responsible for 69.6% of entanglements and ingestions, HI scars and impressions and trap pot gear both for 10%, multiple gears at 5% and fishing nets at 3.6%. For Region 3, hook and line (42.1%) and trap pot gear (36.8%) are responsible for the majority of the entanglements and ingestions. HI scars and impressions, for Region 3, were 15.8% and multiple gears at 5%. For Region 4, hook and line are responsible for 61.5% of entanglements and ingestions, HI scars and impressions for 30.7%, and the rest with trap pot gear at 7.7%. Incidents involving multiple gears were not reported in Region 4. Overall, hook and line make up the majority of the gear found responsible for entanglements and ingestions, except for Region 3, where an even number of trap pot gear and hook and line gear were reported.

5. Discussion:

5.1. Spatial analysis identifying CBD hotspots

The spatial analysis of the CBD strandings due to human interactions in Florida from 2002 to 2014 indicated two strong (n > 71 strandings) and two moderate (n > 16 strandings) "hotspots", accounting for almost 90% of the total strandings that were surveyed. The calculated r^2 values indicate no significant correlations between the strandings and any of the human impacts ($r^2<0.16$) but based visual interpretation of the spatial analysis, each of the human impacts shows clear associations. The low r^2 values

could be due to high variability in the data and the fact that r^2 analysis does not account for biases and outliers in the data. The regression statistics were reassessed by removing the counties not in the identified hotspot regions as shown on the scatterplots in red (Figure 6-9). This was conducted to see if there were any significant predictable correlation in the absence of the outlier counties (Broward, Miami-Dade, and Monroe). All of the r^2 values improved, in particular the stranding densities against SL with a new r^2 value of 0.51264 (Figure 7) and stranding densities against FP with a new r^2 value of 0.30798 (Figure 9). The r^2 value for the BL and HP did improve but only slightly, where BL's $r^2 = 0.15715$ and HP's $r^2 = 0.08204$, both still statistically too low to be considered predictors alone. With these reassessed r^2 values, the length of shoreline and the average number of boat licenses per county could be considered a significant predictor for strandings. Notably on the spatial maps, majority of the counties in the identified hotspot regions were observed to have a greater average number of boating licenses and fishing permits, a larger average human population and longer shoreline lengths.

Counties identified as CBD stranding hotspots such as Pinellas, Lee, Brevard, Duval, and Volusia counties are also within the top ten for the average number of registered boaters, average quantity of commercial and recreational fishing permits, and average human population size (with the exception of Broward, Miami-Dade, Palm Beach counties). From 1960 to 2008, Florida's coastal populations have increased over 75% (Adimey, 2014). The increase in human presence and growing marine industries place a greater pressure on the natural resources and habitats, resulting in a negative impact on the marine wildlife populations (Adimey, 2014). The hotspots counties of CBD strandings were Brevard, Pinellas, Hillsborough, and Duval and were all ranked in the top six for recreational and marine industry based on employment and gross domestic product attributed to the ocean economy (Florida's Ocean Alliance, 2012). In addition, hotspot regions identified by this study are consistent with those identified by Adimey, et al (2014) using CBD, Florida manatee, and sea turtle strandings positive for fishery gear entanglements. The stranding data used in the study for CBD were also acquired from the NMFS Marine Mammal Health and Stranding Response Database. Two of the "hotspots" in the Adimey, et al study were analogous with two of the four regions identified in this

study; Merritt Islands, which is within Region 1, and Tampa bay and Charlotte Harbor, which are both within Region 2.

In this study, Brevard County had the greatest number of strandings (n=70), accounting for 28.3% of all strandings as well as ranking 2nd for the longest shoreline (604 km), 5th in average fishing permits, 7th in average boating licenses, 8th in average human population (Table 2). In addition according to FWC, from 2002 to 2014 Brevard County had the highest commercial finfish landings (FWC, http://myfwc.com/research/saltwater/fishstats). Brevard County's high stranding density may be attributed to the long shoreline consisting of a multitude of seagrass beds, mangrove islands, and lagoons known as popular destinations for recreational boaters for locals and tourists alike (Sidman, 2007). Mangroves and seagrass beds are critical marine habitats that provide shelter and nursery grounds for a large variety of fish species, including major CBD prey items such as soniferous species (McCabe, 2010).

There were three outlier counties in the study: Miami-Dade County, Broward County, and Monroe County. Miami-Dade County and Broward County have the two highest average human populations (>1,730,718) as well as the highest average number of boat license and fishing permits. However, despite ranking high in these human factors, based on the average landed fish by pound in the finfish commercial industry, both Miami-Dade and Broward County attributed to less than half of the commercial finfish landings than the other hotspot counties (FWC, http://myfwc.com/research/saltwater/fishstats). The low average landings of the commercial finfish industry could possibly explain the low number of reported CBD strandings positive for fishery interactions. Miami-Date County, though ranking the highest in almost all of the human factors (average human population, average boat license, and average fishing permits) has very few strandings positive for human impact. This may possibly be explained by poor reporting or by poor carcass recovery due to the proximity of the Gulf Stream to Broward and Miami-Dade counties (personal correspondence with Dr. Jenny Litz, NOAA research fisheries biologist). The Florida current, a component of the Gulf Stream system, passes along Florida, the closest proximity to the coast is a few miles within the Miami and Fort Lauderdale area (Gyory,

2013). The low reporting of strandings in the Miami-Dade and Broward counties could be due to the carcasses getting caught by the Florida current and swept offshore.

Monroe County had seven reported strandings positive for human interactions that could be attributed to the county having the largest average number of issued fishing permits (n=4872) and the highest average landings in the trap pot and finfish commercial industry (FWC, http://myfwc.com/research/saltwater/fishstats). Monroe County is also ranked amongst the top tier for ocean industries and a popular destination for many commercial and recreational fisheries, explaining the high average numbers of fishing permits (Florida's Ocean Alliance, 2012). Despite having a considerable number of strandings (10^{th} out of 36 counties), Monroe County was not considered a hotspot in this analysis because the number of stranding was lower than the number of strandings of the four identified hotspot regions (16 strandings). There could potentially be a higher number of strandings than there were primarily reported due to its long shoreline (1217 km) and high amount of fishing activities. However, due to the low population (n = 75,729) and remoteness of the many islands, it is likely that many strandings can go unreported.

5.1.1. Caveats and assumptions in using stranding data for spatial analysis

Spatial analyses of CBD stranding hotspots based on stranding data have several assumptions and limitations. The higher average human population correlating with a higher density of strandings may be attributed to the fact that the greater human presence in a certain region would result in a higher chance of spotting a stranding. Also, the true number of registered boats and issued fishing licenses could be greater than the reported number of boaters and recreational fishers in coastal counties, such as Brevard County, where recreational ocean activities are popular. Where the fishing permits and boat licenses issued in landlocked counties are utilized is difficult to forecast, underestimating of the true number of boaters and fishers in coastal counties. For example, Sidman (2007) collected vessel registration number and automobile tag numbers for 54 sample days from 28 marinas and 30 boat ramps throughout Brevard county to locate where patrons resided and geocoded into a map (Figure 16). The vessel trailers and tow vehicles totaled 8,966 addresses from Florida where 46.3% were located within Brevard County, 14.5%

from Orange County, 9.2% from Seminole County, 7.5% from Indian River County and 5.2% from Volusia County (Sidman, 2007)

Another caveat is the oceanographic characteristics and current patterns affecting the distribution and frequency of CBD strandings (McLellan, 2002). Oceanographic characteristics of coastal areas can either increase or decrease the possibility of a dead dolphin stranding on a beach (McLellan, 2002). The composition and slope of the shoreline can determine whether or not a dead dolphin will be beach-casted or be swept back into the ocean (McLellan, 2002). The small and large-scale oceanic current patterns can also affect where a dolphin carcass may end up or be discovered. Study by Johnston and Purkis (2013) examining larvae settlement patterns of panther grouper in Florida observed the initial breeding population from Broward county to have settled in two consistent locations, south of Cape Hatteras and Jupiter Florida/Vero Beach. This is explained by the transportation north of the larvae by the Gulf Stream current (Johnston, 2013). This movement not only attributes to the poor carcass recovery in Broward and Miami-Dade counties but can also explain the high stranding density in Region 1. Therefore, going beyond simply analyzing stranding spatial patterns, one must take into consideration physical factors such as oceanic patterns and shoreline composition to provide valuable insight and help predict future stranding patterns (McLellan, 2002).

Another limitation to this spatial analysis based on the stranding database is that many strandings go unreported to stranding organizations. Coastal areas with low monitoring (i.e., attributed to the lack of accessibility to the shoreline) result in few stranding reports. For example, zero strandings were reported from the “Big Bend” counties (Franklin, Gadsden, Jefferson, Leon, Liberty, Madison, Taylor, and Wakulla) and these counties also have the lowest number of average boat licenses, average fishing permits, and average human population (Mattson, 2006). Furthermore, over half the Big Bend area is protected and managed by the Florida Department of Environmental Protection as a part of the Big Bend Seagrasses Aquatic Preserve, therefore limiting human activities and interactions in the region (Mattson, 2006). The lack of organizations that report strandings within the “Big Bend” area along with the low average human populations and near inaccessibility to the coast most likely explains the paucity of reported strandings.

5.2. Temporal analysis of CBD strandings

The statistical summary of the reported data showed higher reported strandings positive for human interactions were observed in the summer season (July and August) for all three types of interactions (25%) and the different types of fishery gear (30%). The influx of tourism during the summer season, leading to higher commercial and recreational activities in many of the coastal counties could attribute to the increase in the summer months (Adimey, 2014). For example, Wells, et al (1997) noted that based on local fuel sales near the marinas in Sarasota, FL, there was a 65% increase in boating activity on summer holiday weekends, in particular Independence Day weekend. In Brevard County stranding densities were highest during peak season for recreational boating (May – July) as noted by Sidman, 2007. However, the increase in reported strandings during this season could also be credited to the fact that there are more people out on the beaches and coastal waters who might observe and report a stranded animal (Wells, 1997).

5.3. Biological factors of CBD impacting stranding trends

Many of the CBD stranding spatial and temporal trends observed in the study may also be attributed to the natural history of the CBD such as habitat distribution, foraging patterns, and social behaviors. CBD have a wide habitat distribution, not only in the state of Florida but also worldwide, influencing the extent of the human interaction and the types of gear involved. In this study, the four "hotspots" can be geographically divided by ocean basin where Region 1 and 3 are in the Atlantic Ocean and Region 2 and 4 are in the Gulf of Mexico Ocean (GOM). Comparing the two regions in the Atlantic (n=135) against the two regions in the GOM (n=87), the Atlantic Ocean has 150% more strandings than the GOM. The 2015 stock assessment report by NOAA reported an estimated abundance of 15,287 in coastal Atlantic Ocean stock and 12,388 in the coastal GOM stock (NOAA, 2015b). Due to insufficient data, the stock abundance of the four estuary stocks (Jacksonville, Indian River, Biscayne Bay, and Florida Bay) in the Atlantic Ocean was not estimated. Therefore, the higher density of strandings in the Atlantic Ocean compared to the GOM could be explained by the overall natural abundance of the stocks.

The difference in CBD stranding densities between the GOM and Atlantic Ocean may also be attributed to the distribution of ocean industries (fishing/living resources, marine industry, seaports/water transportation, recreation, and ocean tourism) in Florida. The Atlantic coastal counties contribute to 50% of the ocean industries, while the Gulf coastal counties only contribute 29% to the ocean industries (Florida's Ocean Alliance, 2012). Therefore in Florida, the higher spatial density of strandings positive for human interactions in the Atlantic Ocean may be attributed to the higher percentage of ocean industries in the Atlantic coastal counties compared to the GOM.

Popular recreational and commercial fishing locations commonly overlap with CBD feeding locations, especially when the target preys are of the same species. This spatial conflict can result in a greater chance of the animal and fishing gear interacting and with diminishing prey availability, therefore rising behavioral acts of depredation and the associated behaviors such as patrolling, begging, scavenging and provisioning is a growing concern (Powell, 2011). The increase of depredation and the associated behaviors of CBDs could lead to greater negative dolphin fishery interactions therefore possibly increasing the density of strandings in areas of high human population and marine activities (Powell, 2011). This change in activity budget due to depredation could also have an effect on the habitat selection and home range size being that the dolphin would select a habitat with a higher concentration of boaters and anglers, such as fishing piers and water channels (Powell, 2011). This in turn would increase the chance of dolphins being negatively impacted by recreational and commercial fishery interactions.

A study in 2004 in Sarasota Bay observed that direct competition for resources between dolphins and anglers was possibly the cause for an increase of depredation and its associated behaviors (Powell, 2011). The correlation of increased rates of dolphin-human interaction was observed during the peak of tourism season with presumable increased water activities in Sarasota County (Powell, 2011). Furthermore, humans are found to illegally continue to feed CBDs, resulting in individual dolphins learning to pursue boaters as a source of food (Adimey, 2014). This learned behavior is also reinforced by the intentional or unintentional release of undersized or non-targeted fish near dolphins (Adimey, 2014). Due to CBD's social nature, other dolphins (in particular calves from their mothers) can learn this depredation behavior, increasing the likelihood

of this occurring in heavily populated coastal zones (Adimey, 2014). The behavior of depredation and its associated behaviors are exacerbated by declining prey populations due to overfishing by fisheries, transmission of learned behaviors through the population, and the continued feeding of dolphins by humans (Powell, 2011). In order for conservations efforts to successfully work to reduce injuries and mortalities from entanglement or ingestions of fishing gear by dolphins, managing depredation and the associated behaviors are essential.

5.4. Gear Analysis of CBD strandings

In this study, hook and line (HL) fishery gear was found to be the most common fishery gear found in CBD strandings positive for human interactions for both entanglements and ingestion as well as occurring in almost every coastal county (Table 4 and 5). This bias possibly arises because HLs are the most commonly used equipment to fish recreationally and commercially, having a wide variety and function depending on the target species, body of water, and other factors. Also the ability for individual dolphins to exploit and depredate from HL fishery gear is easier and requires less energy than for the other types of fishery gear analyzed in this study, such as trap pot gear (Powell, 2011).

Dolphins are likely to become entangled in trap pot gear (the pot itself and the line/buoy rig) through either passive (unintentionally interacting with the gear) or active (depredation) interactions. For instance, Noke and Odell (2002) observed dolphins becoming attracted to the fish aggregating around the TPG and in some instances observed individuals attempting to obtain the bait inside the trap by tipping the pot. The study also suggested that passive TPG entanglement might parallel to the location of the trap. For example, if the trap is in dense, murky waters or in waters with strong currents, the dolphin would not be able to detect the buoy line and can accidently encounter it (Noke, 2002). Additionally, McFee, et al. (2007) has suggested that the type of buoy line material can increase the rate of entanglement with dolphins based on the assumption that the “stiffer” material would move less in the water column and therefore reduce erratic movement and chance of interaction with the animal.

The number of strandings positive for fishing net interactions for both entanglement and ingestion was the lowest of the different types of fishing gear (Table 6). Based on these stranding records, the absence of fishing net interactions are possibly due to the implementation of the Florida Net Ban Amendment which was enacted in 1995 (Adimey, 2014). This amendment limited the type of nets allowed to frame, bully, dip, cast, and seine nets up to 500 square feet in mesh area as well as prohibiting the use of all entangling nets in Florida waters. However, the stranding data may not include the impacts of offshore federal net-based fisheries due to the probability of a carcass being detected offshore is extremely low (Adimey, 2014).

With the growing global human population and rising demands for seafood, technology has changed and improved fishing gear design by switching from biodegradable natural materials, such as cotton and wood, to more durable, non-biodegradable, synthetic materials, such as nylon and polypropylene (Laist, 1995 and Stelfox, 2016). Therefore, today when the gear is lost, abandoned, or discarded, the phenomenon of "ghost fishing" transpires, when the gear continues to indiscriminately catch wildlife. There is an estimate of almost 640,000 tons of ghost fishing gear lost globally per year and accounts for over 10% of the total marine debris floating in the oceans (Stelfox, 2016). Cetaceans are the most vulnerable group to ghost fishing and found to be the most common animal group to become entangled in the gear (Powell, 2011). CBDs are the most commonly entangled odontocete and generally involving monofilament or HL attached to the dorsal fin and other appendages (NOAA, 2014c).

Quantifying the impact of ghost gear is extremely difficult being that there are reporting/survey biases and that the survival rate of an animal escaping the entanglement is near impossible. The findings of this study has found HL gear to make up over half of the entanglement related strandings, even though the stranding data did not differentiate if the entanglement was from ghost or active fishing. With the growing human population and activities in coastal regions along with expanding improvements and resilience of fishing gear technology, the impact of ghost gear must be considered in future conservation mitigation and policies.

Strandings positive for vessel strikes in this study was the lowest of the three human interactions with sharp force trauma making up most of vessel strikes at 81.3%

(Table 3). This is possibly attributed to the difficulty of detecting blunt force trauma being that external characteristics, such as bruising, and internal characteristics, such as internal damage, fractures, and hemorrhages, are not apparent on physical examinations and only observed during necropsies (Bechdel, 2009). This will result in a reporting bias, understating the impact of blunt force traumas as well as the total vessel strikes in a CBD population. There are also concerns that chronic exposure to vessels will result in habituation to vessels, potentially increasing susceptibility to strikes, shifts in habitat utilization and foraging patterns, and reduced reproductive success (Bechdel, 2009). CBD populations in Florida are widely distributed, coastal and offshore, and are at a greater risk of collision with vessels. This is especially a concern in areas containing major ports, high commercial and recreational boating traffic, and coastal human populations. Conservation managers need to have a better understanding of areas that pose a greater threat in order to protect vulnerable CBD populations in Florida waters.

5.5. Future recommendations

Understanding and identifying "hotspots" of CBD stranding can assist the focus of conservation management actions and allow prioritization of stranding responses to areas with high overlapping activities. Reaching out to the public and educating anglers about safe practices, such as monofilament line recycling and responsibly fishing around marine wildlife, are essential. Improvements to current legislations and conservation managing practices could include mandatory boater education courses with the boating license. Constructing and enforcing slow speed zones in areas of high densities of dolphin populations could result in a reduction of dolphin injuries and mortalities if critical habitats are delineated and protected (Bechdel, 2009). Finally, the installation of propeller guards would reduce the frequency of propeller-caused injuries may not eliminate blunt-force injuries and the extent of the injury of blunt-force trauma would be difficult to determine the severity of the injury and survivability of the animal. Several studies suggest the mandatory installation of propeller guards on vessels that experience regular contact with cetaceans, especially in near shore waters and dolphins (Van Waerebeek, 2007; Dwyer, 2014). In addition, the results of this study could be also be used for other programs such as the removal and disposal of marine debris such as derelict fishing line

and crab traps as an effort to reduce their negative impact on the marine wildlife.

Reporting organizations and agencies could focus resources on volunteer recruiting and training courses in areas of high stranding densities, improving the quality of the report as well as data collection. In addition, training other local responding agencies, such as law enforcement, park rangers, and lifeguards, in assisting and reporting strandings could result in more consistent and timely reports as well as increasing the number of reports in areas where stranding organizations have limited reach and accessibility. Finally, in order to improve and increase individual reporting of strandings, using social media applications with geo-tagging capabilities such as Twitter are not only user friendly and encourage public participation but can also improve GPS location accuracy of a stranding.

6. Conclusion:

The total number of CBD strandings positive for fisheries interactions in Florida from 2002 to 2014 was 247, with two moderate (Region 2 and 4) and two high (Region 1 and 3) areas of stranding densities. The stranding densities compared with four different human factors (average human population, coastline length, average number of boat licenses, and average number of fishing permits) was found to have low to moderate association with the exception of Broward, Miami-Dade, and Monroe counties. Temporal analysis of CBD strandings found a significant increase from July to August. Fishery gear summary statistic of the strandings found entanglements make up more than half of the interactions and HL the most frequently found gear in both entanglements and ingestion events.

The reported data are considered minimum estimates due to several human and natural factors. Cases that go unreported and undetected can be attributed to several things such as inaccessibility in different aquatic habitats and scavenged carcasses by sharks and other predators. The limited resources, facilities, and staff to conduct necropsies can result in undetected ingestion of fishing gear and blunt force trauma cases. Entanglement cases can also be underreported due to the inability to quantify survival rates of individuals, especially if the individuals escape from entanglements. There are also reporting biases for the hotspot regions being that stranding reports do not always

accurately reflect where the animal originally interacted with the human fishing activity as well as regional data being biased in areas of high human population. Also, stranding data is grossly predisposed towards inshore interactions being that at-sea interactions and mortality is very difficult to quantify.

Habitat degradation, overfishing, and anthropogenic noises from powerboats can affect the foraging costs and the overall abundance of prey items, affecting the dolphin's distribution as well as increasing depredation and negative human interactions. Reducing dolphin's opportunities of interaction with anglers and boaters are essential to managing depredation and associated behaviors that could lead to serious injuries and mortalities caused by entanglement or ingestion of fishery gear. Negative human interaction with fishery gear is a growing global issue that is expected to escalate with growing coastal human populations, therefore reducing and minimizing human impact through multifaceted management policies in these "hotspots" are essential for preserving wildlife populations.

List of Figures

Figure 1: Kernel density plot of CBD strandings from 2002 to 2014.

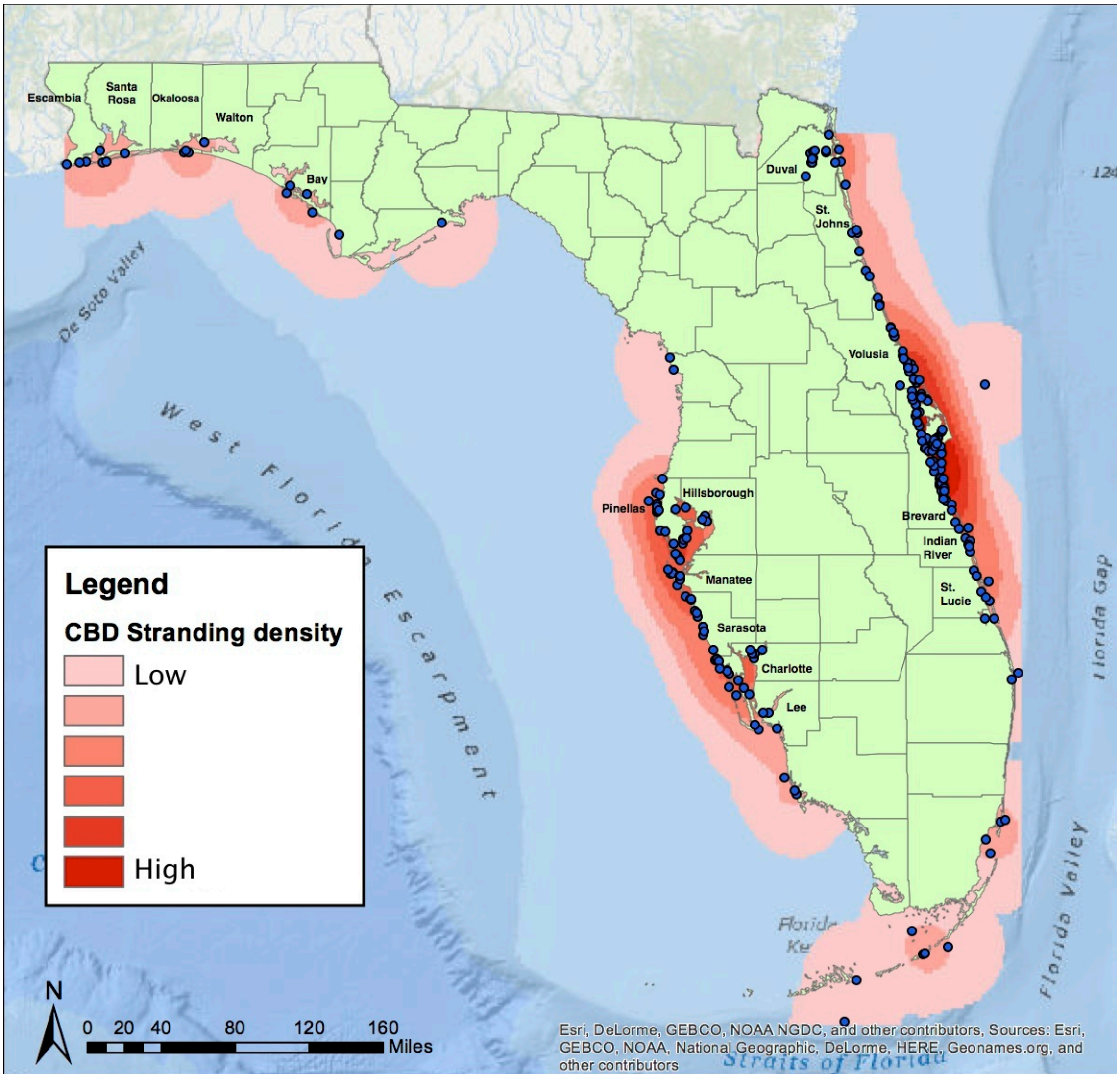


Figure 2: Kernel density of CBD strandings with the average human population by county.

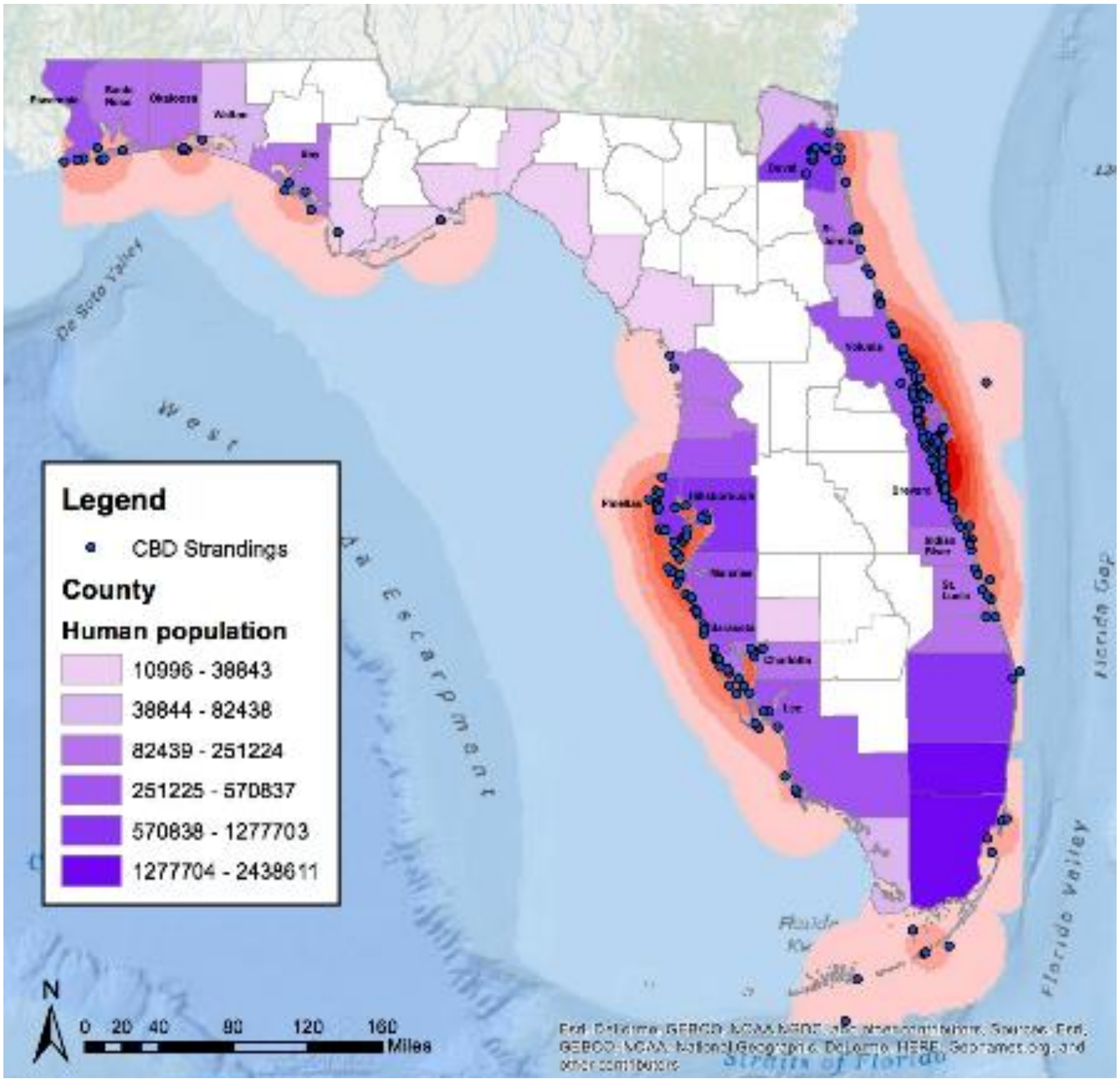


Figure 3: Kernel density of CBD strandings with the length of shoreline (km) by county.

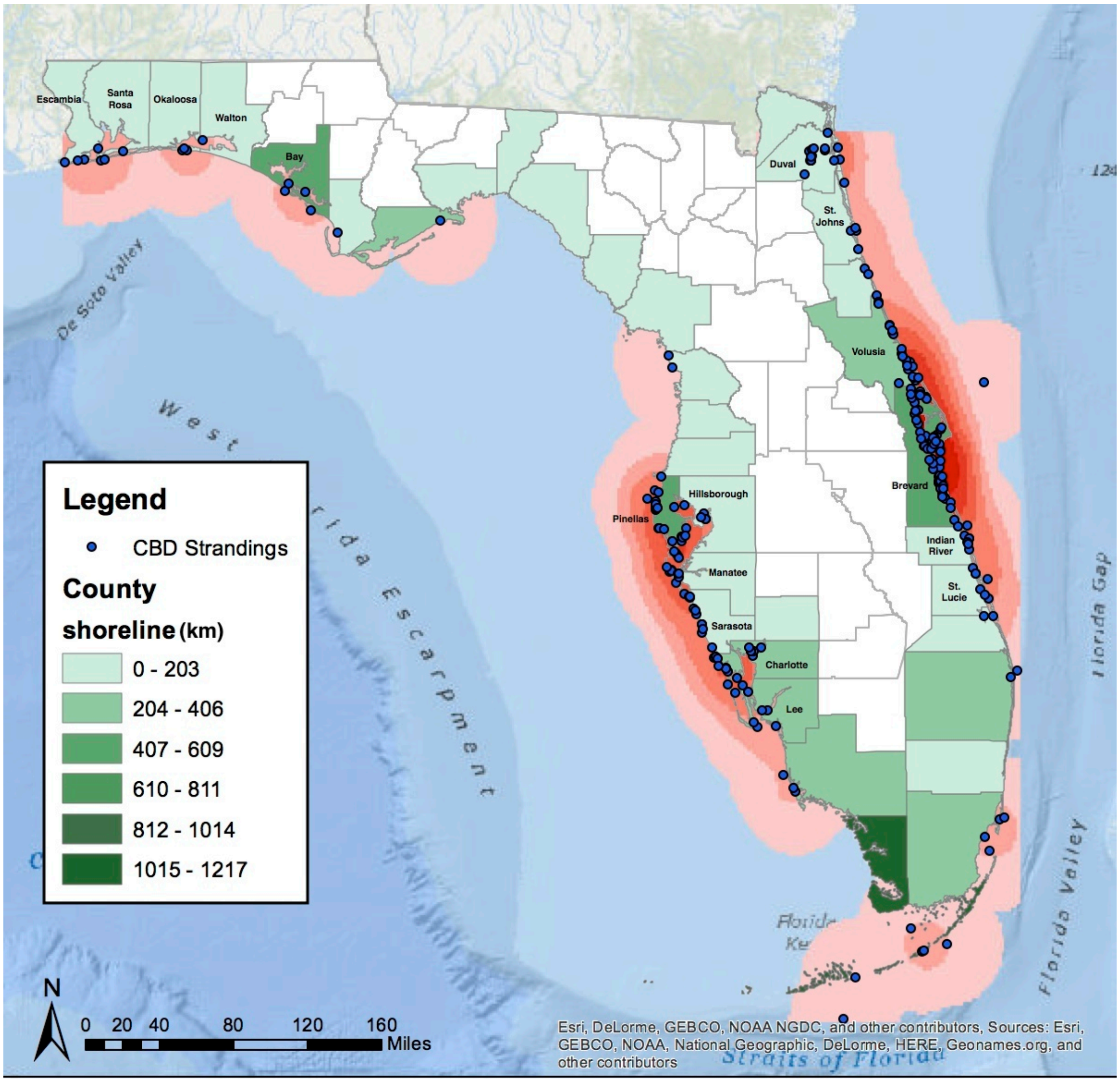


Figure 4: Kernel density of CBD strandings with the average number of boat licenses by county.

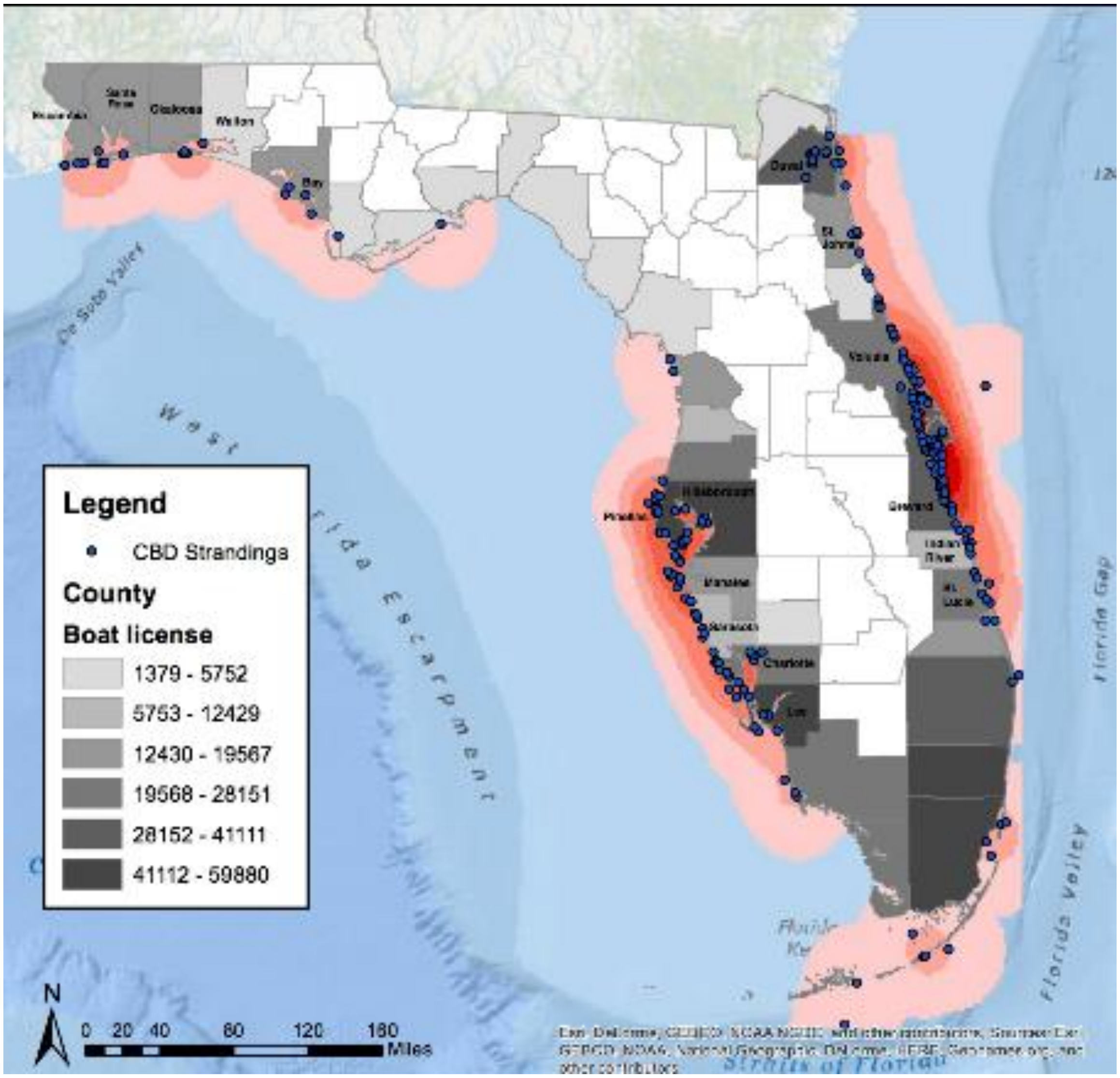


Figure 5: Kernel density of CBD strandings with the average fishing licenses by county.

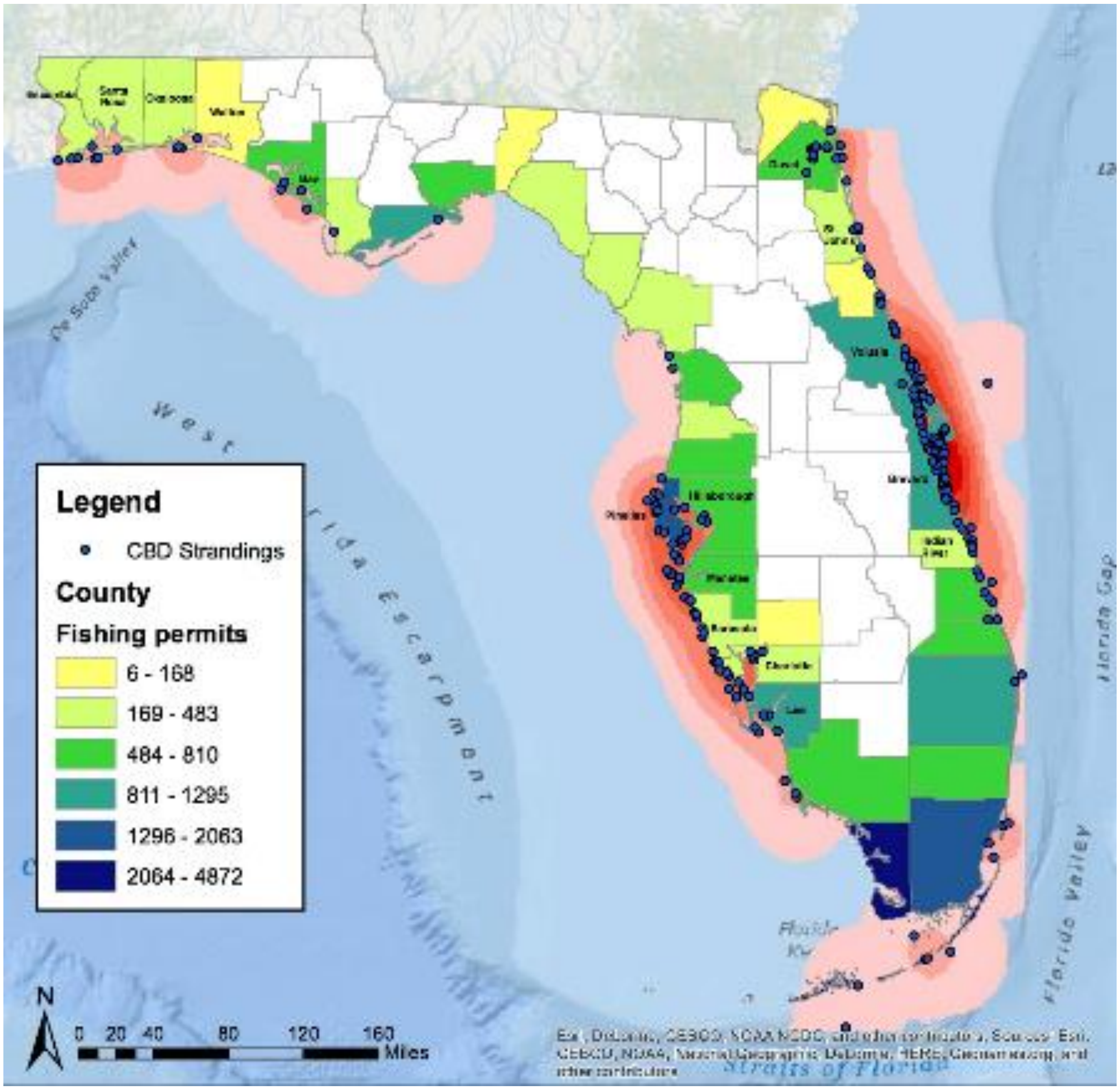


Figure 6: Scatterplot of the stranding density by the average human population per county.

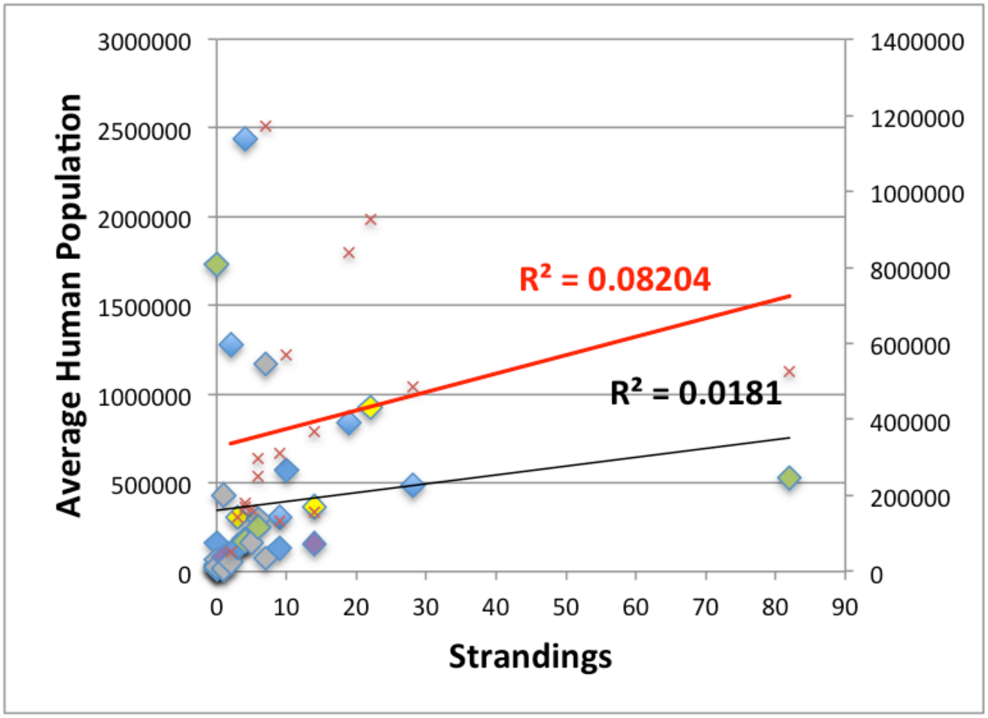


Figure 7: Scatterplot of the stranding density by the length of shoreline per county.

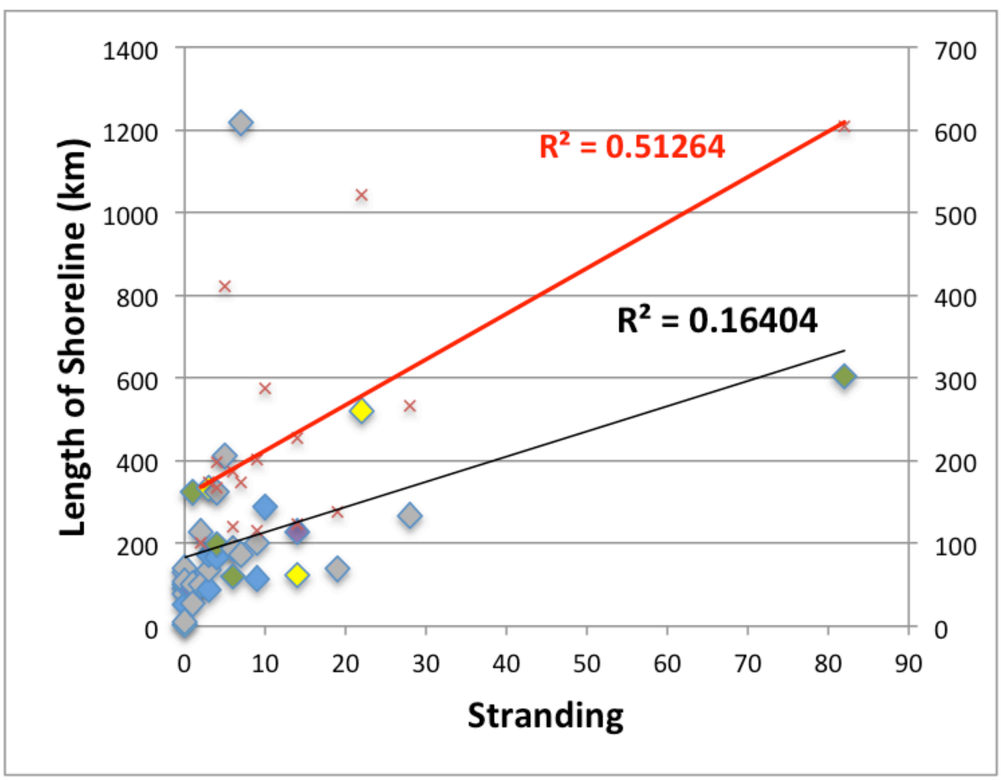


Figure 8: Scatterplot of the stranding density by the average number of boat licenses per county.

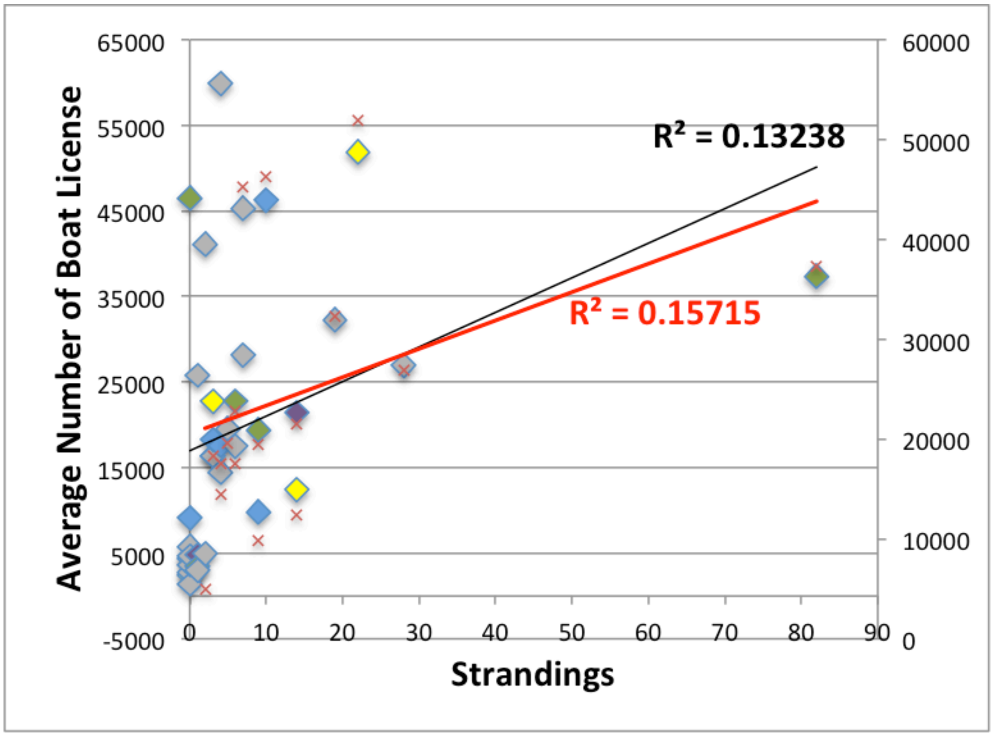


Figure 9: Scatterplot of the stranding density by the average number of fishing permits per county.

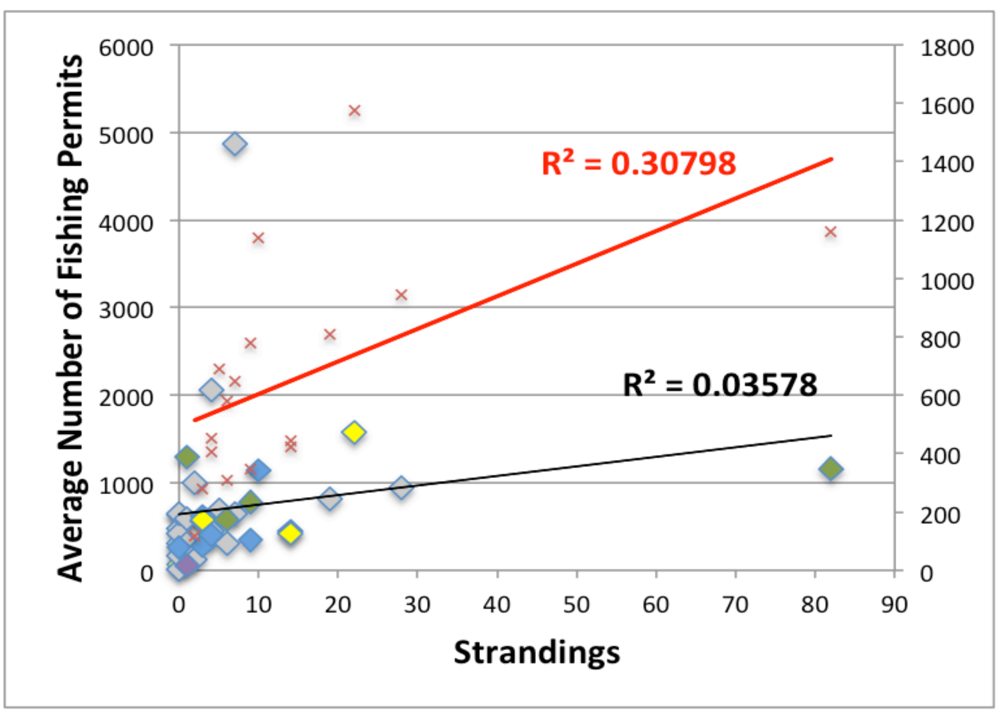


Figure 10: Number of strandings, by year, associated with each fishery interaction.

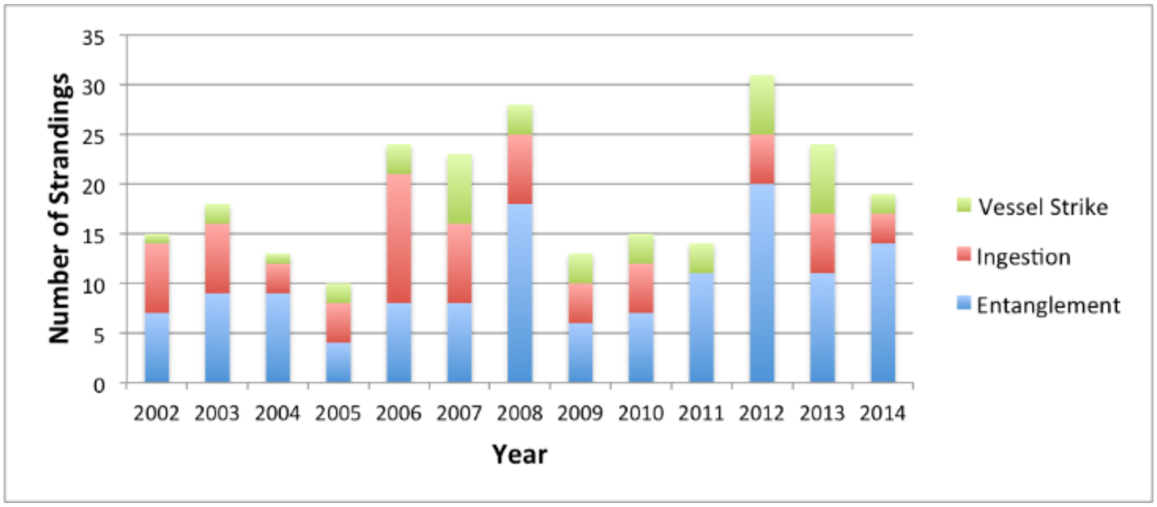


Figure 11: Number of strandings, by month, associated with each fishery interaction.

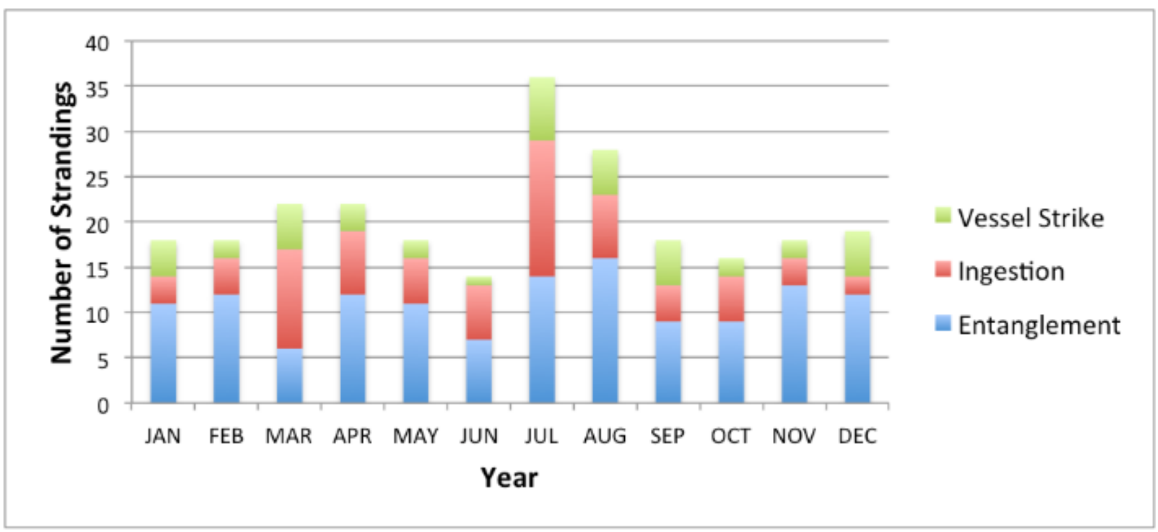


Figure 12: Number of CBD strandings and boat licenses by year from 2002 to 2014.

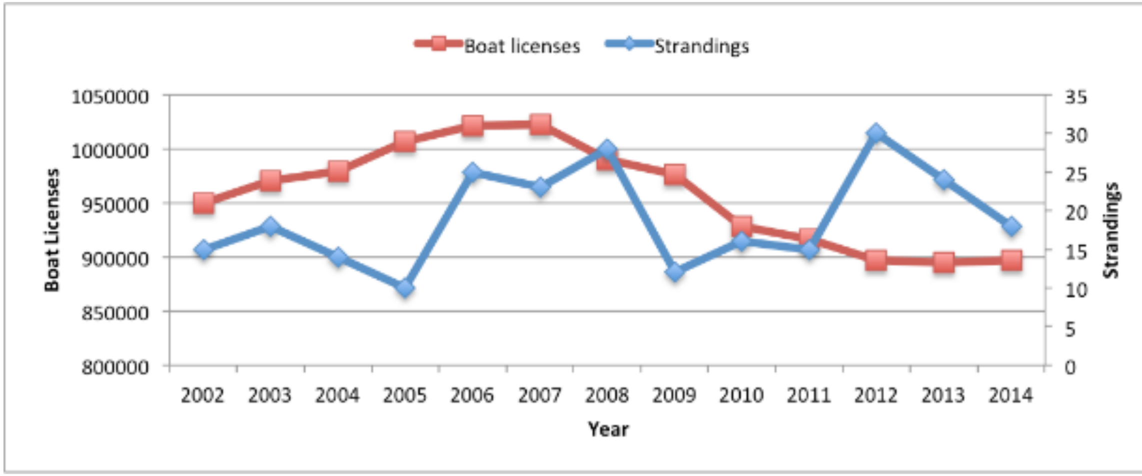
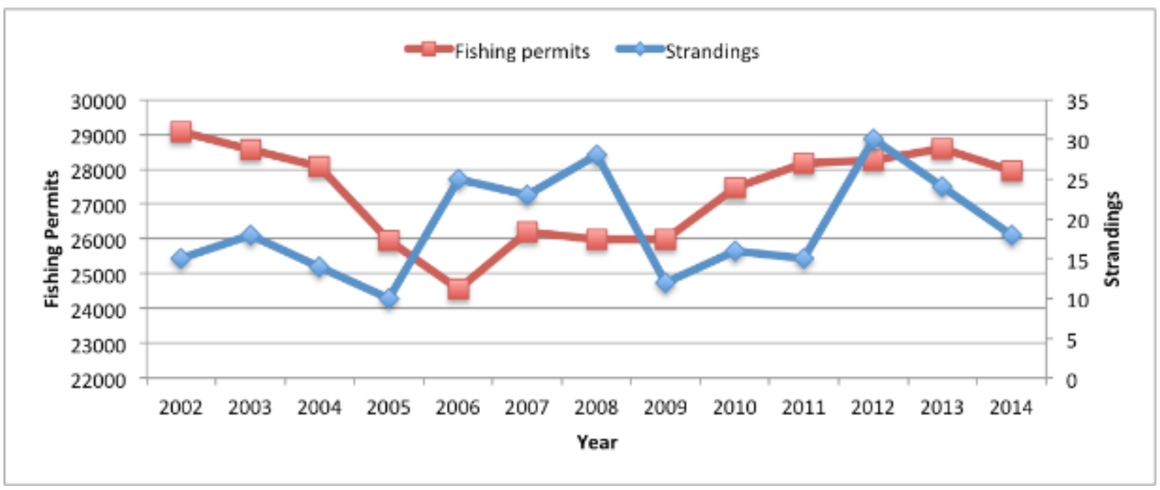


Figure 13: Number of CBD strandings and fishing permits by year from 2002 to 2014.



List of tables:

Table 1: Summary of human interactions that were reported for CBD strandings within the year 2002 to 2014 for each region and its respective counties.

	County	Entanglement	Ingestion	Vessel Strike	Total
Region 1	Brevard	30	35	5	70
	Volusia	13	6	8	27
	Indian River	5	2	2	9
	St. Lucie	4	2	0	6
	Total	**52**	**45**	**15**	**112**
Region 2	Pinellas	8	5	7	20
	Sarasota	4	6	2	12
	Charlotte	11	3	0	14
	Lee	7	1	1	9
	Manatee	1	4	4	9
	Hillsborough	3	3	1	7
	Total	**34**	**22**	**15**	**71**
Region 3	Duval	15	1	3	19
	St. Johns	2	1	1	4
	Total	**17**	**2**	**4**	**23**
Region 4	Escambia	4	0	1	5
	Bay	3	0	1	4
	Okaloosa	3	0	0	3
	Santa Rosa	1	0	1	2
	Walton	2	0	0	2
	Total	**13**	**0**	**3**	**16**

Table 2: Summary of human impact factors and CBD strandings by region and their respective counties.

	County	CBD strandings	Average human population	Length of shoreline (km)	Boat Licenses	Fishing Permits
Region 1	Brevard	70	527494	604	37358	1159
	Volusia	27	484551	267	26921	943
	Indian River	9	131058	115	9823	346
	St. Lucie	6	251224	120	22811	580
	Average	**28**	**348581**	**276.5**	**24228**	**757**
Region 2	Pinellas	20	924960	521	51871	1575
	Sarasota	12	366549	124	12429	421
	Charlotte	14	156541	228	21455	444
	Lee	9	570837	288	46228	1140
	Manatee	9	309222	202	19409	777
	Hillsborough	7	1170423	173	45290	646
	Average	**12**	**583088**	**256**	**32780**	**833**
Region 3	Duval	19	840067	138	32251	810
	St. Johns	4	170516	198	14480	451
	Average	**12**	**505291**	**168**	**23365**	**630**
Region 4	Escambia	5	298788	187	17497	307
	Bay	4	162648	411	19567	609
	Okaloosa	3	181185	167	17547	405
	Santa Rosa	2	143163	173	18268	281
	Walton	2	51488	100	4956	120
	Average	**3**	**167454**	**207.6**	**15567**	**344**

Table 3: Summary of human interactions by type of gear or impact associated with CBD strandings.

Type of Interaction	Total
Entanglement	**132**
HI Scars/Impression	21
Hook and line	69
Trap pot gear	36
Fishing Net	5
Multiple gears	1
Ingestion	**72**
Hook and line	59
Multiple gears	12
Vessel Strike	**43**
Blunt force	8
Sharp force	35

Table 4: Summary of gear interaction in the stranded animal's body due to gear ingestion.

Type of Ingestion	Total
Hook and line	**60**
Embedded gear	15
Free floating gear	38
Strangulation	15
Multiple gears	**12**
Embedded gear	4
Free floating gear	6
Strangulation	2

Table 5: Summary of fishing gear found from strandings by each of the regions and their respective counties.

	County	Hook and line	HI Scars/ Impressions	Trap pot gear	Fishing Net	Multiple gears	Total
Region 1	Brevard	44	4	9	1	7	**65**
	Volusia	12	1	3	1	2	**19**
	Indian River	3	2	1	1	0	**7**
	St. Lucie	5	0	1	0	0	**6**
	Total	**64**	**7**	**14**	**3**	**9**	**97**
Region 2	Pinellas	8	3	1	1	0	**13**
	Sarasota	7	1	1	0	1	**10**
	Charlotte	9	1	3	0	1	**14**
	Lee	6	1	1	0	0	**8**
	Manatee	4	0	0	0	1	**5**
	Hillsborough	5	0	0	1	0	**6**
	Total	**39**	**6**	**6**	**2**	**3**	**56**
Region 3	Duval	6	3	7	0	0	**16**
	St. Johns	2	0	0	0	1	**3**
	Total	**8**	**3**	**7**	**0**	**1**	**19**
Region 4	Escambia	3	1	0	0	0	**4**
	Bay	1	2	0	0	0	**3**
	Okaloosa	3	0	0	0	0	**3**
	Santa Rosa	1	0	0	0	0	**1**
	Walton	0	1	1	0	0	**2**
	Total	**8**	**4**	**1**	**0**	**0**	**13**

References

Adimey, N. M., Hudak, C. A., Powell, J. R., Bassos-Hull, K., Foley, A., Farmer, N. A., White, L., and Minch, K. (2014) Fishery gear interactions from stranded bottlenose dolphins, Florida manatees and sea turtles in Florida, U.S.A. *Marine Pollution Bulletin* 81: 103-115 doi: 10.1016/j.marpolbul.2014.02.008

Balmer, B.C., Wells, R. S., Nowacek, S. M., Nowacek, D.P., Schwacke, L.H., Mclellan, W.A., Scharf, F.S., Rowles, T.K., Hansen, L. J., Spradlin, T.R., Pabst, D.A. (2008) "Seasonal abundance and distribution patterns of common bottlenose dolphins (*Tursiops truncatus*) near St. Joseph Bay, Florida, USA." *J. Cetacean Res. Manage.* 10(2): 157-167.

Basso-Hull, K., Powell, J. (2010). "Entanglement hotspots along the Florida coastline: a need for outreach and action" *Nicks n Notches, Chicago Zoological Society.* <http://sarasotadolphin.org/wp-content/uploads/2010/11/Nicks_n_Notches_Jan_2012.pdf>

Bearzi, G., Fortuna, C. F., and Reeves, R. R. (2008) "Ecology and conservation of common bottlenose dolphins *Turciops truncatus* in the Mediterranean Sea." *Mammal Review* 39: 92-123. doi: 10.1111/j.1365-2907/2008.00133.x

Brownell Jr, R. and Reeves, R. (2008) "Biological Background on Bottlenose Dolphins (*Tursiops* spp.) in the 'Live-Capture' Trade and Specifically on the Indo-Pacific Bottlenose Dolphin, *T. Aduncus*." *Convention of International Trade in Endangered Species of Wild Fauna and Flora*. AC23 Inf 5: 1-10.

Cassoff, R. M., Moore, K. M., McLellan, W. A., Barco, S. G., Rostein, D. S., and Moore, M. J. (2011) Lethal entanglement in baleen whales. Diseases of Aquatic Organisms. 96: 175-185. doi: 10.3354/dao02385.

Dahdouh-Guebas, F. (2002). The use of remote sensing and GIS in the sustainable management of tropical coastal ecosystems. *Environment, development and sustainability*. 4(2): 92-112.

Dolman, S., Williams-Grey, V., Asmutis-Silva, R., and Issac, S. (2006) Vessel collisions and cetaceans: What happens when they don't miss the boat. *A WDCS Science Report* doi: 10.1080/00288330.3013.866578

Dwyer, S. L., Kozmain-Ledward, L., and Stockin, K. A. (2014) Short-term survival of severe propeller strike injuries and observations on wound progression in bottlenose dolphin. *New Zealand Journal of Marine and Freshwater Research.* 48(2): 294-302. http://dx.doi.org/10.1080/00288330.2013.866578

Florida's Ocean Alliance (2013) "Florida's Oceans and Coasts: An Economic and Cluster Analysis" *Florida's Ocean Alliance*

FWC (2015) Economic Impact of Saltwater Fishing in Florida. *Florida Fish and Wildlife Conservation Commission*. < http://myfwc.com/conservation/value/saltwater-fishing/>

Gomrecic, M. D., Galov, A., Govercic, T., Skrtic, D., Arbanasic, H., and Gomercic, H. (2008) Bottlenose Dolphin (*Tursiops truncatus*) depredation resulting in larynx strangulation with gill-net parts. *Marine Mammal Science*. 25(2): 392-401. doi: 10.1111/j.1748-7692.2008.00259.x

Green, M. A., McFee, W. E., and N. Levine. (2010). "A GIS analysis of coastal development and trends in bottlenose dolphin strandings in Charleston, SC: implications for coastal marine spatial planning." *NOAA Technical Memorandum* NOS NCCOS 124. 56 pp.

Gyory, J., Rowe, E. Mariano, A.J., Ryan, E.H. (2013) "The Florida Current." *Ocean Surface Currents.* http://oceancurrents.rsmas.miami.edu/atlantic/florida.html

Hastie, G. D., Wilson, B., Wilson, L. J., Parons, K. M., Thompson, P. M. (2004) "Functional mechanisms underlying cetacean distribution patterns: hotspots for bottlenose dolphins are linked to foraging." *Marine Biology*. 144: 397-403

Jacobsen, J. K., Massey, L., and Gulland, F. (2010) "Fatal ingestion of floating net debris by two sperm whale (*Physeter macrocephalus*)." *Marine Pollution Bulletin*. 60(5): 765-767. doi: 10.1016/j.marpolbul.2010.03.008.

Johnston, M.W., Purkis, S. J. (2013) "Modeling the Potential Spread of the Recently Identified Non-Native Panther Grouper (*Chromileptes altivelis*) in the Atlantic Using a Cellular Automaton Approach." *PLoS ONE* 8(8): e73023. doi:10.1371/journal.pone.0073023

Laist, D. "Marine Debris Entanglement and Ghost fishing: A Cryptic Type of Bycatch?" *Conference Paper: Solving Bycatch: Considerations for Today and Tomorrow*.

Lowry, L., Laist, D.W., and Taylor, E. (2007) "Endangered, Threatened, and Depleted Marine Mammals in U.S. Waters." *Marine Mammal Commission*.

Mattson, R.A., Frazer, T.K., Hale, J., Blitch, S., Ahijevych, L. (2006). "Florida Big Bend." United States Geological Survey. Accessed: 26 Jan 2017. <https://pubs.usgs.gov/sir/2006/5287/pdf/FloridaBigBend.pdf>

McCabe, E.J.B., Gannon, D.P., Barros, N.B., Wells, R.S. (2010) "Prey selection by resident common bottlenose dolphins (*tursiops truncatus*) in Sarasota Bay, Florida. *Mar Biol*. 157: 931-942. doi: 10.1007/s00227-009-1371-2

McDonald, S. L., Lewison, R.L., Read, A.J. (2016) "Evaluating the efficacy of environmental legislation: A case study from the US marine mammal Take Reduction Planning process." *Global Ecology and Conservation*. 5:1-11. Doi:10.1016/j.gecco.2015.11.009

Mcfee, W.E., Pennington, P.L., Burdett, L.G., Powell, J.W.B., Schwacke, J.H., Dockery, F.E., (2007) "Assessing movements of three buoy line types using DSTmilli logger: implications for entanglements of bottlenose dolphins in the crab pot fishery. *NOAA Technical Memorandum NOS NCCOS*. 67: 58p.

McLellan, W.A., Mead, J.G., Potter, C.W., Pabst, D.A. (2002) "Analysing 25 years of bottlenose dolphin (*Tursiops truncatus*) strandings along the Atlantic coast of the USA: do historic records support the coastal migratory stock hypothesis?" *J. Cetacean Res. Manage.* 4(3): 297-304

Moore, J. C. (1953) Distribution of Marine Mammals to Florida Waters. *American Midland Naturalist*. 49(1): 117-158.

Moore, M. J., van der Hoop, J., Barco, S. G., Costidis, A. M., Gulland, F. M., Jepson, P. D., Moore, K. T., Raverty, S., McLellan, W. A. (2013) "Criteria and case definitions for serious injury and death of pinnipeds and cetaceans caused by anthropogenic trauma." *Diseases of Aquatic Organisms*. 103: 229-264. Doi: 10.3354/dao02566.

National Oceanic and Atmospheric Administration (NOAA). (1998) "Population: Distribution, Density, and Growth." *NOAA's State of the Coast Report*. http://oceanservice.noaa.gov/websites/retiredsites/sotc_pdf/POP.PDF

National Oceanic and Atmospheric Administration (NOAA). (2006) "Taking of Marine Mammals Incidental to Commercial Fishing Operations; Bottlenose Dolphin Take

Reduction Plan Regulations; Sea Turtle Conservation; Restrictions to Fishing Activities." *Federal Register.* 71(80): 24776-24797

National Oceanic and Atmospheric Administration (NOAA). (2013) "Southeast U.S. Marine Mammal Stranding Network 1-877-WHALE HELP (1-877-942-5342)." *NOAA Fisheries Southeast Regional Office*.

National Oceanic and Atmospheric Administration (NOAA). (2014b) "Protected Resource Glossary" *NOAA Fisheries* <http://www.nmfs.noaa.gov/pr/glossary.htm>

National Oceanic and Atmospheric Administration Marine Debris Program (2014c) "Report on the Entanglement of Marine Species in Marine Debris with an Emphasis on Species in the United States" Silver Springs, MD. 28 pp.

National Oceanic and Atmospheric Administration (NOAA). (2015a) "CITES" *NOAA Fisheries* <http://www.fisheries.noaa.gov/ia/agreements/global_agreements/cites_page/cites.html>

National Oceanic and Atmospheric Administration (NOAA). (2015b) "Marine Mammal Stock Assessment Reports (SARs) by Species/Stock." *NOAA Fisheries*. <http://www.fisheries.noaa.gov/pr/sars/species.htm#bottlenose>

National Oceanic and Atmospheric Administration (NOAA). (2015c) "Bottlenose Dolphin (*Tursiops truncatus*)" *NOAA Fisheries*. <http://www.nmfs.noaa.gov/pr/species/mammals/dolphins/bottlenose-dolphin.html>

National Oceanic and Atmospheric Administration (NOAA). (2013) "Southeast U.S. Marine Mammal Stranding Network 1-877-WHALE HELP (1-877-942-5342)." *NOAA Fisheries Southeast Regional Office*.

Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). "Future coastal population growth and exposure to sea-level rise and coastal flooding - A global assessment." *PLoS One* 10(3) doi:http://dx.doi.org/10.1371/journal.pone.0118571

Noke, W.D. and Odell, D.K. (2002) "Interactions between the Indian River Lagoon blue crab fishery and the bottlenose dolphin, *Tursiops truncates*. *Mar. Mamm. Sci*. 18: 819-832

Nowacek, S. M., Wells, R. S., and Solow, A. R. (2001) Short-term Effects of Boat Traffic on Bottlenose Dolphins, *Tursiops truncatus*, in Sarasota Bay, Florida. *Marine Mammal Science*. 17(4): 673-688.

Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O.V., Doremus, G., Huon, M., Ridoux, V. (2012) "The significance of stranding data as indicators of cetacean populations at sea: Modelling the drift of cetacean carcasses." *Ecological Indicators.* 18: 278-290.

Powell, J. R. and Wells, R. S. (2011). "Recreational fishing depredation and associated behaviors involving common bottlenose dolphins (Tursiops truncatus) in Sarasota Bay, Florida" *Marine Mammal Science.* 27(1): 111-129. DOI: 10.1111/j.1748-7692.2010.00401.x

Read, A. J. and Murray, K. T. (2000) Gross Evidence of Human-Induced Mortality in Small Cetaceans. *NOAA Technical MemorandumNMFS NMFS-OPR*. 15: 1-20.

Reynolds III, J.E. and Odell, D. K. (1991) "An Assessment of the Accomplishments of the Regional Marine Mammal Stranding Networks and Some Recommendations

for Enhancing Their Productivity in the Future." *NOAA Technical Report NMFS 98*.

Reynolds, J.E. III, R.S. Wells, and S.D. Eide. (2000). "The Bottlenose Dolphin: Biology and Conservation." *Marine Mammalsof the World: A Comprehensive Guide to Their Identification*. 289 pp.

Ritter, F. (2012) Collisions of sailing vessels with cetaceans worldwide: First insights into a seemingly growing problem. *Journal of Cetacean Research and Management.* 12(1): 119-127.

Rossman, S.(2014) "The foraging habits of bottlenose dolphins: insights into temporal, demographic, and individual variation." *Michigan State University Dissertation*.

Stelfox, M., Hudgins, J., Sweet, M. (2016) "A review of ghost gear entanglement amongst marine mammals, reptiles, and elasmobranchs" *Marine Pollution Bulletin*. <http://dx.doi.org/10.1016/j.marpolbul.2016.06034>

U.S. Department of the Interior, Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau. (2011). "National Survey of Fishing, Hunting, and Wildlife-Associated Recreation" 143p.

Van Waerebeek, K., Baker, A. N., Feliz, F., Gedamke, J., Iniguez, M., Sanino, G. P., Secchi, E., Sutaria, D., van Helden, A., and Wang, Y. (2007) Vessel Collisions with Small Cetaceans Worldwide and with Large Whales in the Southern Hemisphere, an Initial Assessment. *Latin American Journal of Aquatic Mammals.* 6(1): 43-69. doi: 10.5597/lajam00109.

Wagner, A. N. (2015) "A Comparative Analysis of the Status of the U.S. Marine Mammal Stock Assessment Program." *Master's Project for Nicholas School of the Environment of Duke University*.

Waring, G.T., Josephson, E., Maze-Foley, K., and Rosel, P.E. (2014) "U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2013" *NOAA Tech Memo NMFS-NE-228*

-

Waring GT, Josephson E, Maze-Foley K, Rosel, PE, editors. (2015). "US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2014". *NOAA Tech Memo NMFS* doi: 10.7289/V5TQ5ZH0

Wells, R., Scott, M. (1997) "Seasonal incidence of boat strikes on bottlenose dolphins near Sarasota, Florida." *Marine Mammal Science.* 13(3): 475-480.

Wells, R. S., Allen, J. B., Hofmann, S., Fauquier, D., and Scott, M. D. (2008) Consequences of injuries on survival and reproduction of common bottlenose dolphin (*Tursiops truncatus*) along the west coast of Florida. *Marine Mammal Science.* 24(4): 774-794. doi: 10.1111/j.1748-7692.2008.00212.x.

Wilkinson, D. and Worthy, G. A. J. (1999) Marine Mammal Stranding Networks. *Conservation and Management of Marine Animals.* 396-411.

Wilson, S. G. and Fischetti, T. R. (2010) "Coastline Population Trends in the United States: 1960 to 2008" *U.S. Census Bureau*. P25-1139 < https://www.census.gov/prod/2010pubs/p25-1139.pdf>

Zollett, E. A., and Read, A. J. (2006) "Depredation of catch by bottlenose dolphins (*Tursiops truncatus*) in the Florida king mackerel (*Scomberomorus cavalla*) troll fishery." *Fishery Bulletin* 104: 343-349.

Appendices

Figure 14: CBD strandings from 2002 to 2014 with reporting stranding network locations.

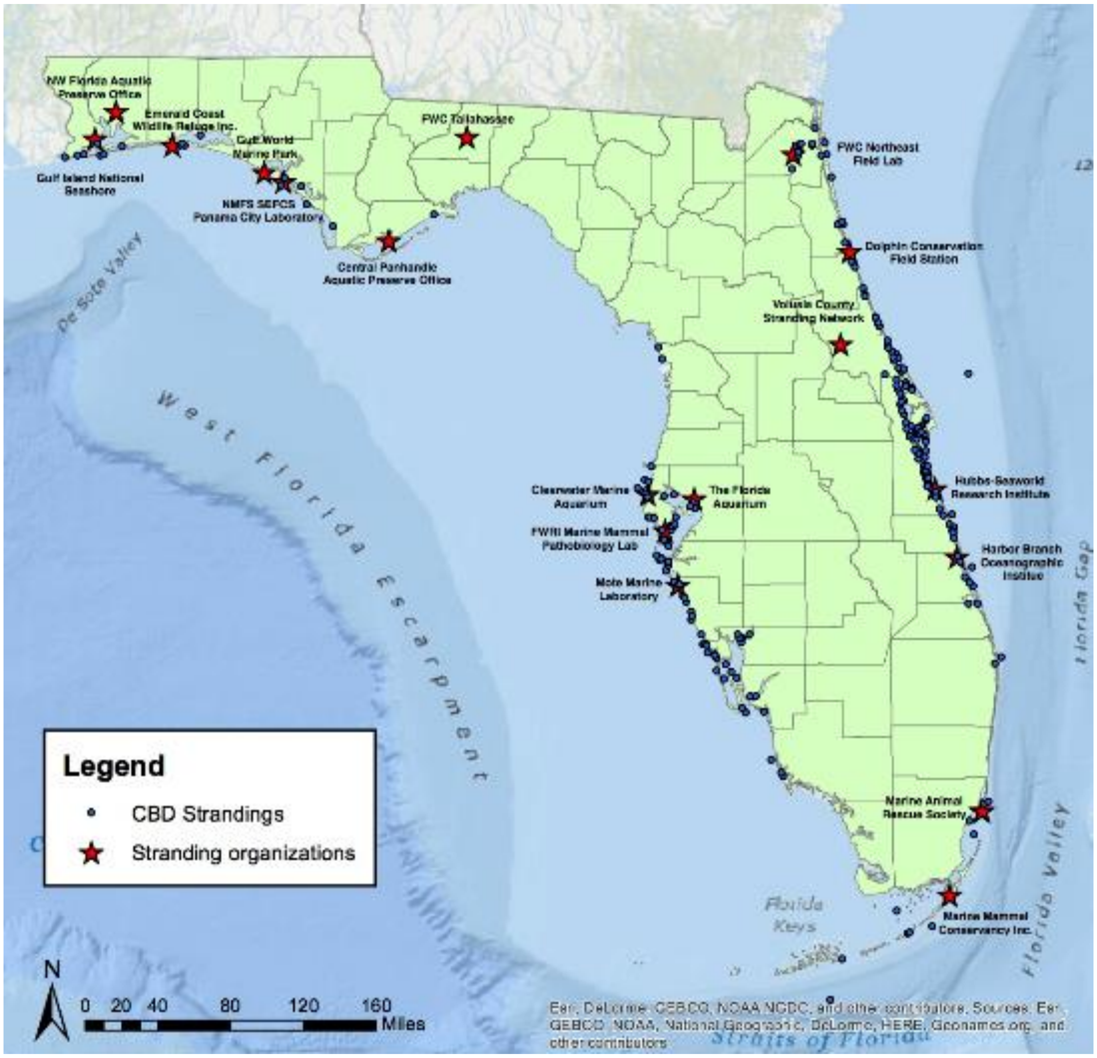


Figure 15: Example of Level A Stranding report from stranding Hubbs-0885-Tt-R-3 by Hubbs Seaworld stranding organization

Marine Mammal Stranding Report - Level A Data

SEP-30-11 09:06 AM

FIELD #: Hubbs-0885-Tt-R-3 **NMFS REGIONAL #:** SER11-2349 **NATIONAL DATABASE #:** SE-2011-1135558

COMMON NAME: BOTTLENOSE DOLPHIN **GENUS:** Tursiops **SPECIES:** truncatus

EXAMINER Name: Wendy Noke **Affiliation:** Hubbs-SeaWorld Research Institute

Address: 6295 Sea Harbor Drive Orlando, FL 32821 US **Phone:** 407-370-1650

Stranding Agreement or Authority: Hubbs-SeaWorld Research Institute

LOCATION

Country: United States

State: FL **County:** Volusia

City: New Smyrna Beach

Body of Water: Atlantic Ocean

Locality Details:
Indian River Lagoon, Mosquito Lagoon, ~200 m N of the North Cswy along the W shore

Lat: 29.04098 N
decimal degrees actual

Long: -80.90728 W
decimal degrees actual

How lat/long determined: GPS

OCCURRENCE DETAILS N Restrand GE#:

Group Event: N

If yes, Type: N Cow/Calf Pair N Mass Stranding N UME # Animals:

Findings of Human Interaction: Y

N 1.Boat Collision N 2.Shot Y 3.Fishery Interaction N 4.Other Human Interation:

How Determined: Y 1. External Exam Y 2. Internal Exam Y 3. Necropsy N 4. Other

Gear Collected? Y **Gear Disposition:** HSWRI-Pascaguola

Other Findings upon Level A: Y

Y Illness Y Injury N Pregnant N Other Findings

Describe How Determined

Y External Exam Y Internal Exam Y Necropsy
N Other

INITIAL OBSERVATION

Year: 2011 **Month:** AUG **Day**: 30

First Observed: Swimming

CONDITION AT INITIAL OBSERVATION:
ALIVE

LEVEL A EXAMINATION N *Not Able to Examine*

Year: 2011 **Month:** SEP **Day**: 09

CONDITION AT EXAMINATION
MODERATE DECOMPOSITION

INITIAL LIVE ANIMAL DISPOSITION

Y 1.Left at Site
N 2.Immediate Release at Site
N 3.Relocated
N 4.Disentangled
N 5.Died at Site
N 6.Euthanized at Site
N 7.Transferred to Rehabilitation
N 8.Died During Transport
N 9.Euthanized During Transport
N 10. Other

CONDITION/DETERMINATION

Y 1.Sick
Y 2. Injured
N 3. Out of Habitat
N 4. Deemed Releasable
N 5. Abandoned /Orphaned
N 6. Inaccessible
7. Location Hazardous:
N a. To animal
N b. To public
N 8. Unknown /CBD
N 9. Other

Comment: Intervention attempt on 2 Sept. 2011; could not locate animal

MORPHOLOGICAL DATA

Sex
MALE

Age Class

Whole Carcass Y **Partial Carcass** N

Straight length: 271 cm actual

Weight:

Photos/Videos taken: Y

Disposition:
HSWRI

TAG DATA

Tags Were:
Present at Time of Stranding (pre-existing): N
Applied during Stranding Response: N

ID#	Color	Type	*Placement	Applied	Present
				N	N
				N	N
				N	N
				N	N

* D=Dorsal; DF=Doral Fin; L-Lateral Body
LF=Left Frontl LR=Left Rear; RF=Right Front; RR=Right Rear;

WHOLE CARCASS DISPOSAL (Check One or more)

Y 1.Left at Site
N 2.Buried
N 3.Rendered
N 7.Landfill
N 9.Other:
N 4.Towed Lat Lon
N 5.Sunk Lat Lon
N 6.Frozen for Later Examination
N 8.Unknown

SPECIMEN DISPOSITION

Y 1.Scientific Collection N 2.Educational Collection
N 3.Other:

Comments:

NECROPSIED Y limited fresh

NECROPSIED BY: M. Stolen, W. Noke Durden

Date: 2011-SEP-09

Marine Mammal Stranding Report - Level A Data

ADDITIONAL REMARKS

Additional Identifier:

Hubbs-0885-Tt, Hubbs-0885-Tt-R, Hubbs-0885-Tt-R2, RIO

Additional Remark:

Known animal with three prior interventions and eight entanglements from 2008-present. Animal intially sighted on 30 August 2011 and was extremely emaciated and having difficulty surfacing; but could not be "hand caught". Animal monitored on 31 August 2011, and was seen engaging in feed and probable feed behavior. On 2 Sept. 2011 an intervention was attempted but the animal could not be located. Numerous searches by land, sea and air were conducted between initial observation and date of recovery. The last public report on 4 September 2011 (Ponce Inlet), but animal could not be located. On 8 September 2011 at ~7pm a fisher reported a dead dolphin in a remote location. Due to the setting sun, the animal was recovered at ~6:30AM via boat. The animal is a very late code 3. Eyes are scavenged. Teeth are worn (cranial teeth worn nearly to gum) and two teeth are missing. Dorsal fin is sloughing (animal IDed based on lower radio-tag notches that are still present). The flukes are entangled in thick monofilament and braided line (likely spider wire) that is cutting into the left and right leading edges of the flukes as well as the ventral midline. While the gear is no longer attached to the dorsal fin (due to decomposition), the gear matches gear photographed on 30 August 2011 and was likely initially attached through the leading edge of the dorsal fin as well as the flukes. This is further supported by line marks and open wounds (likely from abrasion) along the dorsal aspect of the peduncle. Another linear wound (slice) is present along the leading edge of the left pectoral flipper that is consistent with monofilament (or fishing line). Blubber layers are very thin (0.7-1cm). Tonsils are prominent and black. Small ulcers are present in the esophagus. All organs are autolyzed. Forestomach contains a large partially digested mullet and numerous fish bones and otoliths. Bladder contains small amount of orange urine.

Figure 16: Distribution of patrons to Brevard County ramps and marina by Sidman, 2007 survey of vessel trailers and tow vehicles.

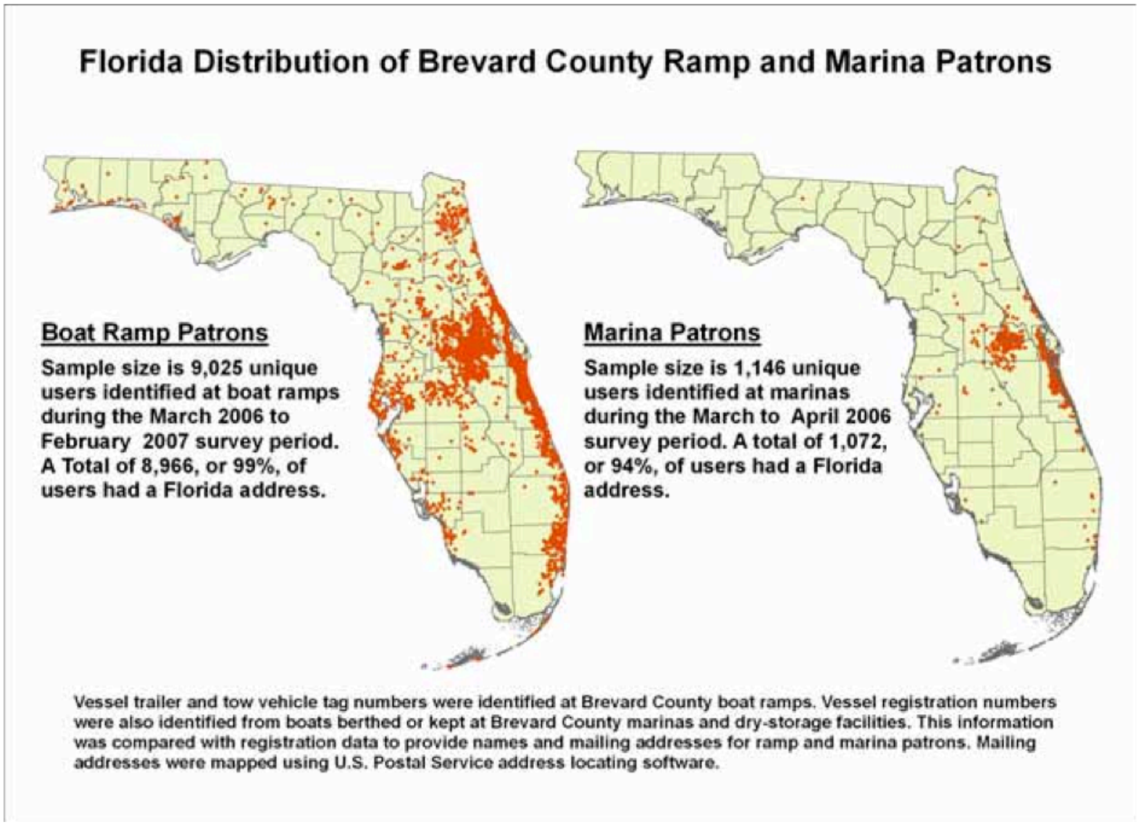


Table 6: Number of strandings, by year, associated with each fishery interaction.

Interaction/Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total
Entanglement	7	9	9	4	8	8	18	6	7	11	20	11	14	132
Ingestion	7	7	3	4	13	8	7	4	5	0	5	6	3	72
Vessel Strike	1	2	1	2	3	7	3	3	3	3	6	7	2	43
Total	**15**	**18**	**13**	**10**	**24**	**23**	**28**	**13**	**15**	**14**	**31**	**24**	**19**	**247**

Table 7: Number of strandings, by month, associated with each fishery interaction.

Interaction/ Month	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Entanglement	11	12	6	12	11	7	14	16	9	9	13	12	132
Ingestion	3	4	11	7	5	6	15	7	4	5	3	2	72
Vessel Strike	4	2	5	3	2	1	7	5	5	2	2	5	43
Total	**18**	**18**	**22**	**22**	**18**	**14**	**36**	**28**	**18**	**16**	**18**	**19**	**247**