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Assessing morphological deformities in cetaceans: Definition of patterns and quantification with a case study (Madeira Island, NE Atlantic)

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Assessing Morphological Deformities in Cetaceans: Definition of Patterns and Quantification with a Case Study (Madeira Island, NE Atlantic)

Erich Dietterle

A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

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Abstract

Documenting deformities in cetaceans can lead to understandings in the health of the populations, but also the state of ocean and human health in an area. Deformities like skin lesions can lead to information about local pollution levels or possible diseases, while physical impacts can give insight into vessel traffic or fishing gear entanglement information. Cetaceans encounter threats like vessel strikes and fishing gear entanglements worldwide, but less obvious activities like whale watching or pollution can also have impacts. Studies have been conducted worldwide and around the Madeira Archipelago to document deformities, but there are various descriptions for what is considered a deformity. This study aimed at producing a clear and unifying definition for the term deformity when dealing with the broad range of species that constitute cetacean marine mammals.

Methods involved the cataloging of deformities on identified individuals. Defining a deformity as “a condition, in which all or part of the body does not have the expected/typical/characteristic or normal species shape, color or appearance, which are congenital or acquired during the course of the individual’s life,” this study analyzed and documented 29 different types of deformities from 1,020 identified individual cetacean specimens covering 11 species found around the Madeira Archipelago. Analysis involved the use of photographs from a database at CIIMAR-Madeira.

Excluding rake marks and nicks, the main species that showed greatest numbers of deformities included *Mesoplodon densirostris, Tursiops truncatus and Balaenoptera brydei*. The percentage of the analyzed population for each of these species were 96.49%; 75.78%; and 87.88% respectively. It was discovered that 597 (58.53%) of the individuals have at least one deformity, while skin lesions were the most prominent category (50.44% of total deformities) and cuts (23.72% of deformities) were the most common deformity. Deformities from possible anthropogenic causes were observed in 80 individuals (7.84% of the total population). This research gives a baseline for the implications of the human impacts on the cetaceans’ deformities.
Though the causes of certain deformities, such as skin lesions, are difficult to establish, pointing toward the need for further research to discover the full extent of the health hazards posed to cetaceans and marine life around the Madeira Archipelago.
1. Introduction

1.1 Overview

The presence and documentation of deformities has occurred throughout history. In human history, deformities have been used to distinguish and identify people from one another (Robertson et al. 1976). Even before knowledge of the causes or consequences of certain deformities were known, deformities, such as extra fingers or possible signs of tuberculosis, were included in sculptures and portraits (Robertson et al. 1976). Robertson et al. (1976) describes several different cultures, like the Greeks and Mayans, which have purposely portrayed deformities to identify the individual in the piece of art, such as Raphael’s Sistine Madona in which the right hand of Pope Sixtus II clearly shows six fully-formed figures.

While the causes or consequences of deformities in history may have been unknown due to a lack of knowledge, they could still be used as a tool for identification (Robertson et al. 1976). This tool has spread to animals as well, but with the improvement in technology deformities have been able to reveal more information. Deformities in anurans have led to discoveries of chemicals causing diseases or conditions which have led to mortalities (Ouellet et al. 1997). Ouellet et al. (1997) documented limb and developmental deformities that showed signs of inhibiting swimming capabilities in anurans around the St. Lawrence River Valley in Québec, Canada. The report concluded that anurans were being exposed to pesticides in the runoff.

In marine life, deformities have continued as identification tools and evidence of possible ecosystem health concerns like in the instances of human history and the anurans. A distinct example of using deformities as an identification tool is the albino humpback whale (Megaptera novaeangliae) of the East coast of Australia, known as Migaloo, which was first sighted in 1991 (Polanowski et al. 2011).
The reason this can be used to identify a certain individual is because there is not another documented occurrence of an albino humpback whale (Forestell et al. 2001).

A physical deformity that can be acquired is the loss of a limb, possibly due to fishing gear entanglement or ship strikes. A grey whale has been documented as having a completely missing fluke (Urbán et al. 2004). It was reported to have a calf associated with it, so it was capable of surviving and reproducing. The presence of deformities on individuals can give researchers data like the age group of an individual, such as Risso’s dolphin (Grampus griseus). Risso’s dolphins acquire rake marks as the individual grows older due to the aggressive behavior of this species (Hartman, et al. 2013). This also gives the species their identifiable feature, many rake marks on the anterior section of the body, to help scientists distinguish this species from others in the field. Another possible result of deformities can show the overall health of the individual.

Some skin lesions can be signs of pollution in the waters or disease, which can be a sign of the overall health of the ocean (Bossart 2011). Bossart 2011 explains that marine mammals can be sentinel species for oceans and human health. Marine mammals, in this case cetaceans, have long life spans, feed at the top of the food chain, can be long term coastal residents, and have fat stores that can serve as reserves for anthropogenic toxins. Dependent on testing capabilities, deformities on cetaceans can reveal the health of not just the individual, but also human and ocean health. Bossart (2011) explains that the buildup of anthropogenic toxins in the systems of the cetaceans can reveal the possible affects human pollution is having on the food chain. The availability and health of the food sources of the cetaceans can be reliant on the effects from human impacts, such as overall abundance or health of the species of prey. A decrease in prey population for cetaceans can mean overfishing or a mass kill off could be due to pollutants from humans. Indicators of these instances can be observed from cetacean health.
Establishing a catalog of deformities for identified individuals allows for the health of the species, in particular the resident species, to be monitored, but also the human and ocean health in the area. This research could aid in understanding the health of the three variables by cataloging possible deformities that could be caused by human pollution (typically skin lesions), which could be harming the human population in the area, and in turn the overall ocean and cetacean health. This can also set the basis line for future research on the cetaceans’ monitoring of deformities surrounding Madeira. Possible outcomes for studies like these can lead to perspectives about interactions between cetaceans and humans and human activities by documenting all deformities and analyzing which ones could be from anthropogenic causes.

A case study was carried out using data from the Madeira Archipelago, Portugal. The Madeira Archipelago is located in the eastern North Atlantic off the southern coast of Portugal, in between the Azores (Portugal) and the Canary Islands (Spain).

1.2 Goals of the Study

This research aimed at exploring the deformities in cetaceans that are individually catalogued in the Madeiran archipelago in Portugal. This project was conducted in an area that has had few studies conducted on deformities (Dinis et al. 2017a, Dinis et al. 2017b, Alves et al. 2017a, Alves et al. 2017b, and Alves et al. in press, and Correia et al. 2014). Many of the studies conducted in Madeira and in literature included a range of 1-3 species. Some other studies may have included more, but this report was designed to cover a higher number of species than literature has shown when it comes to cataloging and analyzing deformities. The span of the species covered in this report is also going to consider both mysticetes and odontocetes, which the other literature covers one or the other. Similar to the study done by Bearzi et al. (2009) this study is going to examine both physical deformities and skin lesions, but this study also included additional categories, such as emaciation and epibionts. The amount of types of deformities considered in this study will be one of the most in any literature that could be found. A study done by Van Bressem et al. (2007) is going to be similar to this thesis based
on the comprehensiveness, but their report focuses on small cetaceans from the waters around South America.

The first goal of the study is to establish a definition of a deformity. Based on literature, there has not been an established definition for a deformity, only types of deformities. The subsequent goals are to find out the percentage of the population with deformities, types of deformities per species, assess which species are more vulnerable to deformities in Madeira, which type of deformity is more prevalent, the total amount of deformities, try to assess its origin, percentage of deformities due to possible anthropogenic causes in total, percentage of possible anthropogenic causes by species, average number of deformities per individual by species, and proportion of individuals with deformities based on the number of deformities.

1.3 Importance to Sustainable Development and Environmental Management

Whaling as been known to have occurred in Portugal starting in the 12th century, but commercially, land-based whaling started in Madeira in 1941 (Brito 2008). Brito (2008) explains that throughout the history of land-based whaling in Madeira there was a total of 4,484 great whales captured, which consisted of sperm, fin, humpback, and right whales between 1941 and 1981.

The decline in the land-based whaling industry was due to the decline in species abundance. Environmentally, the whaling was not sustainable. The areas reliance on whales for hunting eventually switched to whale watching. Today there are several companies that provide services for locals and visitors to go whale and dolphin watching, as well as swimming with the dolphins. This is combined with other activities such as sailing trips between the islands of Desertas and Madeira, ferry transportation between Madeira and Porto Santo, and everyday coastal activities that allow people to see whales and dolphins. Based on the topography of the ocean floor, cetaceans can be spotted from land. This advantage is used by whale and dolphin watching companies to spotters for the boats.
The three pillars of sustainability are being met. Environmentally, the cetaceans are being protected, which will be discussed in a later section. Economically, the whale and dolphin watching companies are making money and contributing to the local economy. Socially, those same companies are creating opportunities for locals and other members of the European Union to obtain jobs. Research is also being conducted, which allows for more job opportunities. This also circles back to protecting and understanding cetaceans more, so that this sustainable trend can continue into the future.

1.4 Threats to Cetaceans

There are several major threats affecting cetaceans such as whaling, vessel traffic, and fishing gear entanglements.

1.4.1 Whaling

One of the first threats to cetaceans was whaling. The controversial time of whaling started in the late 1600s and lasted until the late 1900s (Ciserneros-Montemayor et al. 2010). Perrin et al. (2008) tell the history of aboriginal cultures whaling and first interactions with whales. There are documentations of interactions with beached whales from the Greek, Vikings, and Icelandic people, but the first known people to hunt whales in an organized manner were the Basques in the 11th century, at least as the records show. There is a possibility it could date back as far as the Stone Age.

Over time the primary whales targeted for whaling were *Physeter macrocephalus, Balaenoptera musculus, Megaptera novaeangliae, Balaenoptera physalus, Eubalaena glacialis,* and *Balaenoptera borealis* (Perrin et al., 2008). This was due to their large size and the amount of resources that could be gained from one individual. Most of the species are mysticetes, except for the sperm whale. The sperm whale was target due to the large amount of spermaceti in the whale’s head, which could be used as oil. Perrin et al. (2008) explains that whaling has caused some species to almost go extinct. *E. glacialis* was on the brink of extinction due to whaling. At one point, population estimates were as low as approximately 200 individuals. Today, the population is approximately 500 individuals. This
species gained its named due to the ease at which it could be hunted. It is a very slow moving species. When it is killed, the body floats to the surface due to the thick blubber layer causing the species to be positively buoyant. Therefore it earned the name right whale because it was the “right” whale to hunt (Perrin et al., 2008. Eventually whaling became unsustainable in certain regions and a global decrease in whale populations lead to a moratorium for whaling by the International Whaling Commission in 1986 (International Whaling Commission).

1.4.2 Vessel traffic

Vessel traffic can encompass a wide variety of sources ranging from small recreational boats, even kayaks, to large cargo ships. Cunha (in press) states that with increase in human growth there has been an increase in marine traffic. The ability to travel farther distances and to more places has increase the amount of vessels that transit around the globe. Cetaceans are susceptible to disturbances due to vessel traffic, whether it is through vessel strikes, vessel noise, or overexposure to vessels. The impacts of these stresses can lead to drastic effects such as fatalities.

Laist et al. (2001) studied ship strikes involving the great whales. These whales are fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), gray whales (*Eschrichius robustus*), blue whales (*B. musculus*), sei whales (*B. borealis*), Bryde’s whales (*B. brydei*), bowhead whales (*Balaena mysticetus*), southern right whale (*Eubalaena australis*), northern right whales (*E. glacialis*), minke whale (*B. acutorostrata*), and sperm whale (*P. macrocephalus*). The studied concluded that fin whales were hit most frequently. This was followed by northern and southern right whales, humpback whales, gray whales and sperm whales, which were hit relatively common in some areas. There were few collision records for minke whales, blue whales, and sei whales. There were rarely records of Bryde’s whales and bowhead whales being struck.

One of the more well known cases of trying to limit vessel strikes is by reducing speed to protect the North Atlantic right whale off the East coast of North America. Silber and Brettridge (2012) analyze
the effectiveness of the speed reduction for large whale species. Though their report states there is not sufficient data to conclude whether or not the speed reduction is decreasing fatalities from ship strikes, reports by Lagueux et al. (2011) and Wiley et al. (2011) do support that the speed reduction is being effective. Other reports in other geographic locations have also supported to the reduction in speed to reduce fatalities from ship strikes on large whales (Gende et al. 2011, Vanderlaan et al. 2009, Vanderlaan and Taggart 2009, and Constantine et al. 2015).

Even though larger whales, such as the great whales, might be more commonly involved in ship strikes, smaller whales and dolphins are still affected. Ng and Leung (2003) studied the behavioral response of the Indo-Pacific humpback dolphin, Sousa chinensis, to vessel traffic and found that vessel traffic caused behavioral changes in certain situations. Areas with heavy vessel traffic caused individuals to dive for longer durations or when there was a presence of an oncoming vessel. Fast-moving vessels also caused disruption of behavior and social life.

### 1.4.3 Noise Pollution

Another potential threat to cetaceans is noise pollution. Vessel traffic is one factor that can be a contributor, as well as seismic exploration, naval sonar operations, or underwater explosions (Weilgart 2007). Cetaceans are known to be a very vocal taxonomic group, relying on vocalizations for things ranging from social interactions to sensory biology (Tyack and Miller 2002). Since sight is limited to only tens of meters, hearing is more crucial since it can be heard for up to thousands of kilometers (Weilgart 2007). For example, a seismic survey was conducted in eastern Canada and the noise from the survey was measured 3,000 km away in the middle of the Atlantic (Nieukirk et al. 2004).

The effects that noise pollution has on cetaceans are still being studied, but some of the consequences on cetaceans can range from avoidance of the source of noise to strandings (Jensen et al. 2009, and Weilgart 2007). According to a report by Southall (2005) baleen whales are thought to be more
sensitive to low frequency sounds, while odontocetes have better hearing across a broader range of mid to high frequencies. This difference is due to the characteristics of their auditory morphology and sound production (Southall 2005). By using bottlenose dolphin species and short-finned pilot whales, a study conducted by Jensen et al. (2009) concluded that small vessels with an outboard can significantly affect delphinid communication by vessels traveling at speeds of >5 knots and approaching closer than 50 m. The report further states that based on the specifications of the vessel, such as the engine or propeller, the effects can increase. Noise pollution has been connected to strandings in cetaceans, for instance in beaked whales (Weilgart 2007). This was discovered during a mass stranding where there was not another threat that could explain how so many whales were affected over a large area and the strandings were occurring during the track of a noise-producing vessel (Weilgart 2007). A mass stranding event occurred in the Bahamas in 2000 in which four species, a total of 17 individuals, of cetaceans were found stranded within 36 hours of each other due to sonar exercises being conducted by the Navy (Evans and England 2001). Evidence of hemorrhaging was discovered in the brain, inner ears, and the acoustic fats (which include the melon) (Evans and England 2001).

1.4.4 Fishing Gear Entanglements and Bycatch

The International Whaling Commission (IWC) lists bycatch the most serious, direct threat to cetaceans worldwide. A report from the IWC in 2012 estimated that over 300,000 cetaceans die each year as a result of fishing gear interactions. The IWC considers any entanglements in fishing gear as bycatch. In 2016 the IWC endorsed a proposal to set up a new Bycatch Initiative, which would work with other organizations to “develop, assess and promote by catch prevention and mitigation measures world-wide.” (International Whaling Commission 2017)

There are disentanglement teams around the globe that respond to cetaceans and other marine life, such as sea turtles, that are entangled in fishing gear. A few well known locations are out of British Columbia, Canada, Provincetown, Massachusetts and Australia.
DeMaster et al. (2001) states that interactions between marine mammals and fisheries are increasing in frequency and intensity, which will continue into the foreseeable future. Read et al. (2006) furthers this statement by saying that this trend is due to continued human population growth, increasing industrialization of fisheries, and the expansion of fisheries into new areas.

The fishing gears that have caused the most entanglements for cetaceans are gillnet and trap or pot fisheries (Reeves et al. 2013). The smaller the cetacean is the more likely it is to drown when it comes to fishing gear entanglements. This is due to their smaller size not having as much strength as larger whales to break through the gear or to carry the gear, further increasing the chance of drowning. While baleen whales may be able to carry fishing gear as they swim, the gear can hinder their feeding habits leading to mortality. (Clapham et al. 1999)

An important step taking to preventing cetacean interactions with fishing gear was the 1990 Symposium and Workshop on the Mortality of Cetaceans in Passive Fishing Nets and Traps, which was organized by the IWC. This workshop produced a global summary of fishery and bycatch data by region, fishery and species. The report from the workshop labeled certain species of concern. The top six species that urgently needed attention were the Yangtze River dolphin (Lipotes vexillifer), the Gulf of California porpoise or vaquita (Phocoena sinus), coastal populations of humpback dolphins (Sousa sp.) and bottlenose dolphins (Tursiops sp.) in KwaZulu-Natal (South Africa), striped dolphins (Stenella coeruleoalba) in the Mediterranean Sea, and harbor porpoises (Phocoena phocoena) in the western North Atlantic. There were also three other populations of particular concern, which were dusky dolphins (Lagenorhynchus obscurus) in the eastern South Pacific, northern right whale dolphins (Lissodelphis borealis) in central North Pacific, and sperm whales (Physeter macrocephalus) in the Mediterranean Sea. These last three species were of concern due to high, unsustainable known bycatch levels.
To further the efforts to develop, assess, and promote bycatch prevention and mitigation measures worldwide, the IWC set up a new Bycatch Initiative in 2016. This initiative has four inter-related areas of work as their focus: investigation of mitigation methods, transfer of expertise, technology and management measures, improve assessment of bycatch, and engagement with other relevant organizations. (IWC)

1.4.5 Diseases

A prominent disease affecting cetaceans is the cetacean morbillivirus (CeMV). The first case of morbillivirus in cetaceans was in the Gulf of Mexico from June 1987 to April 1988, which caused 742 deaths of common bottlenose dolphins (Schulman et al. 1997). Originally, it was thought that brevetoxin was the cause based on a federal government-sponsored investigation (Geraci 1989). Schulman et al. (1997) discovered that it was more than likely not caused by brevetoxin, but instead caused by morbillivirus. The tests for brevetoxin were not reliable due to false positives and false negatives, which were the reason for concluding that the brevetoxin was the cause. Schulman et al. (1997) found that 97% (35/36) had morbillivirus RNA.

There are three strains of this virus: dolphin morbillivirus (DMV) (Domingo et al. 1990), porpoise morbillivirus (PMV) (Kennedy 1998), and pilot whale morbillivirus (PWMV) (Bellière et al. 2011, Taubenberger et al. 2000).

DMV is known for causing at least two epizootics. The first was in the Mediterranean Sea, which affected Mediterranean striped dolphin (*Stenella coeruleoalba*) starting in 1990 and evidence of DMV still causing deaths until 1992 (Domingo et al. 1990, Van Bressem et al. 1993). The second case was from 2006-2007 where over 27 long-finned pilot whales, *G. melas*, were found stranded in the Mediterranean Sea, some were alive, and over 100 striped dolphins were found dead or were rescued and later died, in the Gulf of Valencia (Fernández et al. 2008, Raga et al. 2008). It was
discovered that sexually mature adults were most affected by the DMV in the epizootic from 1990-1992, but dependent calves showed signs of mortality due to reliance on deceased mothers (Calzada et al. 1994). DMV was not considered endemic to the Mediterranean striped dolphin population after the epidemic ceased (Van Bressem et al. 2001). This was presumed to be due to the abundance of Mediterranean striped dolphins being too low for a sustained endemic infection (Van Bressem et al. 2009). The opposite was discovered statistics for affected age in the second outbreak in 2006-2007, juveniles were more commonly affected. This was assumed to be due to adults developing immunity to the virus from the 1990-1992 epizootic (Raga et al. 2008). Dolphins are not the only cetaceans affected by the DMV. Two studies have shown that large whales can become infected with DMV; fin whales and sperm whales have shown evidence of DMV (Mazzariol et al. 2016, Mazzariol et al. 2017). From 2006-2014, Mazzariol et al. 2016 studied 23 fin whales that were found stranded along the Italian coastline. Of the 23, full necropsies were conducted on nine individuals. DMV was found in five of the nine, which consisted of two calves, two juveniles and one newborn. All of these would found between January 2011 and October 2013. In September 2014, Mazzariol et al. (2017) studied seven sperm whales that were discovered washed up on shore. Out of the seven, necropsies were performed on four of them, three females and one male fetus. All four of the individuals that were necropsied showed evidence of DMV. Based on the study by Mazzariol et al. (2017) and one done by West et al. (2015), it is shown that DMV can be spread through maternal-fetal transfer. This can show concern for possible populations to become infected.

Porpoise morbillivirus was first documented in cetaceans in 1988 off the coast of Ireland in six harbor porpoises (Phocoena phocoena) (Kennedy et al 1991). Prior to this discovery morbillivirus had been known in a local colony of harbor seals, which lead to the suspicion that the virus had spread from the pinnipeds to the cetaceans (Kennedy 1998). Further discovery of morbillivirus infections in harbor porpoises from the coasts of England, Scotland, and the Netherlands, and also from the coasts of
Ireland lead to characterization of a new strain of morbillivirus (PMV) (Visser et al. 1993, Kennedy et al., 1992). This disproved that the transmission of PMV could have been from infected pinnipeds.

The third strain of CeMV is pilot whale morbillivirus (PWMV), which was first documented in a stranded long-finned pilot whale found in New Jersey (Taubenberger et al. 2000). Based on a reverse transcriptase polymer chain reaction (RT-PCR) it was established that this strain of CeMV was similar to DMV and PMV, but also distinct. Taubenberger et al. (2000) believes that the virus could have gone through species-adaptive changes. An example of a PWMV-like strain was found in a short-finned pilot whale along the coast of Tenerife, Canary Islands on 28 July 1996 (Belière et al. 2011). Since Taubenger et al. (2000) is said to be the first case of PWMV, the necropsy of the individual short-finned pilot whale must have been after the 2000, but Belière et al. (2011) does not say when the necropsy was performed exactly. A RT-PCR was conducted on the individual and came back with results that were more similar to the ones from Taubenberger et al. (2000) than to DMV or PMV, so it was concluded that it was a PWMV-like strain. Based on the two studies conducted on Atlantic pilot whales (Taubenberger et al. 2000, Belière et al. 2011), Belière et al. (2011) explains that PWMV is the only strain found in the Atlantic populations of pilot whales. DMV was found in a population of Mediterranean long-finned pilot whales (Fernández et al. 2008), which can raise concerns that PWMV could be spread widely among Atlantic populations of pilot whales (Belière et al. 2011).

2. Literature Review

2.1 Target Species

Members of the Order Cetacea consist of whales, dolphins, and porpoises and can be found throughout the world. This cosmopolitan Order has approximately 89 species ranging two suborders, Mysticeti and Odontoceti (The Society for Marine Mammalogy 2017).
Cetaceans have developed intrinsic value in the eyes of some people, so protection efforts have increased. There have been conservation efforts at different scales, ranging from regional efforts to international efforts, to protect these species. This will be discussed later in the thesis.

To better understand the conservation efforts and possible dangers to cetaceans, it is important to understand their behavioral patterns and physical characteristics. Mysticetes and odontocetes have some general behaviors and characteristics that apply to each suborder, which can help in identifying species and can aid in understanding why some might be more impacted by anthropogenic influences than others.

2.1.1 Mysticeti

Mysticeti consists of approximately 14 species (The Society for Marine Mammalogy 2017). These species are typically larger species compared to odontocetes, such as *Eubalaena glacialis* (North Atlantic right whale), *Megaptera novaeangliae* (humpback whale), and the largest animal on the planet, *Balaenoptera musculus* (blue whale). Members of this suborder have baleen plates, also known as whalebone, in their upper jaw instead of teeth. This is where the common name for this order originates, baleen whales. Besides the size and baleen plates, mysticetes are distinguished from odontocetes by having two blowholes rather than one.

The difference in feeding mechanisms has lead to different feeding behaviors. Food sources for mysticetes can range from organisms as small as zooplankton to small fish. These feeding behaviors occur throughout the water column, but can still be affected by anthropogenic influences. Behaviors occurring towards the surface include *E. glacialis*, which skim feeds or subsurface feeds. Both behaviors consist of the whale swimming with its mouth open and swallowing anything in its path. This increases the time the species spends just under, subsurface feeding, or at the surface, skim feeding. Another surface feeding behavior is done by *M. novaeangliae* and *Balaenoptera physalus*.
(fin whale). These whales lunge feed, which causes the whale to break the surface of the water at an angle with their mouth wide open. This behavior occurs quickly and suddenly. As for behaviors at the bottom of the water column, *Eschrichtius robustus* (grey whale) tends to feed on benthic amphipods by sucking up sediment. All of the behaviors can interact with anthropogenic factors, such as fishing gear, but the ones that occur towards the surface are particularly susceptible to vessel interactions.

Photos have been added to show how each species may be sighted in the field. Based on behavior not all species are easy to get good photos.

2.1.2 Family Balaenopteridae

2.1.3 *Balaenoptera borealis* and *Balaenoptera brydei*

The two mysticetes catalogued in this report are from the Family Balaenopteridae. Species from this Family are characterized by their sleek, streamlined bodies, and long pleats on their lower jaw, which is where the common name, rorquals or “pleated” whale originates. *Balaenoptera borealis* (sei whale) and *Balaenoptera brydei* (Bryde’s whale) are the two members of this family that are analyzed in this report. Based on the number of identified individuals and the amount of individuals with multiple sightings over time, *B. brydei* are more commonly seen and identified around the archipelago of Madeira (Alves *et al.* 2010, Freitas *et al.* 2012) Bryde’s and sei whales can often be confused for each other in the field. The key features to distinguish the two are that sei whales have a tall, straight and erect dorsal fin compared to the sickle-shaped dorsal of the Bryde’s whale. Sei whales also have a single longitudinal rostrum ridge, while Bryde’s whales have three.
Figure 1: Bryde’s whale (*Balaenoptera brydei*) (top). The three ridges are evident to distinguish the two species. Sei whale (*Balaenoptera borealis*) (bottom). Only a single rostral ridge is evident. (Photos courtesy of A. Sambolino)

2.1.4 Odontoceti

*Odontoceti* contains approximately 75 species, which all contain teeth rather than baleen plates. These species tend to be smaller than mysticetes, but the largest odontocete, *Physeter macrocephalus* at a possible 18.3m, is comparable to a medium sized baleen whale like *M. novaeangliae* at a possible 18m.

Diets for odontocetes can vary from small fish to giant squid, but these are typically eaten a single prey at a time. The interactions with the same marine life that can be associated with fisheries and being smaller can lead to injuries due to anthropogenic causes, such as fishing gear entanglements or becoming bycatch (Waring *et al.*, 2007). Odontocetes are also known for having a melon structure, which allows them to use echolocation. Echolocation aids the animals in finding prey, but this also can make them more susceptible to negative effects from noise pollution (Shirihai and Jarrett, 2006).
There are nine species of odontocetes in this report, which belong to the Families Delphinidae (seven species), Ziphiidae (one species), and Physteridae (one species).

2.1.5 Family Delphinidae

Odontoceti contains the largest family of cetaceans, Delphinidae, which contains approximately 36 species (The Society for Marine Mammalogy).

2.1.6 *Delphinus delphis*

The short-beaked common dolphin is typically found in temperate and tropical waters around the world with a seasonal presence, being most abundant species during the winter and spring (Halicka 2015). It is a very sociable species that can have pods with hundreds or thousands of individuals. As well as an active and fast swimmer, this species is commonly seen breaching or bow riding on whales or boats. (Shirihai and Jarrett, 2006)

The distinguishing features to identify *D. delphis* in the field from other similar sized and oceanic dolphins are the well defined yellowish thoracic panel and a dark v-shaped saddle, which dips from the side of the cape below the dorsal fin. These can still be confused with *Delphinus capensis*, long-beaked common dolphin, but as the name suggests, the length of the beak can be used to distinguish between these two species. Also, knowing the geographical habitat of these two species can help. (Shirihai and Jarrett, 2006)

Figure 2: Short-beaked common dolphin (*Delphinus delphis*) (Photo courtesy of D. Sousa)
2.1.7 *Tursiops truncatus*

The common bottlenose dolphin is another delphinid species that is found in temperate and tropical waters worldwide. There are many populations of this species that are typically segregated into smaller inshore, or coastal, and larger offshore, or oceanic, animals. It is among the largest dolphin reaching a maximum of 4.1m, which is more associated with offshore populations. (Shirihai and Jarrett, 2006)

This species is known to have residency patterns across their distribution. Around the archipelago of Madeira, there is a small resident population (15 individuals out of 501 studied) that shows a long-term residency pattern (Dinis et al., 2016). Unlike the common dolphin, pods of coastal common bottlenose dolphins typically consist of 3-7 individuals, but can have been sighted in Spain having large offshore aggregations of 180 individuals (Cañadas and Hammond 2006).

These dolphins can easily be confused with several different species in the wild, such as the following two species, *Steno bredanensis* and *Stenella frontalis*. The way to tell them apart is that *T. truncatus* has a very different shape to the dorsal fin, a well-pronounced mid-length beak, a thick head, and a shoulder blaze in a dark cape. (Shirihai and Jarrett, 2006)

![Common bottlenose dolphin](Photo courtesy of D. Sousa)
2.1.8 Steno bredanensis

The rough-toothed dolphin is found worldwide in tropical to subtropical waters, and is sighted occasionally in Madeira (Freitas et al. 2012, Alves et al. 2017b). This species can reach a maximum of 2.65 m. Similar to D. delphis, this species is found in small pods of 5-10 individuals (Shirihai and Jarrett, 2006). While it may have small interspecific pods, it often associates with other species, such as bottlenose, spotted, and spinner dolphins (Shirihai and Jarrett, 2006).

Besides the physical differences mentioned above, S. bredanensis has a distinctive sloping forehead, a cone-shaped head and beak, and a falcate dorsal fin. These features help differentiate the rough-toothed dolphin from the common bottlenose dolphin. (Shirihai and Jarrett, 2006)

Figure 4: Rough-toothed dolphins (Steno bredanensis) (Photo courtesy of C. Martins)

2.1.9 Stenella frontalis

Atlantic spotted dolphins are found in warm, tropical waters of the Atlantic. Around Madeira they are abundant during summer and autumn (Alves et al., 2017). These dolphins can reach lengths of up to 2.3 m and be found in pods from 5-200 individuals (Shirihai and Jarrett, 2006). This species is a very acrobatic and is often attracted to fast-moving boats (Shirihai and Jarrett, 2006).
Juveniles and immature individuals do not develop spots, so these can be easily confused with common bottlenose dolphins. The size and shape, *S. frontalis* are usually slimmer, of the individuals are used to differentiate these species. As this species ages, spots develop around the body. The more spots the individual has the older it is. (Shirihai and Jarrett, 2006)

Figure 5: Atlantic spotted dolphin (*Stenella frontalis*). Juvenile without spots in the forefront and an older individual in the back. (Photo courtesy of C. Gomes)

2.1.10 *Orcinus orca*

An occasionally sighted species of delphinid species, also known as “blackfish”, that is commonly mistaken for whales are *Orcinus orca*, killer whale (Freitas *et al.* 2012, Alves *et al.* 2017b). *O. orca* is a cosmopolitan species, but is more commonly found in cold-temperate coastal waters. *O. orca* is the largest dolphin species reaching a maximum of 9.8 m (Shirihai and Jarrett, 2006).
20

Figure 6: Killer whale (Orcinus orca)

2.1.11 Pseudorca crassidens

Another species of “blackfish” that is occasionally sighted in Madeira is Pseudorca crassidens, the false killer whale (Freitas et al. 2012, Alves et al. 2017b). This species is found in tropical waters and can reach lengths of up to 6.1 m. (Shirihai and Jarrett, 2006)

Even though the names suggest they may look similar, O. Orca and P. crassidens can be differentiated by O. orca having a much longer sword-like dorsal fin and having large, white eye patches. P. crassidens has a smaller sickle-like dorsal fin, are smaller in size, and have a more slender head and body. (Shirihai and Jarrett, 2006)

Figure 7: False killer whale (Pseudorca crassidens) (Photo courtesy of C. Martins)
2.1.12 *Globicephala macrorhynchus*

One of the most common species of dolphin found around Madeira is the short-finned pilot whale. It is sighted year-round and there is an island associated community of around 140 individuals (Alves *et al.* 2013, Alves *et al.* 2015) This species is found in temperate to tropical waters and can reach a maximum of 7.2 m for males and 5.5 m for females. This sexual dimorphism is also displayed by the dorsal fin. The males have larger, broader dorsal fins than the females (Shirihai and Jarrett, 2006). This beakless species is highly sociable and found in pods with an average of 20-90 individuals (Olson and Reilly 2009).

This species is very hard to distinguish in the field from *Globicephala melas*, long-finned pilot whales, because there are not many easily noticeable, physical features between the two in the field. The two species mainly differ in their habitats. *G. macrorhynchus* lives in the previously mentioned temperate to tropical waters, while *G. melas* live in temperate to subpolar waters. There is slight habitat overlap in the temperate waters, so field experience is important to identifying the two species. (Shirihai and Jarrett, 2006)

![Figure 8: Short-finned pilot whales (*Globicephala macrorhynchus*) (Photo courtesy of Z. Halicka)](image-url)
2.1.13 Family Ziphiidae (Beaked whales)

2.1.14 Mesoplodon densirostris

The Blainville’s beaked whale is the most common beaked whale found around the Madeira archipelago (Dinis et al. 2017a). They can be found in tropical and warm-temperate waters of all the oceans. This species tends to go on deep foraging dives >1400 m depths and these dives can last around one hour (Rudolph and Smeenk 2009).

This species is difficult to identify in the field. The body structure is similar to dolphins, but if the head is visible, protruding teeth from the lower jaw of males can be used as identification features. Besides the teeth, males have a strongly arched bulging lower jaw, tend to be darker, and have more rake marks due to intraspecific interactions. (Shirihai and Jarrett, 2006)

Figure 9: Male (top) and female (bottom) Blainville’s beaked whales (Mesoplodon densirostris). Notice the protruding teeth on the male and the absence of protruding teeth on the female. (Photos courtesy of D. Sousa)
2.1.15 Family Physteridae (Sperm whale)

2.1.16 Physeter macrocephalus

The sperm whale, which can be sighted year-round in Madeira, is the only member of the Family Physteridae (Freitas et al. 2012, Alves et al. 2017b). This cosmopolitan species is the largest odontocete reaching a maximum length of 18.3 m for males and approximately 9 m for females. It is distinguishable at sea by seeing a bushy blow that is directed at a low angle to the left since the single blowhole is off centered to the left towards the anterior part of the head. Another sign at sea for identification is a blunt, box-like head, which is unique from other cetaceans of this size. The preferred diet for the sperm whale is large squid in very deep water. Hence, this species is commonly found near continental shelves or locations with upwelling, and is known for its ability to take long dives, up to 3 km below the surface. (Shirihai and Jarrett, 2006)

![Photo of a sperm whale](image)

Figure 10: Sperm whale (*Physeter macrocephalus*) (Photo courtesy of L. Berninsone)

2.2 Conservation Efforts

2.2.1 International Whaling Commission (IWC)

The International Whaling Commission (IWC) was established through the International Convention for the Regulation of Whaling, which was signed in Washington DC on 2 December 1946, to help this transition. The purpose of the IWC is “the proper conservation of whale stocks and thus makes possible the orderly development of the whaling industry.” Through a moratorium commercial
whaling was prohibited, but there are still some countries, cultures, and small villages that still go whaling for different reasons. The IWC recognized three types of whaling: aboriginal subsistence whaling, which supports the need of indigenous people, commercial whaling, which is prohibited based on the moratorium, special permit or scientific whaling, which asks countries to apply for permits through the advisory role of the IWC. (International Whaling Commission)

### 2.2.2 Conventions, Agreements, and Acts

Besides the global reach of the IWC, there are three conventions that have helped pave the way for marine conservation efforts: the Bonn Convention (also known as the Convention on the Conservation of Migratory Species of Wild Animals), the Bern Convention (also known as the Council of Europe’s Convention on the Conservation of European Wildlife and Natural Habitats), and the Barcelona Convention.

#### 2.2.3 Bonn Convention

The Bonn Convention, which was put into force on 1 November 1983, is the only global convention specializing in the conservation of migratory species. There are currently 124 parties to this convention, which include Malta and Portugal. The United States of America is a non-party. This convention helps set the framework for other conservation efforts by not only protecting species, but also protecting habitats as well. Several cetacean species are covered under this convention. (Convention on the Conservation of Migratory Species of Wild Animals)

#### 2.2.4 Bern Convention

The Bern Convention, which entered into force in 1979, was the first international treaty to protect both species and habitats. This convention brought countries together to decide how to conserve nature. It covers Europe, but also extends to some States in Africa. The main focus is to conserve
natural wild flora and fauna and their habitats with taking into consideration the intrinsic value of nature for the future preservation. (Council of Europe)

### 2.2.4 Barcelona Convention

The previous two conventions were broad reaching conservation efforts. The third convention, the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, focuses on the protection of the marine environment. This convention, which was originally adopted in 1975 and then later amended in 1995, focuses on the abatement and prevention of pollution from ships, aircrafts and land based sources in the Mediterranean. Malta is one of the 22 parties to this convention. (European Commission).

### 2.2.5 ACCOBAMS/ASCOBANS

The three previous conventions put forward important steps towards the conservation of species. Two regional conservation efforts for cetaceans are the Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea, and Contiguous Atlantic Area (ACCOBAMS), which entered into force on 1 June 2001, and the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS), which was passed into force in 1994. These agreements are possible due to the Bern, Bonn, and Barcelona Conventions. (ACCOBAMS and ASCOBANS)

Both Malta and Portugal are parties for ACCOBAMS. Malta does not fall under the range of ASCOBANS, but Portugal does. However, Portugal is only a non-party range states to ASCOBANS.

The efforts put forth by these two agreements are to reduce threats to cetaceans by increasing and improving knowledge of these species. These legal conservation tools show the dedication and importance that countries show to conserve cetaceans and their habitats.
2.2.6 Marine Mammal Protection Act (MMPA)

In the United States of America, the Marine Mammal Protection Act was enacted to prohibit “the ‘take’ of marine mammals in the U.S waters and by U.S citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.” This act was enacted by congress on 21 October 1972 and protects all marine mammals. (NOAA)

Based on the findings that showed marine mammal stocks may be in danger as a result of human activities, there were four concerns: 1) the populations falling below their optimum sustainable population level, 2) there is a lack of knowledge of the ecology and population dynamics, 3) measure should be taken to replenish their populations, and 4) marine mammals are significant international resources. (NOAA)

The previously mentioned conservation tools importance cannot be understated. They are significant steps into protecting cetaceans and their habitats, as well as increasing the amount of research that can be done to understand these species and their influence on ecosystems.

2.2.7 Whale and Dolphin Watching

As previously mentioned, the occurrence of whaling around the globe has decreased and cetaceans are gaining a more intrinsic value. Protection of these animals and their habitats have allowed for some populations to increase, which has given regions the chance for whale and dolphin watching. This has further increased the intrinsic value that these species have. It can also increase people’s appreciation for nature and it can promote conservation issues that concern the targeted species (Orams 1997, Duffus and Dearden 1993).

Environmentally, proper whale watching has positively benefitted ecosystems. As Bossart (2011) explains and previously mentioned, marine mammals, including cetaceans, can be used as sentinel
species for oceans and human health. These animals play an important role in the sustainability and regulation of marine ecosystems (Cunha, in press). Socially and economically, whale and dolphin watching is a lucrative business and creates job opportunities. In 2009, it was estimated that 13 million tourists went whale watching (which includes dolphins and porpoises) and generated $2.1 billion dollars, while employing 13,000 people in 119 countries (O’Connor et al., 2009). On top of those numbers, whale watching could accrue an additional $413 million and 5,700 jobs from countries that do not currently operate whale watching companies (Cisneros-Montemayor et al., 2010). Cisneros-Montemayor et al. (2010) explains that based on worldwide mammal distributions, almost any coastal country can be involved in whale watching.

Besides the benefits of whale watching, there are concerns. Two concerns of importance are how to monitor whale watching and what is proper protocol. One difficulty to making regulations for whale watching is the vast diversity of situations for which whale watching occurs. Whale watching falls under the common pool resource. Depending on the topography of the ocean floor, whale watching can occur within eyesight of land, like in the case of Madeira or Cape Cod, Massachusetts, or it could occur several miles offshore. Marine resources, especially pelagic, can be difficult to monitor. The IWC is the leading organization when it comes to the guidelines for responsible and sustainable whale watching. Since the IWC mainly recommends guidelines, it is up to local organizations or governments to come up with legal protocols. In the United States of American, the MMPA has regulations when it comes to whale watching. There are regulations that cover topics ranging from how many boats can be around cetaceans at a certain time or how close a boat can get to cetaceans. Some of these regulations are specific for certain species. The North Atlantic right whale (E. glacialis), which is commonly seen off the East coast of the United States during the winter months, is a protected species. There are regulations put into place that require boats to be at least 500 yards away (NOAA). A problem with setting a limit like this is how to measure exactly how far away a vessel is at the moment, especially at sea in rough weather (Parsons 2012). Parsons (2012) continues
to explain the difficulties of how to handle a situation if a whale approaches a vessel. Should the operator move away from the whale, stay still, turn off the engine, or do nothing at all? To inexperienced operators, and even the experienced ones sometimes, these can be difficult situations with negative consequences, like harm to the animal or breaking regulations, if they make the wrong decision. Another difficult situation to assess is the behavior of the animal. Feeding or distress behaviors could be misinterpreted or missed completely (Whitt 2006).

A report published by the International Fund for Animal Welfare (IFAW) in 2009 explains that Madeira had a noticeable growth in whale watch activity from the period of 1998 to 2008. This report separated the areas of mainland Portugal, the Madeira Archipelago, and the Azores into separate regions and considered as countries. Over this span the Madeira Archipelago was one of the fastest growing whale watching industries at 72.9%. The amount of whale watchers was considered “none” in 1998, but increased to 59,731 by 2008. Madeira was only behind China (107% growth per annum since 1998), Maldives (86%), Cambodia and Laos together (79%), and St. Lucia (74%). Overall, Madeira accounts for 7% of all whale watch revenue in Europe, while mainland Portugal, Madeira, and the Azores account for 23% of total revenues. That is the largest portion for Europe.

The importance of whale watching around Madeira was quickly understood through the increase in whale watching companies and operating platforms. This led the Madeira Whale Museum (MWM) to come up with voluntary protocols for whale and dolphin watching to lessen the stress to the cetaceans. These protocols, which were proposed in 2003, were adopted by the majority of the companies, but set the basis for legislation. The Regional Government created the Decreto Legislativo Regional n. ° 15/2013/M - Regulamento da Atividade de Observação de Vertebrados Marinhos na Região Autónoma da Madeira. (CETACEOSMADEIRA II)

Since the IWC mainly recommends guidelines, this legislation has set the regulations for marine vertebrate observation around the Madeira Archipelago. Cetaceans are covered under this legislation.
It defines topics ranging from what is defined as a cetacean to how close vessels can be to cetaceans, but also what the consequences are if there is an offense against this legislation. (Autonomous Region of Madeira 2013)

2.3 Research

When it comes to researching cetaceans photo-identification (photo-ID) is an important, noninvasive, and inexpensive tool. Auger-Méthé (2007) defines photo-ID as a method of using photographs of natural markings, such as scars and pigmentation patterns, to identify individuals. Using natural markings for photo-ID can have many disadvantages, but it can also be problematic. Natural markings like nicks and scars can change over time or markings on different individuals can be indistinguishable from each other (Hammond 1986). For example, some dolphin species tend to have many nicks along the trailing edge of their dorsal fin that can be complicated to distinguish from one another.

One prominent study published by Würsig and Jefferson (1990) explains the methods of photo-ID for small cetaceans. Out of the 16 species described in that report four of them are used in this study, which are:

*Orcinus orca*: the dorsal fin shape and nicks, scars on the back and shape of light saddle patch.

*Globicephala macrorhynchus*: Nicks, scratches, scars and pigment patterns on the dorsal fin and back.

*Tursiops truncatus*: nicks, scars, scratches and pigment spots on dorsal fins.

*Stenella frontalis*: fin and fluke marks and body spot patterns.

Würsig and Jefferson (1990) further explain that for most dolphins and porpoises the trailing edge of the dorsal fin is the most identifiable feature. This is the area of the dorsal fin that tapers from the front to back. The reason for this is the area easily abrades and tatters.
There have been many studies that have used photo-ID as the primary identification tool (Auger-Méthé 2007, Baird et al. 2014, Baird and Gorgone 2005, Baird et al. 2009, Wilson et al. 1997, Kiszka et al. 2008, Luksenburg 2014, Bearzi et al. 2009, and Ritter et al. 2015). To use photo-ID the photograph should meet certain standards. The photo quality and distinctiveness ratings are important characteristics when evaluating the photograph. Photo quality rating consists of focus, clarity, contrast, angle, and the portion of the individual in the frame (Friday et al. 2000). The distinctiveness rating is separated into four categories: 1) not distinctive, 2) slightly distinctive, 3) distinctive, and 4) very distinctive. This rating is used to assess the possibility that the individual has enough natural markings to be able to identify it from other individuals (Baird et al. 2014).

The photo-ID tool was used to conduct the database that was used in this study. Some of the previously mentioned studies have used it in a similar way as this report. Wilson et al (1997) conducted a study on skin lesions and physical deformities in bottlenose dolphins in the Moray Firth. The study used photographs to analyze the percentage of the fin that were covered in lesions. The individuals were categorized by age group and sex (males, probable males, and females). This report ended up using the skin lesions categories from Wilson et al. (1997). The report found that 70 out of the 74 individuals had lesions. Adult females had a significantly greater coverage of lesions than adult males, while calves were the most affected with skin lesions.

A study conducted by Kiszka et al. (2008) investigated the interactions between small cetaceans and fisheries around the Mozambique Channel Island of Mayotte using body scars and dorsal fin disfigurements as indicators. The species included in the study were Tursiops aduncus (Indo-Pacific bottlenose dolphins), Peponocephala electra (melon-headed whales), and Globicephala macrorhynchus (short-finned pilot whales). The study found evidence of interactions with fisheries amongst the three species, and that the more coastal species, in this case T. aduncus, had the highest occurrence of interactions. There were also signs of body scars and dorsal fin disfigurements from
inter-/intra-specific interactions, include sharks bites. The researchers were able to distinguish between anthropogenic disfigurements and predatory markings.

An extensive report by Van Bressem et al. (2007) reviewed and documented new cases of diseases in 7,635 specimens that spanned 12 odontocete species. These deformities covered skin and skeletal system and external traumata in cetaceans in South American waters. This study was done through hands-on work, which included necropsy and lab work, as well as photo-ID. Skin lesions and diseases of concern were Tattoo skin disease (TSD), lobomycosis-like disease (LLD), and cutaneous diseases of unknown etiology. The study was the first to report the presence of TSD in cetaceans other than the bowhead whale (Bracht et al. 2006), of which *T. truncatus* was one of the species along with *Phocoena spininnipis*, *Cephalorhynchus eutropia*, *Cephalorhynchus commersonii*, and *Sotalia guianensis*. The diseases documented can impact the populations of cetaceans in the South American waters in multiple ways, ranging from infertility to death, which can be present through pathways such as being acquired, congenital, traumatic, infectious or parasitic. Anthropogenic traumata are also covered in this article, which fishing gear entanglements were the primary cause. In the affected individuals of traumata, 70.5% could be attributed to interactions with fisheries. Boat collisions were to a lesser extent, but injuries such as propeller wounds were observed. The importance of this study by Van Bressem et al. (2007) is the how comprehensive and extensive it is. The deformities are reviewed and documented, but the causes, when feasible, are included.

Luksenburg (2014) published a report studying the prevalence of external injuries in small cetaceans in Aruban waters in the Southern Caribbean. Three species were part of the study: *S. frontalis*, *T. truncatus*, and *P. crassidens*. This study focused on external injuries pertaining to anthropogenic or natural causes. All three species showed examples of interactions with fishing gear. Out of the 18.7% of individuals that showed some sort of external injury, almost half of them (41.7%) could be attributed to human interactions. A study that is similar to the one conducted by Luksenburg (2014) was done by Baird and Gorgone (2005). This studied the fin disfigurements of false killer whales in
Hawaiian waters as a possible indicator of long-line fishery interactions. Out of the 80 distinctive individuals identified there were three with major dorsal fin disfigurements. A major dorsal fin disfigurement was defined as a completely bent over fin or a missing dorsal fin. There was the conclusion that these injuries were more than likely due to interactions with longlines from Hawai‘i-based tuna and swordfish fishery in offshore Hawaiian waters. The population of false killer whales that were found to be injured was also concluded to be part of the same population that interacts with the fishery. These results were also found to be more than four times greater than for other odontocete populations. Baird and Gorgone published another report furthering a similar study (Baird et al., 2014) that analyzed sex bias and variation among populations and social groups of false killer whales in Hawaiian waters focusing on fisheries interactions. The results showed that females were the only individuals, out of the seven sexed individuals, that showed injuries consistent with fisheries interactions. This could imply that fisheries-related mortality has a disproportionate impact on population dynamics.

Dusky dolphins, *Lagenorhynchus obscurus*, were studied by Kügler and Orbach (2014) off Kaikoura, New Zealand. This project studied the sources of notch and scar patterns on the dorsal fins, which also considered pigmentation as marks. Based on previous studies that analyzed the origins of similar markings, the study was able to conclude what caused the markings. Their findings showed that 1,019 out of the 1,171 individuals had notches. Most of the marks were attributed to intraspecific interactions (notches: 84% and scars 30%). This was followed by predation attempts (sharks: 0.17%, killer whales: 0.09%, and unclassified natural predators: 0.26%) and human impact (net/line: 0.43%, vessel 0.17%, and unclassified human impact 0.34%). The last two categories were comparatively low.

Two studies that are more similar to this one were conducted by Bearzi et al. (2009) and Ritter et al., (2015). Bearzi et al. (2009) looked at skin lesions and physical deformities of coastal and offshore common bottlenose dolphins in Santa Monica Bay and adjacent areas in California. It found 79% of
the 637 examined individuals showed at least one type of skin lesion and only one individual showed a physical deformity. These categories excluded physical injuries and dorsal fin notches. The study shows that skin lesions affect a large portion of the common bottlenose dolphin population in that area. Ritter et al., (2015) examined the physical anomalies in small cetaceans off La Gomera in the Canary Islands, Spain. This gives a closer comparison to the Madeira Archipelago. Results showed that a high number of individuals suffered from moderate to severe injuries.

There have been studies that have mainly focused on deformities that have to do with skin pigmentation such as leucism, melanism, and piebaldism (Abreu et al. 2013, Schaeff et al. 1999, Alves et al. 2017a). A collection of records including non-aquatic species and aquatic species was documented by Abreu et al. 2013, which included cetaceans. There were 149 cetaceans reported in scientific specimens to have anomalous coloration, which included 146 southern right whales from the Argentine coast (Schaeff et al. 1999). Around Madeira there has been a recent study that documented cases of leucism and melanism in short-beaked common dolphins and Atlantic spotted dolphins (Alves et al. 2017). Overall, at the time of the study for Acevedo et al. (2009), there had been 25 cetacean species recorded as anomalously white.

Rostral deformities of beaked whales around Madeira have been studied by Dinis et al. (2017a). One adult female Blainville’s beaked whale with a “displacement of the rostrum to the right of the midline, with the tip extending ventrally beyond the mandible” was seen in 2012 and 2013. The origin of the rostral deformity is not known, but Dinis et al. (2017a) explain that based on the repeated sightings in Madeira, the individual being an adult, and no signs of emaciation the deformity has not inhibited its feeding capabilities. Along with the Blainville's beaked whale, an adult female Cuvier’s beaked whale in the Canary Islands, two adult female Blainville’s beaked whales, and one stranded northern bottlenose whale from the southeast coast of Fuerteventura were documented as having rostral deformities in the report. All of the individuals were female and either adult or young adults, which means they were able to survive with their deformities, except for the northern
bottlenose whale which was assumed to have stranded due to naval exercises using active sonar. Dinis et al. (2017a) speculates that females have a higher capability of surviving to adult age with rostral deformities than males due to males having different major rostrum anatomy, but could use further research to assess longevity and autonomy in cases of rostral deformities.

Another skeleton deformity documented in this study is an abnormal deviation of the vertebral column. Scoliosis, kyphosis, and lordosis are documented in eight cases of white-beaked whales from Iceland, the UK, Denmark and The Netherlands (Bertulli et al. 2015). Not all of the causes of these deformities could be concluded, but four out of the eight cases had evidence of the deformity being caused by an unknown trauma, but presumed to be of anthropogenic origin. Out of the eight individuals five of them were free-ranging and the other three were stranded. The five free-ranging cases were found to survive with the deformities and the presence of food in the stomach of one of the stranded individuals shows that the deformity did not impair normal locomotory functions. There have been other documented cases of individuals surviving with vertebral deformities, such as a bottlenose dolphin with two prominent kyphotic deformations that did not show any changes for eight consecutive years (Berghan and Visser 2000) and a female bottlenose dolphin with slight lordosis documented by Haskins and Robinson (2007) which was photographically recaptured over seven years and gave birth two times over that time span.

A study by Vecchione and Aznar (2014) has connected epibionts, like Pennella balaenopterae, and the overall health of individuals and populations. The report suggests that the epibionts take advantage of the poor health of the individual to settle on the body, typically found on the dorsal fin or laterally on the midsection. P. balaenopterae is the most common mesoparasitic copepod found to infest baleen whales and dolphins (Vecchione and Aznar 2014). Another epibionts found on cetaceans is Xenobaalanus globicipitis, which is a coronulid barnacle that is exclusively found on cetaceans and is found worldwide (Carillo et al. 2015). Carillo et al. (2015) postulates that chemical recognition of cetaceans is the determining factor for X. globicipitis to settle and that the fins,
particularly the leading edge, are the preferred location to settle. During the previously mentioned DMV epizootic of the late 1990s in the Mediterranean that affected striped dolphins and long-finned pilot whales, both *P. balaenopterae* and *X. globicipitis* were found to infest striped dolphins (Aznar *et al.* 1994, Aznar *et al.* 2005). Data were collected about pre- and post-epizootic striped dolphins stranded along the Mediterranean central coast of Spain from 1981 to 2004. The results showed that there was an increase in the prevalence of *P. balaenopterae* and *X. globicipitis*, so it was concluded that there was a possibly a short-term increase in the probability of infestation due to the increase in susceptible hosts. This was likely caused by the immunosuppressive effects of the viral infection (Aznar *et al.* 2005).

Migratory species like *B. borealis*, *B. physalus*, *B. brydei*, and *P. macrocephalus* have been documented to have the presence of “crater-like wounds,” which have been attributed to cookie-cutter sharks (*Isistius* sp) (Best and Photopoulou 2016). Moore *et al.* (2003) documented cookie-cutter bites in a possible resident group of fin whales and humpback whales, which were not reported in any other North Atlantic fin and humpback whales. The report further concludes that the absence of cookie-cutter markings on other populations of fin and humpback whales means those markings could be used to identify individuals from the possible resident population of those two species. This data could use further research to verify these findings (Moore *et al.* 2003).
3. Methods

3.1 Study Area

Figure 11: A map of the northern section of the Atlantic Ocean with the Madeira archipelago in the box.

The Madeira Archipelago (Portugal) is situated at an average latitude and longitude of 32° 46’N and 16° 46’W and is approximately 670 km from Morocco in the northeastern part of Atlantic Ocean (Figure 11). Five volcanic islands make up this archipelago: the island of Madeira, three islands that make up Desertas, and the island of Porto Santo (Geldmacher et al., 2000) (Figure 12). Surrounding these islands are steep submarine canyons and deep waters that are common due to a reduced continental shelf (Geldmacher et al., 2000). There are 29 documented species recorded in the
archipelago of Madeira, which is updated from 15 species (Freitas et al. 2012, Ferreira et al. 2017).

![Map of the Madeira Archipelago](image)

Figure 12: Map of the Madeira Archipelago. The island of Madeira is to the west, Porto Santo is to the northeast, and the islands of Desertas are to the southeast.

### 3.2 Data Collection/Used

The database was provided by the Centro Interdisciplinar de Investigação Marinha e Ambiental da Madeira (CIIMAR Madeira). This database contains photographs that have been collected since 2003 through platforms of opportunity. These are from whale and dolphin watching vessels operating bi-daily trips year-round mainly in the south, southwest and southeast of Madeira Island.

The first part of the database that was primarily used was organized by identified individuals, which were broken down by species, i.e. there was a photo-ID catalogue per species. Each individual was
given an identification number as well as the abbreviation from the first letters of their genus and species, for example *Tursiops truncatus* is abbreviated as Tt. These photographs focused on features of the individuals so that photo-ID could be used. Species that demonstrated abundant nicks were organized by the amount of nicks (1N, 2N, 3N, 4N, +4N). Individuals were also organized into folders that showed nicks or deformities in general on the leading edge of the dorsal fin (MAD) and individuals without nicks on the dorsal fin (WN). These species included *T. truncatus* and *G. macrorhynchus*. One species, *M. densirostris*, was organized by sex. Male and females were organized based on at least one photograph that showed the presence or absence of protruding teeth.

The deformities were categorized into six general groupings: skin lesions, anatomical malformations, physical impacts, emaciation, epibionts, and uncategorized.

Photographs from 11 different species were analyzed ranging from photos of dorsal fins to full body. The amount of individuals for each species varied, as well as the amount of photos for each species and individuals. There were a minimum of 2 individuals for *B. borealis* and a maximum of 458 individuals for *G. macrorhynchus*.

The photographs in the database had a photograph quality (PQ) rating from 1-3 in increasing order: 1) bad, 2) fair, and 3) good). Since the photos were originally used for photo-ID, distinctive features like nicks on the dorsal fin or permanent scars were usually the focus of the photo. This could be the case for the photographs with a PQ of 1, but in the case of this report, the quality of the photo did not allow for clear inspection of the individual based on photograph characteristics such as lighting, contrast, or shadows. Therefore, photos with a PQ of 1 were discarded. Some of the discarded photos were from individuals that only had photos’ of which the quality was not sufficient enough to make a quality examination. This means that even though there might have been an identified individual in the database for photo-ID, it was not included in this report. Other instances of discarded photographs were from resighted individuals, so the amount of sightings for each individual is based on the
amount of quality photos that allowed for a proper examination. Overall, photos with a PQ of 1 were typically discarded, while some photos with a PQ were sometimes discarded. A photo with a PQ of 3 was rarely discarded.

The photos were opened in either Windows Photo Viewer or the default photo viewer from Toshiba, which is the kind of computer used for the examinations of the photos. Using the zoom ability of both programs, I examined the photos for any deformities that were previously explained. The deformities were quantified based on presence and location. If there was a deformity, a 1 was entered into the datasheet along with a section number that corresponded with the area of the body of the individual. Two drawings were made to show the sections of a baleen whale, *B. brydei*, and a dolphin, *D. delphis*. The number sections of the bodies were following drafts by Hill *et al* (2017) and Hupman *et al* (2017). During the examination of the photographs, if there was a possible sign of the deformities being caused by anthropogenic causes, the photographed was highlighted. Due to the lack of time and access to verify that these were in fact due to anthropogenic causes, these were theorized as being anthropogenic.

Rake marks and nicks were originally analyzed, but were not factored into other analyses besides the prevalence of each type of deformity. This was based on these two deformities being considered commonplace, especially for dolphin species, which is following work done by Wilson *et al* (1997).

Using Microsoft Excel, the amount of individuals with one or more deformities was calculated compared to individuals without deformities. This includes results with and without rake marks and nicks. After those initial analyses, rake marks and nicks were not included. Percentages for each category of deformity based on total individuals and species were then analyzed. The averages for both the amount of deformities for each individual based on the total amount of individuals and the amount based on species were calculated.
3.3 Types of Deformities

Deformities are defined as “a condition, in which all or part of the body does not have the expected/typical/characteristic or normal species shape, color or appearance, which are congenital or acquired during the course of the individual’s life.” Throughout scientific literature, there had not been a definition for a deformity, so this definition was established.

3.3.1 Skin lesions

Skin lesions consisted of 13 subcategories. The first 10 subcategories were based on literature from Wilson et al (1997), except that abraded fin tips was not included. This was due to white fin-fringe lesions and abraded fin tips being considered as redundant.

- **Black lesions**: uniformly black, circular or amorphous patches with rounded edges. With appropriate lighting they appear to be slightly depressed below the surrounding skin. The lesion surface itself appeared to be smooth.

- **Pale lesions**:
  - **White lesions**: either circular or amorphous with rounded edges. Their surface was smooth and lay flush with the rest of the skin. White and sometimes had a matt, chalky appearance.
  - **Cream lesions**: much like white lesions but often had a diffuse border and were cream colored. Difficult to distinguish from white lesions.
  - **White fin-fringe lesions**: probably a subset of white lesions. Smooth, flush with the rest of the skin and white. By definition, they occurred specifically along the leading and trailing edges of the dorsal fin. Inner margins of the white fin-fringes were often rounded, sometimes jagged and more often distinct than diffuse.
• **Cloudy lesions**: blue-grey color, occurred on the back or dorsal fin and had both distinct and diffuse, rounded edges. Had the appearance of a sheen, being smooth, flush with the skin and often extended over other lesion types.

• **Lunar lesions**: represented a complex mixture of black, grey, blue-grey, and white skin. The surface of these lesions was uneven, being both raised and pitted and gave the skin an appearance of corroded aluminum. Borders were either jagged or rounded but were always distinct. Appeared to be a combination of black, white, cream, and cloudy lesions.

• **Dark-fringed spots**: pale areas of skin surrounded by a dark halo and were most often circular. Difficult to distinguish from white or cream lesions due to skin being dark.

• **White-fringed spots**: cream or white halos surrounding small circles of normally colored or black skin.

• **Orange lesions**: (Most likely caused by diatoms)
  - **Orange hue**: entire skin of some animals appeared orange. Most obvious on areas which were pale in unaffected animals, such as flanks and belly.
  - **Orange patches**: similar orange or a rusty color, but occurred only in distinct patches. Edges could be either jagged or rounded or both.

In addition to the 10 subcategories that Wilson et al (1997) describes, three more were added to include larger skin pigmentation irregularities. These three are:

**Leucism**: the total or partial absence of pigmentation in the whole body (Fertl and Rosel, 2002)

**Melanism**: increased amount of black or nearly black pigmentation (Acevedo and Aguayo 2008)

**Piebaldism**: lack of pigmentation in some parts of the body, but presenting normal coloration in the eyes (Fertl and Rosel, 2002)
3.3.2 Anatomical malformations

Anatomical malformations are defined as “any deviation from normal formation” (Berghan and Visser, 2000). This grouping is focusing on formation of the body from natural or possibly internal causes. There are eight subcategories which are:

*Bent dorsal* which can be considered bent to the left or the right, and completely or partially bent.

*Rostrum abnormality* is the displacement of the rostrum to the right or left, or having a reduced mandible.

*Depression* is a collapsed portion of the skin.

*Neoplasia* is the formation of a tumor (Merriam-Webster Dictionary)

*Scoliosis* is the abnormal deviation of the vertebral column in a dorsal plane with lateral curvature, which can be left- and/or right-sided (Bertulli et al, 2015)

*Kyphosis* is the abnormal deviation of the vertebral column with concavity on the ventral side (Bertulli et al, 2015)

*Lordosis* is the opposite of kyphosis. It is the abnormal deviation of the vertebral column with concavity of the dorsal side (Bertulli et al, 2015)

*Raised skin patch* is a portion of the skin raised above the surrounding skin.

3.3.3 Physical impact

The physical impact group is considering an external force affecting the physical appearance of the individual. There are four subcategories, which are:
Nicks are defined as an indentation in the leading or trailing edge of the dorsal fin, identifiable from both sides. (Alves et al. 2013)

Cuts are typically straight lines impacting the skin. These can also be deeper or larger impressions or incisions than nicks. Cuts can seem similar to rake marks, but are distinguished

Cookie-cutter marks are circular crater-like wounds (Best and Photopoulou, 2016)

Rake marks are parallel lines caused by inter- or intraspecific interactions.

3.3.4 Emaciation

Emaciation is defined as unnatural thinning, which is characterized by muscular and adipose tissue atrophy, with consequent postcranial depression and clearly defined rib impressions under the skin. (Domiciano et al. 2016)

3.3.5 Epibionts

Epibionts are defined as an organism that lives on the body surface of another. The species of epibionts were not identified, so it is a general identification as epibionts. Parasitic organisms like these can be used an indicator for the health of the individual (Vecchione and Aznar, 2014).

3.3.6 Uncategorized

The last group of deformities is uncategorized. These were deformities that were too difficult to identify as other deformities. There was a consensus among multiple researchers that the deformities in this group could not be identified, nor could the cause.
4. Results

Overall 1,020 individual cetacean specimens were analyzed comprising 11 species. The amount of individuals per species ranged from two (B. borealis) specimens to 458 (G. macrorhynchus) specimens. A total of 35 mysticetes and 985 odontocetes were included in this study.

A total of 2,588 deformities were documented. Out of these there were 622 individuals with rake marks and 933 with nicks. Only 15 (1.47%) of the total sample analyzed did not show any signs of deformities. These included two D. delphis, two M. densirostris, eight P. macrocephalus, and three P. crassidens. Table 1 shows the amount of identified individuals for each species.

Table 1: Amount of identified individuals for each species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Individuals Sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balaenoptera borealis</td>
<td>2</td>
</tr>
<tr>
<td>Balaenoptera brydei</td>
<td>33</td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>40</td>
</tr>
<tr>
<td>Globicephala macrorhynchus</td>
<td>458</td>
</tr>
<tr>
<td>Mesoplodon densirostris</td>
<td>57</td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>11</td>
</tr>
<tr>
<td>Physeter macrocephalus</td>
<td>64</td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>10</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>5</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>18</td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>322</td>
</tr>
<tr>
<td><strong>Total = 1020</strong></td>
<td></td>
</tr>
</tbody>
</table>

Based on the overall six categories (skin lesions, anatomical malformations, physical impacts, emaciation, epibionts, and unclassified deformities) the most prevalent deformities were part of the physical impact group with 70.44%. This included rake marks and nicks. The rest of the categories in
descending order were skin lesions (20.13%), epibionts (5.22%), anatomical malformations (3.17%), emaciation (0.77%), and unclassified (0.27%). Table 2 shows the percentages of the overall six categories. Rake marks and nicks are included in the second column, but are then excluded in the third column. The most commonly found category of deformity changes to skin lesions with 50.44% followed by physical impacts (25.94%), epibionts (13.07%), anatomical malformations (7.94%), emaciation (1.94%), and unclassified (0.68%).

Table 2: The overall six categories of deformities and their percentages. Rake marks and nicks are included in the physical impacts category.

<table>
<thead>
<tr>
<th>Category of Deformity</th>
<th>% With Nicks and Rake Marks</th>
<th>% Without Nicks and Rake Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin lesions</td>
<td>20.13%</td>
<td>50.44%</td>
</tr>
<tr>
<td>Anatomical malformations</td>
<td>3.17%</td>
<td>7.94%</td>
</tr>
<tr>
<td>Physical impacts</td>
<td>70.44%</td>
<td>25.94%</td>
</tr>
<tr>
<td>Emaciation</td>
<td>0.77%</td>
<td>1.94%</td>
</tr>
<tr>
<td>Epibionts</td>
<td>5.22%</td>
<td>13.07%</td>
</tr>
<tr>
<td>Unclassified</td>
<td>0.27%</td>
<td>0.68%</td>
</tr>
</tbody>
</table>

Table 3 shows the percentages and total amounts of each type of deformity, including rake marks and nicks. Even though there were no results for piebaldism, scoliosis, or kyphosis these types of deformities included to be comprehensive for skin pigmentation deformities of similar kinds and vertebral deformities that included spinal curvature. In the case of piebaldism, it is similar to melanism and leucism in the sense that they are types of skin deformities pertaining to either hypo- or hyper-pigmentation. Scoliosis and kyphosis are similar to lordosis because they are conditions pertaining to the abnormal deviation of the vertebral columns.
Table 3: The total number of each category of deformity and the percentage of each by the total number of deformities.

<table>
<thead>
<tr>
<th>Deformities</th>
<th>Percentage of Total Deformities</th>
<th>Total Number of Deformities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>2.28%</td>
<td>59</td>
</tr>
<tr>
<td>White</td>
<td>5.29%</td>
<td>137</td>
</tr>
<tr>
<td>Cream</td>
<td>1.58%</td>
<td>41</td>
</tr>
<tr>
<td>White fin-fringe</td>
<td>3.86%</td>
<td>100</td>
</tr>
<tr>
<td>Cloudy</td>
<td>2.24%</td>
<td>58</td>
</tr>
<tr>
<td>Lunar</td>
<td>0.12%</td>
<td>3</td>
</tr>
<tr>
<td>Dark-fringe</td>
<td>0.97%</td>
<td>25</td>
</tr>
<tr>
<td>White-fringed</td>
<td>0.62%</td>
<td>16</td>
</tr>
<tr>
<td>Orange hue</td>
<td>0.43%</td>
<td>11</td>
</tr>
<tr>
<td>Orange patch</td>
<td>2.51%</td>
<td>65</td>
</tr>
<tr>
<td>Leucism</td>
<td>0.08%</td>
<td>2</td>
</tr>
<tr>
<td>Melanism</td>
<td>0.15%</td>
<td>4</td>
</tr>
<tr>
<td>Piebaldism</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Bent dorsal</td>
<td>0.23%</td>
<td>6</td>
</tr>
<tr>
<td>Missing limb (Completely/Partial)</td>
<td>2.20%</td>
<td>57</td>
</tr>
<tr>
<td>Rostrum abnormality</td>
<td>0.04%</td>
<td>1</td>
</tr>
<tr>
<td>Depression</td>
<td>0.43%</td>
<td>11</td>
</tr>
<tr>
<td>Neoplasia</td>
<td>0.08%</td>
<td>2</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Kyphosis</td>
<td>0%</td>
<td>0</td>
</tr>
<tr>
<td>Lordosis</td>
<td>0.04%</td>
<td>1</td>
</tr>
<tr>
<td>Raised skin patch</td>
<td>0.15%</td>
<td>4</td>
</tr>
<tr>
<td>Nicks</td>
<td>36.05%</td>
<td>933</td>
</tr>
<tr>
<td>Cuts</td>
<td>9.47%</td>
<td>245</td>
</tr>
<tr>
<td>Cookie-cutter (Healed/Unhealed)</td>
<td>0.89%</td>
<td>23</td>
</tr>
<tr>
<td>Rake Marks</td>
<td>24.03%</td>
<td>622</td>
</tr>
<tr>
<td>Emaciation</td>
<td>0.77%</td>
<td>20</td>
</tr>
<tr>
<td>Epibions</td>
<td>5.22%</td>
<td>135</td>
</tr>
<tr>
<td>Unclassified</td>
<td>0.27%</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td><strong>2,588</strong></td>
</tr>
</tbody>
</table>
When discarding rake marks and nicks, there were 423 (41.47%) individuals without deformities and 597 (58.53%) individuals with at least one deformity. Table 4 displays the deformities after discarding rake marks and nicks.

Table 4: The percentage of each deformity by total amount of deformities after discarding rake marks and nicks.

<table>
<thead>
<tr>
<th>Deformities</th>
<th>Percentage of Total Deformities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td>5.71%</td>
</tr>
<tr>
<td>White</td>
<td>13.26%</td>
</tr>
<tr>
<td>Cream</td>
<td>3.97%</td>
</tr>
<tr>
<td>White fin-fringe</td>
<td>9.68%</td>
</tr>
<tr>
<td>Cloudy</td>
<td>5.61%</td>
</tr>
<tr>
<td>Lunar</td>
<td>0.29%</td>
</tr>
<tr>
<td>Dark-fringe</td>
<td>2.42%</td>
</tr>
<tr>
<td>White-fringed</td>
<td>1.55%</td>
</tr>
<tr>
<td>Orange hue</td>
<td>1.06%</td>
</tr>
<tr>
<td>Orange patch</td>
<td>6.29%</td>
</tr>
<tr>
<td>Leucism</td>
<td>0.19%</td>
</tr>
<tr>
<td>Melanism</td>
<td>0.39%</td>
</tr>
<tr>
<td>Piebaldism</td>
<td>0.00%</td>
</tr>
<tr>
<td>Bent dorsal</td>
<td>0.58%</td>
</tr>
<tr>
<td>Missing limb (Completely/Partial)</td>
<td>5.52%</td>
</tr>
<tr>
<td>Rostrum abnormality</td>
<td>0.10%</td>
</tr>
<tr>
<td>Depression</td>
<td>1.06%</td>
</tr>
<tr>
<td>Neoplasia</td>
<td>0.19%</td>
</tr>
<tr>
<td>Scoliosis</td>
<td>0.00%</td>
</tr>
<tr>
<td>Kyphosis</td>
<td>0.00%</td>
</tr>
<tr>
<td>Lordosis</td>
<td>0.10%</td>
</tr>
<tr>
<td>Raised skin patch</td>
<td>0.39%</td>
</tr>
<tr>
<td>Cuts</td>
<td>23.72%</td>
</tr>
<tr>
<td>Cookie-cutter (Healed/Unhealed)</td>
<td>2.23%</td>
</tr>
<tr>
<td>Emaciation</td>
<td>1.94%</td>
</tr>
<tr>
<td>Epibionts</td>
<td>13.07%</td>
</tr>
<tr>
<td>Unclassified</td>
<td>0.68%</td>
</tr>
</tbody>
</table>

The results obtained (Table 4) without rake marks and nicks show that the most common deformities are cuts (245 cases, 23.72%), white skin lesions (137 cases, 13.26%), and epibionts (135 cases,
13.07%). Of the 423 individuals without deformities, *G. macrorhynchus* had the most individuals with 254, while *B. borealis* had zero individuals showing no deformities. This is based on just identified individuals, so it is not proportional.

The species with the highest proportion of its population without deformities based on identified individuals is *P. macrocephalus* with 73.44%. Table 5 shows the breakdown by species of the total amount of individuals and percentage of the total amount of identified individuals that do not have any deformities. To compare those numbers, Table 6 shows the number of individuals and the percentage of their overall identified population that have at least one deformity.

Table 5: The amount and percentages of identified populations that do not have deformities by species. This does not include rake marks and nicks.

<table>
<thead>
<tr>
<th>Species</th>
<th># of Individuals of Each Species Without Deformities (No. of Individuals Analyzed)</th>
<th>Percentage of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Balaenoptera borealis</em></td>
<td>0 (2)</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Balaenoptera brydei</em></td>
<td>4 (33)</td>
<td>12.12%</td>
</tr>
<tr>
<td><em>Delphinus delphis</em></td>
<td>13 (40)</td>
<td>32.50%</td>
</tr>
<tr>
<td><em>Globicephala macrorhynchus</em></td>
<td>254 (458)</td>
<td>55.46%</td>
</tr>
<tr>
<td><em>Mesoplodon densirostris</em></td>
<td>2 (57)</td>
<td>3.51%</td>
</tr>
<tr>
<td><em>Orcinus orca</em></td>
<td>4 (11)</td>
<td>36.36%</td>
</tr>
<tr>
<td><em>Physeter macrocephalus</em></td>
<td>47 (64)</td>
<td>73.44%</td>
</tr>
<tr>
<td><em>Pseudorca crassidens</em></td>
<td>6 (10)</td>
<td>60.00%</td>
</tr>
<tr>
<td><em>Stenella frontalis</em></td>
<td>2 (5)</td>
<td>40.00%</td>
</tr>
<tr>
<td><em>Steno bredanensis</em></td>
<td>13 (18)</td>
<td>72.22%</td>
</tr>
<tr>
<td><em>Tursiops truncatus</em></td>
<td>78 (322)</td>
<td>24.22%</td>
</tr>
<tr>
<td><strong>Total individuals</strong></td>
<td><strong>423 (1,020)</strong></td>
<td></td>
</tr>
</tbody>
</table>
Table 6: The amounts and percentages by species of each identified populations that have at least one deformity. This does not include rake marks and nicks.

<table>
<thead>
<tr>
<th>Species</th>
<th># of Individuals of Each Species With Deformities (No. of Individuals Analyzed)</th>
<th>Percentage of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balaenoptera borealis</td>
<td>2 (2)</td>
<td>100.00%</td>
</tr>
<tr>
<td>Balaenoptera brydei</td>
<td>29 (33)</td>
<td>87.88%</td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>27 (40)</td>
<td>67.50%</td>
</tr>
<tr>
<td>Globicephala macrorhynchus</td>
<td>204 (458)</td>
<td>44.54%</td>
</tr>
<tr>
<td>Mesoplodon densirostris</td>
<td>55 (57)</td>
<td>96.49%</td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>7 (11)</td>
<td>63.64%</td>
</tr>
<tr>
<td>Physeter macrocephalus</td>
<td>17 (64)</td>
<td>26.56%</td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>4 (10)</td>
<td>40.00%</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>3 (5)</td>
<td>60.00%</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>5 (18)</td>
<td>27.78%</td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>244 (322)</td>
<td>75.78%</td>
</tr>
<tr>
<td><strong>Total individuals</strong></td>
<td><strong>597 (1,020)</strong></td>
<td></td>
</tr>
</tbody>
</table>

Of the individuals with deformities, there were more individuals that had one deformity (34.12%) than any other amount of deformities. The highest number of deformities recorded in one individual was eight (0.10% of the population), which was only on one species, *T. truncatus* (Table 7).
Table 7: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with eight deformities.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 8 Deformities</th>
<th>Percentage by 8 Deformities</th>
<th>Percentage of Total Population</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Balaenoptera borealis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Balaenoptera brydei</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Delphinus delphis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Globicephala macrorhynchus</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Mesoplodon densirostris</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Orcinus Orca</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td>* Physeter macrocephalus*</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Pseudorca crassidens</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Stenella frontalis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Steno bredanensis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
<td></td>
</tr>
<tr>
<td><em>Tursiops truncatus</em></td>
<td>1</td>
<td>100.00%</td>
<td>0.10%</td>
<td></td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>1</strong></td>
<td></td>
<td></td>
<td><strong>1</strong></td>
</tr>
</tbody>
</table>

The percentage of the overall population that had deformities decreased as the number of deformities increased. Table 8 shows the percentage of the total population by number of deformities.

Table 8: The amount and percentages of individuals based on the amount of deformities.

<table>
<thead>
<tr>
<th>Number of Deformities</th>
<th>Number of Individuals</th>
<th>Percentage of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 Deformity</td>
<td>423</td>
<td>41.47%</td>
</tr>
<tr>
<td>1 Deformity</td>
<td>348</td>
<td>34.12%</td>
</tr>
<tr>
<td>2 Deformities</td>
<td>127</td>
<td>12.45%</td>
</tr>
<tr>
<td>3 Deformities</td>
<td>81</td>
<td>7.94%</td>
</tr>
<tr>
<td>4 Deformities</td>
<td>25</td>
<td>2.45%</td>
</tr>
<tr>
<td>5 Deformities</td>
<td>10</td>
<td>0.98%</td>
</tr>
<tr>
<td>6 Deformities</td>
<td>5</td>
<td>0.49%</td>
</tr>
<tr>
<td>7 Deformities</td>
<td>0</td>
<td>0.00%</td>
</tr>
<tr>
<td>8 Deformities</td>
<td>1</td>
<td>0.10%</td>
</tr>
<tr>
<td><strong>Total individuals</strong></td>
<td><strong>1020</strong></td>
<td></td>
</tr>
</tbody>
</table>
There were a total of 80 individuals that showed deformities that were possibly from anthropogenic causes (Table 9). Of the individuals that displayed a possibly anthropogenic deformity, there was an average of 1.95 deformities per individual. This is a percentage of 7.84% of the total population, and refers to four species: \textit{T. truncatus} (54 individuals), \textit{G. macrorhynchus} (23 individuals), \textit{M. densirostris} (2 individuals) and \textit{D. delphis} (1 individual) (Table 9).

Table 9: The amount of individuals by species that have deformities possibly from anthropogenic causes.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Individuals With Anthropogenic Deformities</th>
</tr>
</thead>
<tbody>
<tr>
<td>\textit{Balaenoptera borealis}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Balaenoptera brydei}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Delphinus delphis}</td>
<td>1</td>
</tr>
<tr>
<td>\textit{Globicephala macrorhynchus}</td>
<td>23</td>
</tr>
<tr>
<td>\textit{Mesoplodon densirostris}</td>
<td>2</td>
</tr>
<tr>
<td>\textit{Orcinus orca}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Physeter macrocephalus}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Pseudorca crassidens}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Stenella frontalis}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Steno bredanensis}</td>
<td>0</td>
</tr>
<tr>
<td>\textit{Tursiops truncatus}</td>
<td>54</td>
</tr>
<tr>
<td>\textbf{Total individuals}</td>
<td>\bf{80}</td>
</tr>
</tbody>
</table>

Overall, there was an average of 1.01 deformities per individual. \textit{M. densirostris} had the highest average amount of deformities, followed by \textit{B. brydei} (1.88) and \textit{T. truncatus} (1.52). Table 10 shows the full list of average amounts of deformities by species.
Table 10: Average number of deformities by species per individual excluding rake marks and nicks.

<table>
<thead>
<tr>
<th>Species</th>
<th>Average Number of Deformities</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Balaenoptera borealis</em></td>
<td>1.0</td>
</tr>
<tr>
<td><em>Balaenoptera brydei</em></td>
<td>1.9</td>
</tr>
<tr>
<td><em>Delphinus delphis</em></td>
<td>1.0</td>
</tr>
<tr>
<td><em>Globicephala macrorhynchus</em></td>
<td>0.5</td>
</tr>
<tr>
<td><em>Mesoplodon densirostris</em></td>
<td>2.8</td>
</tr>
<tr>
<td><em>Orcinus orca</em></td>
<td>0.8</td>
</tr>
<tr>
<td><em>Physeter macrocephalus</em></td>
<td>0.3</td>
</tr>
<tr>
<td><em>Pseudorca crassidens</em></td>
<td>0.4</td>
</tr>
<tr>
<td><em>Stenella frontalis</em></td>
<td>0.6</td>
</tr>
<tr>
<td><em>Steno bredanensis</em></td>
<td>0.3</td>
</tr>
<tr>
<td><em>Tursiops truncatus</em></td>
<td>1.5</td>
</tr>
</tbody>
</table>

There was only one species that could be analyzed based on sex, *M. densirostris*, due to the available data and set up of the database. It was found that females (n=28) had, on average, more deformities per individual than males (n=14) did both including and excluding rake marks. Including rake marks, females had an average of 3.21 deformities per individual, while males had 3.36. After disregarding rake marks and nicks, females still had a higher average (2.61) than males (2.21).

5. Discussion

This study provided the first assessment of deformities of cetaceans in Madeira. A large portion of identified individuals showed signs of at least one deformity, and the greatest number of deformities observed on an individual was eight, which were found on a single common bottlenose dolphin (Table 8).

A definition of a deformity was established in this study: “a condition, in which all or part of the body does not have the expected/typical/characteristic or normal species shape, color or appearance, which are congenital or acquired during the course of the individual’s life.” This definition is not specific to Madeira and has a broad coverage, which allows replication in other areas in order to help assessing health status of top predators.
The overall analysis of the identified individuals in this study is considered a conservative one and represents a preliminary investigation on cetacean deformities in this study area. This is due to the photographs tending to focus on identifiable features and sections of the individuals, typically the dorsal fin and back. A more extensive selection of photographs for each individual that shows the full body could reveal more deformities and give a more comprehensive analysis.

This study is consistent with the results obtained about the prevalence of dorsal fin nicks from Kügler and Orbach (2014). Even though *Lagenorhynchus obscurus* was the only species in that study, the prevalence of 87% was just lower than 91.47% for this study. The cause of nicks was not explored for this study, but inter-/intra-specific interactions were assumed to be the cause. This is supported by Kügler and Orbach (2014) finding that 84% of nicks were due to inter-/intra-specific causes. Other studies did not factor in nicks into the results as well due to being highly common (Wilson *et al.* 1997, Bearzi *et al.* 2009).

This study shows that, when even disregarding rake marks and nicks, just over half (58.53%) of the identified individuals from 11 different species around Madeira show signs of at least one other type of deformity. Overall, this is a positive outcome compared to some studies that have concluded that certain species in some areas have a higher occurrence of deformities. Wilson *et al.* (1997) concluded that 95% of the *T. truncatus* population in the Moray Firth, Scotland showed signs of at least one deformity. That compares to 75.78% in this study. There was also a difference in the prevalence of multiple lesions occurring on the same individuals. Wilson *et al.* (1997) found that 61% of individuals had three or more types of lesions; and 5% had six or seven types. Those results are higher than this study, which found 29.1% of individuals with deformities had three or more types and 1.2% had six or more deformities. This difference in these statistics can possibly show the conditions of the habitat for *T. truncatus* when comparing the Moray Firth (Scotland) and Madeira (Portugal). Both of these studies were unable to provide causes for the deformities, but Wilson *et al.* (1997) does provide possibilities. Viral, fungal and bacterial infections, vitamin deficiencies,
parasites, and anthropogenic pollutants are some of the examples given. To know for sure what the causes are for the deformities more research would have to be done, including biopsy samples or necropsies.

When it comes to anthropogenic caused deformities, Kiszka et al. (2008) observed signs of interactions with fishing gear in Indo-Pacific bottlenose dolphins (14%), melon-headed whales (1.5%), and short-finned pilot whales (4.4%). Compared to this study which found four species to have deformities possibly caused by anthropogenic interactions, this study observed more instances. According to Kiszka et al. (2008), the results showed that the more inshore species, Indo-Pacific bottlenose dolphins, showed more signs of fishing gear interactions, which could translate over to Madeira. The common bottlenose dolphin showed the most signs of anthropogenic interactions (16.8%), of which there are inshore and offshore populations that inhabit the waters of Madeira. This study did not distinguish amongst different anthropogenic causes, such as fishing gear entanglement and vessel strikes, so these numbers could be higher than just analyzing fishing gear entanglements.

The large portion of skin lesions (50.44%) compared to the other categories of deformities can be concerning, but further research would be needed to conclude the severity level. This study showed a smaller portion of individuals showing signs of skin lesions than other studies, such as Bearzi et al. (2009), which showed 79% of coastal and offshore bottlenose dolphins having at least one type of skin lesion. Skin lesions can be signs of overall individual, ocean, and human health (Bossart 2011). As previously described, the three strains of cetacean morbillivirus can show signs through skin lesions. The only way to test for CeMV would be through necropsies, but that was outside the scope of this study. Although in Madeira there are only a small number of strandings per year (if coastal/mainland areas), this could be due to the wild orography and small coastline of the island as well as being surrounded by pelagic/oceanic waters.
Similarly, to the study by Baird et al. (2014) on *P. crassidens*, this study showed a sex bias in *M. densirostris* when it comes to the average amount of deformities between males and females. This species is known for the males to have more rake marks due to the aggression between males and the protrusive teeth, but this study shows that females (2.61) have more overall types of deformities on average than males (2.21). The relatively small and unbalanced sample size (females: n=28, males n=14) could lead to a bias in the results, so further research is needed. Research could be done to analyze exactly which deformities are more commonly found on males compared to females. This could lead to behavioral analysis if there are more skin lesions found to be caused by pollution or more anthropogenic injuries could indicate travel patterns or preferences.

Epibionts were observed in 13.07% of individuals. Though the amount and location, typically on the dorsal fin, varied, the possible effects or causes of epibionts could be consequential. Epibionts can be indicators of the overall health of individuals and populations (Vecchione and Aznar 2014). Some epibionts were observed on individuals that also showed signs of emaciation. More susceptible hosts, such as ones that are emaciated, have shown signs of increased infestation of epibionts (Aznar et al. 1994, Aznar et al. 2005). Further research on the correlation between epibionts and individual and population health could be done around Madeira.

Extensive research is still needed to understand more about the deformities in the populations of cetaceans around the Madeira Archipelago. More like the comprehensive study by Van Bressem et al. (2007) would give a better idea of the effects the deformities have on the cetaceans and their causes. This would require more financial backing, technology, but most importantly access to cetaceans. This report did not have access to strandings or necropsies, so there were limitations.
5.1 Future Conservation Efforts

The rather small percentage of animals that show deformities due to anthropogenic causes shows that the conservation efforts around the Madeira archipelago are working. The sustainable approach is benefitting the environment, society, and economy. This dynamic can improve since there are still some signs of anthropogenic effects on cetaceans, primarily in *T. truncatus* and *G. macrorhynchus*.

The small proportion of deformities that could possibly be attributed to vessel strikes is consistent with a report published by Cunha *et al.* (in press), which states that the current impact level from vessels on cetaceans is tolerable. The report did find a “higher use corridor” that is used by both vessels and cetaceans, but evidence still supports that marine traffic impacts are not relatively high when compared to other areas. Such a threat should not be disregarded and more research is needed to quantitatively assess this impact.

Along with vessel traffic, noise pollution should be considered. As previously mentioned, vessel noise can cause severe damage to cetaceans, such as strandings (Weilgart 2007). Mitigation efforts for noise pollution are constantly being improved. Southall (2005) talks about how vessel-quieting techniques have been implemented in military vessels to improve stealth from enemy vessels and to improve detection rates of submarines. The military technology also benefits the cetaceans by reducing the amount of noise pollution. These vessel-quieting techniques have carried over to the commercial industry as well. The reduction in noise allows for reduction in drag or allows for unnecessary energy expenditure to be allocated to more efficient locations of the vessel (Southall 2005). Though the report by Southall (2007) was from a meeting in the United States of America, the mitigation efforts can still be implemented around the world.
5.2 Habitat Protection/Management

Further steps for the protection and management of cetaceans and their habitats can use marine protected areas (MPAs), marine spatial planning (MSP), and the International Maritime Organization (IMO) as tools.

Marine Protected Areas (MPAs) are “spatially-delimited areas of the marine environment that are managed, at least in part, for conservation of biodiversity” (Edgar et al. 2007). The main goals of an MPA are protecting and conserving biodiversity and allowing for the recovery of species depleted by human activities (Edgar et al. 2007). Protecting and managing migratory species, like cetaceans, is a more inherently difficult project due to the spatio-temporal scale involved than non-migratory species (Shuter et al. 2011). MPA networks, which is “a collection of individual MPAs or reserves operating cooperatively and synergistically, at various scales, and with a range of protection levels that are designed to meet objectives that a single reserve cannot achieve” (IUCN 2008). Consideration for migratory species is a difficult task for MPAs due to the large distances these species can travel over the course of the year (Laffoley and Kilarski 2008). To use MPA for migratory species, such as cetaceans, there should be particular focus on areas of key importance for life stages of the species, such as feeding and nursery areas (Laffoley and Kilarski 2008). An MPA network can be used to include a mixture of permanent closures with temporal closures such as Seasonal Management Areas (SMAs) (Hyrenbach et al. 2000). Hyrenbach et al. (2000) describes how static MPAs could be used for more residential species such as the northern bottlenose whale in the Gully, Nova Scotia.

In the case of the Madeira Archipelago, there has been a recent proposal for the establishment of a Natura 2000 Site of Community importance in the waters surrounding Madeira, Desertas, and Porto Santo Islands, from 1.85 km off the coast out to 2,500 m depth. This will help to minimize any potential threat towards the populations of cetaceans using Madeiran waters on a regular or occasional basis. (Ferreira et al. 2017)
Marine spatial planning is “a public process of analyzing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives that are usually specified through a political process” (Ehler and Douvère 2009). This tool has alleviated some pressures: a spatial and temporal overlap of human activities and their objectives, a lack of connection between the various authorities responsible for individual activities or the protection and management of the environment as a whole, the lack of connection between offshore activities and resource use and onshore communities that are dependent of them, and a lack of conservation of biologically and ecologically sensitive marine areas (Douvere 2008). MSP could be implemented in Madeira and the surrounding areas, like the Azores and Canaries, for the use of better quantifying or modeling the marine traffic as well as to test the use of acoustic transmitters (using fixed buoys) to inform the ferries when whales are around (mainly work with sperm whales). The speed of ferries and interactions with whales can also be factored. According to Ritter (2010) the Canary Islands have ferries that have three different speeds: normal, fast, and high speed vessels. Similar to Madeira, there are 29 record species of cetaceans around the Canary Islands and there have been identified areas of high risk for ship strikes on cetaceans (Ritter 2010, Carrillo and Ritter 2010). The report by Ritter (2010) concludes that there is an urgent need for policy to counteract the situation and MSP could be used. Reports by Cunha et al (in press) and Sambolino et al (2017) have done research about the vessel traffic and the risk of vessel strikes around Madeira. According to the two reports, the ferry vessel traffic has not been of high concern, but there has been a relatively high encounter rate with cetaceans during the ferry transits. Though the ferry speed and risk of vessel strikes on cetaceans are lower around Madeira than the Canary Islands, there is some overlap when it comes to populations of cetaceans visiting both waters (Quérouil et al. 2007, Quérouil et al. 2010, and Quérouil et al. 2013). Genetic testing concluded that populations of short-beaked common dolphins, Atlantic spotted dolphins, and common bottlenose dolphins have been recorded in the waters around Madeira and the Azores (Quérouil et al. 2007, Quérouil et al. 2010, and Quérouil et al. 2013). On top of the genetic testing, photo-ID has been recorded by Molina et al. (2017) for common
bottlenose dolphins and by Alessandrini (2016) for short-finned pilot whales being sighted in the three archipelagos (Madeira, Azores, Canary Islands). The implication of large overlapping single populations of each of the three species (short-beaked common dolphins, Atlantic spotted dolphins, and common bottlenose dolphins) can require cooperation for conservation efforts in the North Atlantic among different archipelagos (Quéroil et al. 2007).

The IMO is an international organization that legislate vessel regulations, such as vessel speeds in certain areas or shipping lane locations. The most efficient way to protect or manage a habitat or ecosystem for the protection of certain species is a situational decision. The IMO has been influential in several locations around the world, including the Bay of Fundy, the Roseway Basin, and off the coast of Boson, Massachusetts (Vanderlaan and Taggart 2009, Vanderlaan et al. 2008, Merrick 2005). Vanderlaan and Taggart (2009) studied the recommendatory compliance of the Roseway Basin Area To Be Avoided (ATBA) when it comes to protecting endangered whales. It was concluded that the risk reduction was estimated at 82%, which means that the ATBA was an effective means to protect the endangered whales. In the Bay of Fundy, Vanderlaan et al. (2008) reported a risk reduction of 62% when it came to vessel re-routing and a risk reduction of 52% for speed reductions. This showed to have little effects on maritime operations. The final location focused on the Boston Traffic Separation Scheme (TSS). Merrick (2005) estimated vessel strike reductions of 58% and 81% for North Atlantic right whales and large whale species, respectively, if the TSS was amended as proposed. The IMO-endorsed measures and their effectiveness show how influential the IMO can be when it comes to maritime related efforts to protect cetaceans (Silber et al. 2012).

Depending on the situation, influence from the IMO can be more effective than MPAs, such as the case of the Mediterranean fin whale. Geijer and Jones (2015) describe the difficulties of establishing an MPA, specifically in this case Specially Protected Areas of Mediterranean Importance (SPAMI), network that spans multiple countries or that is part of an Area Beyond National Jurisdiction (ANJB). Establishing a regional network of industry-specific regulations can be an ambitious effort to protect
the Mediterranean fin whale. A key component of establishing relevant measures in any area is stakeholder participation. Geijer and Jones (2015) explain that stakeholder participation spanning multiple countries can be politically complicated and that SPAMIs do not legally enforce compliance to protect the fin whale throughout the course of its migration patterns. On top of the political difficulty and lack of legal enforcement for SPAMIs, there is a lack of knowledge about Mediterranean fin whales and their complete migration patterns. Geijer and Jones (2015) concluded that based on those factors, the IMO would be more effective at reducing ship strikes on the Mediterranean fin whale, and in turn, other cetaceans. Silber et al. (2012) supports the effectiveness of the IMO in Mediterranean waters, but further explains that areas like the Strait of Gibraltar and the Cabo de Gata (Cape Gata) region had the TSS relocated to reduce the chances of vessel collisions with cetaceans.

When multiple management tools like marine protected areas, marine spatial planning, and organizations like the IMO, can be used together, more effective measures can be taken to ensure protection for marine ecosystems (Laffoley and Kilarski 2008).

6. Conclusion

In conclusion, there is a concerning amount of individuals showing signs of at least one deformity (41.47%). The causes and consequences of the deformities were not explored in this study, so severity would need to be researched for a more comprehensive understanding. This study creates a baseline for the Madeira Archipelago to allow further research on understanding deformities in the area, and also the surrounding areas of the Azores and Canary Islands due to some species populations being found in all three archipelagos (short-beaked common dolphins, Atlantic spotted dolphins, short-finned pilot whales, and common bottlenose dolphins). Even though vessel traffic has been considered “tolerable,” it is still a factor that should be
researched further (Cunha et al. in press). Mitigation efforts using MPAs and MSP or efforts through the IMO could aid with reducing vessel strikes.

6.1 Further Research

The research done here is a baseline study done for the cetaceans around the Madeira archipelago. This could be furthered by extending the photo analysis to the rest of the catalog available at CIIMAR-Madeira. Due to time constraints and logistics not all photographs were able to be included in this study. Those photographs contain more images of previously identified cetaceans, as well as photos of unidentified cetaceans. Those unidentified individuals could be added to both this study and the catalog of CIIMAR-Madeira. Another advantage to analyzing those photographs would be that those photographs may not be for photo-ID purposes. That means the images could include different portions of the individuals, rather than primarily the dorsal fin, like in this study. There are many photographs in those archives, so a long period of time would be needed.

Another additional aspect to this research could be an analysis of the proportion of missing dorsal fins and finding out what could be considered a significant portion. This was going to be included in this study, but time was limited. ImageJ was going to be used to analyze the proportions missing, but it would have been a slow process and there would need to be extensive analysis to determine what could be considered a “significant” percentage of a missing dorsal fin.
7. References


Geraci, J. R. (1989). *Clinical investigation of the 1987-88 mass mortality of bottlenose dolphins along the US central and south atlantic coast: Final report to national marine fisheries service and US navy office of naval research and marine mammal commission* Wildlife Disease Section, Department of Pathology, Ontario Veterinary College, University of Guelph.

Halicka Z (2015). Temporal distribution of the short-beaked common dolphin (*Delphinus delphis*) in the south of Madeira Island (Portugal) and relationship with oceanographic variables. Master thesis, University of Algarve, Portugal-


Orams, M. B. (1997). The effectiveness of environmental education: can we turn tourists into 'Greenies'? *Progress in tourism and hospitality research, 3*, 295-306.


8. Appendices

8.1 Appendix I

8.1.1 Skin Lesions

Figure 13: A) Gma0734 showing an example of a black lesion just under the dorsal fin and on the lower back. B) Gma0779 exhibiting a white lesion.

Figure 14: A) Md090 has cream lesions on its back mixed in with rake marks. B) Tr293 has white fin fringe.

Figure 15: A) Gma0313 showing multiple skin lesions: black lesion, cloudy lesion, orange patch, and a dark fringed lesion. B) Gma0031 has a black fringe lesion on the back behind the dorsal fin.
Figure 16: Bbr016 has a lunar lesion just above the surface of the water.

Figure 17: A) an orange hue surrounding the head and blowhole of Md074.

Figure 18: A) Individual Dd001 has leucism. B) Dd005 has melanism.

8.1.2 Anatomical Malformations

Figure 19: A) A bent dorsal of Dd042 and epibionts on the dorsal fin. B) Missing fluke tip from Md052.
Figure 20: A) the upper mandible of Md017 is displaced to the right of the midline. B) Bbr032 has a depression on the right side below the dorsal fin.

Figure 21: Neoplasia of Bbr005.

Figure 22: Lordosis of Bbr020.

Figure 23: A) a raised skin patch on the back of Oo002. B) Neoplasia of Tt536.
8.1.3 Physical Impact

Figure 24: A) Rake marks and nicks on the dorsal fin of Gma0062. B) Cut marks on the dorsal fin of Tt354, which could be from anthropogenic causes.

Figure 25: Cookie-cutter scars on the back of Bbr029.

8.1.4 Emaciation

Figure 26: Signs of emaciation due to the exposed ribs of Tt650.

Figure 27: Another example of emaciation due to exposed ribs, Tt481.
8.1.5 Epibionts

Figure 28: Epibionts on the protruding teeth from the lower jaw of Md085.

Figure 29: Epibionts on the dorsal fin of Tt650.

Figure 30: Epibionts on the left side of Bbr016.

8.1.6 Unclassified

Figure 31: An unclassified deformity on Bbr029.
8.2 Tables

Table 10: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with one deformity.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 1 Deformity</th>
<th>Percentage by 1 Deformity</th>
<th>Percentage of Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balaenoptera borealis</td>
<td>2</td>
<td>0.57%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Balaenoptera brydei</td>
<td>11</td>
<td>3.16%</td>
<td>1.08%</td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>15</td>
<td>4.31%</td>
<td>1.47%</td>
</tr>
<tr>
<td>Globicephala macrorhynchus</td>
<td>173</td>
<td>49.71%</td>
<td>16.96%</td>
</tr>
<tr>
<td>Mesoplodon densirostris</td>
<td>9</td>
<td>2.59%</td>
<td>0.88%</td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>5</td>
<td>1.44%</td>
<td>0.49%</td>
</tr>
<tr>
<td>Physeter macrocephalus</td>
<td>15</td>
<td>4.31%</td>
<td>1.47%</td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>4</td>
<td>1.15%</td>
<td>0.39%</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>3</td>
<td>0.86%</td>
<td>0.29%</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>4</td>
<td>1.15%</td>
<td>0.39%</td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>107</td>
<td>30.75%</td>
<td>10.49%</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>348</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 12: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with two deformities.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 2 Deformities</th>
<th>Percentage by 2 Deformity</th>
<th>Percentage of Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balaenoptera borealis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Balaenoptera brydei</td>
<td>9</td>
<td>7.09%</td>
<td>0.88%</td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>9</td>
<td>7.09%</td>
<td>0.88%</td>
</tr>
<tr>
<td>Globicephala macrorhynchus</td>
<td>23</td>
<td>18.11%</td>
<td>2.25%</td>
</tr>
<tr>
<td>Mesoplodon densirostris</td>
<td>15</td>
<td>11.81%</td>
<td>1.47%</td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>2</td>
<td>1.57%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Physeter macrocephalus</td>
<td>2</td>
<td>1.57%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>1</td>
<td>0.79%</td>
<td>0.10%</td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>66</td>
<td>51.97%</td>
<td>6.47%</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>127</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 13: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with three deformities.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 3 Deformities</th>
<th>Percentage by 3 Deformity</th>
<th>Percentage of Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balaenoptera borealis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Balaenoptera brydei</td>
<td>6</td>
<td>7.41%</td>
<td>0.59%</td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>3</td>
<td>3.70%</td>
<td>0.29%</td>
</tr>
<tr>
<td>Globicephala macrorhynchus</td>
<td>5</td>
<td>6.17%</td>
<td>0.49%</td>
</tr>
<tr>
<td>Mesoplodon densirostris</td>
<td>18</td>
<td>22.22%</td>
<td>1.76%</td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Physeter macrocephalus</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>49</td>
<td>60.49%</td>
<td>4.80%</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>81</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 14: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with four deformities.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 4 Deformities</th>
<th>Percentage by 4 Deformity</th>
<th>Percentage of Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balaenoptera borealis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Balaenoptera brydei</td>
<td>1</td>
<td>4.00%</td>
<td>0.10%</td>
</tr>
<tr>
<td>Delphinus delphis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Globicephala macrorhynchus</td>
<td>2</td>
<td>8.00%</td>
<td>0.20%</td>
</tr>
<tr>
<td>Mesoplodon densirostris</td>
<td>9</td>
<td>36.00%</td>
<td>0.88%</td>
</tr>
<tr>
<td>Orcinus orca</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Physeter macrocephalus</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Pseudorca crassidens</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Stenella frontalis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Steno bredanensis</td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Tursiops truncatus</td>
<td>13</td>
<td>52.00%</td>
<td>1.27%</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>25</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 15: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with five deformities.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 5 Deformities</th>
<th>Percentage by 5 Deformity</th>
<th>Percentage of Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Balaenoptera borealis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Balaenoptera brydei</em></td>
<td>1</td>
<td>10.00%</td>
<td>0.10%</td>
</tr>
<tr>
<td><em>Delphinus delphis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Globicephala macrorhynchus</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Mesoplodon densirostris</em></td>
<td>3</td>
<td>30.00%</td>
<td>0.29%</td>
</tr>
<tr>
<td><em>Orcinus orca</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Physeter macrocephalus</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Pseudorca crassidens</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Stenella frontalis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Steno bredanensis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Tursiops truncatus</em></td>
<td>6</td>
<td>60.00%</td>
<td>0.59%</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>10</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 16: Shows the amount of individuals, the percentage by deformity, and percentage by population of individuals with six deformities.

<table>
<thead>
<tr>
<th>Species</th>
<th>Individuals with 6 Deformities</th>
<th>Percentage by 6 Deformity</th>
<th>Percentage of Total Population</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Balaenoptera borealis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Balaenoptera brydei</em></td>
<td>1</td>
<td>20.00%</td>
<td>0.10%</td>
</tr>
<tr>
<td><em>Delphinus delphis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Globicephala macrorhynchus</em></td>
<td>1</td>
<td>20.00%</td>
<td>0.10%</td>
</tr>
<tr>
<td><em>Mesoplodon densirostris</em></td>
<td>1</td>
<td>20.00%</td>
<td>0.10%</td>
</tr>
<tr>
<td><em>Orcinus orca</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Physeter macrocephalus</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Pseudorca crassidens</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Stenella frontalis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Steno bredanensis</em></td>
<td>0</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td><em>Tursiops truncatus</em></td>
<td>2</td>
<td>40.00%</td>
<td>0.20%</td>
</tr>
<tr>
<td><strong>Total Individuals</strong></td>
<td><strong>5</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>