UTILIZATION OF BODY MASS INDEX AS A HEALTH INDICATOR DURING MASS-STRANDINGS OF SHORT-FINNED PILOT WHALES (*GLOBICEPHALA MACRORHYNCHUS*)

A Thesis

by

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ABSTRACT

Short-finned pilot whales (*Globicephala macrorhynchus*) strand or beach along Florida's coasts regularly (six between the period of 2009 and 2015) and typically in mass numbers. Individual strandings can be caused by, or linked to, changes in environmental conditions, pathogens, stressors, as well as anthropogenic reasons, among others. Historically, it is not understood why an entire pod of these animals would be forced to strand or beach themselves (i.e. mass-strandings), especially when considering that many members of the pod do not exhibit signs of illness or injury. Why do the healthy pod members also strand? Can the healthy animals be isolated and saved?

Stranding data for short-finned pilot whales revealed that length and weight have a direct correlation to the medical condition of the animal at the time of stranding and such information could therefore possibly be utilized to increase survivability among the stranded. Length and weight of 24 short-finned pilot whales were used to compute Body Mass Index (BMI) and results show five young whales and multiple females fell below the plotted regression line (r^2=0.8699). In order to decipher this, a case is made herein for utilizing BMI as a health indicator to pinpoint individuals that may be deemed suitable candidates for rehabilitation and/or immediately releasable and disassociated from the sick. BMI calculations support the theory of isolating stranded individuals according to varying health status. A BMI range of 39.0 to 50.0 for adult males and 41.0 to 55.0 for adult female short-finned pilot whales is being suggested.

The present study also investigated natural events along both Florida coasts to connect plausible situations in which abrupt changes in oceanographic activity lead to disorientation of short-finned pilot whales and subsequently sends into motion a stranding scenario. A review of oceanic data and literature within the targeted geographic area supports the idea that sudden changes in sea-surface currents can affect, either directly or indirectly, the behavior of short-finned pilot whales and increase the probability of a stranding occurrence, whether individually, or in mass numbers. Cyclonic eddies and areas of coastal upwelling and downwelling can be attributed to causing or leading to the catalyst that triggers a mass-stranding of a particularly social species, such as short-finned pilot whales.

DEDICATION

This manuscript is dedicated first and foremost to the two most heart-warming and loving people I have had the pleasure of knowing; my Cuban abuelos, Luis Baeza Martinez and Maria Teresa Martinez (affectionately, Abi and Mimi). For all your love and support along every step of the way in life and for the setting of my core foundations, this is also dedicated to my loving parents, Terry and Gary Morrison and my unrelenting supportive big brother, Erik Linaje. To my amazing wife and best friend, Mariela, whose recent personal accomplishments encouraged me to follow and pursue my own, thank you from the bottom of my heart, well, for just about everything. Finally, to my children, Kevin, Jordan, and Andrew, be sure to find your passion early in life and be relentless in chasing it and remember to always carry with you a great sense or understanding of perspective (it will get you through the good and bad times) and most of all, know that I love you all very much, and that you are my ultimate motivation behind this accomplishment.

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NOMENCLATURE

BCS	Body Condition Scoring
BMI	Body Mass Index
CITES	Convention on International Trade in Endangered Species
GIS	Geographic Information Systems
GPS	Global Positioning System
ICRW	International Convention for the Regulation of Whaling
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
MMPA	U.S. Marine Mammal Protection Act
MSRA	Magnuson-Stevens Fishery Conservation and Management
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
Poddal	Pertaining to the social life structure within a pod of delphinids
SARs	Stock Assessment Reports
SFPW	Short-finned pilot whale
UME	Unusual Mortality Event

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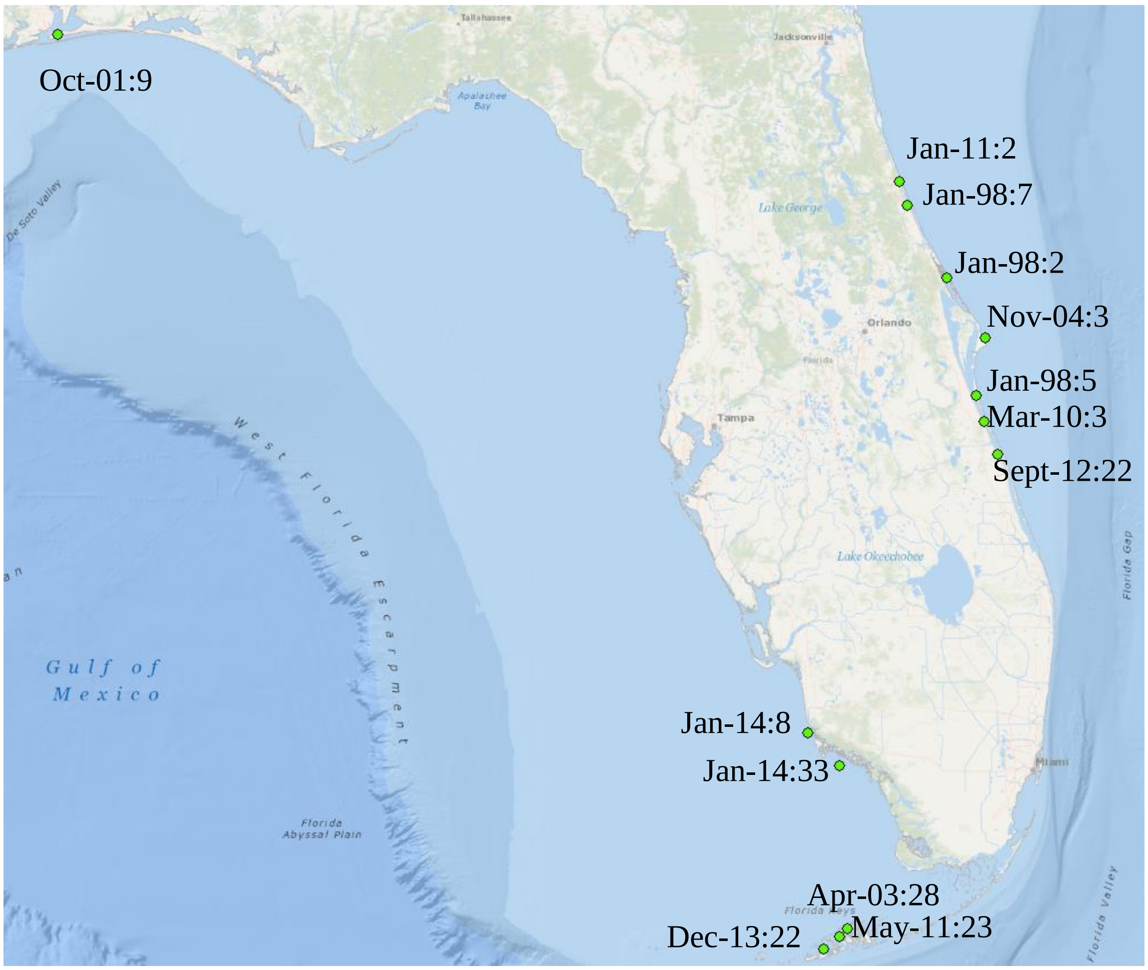
1. INTRODUCTION

1.1 Problem Statement

Cetaceans of all sizes are susceptible to stranding or beaching. Porpoises, dolphins, and whales, both mysticetes and odontocetes, may strand individually or in groups, the latter defined as a mass-stranding (Wilkinson 1991). Mass-strandings are one of three classifications of group events involving cetaceans; a stranding of a cow/calf pair and those designated as Unusual Mortality Events (UMEs), as defined under the Marine Mammal Protection Act (MMPA), are the others. The causes of these events are either unknown or ambiguous (Walsh et al. 2001).

Short-finned pilot whales (*Globicephala macrorhynchus*) are a particularly social species of cetaceans that frequently mass-strand world-wide, throughout their known range. Groups of these whales sometimes come ashore, strand, and die and these events are relatively common on beaches in Florida and the Gulf of Mexico (Geraci and Lounsbury 2005). The earliest known recordings of such phenomenon date back to 2300 BC and official records on strandings have been kept since 1840 (Rake 2010). Of particular interest in this study are those strandings that have occurred in Florida. Since 1998, there have been 13 mass-stranding events involving short-finned pilot whales along the Atlantic and Gulf of Mexico coasts of Florida (Fig. 1). Data from these events show that, on average, 11.8 individual short-finned pilot whales stranded per event, with a minimum of two individuals (multiple occurrences) and a maximum of 33 individuals in January 2014.

Figure 1. Map of short-finned pilot whale mass-stranding locations (1998-2014) in Florida (month-year: number stranded).



The response and management of a mass-stranding event involving any cetacean species is extremely complex; however, the issue is exacerbated even more so when tight-knit social groups, such as short-finned pilot whales, mass-strand. Live mass-strandings, simultaneous strandings of two or more animals (excluding the cow/calf pair), are reported to occur commonly in cetaceans with stable kin-based social structure; sperm whales (*Physeter microcephalus*), short-finned and long-finned pilot whales (*Globicephala macrorhynchus* and *Globicephala melas*), and false killer whales (*Pseudorca crassidens*) are species that frequently mass-strand (Whitehead 2003). It has been theorized that individuals within the stranding pod or group (perhaps even the suspected leader or 'pilot') are generally thought to be compromised due to disease, injury, etc., while others may be healthy (healthier), yet struggle to cope with the trauma of stranding. Common responses to managing a mass-stranding event is to push the animals back out to sea, as logistically this is the most feasible course of action as the capacity of a rehabilitation group would easily be overwhelmed by admitting more animals than what can possibly be facilitated. This solution, which assumes that all is well with both the individuals and the group as a whole, has met with mixed success (Odell et al. 1980). On the west coast of Florida, it has been common practice for cetaceans that strand to be pushed back into the water and often times the animals re-strand themselves, each time with increased mortality (Walsh, et al. 2001), as was the case in the 2014 event that occurred on the sandy, seagrass shores of Florida Bay. Therefore, at the onset of a mass-stranding event, time is of the essence, and it is critical to triage the animals swiftly to gather as much empirical data as possible, especially health status determination, in an effort to distinguish between sick/injured and healthy individuals for recognition of the strongest short-finned pilot whales with the greatest likelihood of survival.

In order to discerningly diagnose the animals and differentiate between those that may be diseased, malnourished, or injured and those exuding more ‘normative’ disposition or behavior with the appearance of being healthy, without waiting for laboratory-based hematology analysis, I hypothesize herein that the use of Body Mass Index (BMI) as a health indicator may prove to be a new approach to increase survivability of stranded cetaceans. Length to weight comparisons using BMI have been a focal point or a secondary objective of many studies related to a number of cetacean species as a model for health, including spinner dolphins (*Stenella longirostris*) (Perrin et al. 2005), fin whales (*Balaenoptera physalus*), sei whales (*B. borealis*) (Vikingsson et al. 1988), and bottlenose dolphins (*Tursiops truncatus*) (Gryzbek 2013 [thesis]). As such, this is a much needed area of further analysis and study. A simplistic BMI equation that can be computed in the field after obtaining basic morphometric information pertinent to the stranded animals would facilitate physical assessments by the on-site veterinarian and make a stranding coordinator’s decision (rehabilitation, return, euthanasia, etc.) much more objective, informative, and therefore, easier - in theory. Managing marine mammal populations requires estimates of vital statistics (growth, mortality, fertility, etc.) that are either problematic or impossible to obtain by direct sampling in the field (Trites and Pauly 1998). This research study will provide a new approach to collecting substantive, high-quality data and information that marine mammal managers can use as real-time health indicators while in the field.

1.2 Research Objectives

Primarily, the objective of this study was to increase the survivability of stranded marine mammals through the utilization of health indicators, in particular, BMI while in the field and establishing strategic parameters as a base model for short-finned pilot whales. A secondary study objective was to investigate the connectivity between cetacean mass-strandings and particular environmental conditions at the time of or just prior to a stranding event. In this research, a relationship was examined between Florida’s oceanic phenomena such as cyclonic eddies and upwelling and/or downwelling systems, and specific short-finned pilot whale stranding occurrences. A final, but important, objective of this work was to provide an up-to-date and modernized framework of stranding response initiatives that details what and how data should be collected at the stranding site in order to make the most effective management decisions possible. The collected data could be uploaded to and used by a national database so that it can be shared with various stranding networks and marine mammal managers.

2. REVIEW OF LEGAL REGIMES

Short-finned pilot whales are protected and managed under varying agencies and statutes, both nationally and internationally. Listed below is a review of laws and literature pertaining to the studied species.

2.1 U.S. Marine Mammal Protection Act (MMPA) Overview

The MMPA of 1972 protects all marine mammals by means of prohibiting the taking of said animals in U.S. waters. The MMPA was established at a time of growing concern regarding whale stocks and aimed to establish protocols on how to manage and protect marine mammals and their ecosystems. Therefore, it is unlawful to take a marine mammal. The MMPA defines “take” as “to hunt, harass, capture, or kill or the attempt to do so.” The Act is governed by the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce. Section 117 of the MMPA requires that NOAA/National Marine Fisheries Service (NMFS) conduct stock assessment reports (SARs) for populations of all marine mammals within U.S. jurisdictional waters, including short-finned pilot whale Atlantic and Gulf of Mexico stocks.

2.1.1 Section 404 of the MMPA

Many short-finned pilot whale mass-stranding events have fallen under the designation of an unusual mortality event (UME). An UME is defined within the MMPA as "a stranding that is unexpected, involves a significant die-off of any marine mammal population, and demands immediate response." This Section was enacted with the intent to gather more data on the bio-toxins, pathogens, pollutants, or environmental factors that may have attributed to a marine mammal stranding event.

2.1.2 Section 408 of the MMPA

Section 408 of the MMPA, also referred to as the John H. Prescott Marine Mammal Rescue Assistance Grant Program, outlines duties and responsibilities, and funds organizations dedicated to the recovery or rehabilitation of marine mammals, live or dead. Data that have been obtained during the short-finned pilot whale mass-stranding events in Florida were collected through the use of equipment, tools, facilities, and personnel funded by the John H. Prescott Marine Mammal Rescue Assistance Grant, via various stranding organizations that operate under the authority of the federal government, and were done so in adherence to the Grant's stipulations.

2.2 Magnuson-Stevens Act

The Magnuson-Stevens Fishery Conservation and Management Reauthorization Act of 2006 (MSRA) fortifies international fisheries management and organizations and addresses illegal and unregulated fishing and bycatch of protected living marine resources. Both *Globicephala macrorhynchus* and *Globicephala melas* are protected as living marine resources under this Act. The overseen area of the preceding Magnuson-Stevens Fishery Conservation and Management Act of 1976 (FCMA) extends as far out as 200 nautical miles from shore. The research, management, and enforcement of the MSRA is also governed by NOAA.

2.3 International Convention for the Regulation of Whaling (ICRW)

Signed for in 1946 by fifteen adherent countries, the international law was set in motion under the acknowledgment that whale stocks were plummeting and over-fished. Soon thereafter, the ICRW was ratified as the IWC and was meant to sustain whale stocks.

2.3.1 International Whaling Commission (IWC)

The IWC establishes the importance of understanding the dynamics of cetacean biology and provides guidance on how to best manage certain populations. The IWC funds many conservation initiatives involving delphinids.

2.4 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)

Although the short-finned pilot whale is not legally listed as an endangered species under CITES Appendix II, the trade of short-finned pilot whales, and all cetacean specimens, live or dead, is prohibited. CITES acknowledges this important classification through the recommendations set forth by the IWC. Appendix II is defined as any species that is not currently threatened with extinction but may become so without proper management.

2.5 International Union for Conservation of Nature (IUCN)

Headquartered in Switzerland, the IUCN was founded in 1948 for the purpose of conserving nature. The organization provides expertise on many environmental issues and has developed a classification system for identifying species that are in danger of global extinction. Many cetaceans are recognized by the IUCN and are listed as 'Critically Endangered' or 'Endangered.' Short-finned pilot whales are categorized under the IUCN as 'Data Deficient,' meaning that presently, insufficient data exists to make an adequate assessment of extinction potential, but is still acknowledged as a category of great concern and calls for continual study.

3. RESEARCH DESIGN

3.1 Biology and Ecology

Short-finned pilot whales (*Globicephala macrorhynchus*) are large-sized delphinids, ranging from 3.7 to 5.5 meters and 1,000 to 3,000 kg (NOAA 2012). Their diet is mainly comprised of squid which may be an exclusive food item for some pods. As with other members of the family delphinidae, short-finned pilot whales echolocate to hunt, navigate, and communicate. Disparate from other pelagic cetaceans, pilot whales tend to be free of barnacles and microorganisms because they secrete an enzymatic gel which denatures proteins and carbohydrates through microscopic pores and nanoridges (Life 2011). They do not usually range north of 50°N or south of 40°S (Jefferson et al. 1993) and travel in pods of anywhere between 25 to 50 members. These may be groups of closely related females of all ages and their offspring, plus one or a few adult males (Gray 1846). As has been studied in long-finned pilot whales (*Globicephala melas)*, short-finned pilot whales are sexually dimorphic (Lockyer 1993). Atlantic short-finned pilot whales tend to be smaller in length and mass when compared to Pacific populations, and even more diminutive when compared to *G. melas*. Short-finned pilot whales are deemed polygynous (Kasuya and Marsh 1984), like *G. melas* (Sergeant 1962). Pacific males mature at a mean length of 422.1 cm, equivalent to a mean age of 17 years, while females mature (sexually) between seven to 12 years in Pacific populations (Kasuya and Marsh 1984). Gestation within the *macrorhynchus* species is approximately 12 to 15 months with calving occurring every three to five years (American Cetacean Society 2006). Life spans for short-finned pilot whales average 45 years for males and 60 years for females (NOAA 2012), with lactation known to occur in females over 50 years old (America Cetacean Society 2006). It can be safely assumed that Atlantic populations of short-finned pilot whales would have lower values across the board, when assessed comparably with Pacific populations, yet there is a lack of sufficient data in this regard.

Short-finned pilot whales have not been well studied in Florida because they are typically found offshore at up to average depths of 305 m (NOAA 2012), with occasional maximum dives of 487 m (Bowers et al. 2007) in order to catch squid. Most sightings are opportunistic and therefore, data are scarce. It is thought that short-finned pilot whales migrate southerly along the Florida Atlantic shelf during winter and continue along the Florida Straits and into the Gulf of Mexico as they follow migrating squid inshore (Reilly 1990) and vice versa in the summer months. Although the species is rarely seen, short-finned pilot whales mass-strand more frequently than any other cetacean species in Florida (Walker et al. 2005). Most available age and growth data for cetacean populations have come from analyses of dead individuals or those mass-stranded or individuals caught as by-catch in fisheries interactions. Opportunities to collect similar information on living populations are rare (McFee et al. 2012).

It is critically important to collect all relevant data during mass-stranding events in order to catalogue individuals, assess stock information, determine health, and help monitor future events, because only a small window of opportunity exists to interact with these animals. Mass-stranding events provide a great opportunity to collect data and samples to learn about these infrequently encountered animals, especially in relation to stock structure, genetics, maternal and fetal health, and life history of not only the individual but of the entire pod.

3.2 Environmental Factors

Mass-stranding events may be triggered by environmental conditions such as topographic and bathymetric characteristics, currents and tides, storms, acoustic events and more (Walsh et al. 2001). The study area has been limited to the Atlantic and the Gulf of Mexico coasts of Florida, and in particular, along the Florida Straits, currents and tides may play a substantial role in the days or weeks prior to an active stranding. The Florida Current is a branch of the Gulf Stream system within the Florida Straits, connected to the Loop Current in the Gulf of Mexico (Olson 1991). Cyclonic cold-core eddies travel along this system, entering in the vicinity of the Dry Tortugas and evolving along the Florida Keys island chain and coral reefs (Kourafalou and Kang 2012). This geographic area is of keen interest as it appears that during normal current/climatic/temperate conditions, short-finned pilot whales may continue traveling just off the shelf of the Florida Straits and proceed to enter the Gulf of Mexico, bypassing the Florida Keys reef tract all together. However, changes in environmental conditions (due to any number of factors, perhaps even climate change and sea-level rise) may shift the ‘normal’ currents and eddies closer to shore, along the shelf, perhaps strong enough to capture schooling squid. Cyclonic eddies have been shown to play a significant role in larval recruitment along the Florida Keys reef tract (Archer et al. 2015). It is not suggested that these currents or eddies are strong enough to throw pilot whales off-course but the whales may follow prey through these areas and into entirely different and unexplored underwater channels which could become treacherous with outgoing tides. Evidence of this are the mass-stranding events that transpired within the shallows of the Florida Keys (bay side) with water depths averaging between only 0.75 and 2.7 meters, well outside of known habitat or foraging ranges for short-finned pilot whales accustomed to greater water depths, not encompassed by landmasses and sand flats.

Other scenarios correlate with seasonal timing of summer upwelling occurrences along the Atlantic coast of Florida. It is speculated that some short-finned pilot whale populations navigate northerly along Florida's east coast during the summer months. Cetaceans respond to changes in water properties, and thus, upwelling and downwelling conditions may influence their movements (Walker et al. 2005), or that of their preferred prey. Perhaps we may be better equipped to, not necessarily predict, but anticipate a stranding by utilizing this knowledge because the original problem may have occurred weeks or months before, out at sea (Walsh et al. 2001).

In a 1998 Florida mass-stranding event of short-finned pilot whales, a shift in wind from upwelling to downwelling was reported four days prior to the stranding event (Walker et al. 2005) in the area of Flagler Beach. However, conflicting research suggests that wind conditions do not appear to be a controlling mechanism in the Straits of Florida (Archer et al. 2015). Seasonal upwelling and downwelling events occur along the Atlantic coast of Florida, primarily between Jacksonville and Vero Beach. Seawater along the east coast of Florida tends to have an apparently anomalous decrease in temperature during the summer months (Taylor and Stewart Jr. 1959). The average prevailing winds during the winter are southward, that is, upwelling-favorable on the west coast of Florida and downwelling-favorable on the east coast (Fernald and Purdum 1981).

3.3 Hypothesis

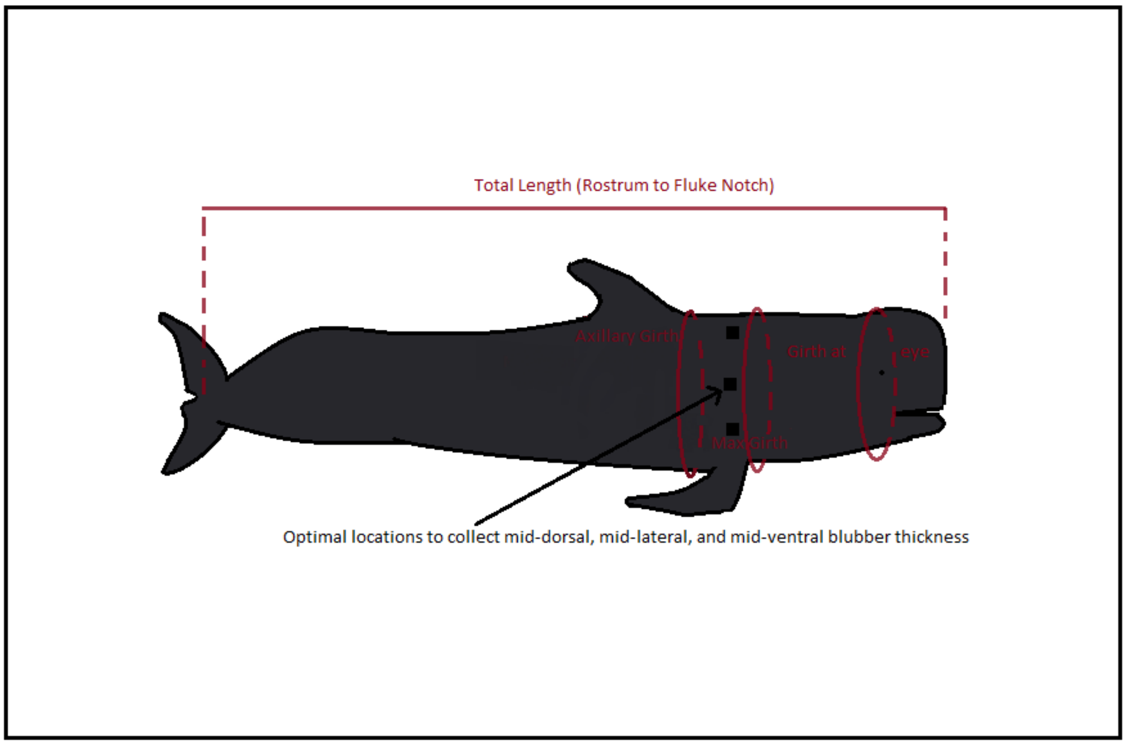
The adaptation of real-time, field-tested calculations to gauge the percentile of healthy, yet stranded short-finned pilot whales, could be a significant management improvement for the marine mammal scientific community. Through the use of a BMI integrated analysis, based on regressions from length versus mass, length versus girth, or even related to blubber thickness, I hypothesize that moderately healthy (BMI > 35.0) animals may be targeted for treatment, hydrated, and potentially repatriated offshore, and eventually returned to their natural habitat, increasing the survivability of stranded animals. Presumably, those animals that are less than moderately healthy should stand a better chance of survival if proper diagnosis and treatment are afforded expeditiously. Secondarily, it is hypothesized that Florida's oceanographic oddities may directly or indirectly lead to mass-stranding events. Knowing the periods of upwelling and downwelling coastal currents and frequency, duration, and strength of cyclonic eddies may, in theory, help anticipate short-finned pilot whale stranding events, contingent on direct observation of a pelagic species within coastal zones.

3.4 Materials and Methods

Raw data were obtained from NOAA/NMFS cetacean data records for strandings in the Southeast region of their district, particularly Florida; spanning from 1998 through 2014. ‘Level A’ data sheets are publically available and typically contain basic morphologic information such as length, weight, girth, blubber thickness, tooth counts, and more (NOAA Form 89-864 rev. 2004). Geographic information as to the stranding locations, displayed on data sheets as GPS points or latitude/longitude, was also collected from the Level A forms. Information was extracted from necropsy notes taken at the time of a stranding or for those performed shortly thereafter. Observational information at the time of stranding such as body condition, injuries, presence of parasites, etc. was extracted from Level A data sheets and cetacean data records and included in the research. Any indication as to suspected group leaders (males) based on length and/or mass found within reports, was assessed and considered to be of great supplemental value to this study.

The following standard methods are described as a practical approach to gathering short-finned pilot whale field measurements to ensure accuracy (Geraci and Lounsbury 2005): total length obtained by measuring a straight line from the tip of rostrum to the fluke notch; girths measured at the axilla, eye, and just cranial to the dorsal fin base (Fig. 2). If it is not feasible to obtain a full girth measurement due to rough surf or other strenuous factors on a stranding beach site, an attempt should be made to gather a half girth that can then be extrapolated.

Figure 2. Short-finned pilot whale illustration (original-K.Linaje) depicting areas for girth measurements, total length, and blubber sampling.



At times where weight could not be recorded, which occurred with some frequency due to the nature of strandings taking place at remote geographic locations where necessary equipment could not logistically be utilized, a correlation between length and girth (Hart et al. 2013) was attempted (i.e. maximum girth, girth at axilla, girth at eyes) in order to obtain a workable BMI ([weight x 703]/[length x length]). As a dimorphic species, distinctions were made between males and females, age class, and seasons. Body fat (girth) and blubber thickness are known to increase in the winter in *Globicephala melas* (Lockyer 1993), and therefore seasonal timing should also be taken into account when determining health status of stranded pilot whales, along with the former. Depletion of these energy reserves by summer implies that decreased prey availability may coincide with increased demand for energy devoted to reproduction during the period winter to summer (Lockyer 1993).

GIS was used via ArcGIS Advanced 2.0 to depict spatial and temporal relations of the listed mass-stranding events of short-finned pilot whales in relation to the proximity of upwelling/downwelling phenomena and eddy formation/depletion. Statistical calculations were processed using SPSS statistics software and graphed via Microsoft Excel.

3.5 Stranding Response

Cetaceans in the geographic range of this study are managed under the umbrella of the Southeast Fisheries Science Center division of the NOAA/NMFS and therefore the initial instruction to engage in stranding response comes from NOAA officials. Typical response for individual cetacean strandings is less complicated than that of a mass-stranding. Of obvious difference is the increased number of stranded animals; however, the subsequent personnel necessary to respond and to facilitate rescue and/or rehabilitation activities can be overwhelming. Therefore, responses can be multi-agency efforts, drawing support from NMFS authorized organizations spanning widespread geographic areas. The general public is typically not aware of the financial burden associated with strandings, especially mass-strandings. Rehabilitation costs have been estimated at $157,000 per individual animal (unidentified dolphin species) for hospitalization fees, including feed and medicinal supplies (Moore et al. 2007). This does not take into account the cost or the actual response to a remote stranding site, i.e. vessel use (fuel), heavy equipment (davits or hoists), dive gear, etc. Most responders are strictly volunteers and members of stranding organizations are typically not reimbursed for their time or own expenditures for arriving at the site and any lodging, if necessary (Wilkinson and Worthy 1999). Many stranding groups are non-profit organizations and rely heavily on monetary contributions or donations from the public in order to function, however the exposure and media coverage associated with a mass-stranding event can benefit these organizations by increasing membership or volunteer registrants. It is worth noting that mass-strandings of short-finned pilot whales and other cetaceans occur at times which may be inconvenient to members or volunteers (Wilkinson and Worthy 1999), i.e. holidays, amidst tropical storms, typical work hours, etc. and is yet another marginalized cost of responding to such events.

While on the beach or shallow flats, every individual must be identified, either with roto-tags affixed to the dorsal fin, or other markings, such as wax-based paints. Once all animals have been accounted; alphabetically or numerically, they should be prepared for blood work. The aforementioned application of a roto-tag also allows for the collection of skin and connective tissue which can be retained for genetic analyses. Morphometric information should be collected at this time, in a manner as detailed in Fig. 2 however, there may be extenuating circumstances that could hinder the process. Upon the completion of all of the above, a decision must be made. The choices available to the rescue team are dependent upon the size of the pod, background of the rescue team, environmental conditions, and the availability of rehabilitation facilities (Walsh et al. 2001) and the concluded health determination.

This is where the aforementioned narrow window of time necessitates the collection and immediate analysis of BMI data in order to isolate individuals according to varying health classifications. Unfortunately, mass-stranding events can be the most logistically challenging and resource taxing of event responses, often resulting in incomplete sampling and data collection. Valuable information would be lost if the only management strategy at this time was a push back to sea. Short-finned pilot whales have been known to restrand after a push back to sea, still exhibiting signs of stress and shock caused by the initial standing (Geraci et al. 1987). The other vital decision of whether to initiate rehabilitation or turn to final disposition options, such as euthanasia (e.g. sodium pentabarbital, acepromazine, meperidine, among others), is typically made by the veterinarian on the scene. Ironically, short-finned pilot whales are one of the few cetacean species that do not currently have a set euthanasia protocol (Barco et al. 2012). The BMI health indicator could help marine mammal managers and the scientific community in the development of euthanasia protocols for short-finned pilot whales.

4. VALIDITY

It is feasible that a nominal number of threats to validity exist within the scope of this work. A large sample size of short-finned pilot whales with the necessary, pertinent measurements would be ideal; however, if the sample size is relatively small but contains all the data preferences necessary to perform this study, it would not substantially hinder the validity of this research. Supplemental data included in this study pertaining to *Globicephala melas* that tend to be larger may reduce the validity of the resultant data. However, there are studies that use regression growth curves to study a number of different cetacean species (Perrin et al. 2005 and Vikingsson et al. 1988).

Due to the unpredictability of Florida's oceanic phenomena, it may be difficult, if not impossible to pinpoint which oceanographic feature had more of an influence on marine mammal strandings. This study does not take into account mass-strandings that may be linked to other environmental factors such as red tides, bio-toxins, magnetic field disturbances, or UMEs such as the Deepwater Horizon oil spill that occurred in the Gulf of Mexico.

5. RESULTS AND DISCUSSION

The Southeast division of the NOAA, NMFS is tasked with conserving, monitoring, permitting, conducting stock assessments, and stranding response, for all marine mammals within the waters of the United States and its territories, excluding manatees, sea-otters, and polar bears as per the U.S. Marine Mammal Protection Act and the Endangered Species Act. Information from the 13 Florida mass-strandings of short-finned pilot whales studied herein was obtained from the archives of the NMFS and affiliate stranding organizations.

Data found in Table 1 were extracted and formulated on a scatter plot to express the direct linear relationship between weight and length (df=45, p=0.00) as a general indicator of health in mass-stranded short-finned pilot whales. Unfortunately, complete weight and length data was available for only 24 short-finned pilot whales, and girth measurements were scarce. Therefore, supplemental data in the form of weight and length measurements from mass-stranded *Globicephala melas*, obtained from a report Beatson and O'shea (2009) were inputted to aid in this study. Although generally larger in size, the data from *G. melas* tied into the regression scatter plot seamlessly.

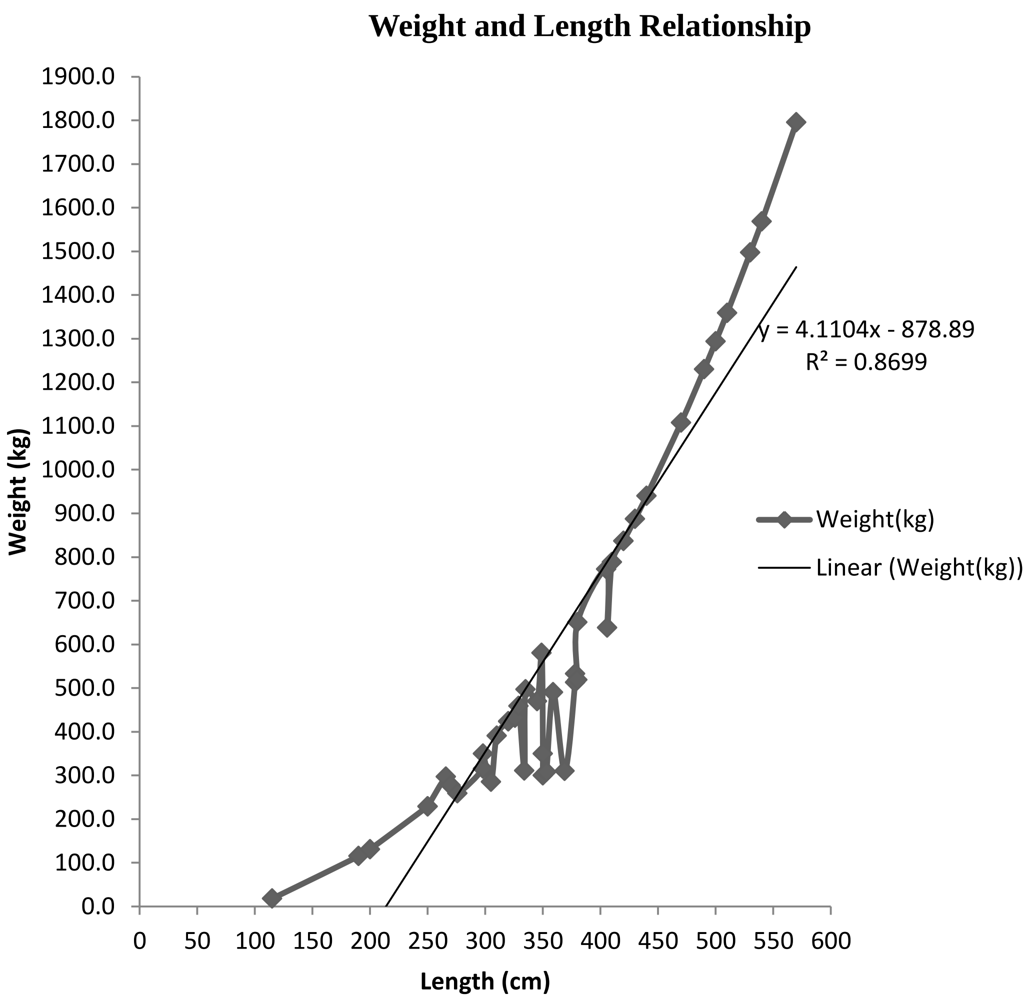
Table 1. Mass-stranded short-finned pilot whales between 1998 and 2012 with known weight and length measurements.

Stranding Date	Whale ID	Sex	Age Class	Length (cm)	Weight (kg)
SEPT 2012	HBOI-1205-Gm	male	adult	335	497
SEPT 2012	HBOI-1208-Gm	male	adult	349	580.5
SEPT 2012	HBOI-1209-Gm	unknown	unknown	329	459
SEPT 2012	HBOI-1214-Gm	female	adult	326	432
SEPT 2012	HBOI-1216-Gm	unknown	unknown	345	470
SEPT 2012	HBOI-1218-Gm	female	juvenile	305	285.5
MAY 2011	MMC-GM-1311	male	adult	378	513
MAY 2011	MMC-Gm-0711	female	pup/calf	276	259
MAY 2011	MMC-Gm-1011	female	adult	298	315.5
MAY 2011	MMC-Gm-0811	female	pup/calf	298	350
MAY 2011	MMC-Gm-0611	female	adult	359	490
MAY 2011	MMC-Gm-1111	male	adult	405	772
MAY 2011	MMC-Gm-1211	female	subadult	334	311
MAY 2011	MMC-Gm-0911	male	adult	406	638
MAY 2011	MMC-Gm-2711	unknown	adult	350	350
MAY 2011	MMC-Gm-2811	unknown	adult	350	300
JAN 2011	DCFS-11-03-Gm	female	adult	380	518.9
JAN 2011	DCFS-11-02-Gm	male	adult	378	532.5
NOV 2004	Hubbs-0485-GM	male	subadult	266	297
JAN 1998	ACS-9802-GM	female	adult	364	290
JAN 1998	ACS-9802-GM b (fetus)	male	fetus	115	18
JAN 1998	ACS-9804-GM	female	adult	353	308
JAN 1998	ACS-9807-GM	male	unknown	494	616
JAN 1998	ACS-9806-GM	female	adult	369	310

Interestingly, of the 24 short-finned pilot whale specimens plotted along the growth curve, 11 fell below the regression line (r^2 =0.869). Nine of those 11 individuals were female short-finned pilot whales, which seems to suggest females are the most vulnerable during mass-strandings, adding validity to the report made by Amano et al. 2014 (Fig. 3). Ironically, two of the outlier male short-finned pilot whales, one of which was deemed the suspected pod leader, that fell below the regression curve were released back to sea after a brief rehabilitation stint (I speculate that perhaps information on these two individuals was inputted erroneously).

The Level A cetacean data sheets and analysis examined herein indicate that in the case of the May-2011 mass-stranding off of the remote island of Cudjoe Key, Florida, many members of this pod were “healthier” than those 11 individuals whose plots fell underneath the established growth curve. Six of the pilot whales in this group appeared physically malnourished and stomach contents were bleak, containing a single squid beak or completely empty, as indicated on datasheet notations. These findings suggest that the environmental factor(s) that may have contributed to this stranding event had manifested days earlier. Also, the lack of food in the stomach supports the theory that the pod was *en route* to calving areas within the Gulf of Mexico and because they were already in a compromised state, a combination of a sizable shift in schooling squid and traveling through shallow and uncharted waters, may have proven too costly, energetically. According to data sheets, some of the pod members received a series of auditory examinations during rehabilitation and the results were positive, however it cannot be assumed that they had not already recovered from auditory trauma or that other pod members, the vast majority of which were not tested, were not suffering from acoustic related injuries.

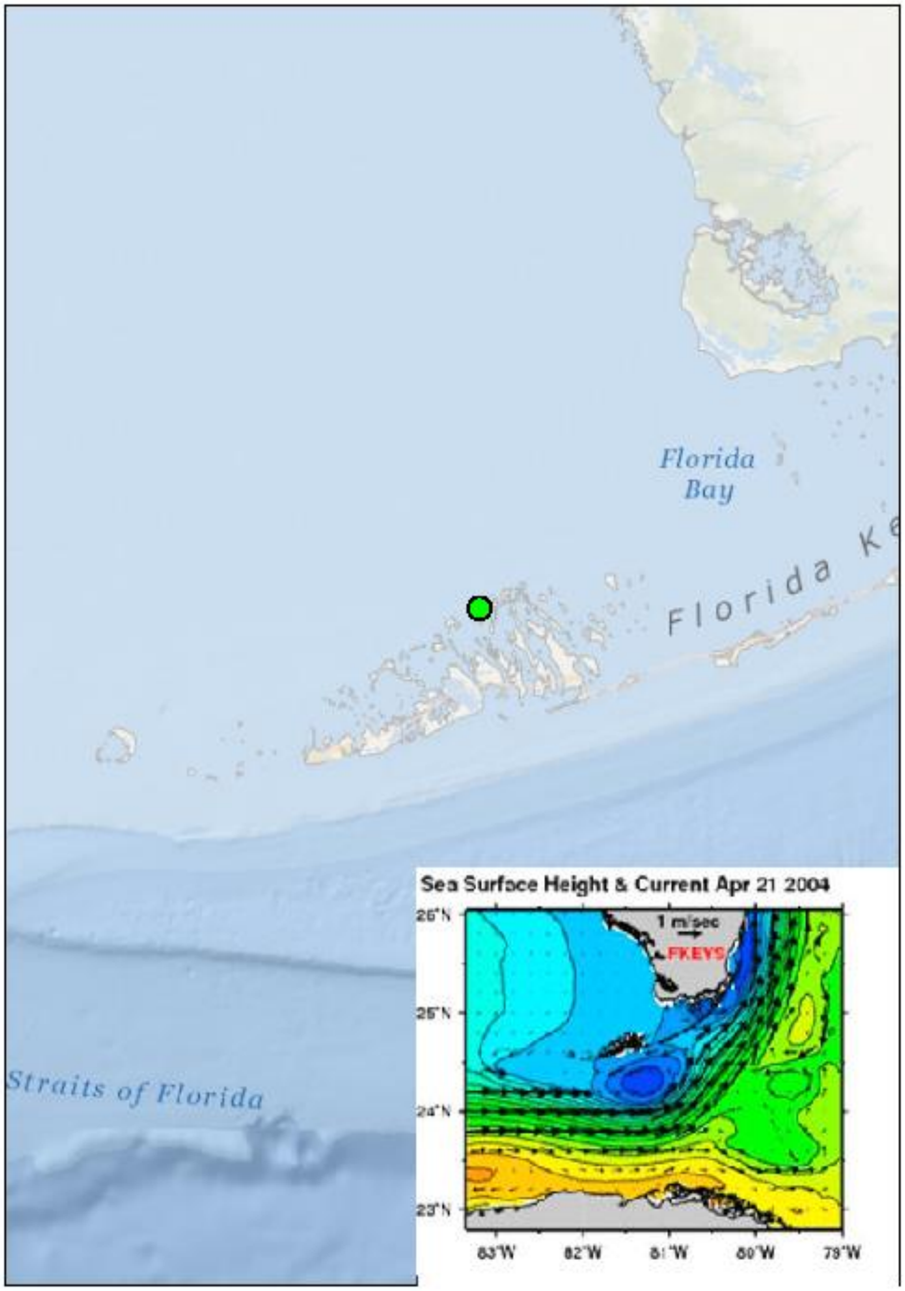
Figure 3. Scatter plot of weight (kg) versus length (cm) for mass-stranded SFPW in Florida. Data was pooled with weight/length information extracted from mass-stranded *Globicephala melas* (Beatson and O'shea 2009.)



The above mentioned event of 2011 is strikingly similar, in location and timing, to the stranding event of April-2003 in which 28 short-finned pilot whales became entrapped and stranded within the shallows of the backwaters of the lower Florida Keys.

Having personally analyzed dozens of these animals during this beaching event, it can be attested that many of them were emaciated and contained small traces of food, if any, in the sampled fore-stomachs, the latter according to necropsy reports. Unfortunately, due to the remote stranding location and extreme environmental conditions (heat, humidity, and geographic isolation), the usual morphometric data were too difficult to obtain. However, this stranding is intriguing because in April of 2004 a strong eddy system formed just off the Florida Keys, only approximately 100 km from the above-detailed stranding event, shifting currents counter-clockwise (Fig. 4). It is presumable that a similar event could have transpired within the same region, both in spatial and temporal contexts, causing or helping to cause the mass-stranding event of April-2003.

Figure 4. April 2003 SFPW mass-stranding event in relation to proximity of eddy formation in April 2004 (courtesy of Kourafalou and Kang 2012).



BMI data were available for only 20 individual short-finned pilot whales (all were members associated with large mass-strandings). Although the sample size is smaller than what would be deemed ideal, it provides the baseline for BMI data in stranded pilot whales and provides preliminary insight into the value of obtaining BMI during triage and demonstrates the need for further studies to better examine dimorphic difference between males and females, various age classes, seasonality, and pathologic findings.

The proposed baseline BMI model may be adapted to similarly sized cetacean species depending on the magnitude and details of mass-strandings, and model predictions, should improve with the collection of more data over time. The opportunity, however, for a secondary phase of research within this study to fortify said baseline exists and will be pursued.

Considering that, of the animals charted in Table 2, two males and two females were released shortly after they stranded, with calculated BMI points between 39.0 and 41.0, and along with statistical assessment, it is suggested that a prime range for optimal candidacy for short-finned pilot whale release, upon receipt of treatment at the stranding site is between 39.0 and 50.0 for adult males and 41.0 to 55.0 for adult females. Subadults and juveniles require more data and supplementary examination in addition to a BMI assessment of their own in order to evaluate health.

Certainly a complimentary tool such as the use of body condition scoring (BCS) would help reinforce these established BMI ranges. Unfortunately, at current, a set scoring system is not in place for short-finned pilot whales. There are, however, a number of species that do have an established BCS within the cetacean order. In a study by Joblon et al. (2014), short-beaked common dolphins (*Delphinus delphis*) were scaled between 1 and 4, where a score of 1 indicates extreme emaciation and an easily recognizable "peanut-head" condition. A score of 2 is noted as thin, 3 as normal and 4 as an animal with excess fat, typically indicated by a bulging melon. Emaciation in cetaceans can be defined as poor condition with a reduced blubber layer, sunken cervical region near the skull, and atrophied muscles (Kuiken 1996). Another supportive study conducted by Fair et al. (2006) involving bottlenose dolphins, BCS was established on a 1 to 5 scale, where a score of 3 is deemed ideal body condition. Comparatively, commonly used equestrian and canine BCS range between 1 and 9, where a score of 5 is categorized as moderate to ideal (Mitavite 2014 and WSAVA 2012). The above referenced BCS observational analyses should be further studied so that they can be modified and formulated to short-finned pilot whales. Hypothetically, a pilot whale with a BMI score of 41.0, but who's BCS is found to be a 1 or 2 (*Delphinus delphis* scale, for this example), may result in a reevaluated BMI of 37.0. To be able to establish both benchmarks would undoubtedly be beneficial in the field during triage and assessment.

Table 2. BMI calculations ([weight x 703]/[length x length]) for SFPW

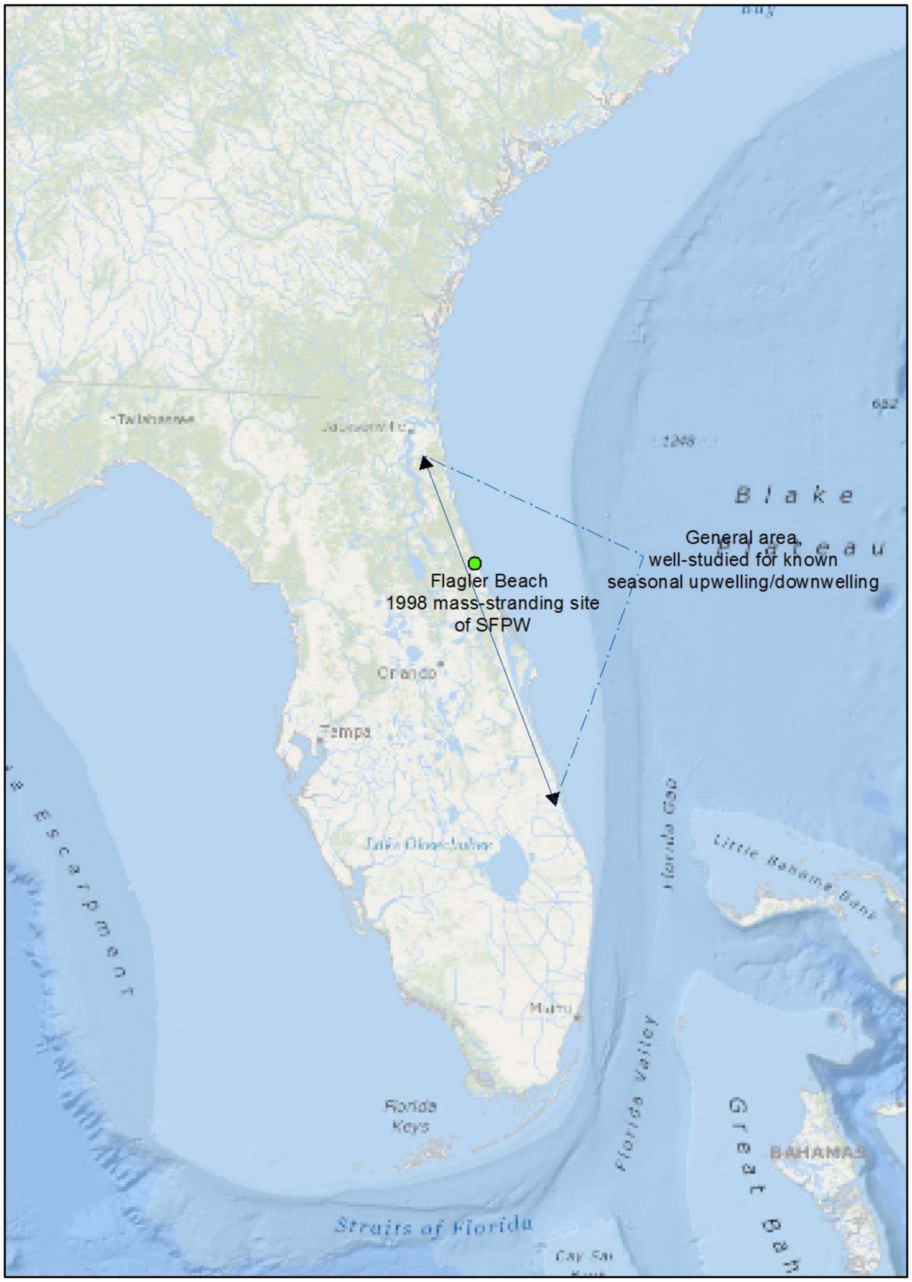
Animal ID	BMI	Sex	Age Class	Stranding Date	Final Disposition
ACS-9802-GM	39.2	F	adult	Jan-98	expired at stranding site
ACS-9804-GM	55.4	F	adult	Jan-98	euthanized at stranding site
ACS-9806-GM	50.1	F	adult	Jan-98	euthanized at stranding site
ACS-9807-GM	56.1	M	unknown	Jan-98	euthanized at stranding site
MMC-Gm-0611	38.2	F	adult	May-11	rehab/expired
MMC-Gm-0711	34.3	F	pup/calf	May-11	rehab/expired
MMC-Gm-0811	39.5	F	pup/calf	May-11	rehab/euthanized
MMC-GM-0911	39.0	M	adult	May-11	released at stranding site
MMC-Gm-1011	35.6	F	adult	May-11	rehab/euthanized
MMC-Gm-1111	47.3	M	adult	May-11	rehab/euthanized
MMC-Gm-1211	28.0	F	subadult	May-11	"sick" at stranding site
MMC-Gm-1311	41.0	M	adult	May-11	released at stranding site
MMC-Gm-2711	28.8	unknown	adult	May-11	expired at stranding site
MMC-Gm-2811	24.7	unknown	adult	May-11	expired at stranding site
DCFS-11-02-Gm	37.6	M	adult	Jan-11	euthanized at stranding site
DCFS-11-03-Gm	36.1	F	adult	Jan-11	euthanized at stranding site
HBOI-1209-Gm	42.0	unknown	unknown	Jan-11	N/A
HBOI-1214-Gm	40.8	F	unknown	Sep-12	euthanized at stranding site
HBOI-1216-Gm	40.5	unknown	unknown	Sep-12	euthanized at stranding site
HBOI-1218-Gm	30.6	M	unknown	Sep-12	euthanized at stranding site

Similar to the establishment of a baseline as mentioned above, yet perhaps more adequate of a stand-alone project, would be the potential research to set a comparable standard for juvenile short-finned pilot whales. This may prove to be challenging due to minimal data and therefore should be a point of emphasis for marine mammal officials to increase proficiencies in data collection during future stranding events.

Unlike many other regions of the United States, the Atlantic coast of Florida is one which experiences well-defined and recurring seasonal upwelling (Pitts 1993). Mainly during winter and spring seasons, strandings of short-finned pilot whales occurred on the east and southwest coasts, coinciding with the occurrence of downwelling-favorable winds (Walker et al. 2005). A major upwelling event, crossing the entire shelf and decreasing temperatures 6-10°C for several weeks, is common for mid to late summer (Pitts and Smith 1997). Cetaceans are known to track frontal convergences, and thus might, hypothetically, follow an upwelling front; a change from upwelling-favorable winds to downwelling-favorable winds would cause the front to move inshore, and if cetaceans were following the front, this may explain their movement towards shore (Walker et al. 2005).

The above scenario may be the cause of the January-1998 mass-stranding that took place on Flagler Beach, Florida, along the Atlantic coast (Fig. 5). Seven short-finned pilot whales stranded on the sandy shores of Flagler Beach, within a specifically well-known, and well-studied, range of seasonal upwelling/downwelling. Review of the available stranding data for this event revealed that all pod members had little to no food in the fore-stomach at the time of stranding, suggesting that food resources, i.e. shoaling or schooling squid, may have dramatically shifted in continuity or changed course altogether. A January stranding, along with empty stomachs, indicates that this particular pod was traveling from north to south on a long migration that proved to be too arduous and daunting as food resources were not readily available. In the case of a pilot whale mass-stranding, it is unlikely that all animals involved are sick; however, events leading up to the stranding could have disrupted typical foraging behavior. Strandings such as these likely represent animals using inshore waters before death yet neritic prey, including cephalopod remains, is likely to be over-estimated in their diet (Beatson and O'shea 2009). A strong downwelling episode, days prior, may have triggered this specific stranding event. In a relevant 1982-83 study, a strong El Niño event brought about major ecosystem changes off the southern California coast. Pilot whales avoided the area (presumably due to the absence of spawning squid) for much of the next ten years (Leet 2001 and Life 2011).

Figure 5. January 1998 mass-stranding event of SFPW at Flagler Beach.



Mass-stranding mortalities may differ by both the sex and size of animals; females, especially adults, are the most vulnerable, and young males are the least vulnerable (Amano et al. 2014). Changes in blubber thickness (i.e. girth), seasonal timing, reproductive status, and migrations may hamper some individuals more so than others by hindering already decreased energy reserves and having little to no emergency protocols (metabolically) to acknowledge and/or escape from strong tidal influences or other ambient factors. Perhaps the weakened state of many females due to fetal demands puts them in the most vulnerable state during strandings. Therefore BMI ranges should be modified and further enhanced for female short-finned pilot whale-specific categorical aspects, such as; seasons, age range (subadult to five years of age, five to 20 years of age, 20 to 30 years of age, 40 years plus, and perhaps even older whales to provide further substantiation), and confirmed reproductive status. BCS could also be integrated with said categories and be used to institute various health status parameters for female short-finned pilot whales.

6. FUTURE RESEARCH

Key points for future research include: First, studying as many captive short-finned pilot whales as possible to establish morphometric benchmarks to use comparatively to wild populations and determine BMI ranges for healthy and sick animals in captivity. Second, expand this research to the wild populations, as mentioned above, in their natural habitat. In order to save time and best utilize funds, drone technology could be used to gather length measurements of migrating short-finned pilot whales while milling or traveling at nominal speeds. Similar approaches with gray whales (*Eschrichtius robustus*) have proven to be successful, i.e. gathering total length and width via aerial surveillance (Perryman and Lynn 2002). I suggest development of a retrofitted dorsal tag with laser capability to analyze total girth. Having these two essential data components would increase chances of identifying healthy and sick individuals in their natural setting. Third, utilize field surveys to pinpoint short-finned pilot whale migration patterns off Florida waters and determine spatial and temporal ranges for periods when pods might enter the Florida Straits, either during ingress or egress. Fourth, publish an updated BMI protocol for data collection at times of mass-stranding episodes and pinpoint what information is most critical to collect. This information could be shared with colleagues, both nationally and internationally. The potential benefit from sharing such information could initiate research interests as related to sub-adult and juvenile pod members which would improve BMI ranges. Fifth, enhance the catalogue of individuals through dorsal fin identification or further genetic studies via biopsy collection to determine short-finned pilot whale poddal family structure and incorporate BMI data into the SAR missions. This may also shed light on whether or not the same individuals that strand in one location also re-strand elsewhere. 'Re-stranders,' in it of themselves, should also be further analyzed. Lastly, develop a BCS evaluation criteria for short-finned pilot whales to be used as a supplemental aid to BMI in prognosis at the time of a stranding.

7. CONCLUSIONS

What is a scientist after all? It is a curious man looking through a keyhole, the keyhole of nature, trying to know what's going on.

- Jacques Yves Cousteau

Substantive data for complete diagnosis and analysis was lacking for this study with only few specimens (<10%) providing all pertinent variables; length, weight, maximum girth, axillary girth, girth at eye, and blubber thickness. However, the data that were available and processed returned intriguing results, allowing for numerous discussion points and future research potential.

Although the hypothesis connecting BMI and girth cannot currently be fully substantiated due to the absence of girth data, it is perceivable that prospective studies would formulate a strong correlation within those factors in determining health status for stranded short-finned pilot whales. It is imperative that girth measurements be recorded in future strandings.

Substantive data were examined and included herein, proving that there is a distinct relationship in length versus weight regression and assessment of BMI in short-finned pilot whales. Data confirm that stranded female pilot whales are most likely to be the most malnourished and at-risk of higher rates of mortality. BMI parameters can provide beneficial applications at stranding times, and can be used to establish step-by-step protocols for providing aid to the animals calculated with increased potential for recovery and release. This BMI application could reduce the time that stranded whales experience insufferable pain and help the marine mammal rescue groups select to administer euthanasia more judiciously. The absence, yet importance of a euthanasia protocol, specifically for short-finned pilot whales, was noted, and justification for its production was expressed. Even though the relationship was formulated with only length and weight data, the evidence supports the hypothesis of the establishment of a BMI range and should increase the rate of survival in future mass-stranding scenarios. Although a model BMI range has been proposed herein, it would be pertinent to attempt to narrow the gap in the range to a degree of +/-, only one or two points. This may be accomplished in future projects or with additional stranding data and with the advent of a short-finned pilot whale-specific BCS protocol. The hypothesized BMI range of 35.0 proves to be slightly less than what was founded within this research. Supportive evidence is suggestive of a BMI range between 39.0 and 50.0 for adult males and 41.0 to 55.0 for adult females as the proposed target. A third or fourth variable such as girth or blubber thickness would help to strengthen BMI assessments and add supportive evidence to this work.

Environmental dynamics are indeed partially, if not fully, culpable for initiating ‘stranding behaviors’ in highly social cetacean family groups, supporting the secondary hypothesis. The analysis utilized and stipulated in this research provides supporting documentation and data for plausible causes of short-finned pilot whale mass-strandings in Florida, with direct or indirect (i.e. prey or lack thereof) correlation to oceanographic currents and counter-currents such as eddy formation in mass-strandings that transpired along the Florida Straits and Florida Keys, and sudden upwelling or downwelling occurrences along the Atlantic continental shelf of Florida. Other environmental influences could also play a significant role in leading to, or causing a mass-stranding but were not studied herein; these influences should be further explored. Of course, health issues, whether natural or anthropogenically linked, would also need to be further researched.

Marine mammal researchers, veterinarians, pathologists, and stranding managers should utilize this information while assessing future strandings and for preparing or anticipating strandings according to certain environmental triggers. Relationships should be forged with oceanographic centers in order to frequently relay this invaluable information. A network such as this would seemingly reduce the costs associated with mass-strandings, benefiting all those involved.

Of key importance, not only for the managers or responders but also for the vulnerable whales, is the protocol establishment for recording morphometric data and the immediate response to administer care with judicious precision. Whatever can be done to extend the opening of that aforementioned window should be done so that we are not lost of a great opportunity to learn, understand, help, and appreciate these creatures.

> “I believe they answered the shrieks of distress…perhaps zoologists won’t agree but I am convinced these noble creatures have a sense of

solidarity." - Jacques Yves Cousteau; speaking of an encounter with a pod of sperm whales; one of which was injured

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