MOUTHLINE INJURIES AS AN INDICATOR OF FISHERIES INTERACTIONS IN HAWAIIAN ODONTOCETES

by

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ABSTRACT

Mouthline Injuries as an Indicator of Fisheries Interactions in Hawaiian Odontocetes

Kelly A. Beach

Evidence from strandings and anecdotal reports indicate that a number of odontocete species interact with near-shore fisheries in Hawai‘i. In the absence of observer programs in these fisheries, I evaluated mouthline injuries from known resident populations of false killer whales and pygmy killer whales, to assess the viability of this method to document injuries associated with hook and line fishery interactions. All individuals with mouthlines visible were selected from photo-ID catalogs and scored for presence of mouthline injuries consistent with fisheries interactions. Ninety-nine false killer whales and 45 pygmy killer whales had ≥50% of the mouthline visible using fair to excellent quality photos, with a mean of 58% and 71% mouthline visible, respectively. Analysis suggests that main Hawaiian Islands insular false killer whales have high rates of mouthline injuries- 22% of adult and sub-adult individuals with ≥50% mouthline visible have injuries consistent with fisheries interactions, supporting studies using dorsal fin injuries that indicate individuals from this population regularly interact with fisheries. Pygmy killer whales also appear to interact with fisheries at high rates. Of adult and sub-adult individuals off Hawai‘i and O‘ahu with ≥50% of the mouthline visible, 31% have mouthline injuries consistent with fisheries interactions. Since pygmy killer whales feed primarily at night, and there are few reports of them depredating lines, mouthline injury analysis provides new insight into fisheries interactions for this species. Scars on pygmy killer whales heal white and are easier to detect than healed injuries on false killer whales, thus a greater proportion of individuals with such injuries may be detected for pygmy killer whales. With both species, the proportion of mouthline visible increased the likelihood of mouthline injuries being detected ($p<0.036$). Injury rates are negatively biased, since those individuals scored as having no mouthline injury may not have had their entire mouthline visible. Further efforts will aim to identify injury rates in short-finned pilot whales and rough-toothed dolphins. An examination of differences in injury rates in a multi-species comparison will also be undertaken to better understand fisheries interactions in Hawaiian odontocetes.

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CHAPTER 1 – LITERATURE REVIEW

Introduction

Of the many issues currently facing marine mammals, one of the most pressing in terms of conservation and management is the interaction between marine fisheries and marine mammals (Gilman et al., 2006; Forney & Kobayashi, 2007; Read, 2008). Cetaceans exhibit a wide variety of behaviors and life history traits that cause them to be especially vulnerable to fisheries interactions (Hall, 2000; Read, 2008). Odontocetes, or toothed whales, are particularly prone to interaction with various types of fisheries, and one United States hotspot of interactions is in Hawaiian waters (Forney & Kobayashi, 2007; Hamer et al., 2012). Interactions between commercial fisheries and federally protected odontocetes have been documented in Hawai‘i since 1948, and continue to occur at increasing rates today (Nitta & Henderson, 1993). This is a cause for concern, particularly for sensitive or threatened and endangered species (Baird et al. 2008). For the purposes of this study, I focused on the interactions between two different species of odontocetes and fisheries in Hawai‘i, and used mouthline assessment as an indicator for these interactions.

Background and History

Odontocetes are abundant in different areas of the world. Most species are considered pack animals, socializing and hunting in family groups (Richardson et al., 1995). Most toothed whales use echolocation to find and hunt prey (Wood & Evans, 1980), and use complex vocalizations to communicate with others in their social groups

(Richardson et al. 1995). Odontocete populations around the world are negatively impacted by a variety of anthropogenic activities, including unsustainable hunting practices, habitat degradation, military sonar testing, bioaccumulation of persistent organic pollutants, ship strikes due to increasing shipping activities, and climate change (Convention on Migratory Species, 2008). However, arguably the largest single threat to odontocete populations worldwide is direct mortality and injury due to various fishing operations, which includes accidental hooking and hook ingestion and/or entanglement in fishing gear, as well as evidence that overfishing is having a negative impact on their prey species populations (Twiss & Reeves 1999; Hall et al. 2000; Demaster et al. 2001; Hamer et al. 2012).

Net entanglements and hook and line injuries have been reported in small cetaceans interacting with various Hawaiian fisheries (Nitta & Henderson, 1993). Eighteen different species of odontocetes live in Hawaiian waters (Barlow, 2006). These species' population statuses range from common and abundant, to cryptic and endangered, and many of these species are known to interact with various fisheries in Hawai‘i.

Injuries and mortality from fisheries interactions are thought to be a major source of population decline for at least one species of odontocete in Hawai‘i. Currently, much conservation attention is focused on the Main Hawaiian Islands insular population of false killer whales (*Pseudorca crassidens*), which was listed under the Endangered Species Act in 2012 due to low population numbers and documented high levels of interactions with fisheries (NOAA Fisheries, 2012). Historically, the pantropical spotted dolphin (*Stenella attenuata*) was a major focus of conservation groups due to their high levels of bycatch mortality in the tuna purse-seine fishery in the 1980s and early 1990s, and this issue became widely known as the tuna-dolphin problem (Hall, 1998). Spotted dolphins live within 100 miles of shore, and although they are considered common, the population in the eastern tropical Pacific is labeled as “depleted” by the National Marine Fisheries Service (NOAA Fisheries, 2012). This tuna-dolphin problem was one of the driving factors behind the enactment of the Marine Mammal Protection Act in 1972 (Hall, 1998).

Current Policy

A variety of policies and laws have been put in place to protect marine mammals in Hawai‘i. The Marine Mammal Protection Act (MMPA) was enacted in the United States in 1972, which outlaws the ‘take’ of marine mammals, with take being defined as to “harass, hunt, capture, kill or collect, or attempt to harass, hunt, capture, kill or collect” (MMPA, 1972, p. 6). The Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) was an international agreement signed in 1973 by 172 countries that guarantees the international trade of species will not threaten their existence in the wild (NOAA Fisheries, 2013). This is relevant because all of the species mentioned in this paper are protected under Appendix II of CITES, which includes species that are not currently endangered or threatened, but may become so in the near future in the absence of trade controls (NOAA Fisheries, 2013).

Arguably, the strongest piece of legislation for the conservation of marine mammals is the Endangered Species Act of 1973, which “protects and recovers imperiled species and ecosystems on which they depend" (US Fish and Wildlife Service, 2013). An "endangered" species is one that is classified as being "in danger of extinction in all or significant parts of its range," while a "threatened" species is one that is "likely to become endangered in the foreseeable future" (US Fish and Wildlife, 2013). Of the species I focused on for my research, only the Main Hawaiian Islands insular population of false killer whales is protected under the Endangered Species Act. Understanding which protections are already in place for Hawaiian odontocetes is important when thinking about possible implications for future protections and policies that could be implemented upon further review of threats to these species.

Hawaiian Fishing Industry

The Hawaiian Islands have a historic fishing industry that dates back before European colonization of Hawai'i, where traditional methods were used by indigenous Hawaiian people. The commercial and recreational fishing industries in Hawai'i are significant contributors to the Hawaiian economy, as well as contributing to cultural and historic benefits to Native Hawaiians, residents, and tourists alike. It is estimated that the commercial fishing contributed $69.7 million dollars to Hawai'i's economy in 2006 (Hawai'i Institute for Public Affairs, 2009).

All international ocean fisheries have Exclusive Economic Zones (EEZ), where countries have the sole right to fish 200 nautical miles out from their shorelines (NOAA Office of Coast Survey, 2013). In Hawai'i's EEZ area, a variety of different commercial fisheries exist. Various different fisheries in this zone, include a handline fishery for bottomfish, a day and night handline fishery for tuna, a handline fishery for Mackeral scad, trolling for tuna and billfish, inshore gillnet fisheries, lobster fishery, and the longline fishery (Nitta & Henderson, 1993). One of the most lucrative fishing industries in Hawaiʻi is the Hawaiian longline fishery, which consists of a shallow-set longline swordfish fishery and a deep-set longline tuna fishery (NOAA Fisheries, 2013).

Types of Fisheries Interactions

Fisheries interactions with marine mammals raise a variety of ecological, social, and economic concerns (Hall, 2000; Gilman et al., 2006; Read, 2008). There are a variety of different types of fisheries interactions between marine mammals and fisheries, most of which are negative for both parties involved. Operational interactions between marine mammals and fisheries occur when animals directly interact with fishing operations (Twiss & Reeves, 1999). One example of an operational interaction is depredation, where marine mammals actually damage or remove fish from fishing gear (Gilman et al., 2006). Odontocetes can become bycatch by getting caught on a hook while attempting to depredate a line (Beverton, 1985; Read, 2005; Secchi et al., 2005). Sometimes individuals depredating lines ingest hooks, which can cause internal injuries or mortality (Secchi et al., 2005, Wells et al., 2008). Bycatch, also known as the taking of non-target species due to entanglement or accidental hooking, is another operational interaction that is detrimental to both odontocetes and fisheries (Hall, 1996). Operational interactions often result in severe injury and mortality of marine mammals, as well as financial loss due to gear damage and fish losses (Twiss & Reeves 1999). This information demonstrates that fisheries interactions are undesirable for both odontocetes and the fishing community in Hawai‘i.

Read (2008) states that odontocete depredation seems to be increasing in scope, frequency, and severity. This is particularly a problem for small populations of odontocetes, because even low numbers of animals taken from these populations can result in takes that exceed the Potential Biological Removal (PBR) level, which is the maximum number of individuals, excluding natural mortalities, that can be eliminated from a marine mammal stock while letting the population reach or sustain its “optimum stable population” (Carretta et al. 2009; NOAA Fisheries, 2014).

Fisheries interactions can be determined in a variety of ways, each having its own advantages and disadvantages, including: 1) placing trained observers on fishing vessels, 2) examining wounds and scars on stranded animals, 3) observing entangled animals in the wild, 4) distributing questionnaire surveys to fisherman (Baird & Gorgone 2005), and 5) examining photographs of marine mammals for injuries. Photograph examination has recently been used as a cost effective method to estimate fisheries interactions. Baird and Gorgone (2005) have used photograph examination to assess fin injuries due to fisheries interactions in Hawaiian false killer whales. For this study, I utilized this type of photo-examination approach to assess scarring and mouthline injury in false killer whales and pygmy killer whales in Hawai‘i.

Species Background

For my study, I conducted mouthline analysis using photographic data from two resident Hawaiian odontocete species and their various subpopulations. These species were false killer whales and pygmy killer whales. Included below are population stock estimates around the Hawaiian Islands, information on general biology, any relevant policy information, as well as known information about the levels of fisheries interactions for each odontocete species.

False Killer Whales

False killer whales (*Pseudorca crassidens)* are odontocetes that inhabit tropical and temperate oceans throughout the world (Sargeant, 1982). They acquired their name because of their similarity in skull morphology to killer whales (*Orcinus orca*), although they are not closely related. False killer whales are a highly social species (Sargeant, 1982) and are known to frequently engage in food sharing (Baird et al., 2008). Attributed to their highly social behavior, they have also been documented mass stranding, the largest which included 832 individuals (Ross, 1984). False killer whales are slow to mature and reproduce, and can live 60 years or more (Ferreira et al., 2014). They generally feed on a variety of oceanic fish and squid, including large gamefish such as mahi-mahi, swordfish, and yellowfin tuna (Baird et al., 2008).

False killer whales are one of the odontocete species most negatively affected by fisheries in Hawai‘i, and are a species of conservation concern. There are known to be three distinct populations of false killer whales living in Hawaiian waters; they include the insular Main Hawaiian Island (MHI) population, the Northwestern Hawaiian Islands (NWHI) insular population, and a pelagic population (Chivers et al., 2007; Baird et al., 2008). Within these populations, there are estimated to be 151 main Hawaiian Island individuals (Oleson et al., 2010), 552 NWHI individuals, and 1,552 pelagic individuals (Bradford et al., 2012). In the longline fishery, individual whales have been documented depredating, (i.e., taking hooked tuna off of these lines) which has resulted in individuals becoming hooked during this practice, which can lead to serious injury or death (Forney & Kobayashi, 2007).

It has been shown through biopsy samples that the MHI insular population is genetically distinct from false killer whales in other areas (Chivers et. al., 2007; Baird et al. 2008), and, therefore, their population is assessed as separate from global population counts of this species. Because of this small population size, the risk of death for this genetically distinct group of even a few individuals is detrimental to the persistence of this population and puts the insular population at greater risk of extinction (Carretta et al., 2014). The MHI population of false killer whales' mortality and serious injury rates due to interactions with fisheries exceed the population's PBR level (Carretta et al, 2014). The MHI population of false killer whales was listed as federally endangered in 2012, and therefore continues to be the focus of much research attention due to their ESA listing, the TRT, and other evidence of fisheries interactions (Baird et al., 2014).

There are three distinct social clusters in the MHI population of false killer whales (Baird et al., 2012). Satellite tag data suggests that individuals from clusters 1 and 3 have little overlap with the longline fisheries, but although their ranges overlap with each other, they appear to have different high-density areas where individuals within a social group frequent (Baird et al., 2010, 2012). While there is no satellite tag data for cluster 2, according to photographic data they appear most frequently off of Hawai‘i (Baird et al., 2012).

The bycatch levels of the pelagic population of false killer whale in the longline fishery also exceed their PBR level (Baird et al., 2014). In 2010 a Take Reduction Team (TRT) was established to address take of pelagic false killer whales by the longline fishery. The TRT is made up of fishery industry representatives, federal agencies, environmental groups, fishery management councils, and academics (NOAA Fisheries, 2010). They developed a Take Reduction Plan (TRP) to decrease mortality and injury in this species (75 FR 2853, 2010).

Pygmy Killer Whales

Pygmy killer whales (*Feresa attenuata)*, one of the most poorly studied species of odontocete, are considered a rare species (McSweeney et al. 2009). A rare species is defined as one that is infrequently seen, inhabits a small range, or has small numbers of individuals (Flather and Sieg, 2007). Because of their cryptic nature, little information is known about their diet, foraging behavior, and preferred prey.

Pygmy killer whales are primarily found in tropical, subtropical, and temperate waters in oceans around the world (Ross and Leatherwood, 1994). Information from stranded pygmy killer whales show that they feed on cephalopods (Zerbini and Santos, 1997) and fish, as determined by otoliths found in a stranded animal’s stomach contents (Leatherwood and Reeves, 1989). Pygmy killer whales are easily mistaken for false killer whales and melon-headed whales, but have characteristic white lips that extend around the whole mouth (Baird, 2010).

The Hawaiian pygmy killer whale population is found throughout the Hawai‘i Exclusive Economic Zone as documented by large vessel surveys, and is estimated to be less than 1000 individuals (Barlow, 2006). Current population estimates say that there is a single sock of individuals (Caretta et al., 2014), however recent studies using photo-ID and satellite-tagging data suggest that there may be a more distinctive island-associated population (Mcsweeney et al., 2009; Baird et al., 2011). These studies have shown that pygmy killer whales in Hawai‘i exhibit high site fidelity, or the extent to which an animal returns to a certain area (McSweeney et. al., 2009). A study by Baird and authors (2011) analyzed the satellite movements of two tagged pygmy killer whales off of the coast. Although the sample size for this study was small, the movements of the whales demonstrated strong associations with the island of Hawai‘i, remaining an average of 4.07 and 4.66 km from shore, and stayed primarily on the West and South sides of the island (Bard et al., 2011). Because of high site fidelity, it is suggested that pygmy killer whales may be especially vulnerable to anthropogenic impacts such as fisheries interactions (McSweeney et. al. 2009).

Pygmy killer whales are known to have been taken in several different fisheries and mortalities have occurred due to bycatch in gillnet fisheries in Sri Lanka, Indonesia, and the Philippines (Ross & Leatherwood 1994). Although no formal fisheries interactions of pygmy killer whales have been documented in Hawai‘i, one dead stranded individual did have hook marks in its mouth, suggesting fisheries interactions may be occurring (Schofield 2007). Despite this information, no policy has been put in place to protect this species from the impacts of injury and mortality due to bycatch (McSweeney et. al. 2009).

Mouthline Injury Assessment

There are no known studies of assessing mouthlines to indicate fisheries interactions in cetaceans in Hawai‘i. However, a recent study at the University of North Carolina at Wilmington provided information that could to help determine whether mouthline injuries seen in photos are fisheries-related or not (McLellan et al., 2014). The authors tested the effects of five different hook types used in longline fisheries on three odontocete species (false killer whale, rough-toothed dolphin, and short-finned pilot whale) that are known to interact with this fishery. The purpose of this study was to determine which types of hooks cause the least damage to odontocetes hooked in the mouthline. McLellan and authors (2014) used fresh dead carcasses of these species, hooked them in the mouth, and applied pressure consistent with a struggling whale. Their study found that depending on the type of hook used, the hook either: 1) tore through the tissue around the lip, creating scarring, 2) tore the lip and broke off, leaving part of the hook remaining in the lip tissue, or 3) fractured the jaw/mandible. A study by Wells et al. (2008) assessed survivorship of Florida resident common bottlenose dolphins after being hooked in the mouth or ingesting fishing gear, and found that gear ingestion likely eventually lead to mortality. These studies combined with existing extensive false killer whale research, and available information on pygmy killer whales will provide the framework for this study.

CHAPTER 2 - MOUTHLINE INJURIES AS AN INDICATOR OF FISHERIES INTERACTIONS IN HAWAIIAN ODONTOCETES

Introduction

Marine mammals, in particular cetaceans, face a variety of anthropogenic threats at varying scales of impact, including habitat degradation, military sonar testing, bioaccumulation of persistent organic pollutants, unsustainable hunting practices, ship strikes due to increased global trade, and climate change (Convention on Migratory Species, 2008). At a global scale, mortality and injury due to interactions with various fisheries is likely the most serious conservation concern for cetaceans worldwide (Read, 2006). Odontocetes (toothed whales) may be particularly at risk to fisheries interactions due to certain life history traits, including feeding behaviors and slow growth and reproductive rates. Direct interactions between odontocetes and fisheries are of particular conservation concern for Hawaiian species of odontocetes. A number of odontocete species have been documented interacting with fisheries in Hawai‘i, which can result in injuries due to accidental hookings and entanglement, as well as mortality (Nitta and Henderson, 1993).

Direct, or operational, interactions with fisheries are described by Beverton (1985) as instances where ‘marine mammals come into physical contact with fishing gear’, usually with negative consequences for the animal, as well as damage to the fishermen’s catch. Types of direct fisheries interactions include depredation, where animals damage or remove fish from fishing gear (Gilman et al, 2006). Bycatch, or the taking of non-target species due to entanglement or accidental hookings, is another operational interaction that is detrimental to both odontocetes and fisheries (Hall, 1996). Direct/operational interactions often result in severe injury and mortality of marine mammals, as well as financial loss due to gear damage and fish losses (Twiss and Reeves, 1999).

Although there is sufficient evidence from marine mammal observer programs that odontocetes sometimes accidentally become hooked on longlines, no study has been undertaken to assess mouthline injuries as an indicator for fisheries interactions around the Hawaiian Islands. Baird and Gorgone (2005) looked at fin injuries in false killer whales as indicators of fisheries interactions in Hawaiʻi, however these injuries were likely a secondary injury acquired from struggling against a line after being hooked in the mouth.

There are 18 species of odontocetes documented living in the waters surrounding the main Hawaiian Islands, of which there are 11 small resident populations (Baird et al., 2015). Evidence suggests that direct fisheries interactions are most detrimental for small populations of cetaceans (Read, 2008). For this study, I chose to examine two of these species, the false killer whale and pygmy killer whale.

False killer whales in Hawaiʻi are documented as having three distinct populations: two insular populations (one around the main Hawaiian Islands and one around the Northwestern Hawaiian Islands) and a pelagic or open-ocean population (Carretta et al., 2014). There are estimated to be 151 main Hawaiian Island individuals (Oleson et al., 2010), 552 NWHI individuals, and 1,552 pelagic individuals (Bradford et al., 2012). False killer whales are known to be taken in the Hawaiian longline fishery, and have been documented taking fish off of lines. In 2010 a Take Reduction Team (TRT) was established to address the incidental take of pelagic false killer whales by the longline fishery, and a Take Reduction Plan was developed to decrease mortality and injury in this species (75 FR 2853, 2010). The MHI population of false killer whales' mortality and serious injury rates due to interactions with fisheries exceed the population's Potential Biological Removal (PBR) level (Carretta et al, 2014). Listed as federally endangered in 2012, the MHI population of false killer whales continues to be a focus of research due to their ESA listing, the TRT, and other evidence of fisheries interactions (Baird et al., 2014).

Within the MHI population, there are three distinct social clusters (Baird et al., 2012). Satellite tag data suggests that individuals from clusters 1 and 3 have infrequent overlap with the longline fisheries, and while their ranges overlap they appear to have different high-density areas (Baird et al., 2010, 2012). While information on the movements of cluster 2 is limited to photo-identification data, they appear most frequently off of the island of Hawai‘i (Baird et al., 2012).

Pygmy killer whales are one of the most poorly understood species of odontocete and are considered rare throughout their range (Pryor, 1965). Because of their natural rarity and low sighting rate, little is known about their diet, foraging behavior, and preferred prey. Pygmy killer whales in Hawaii are currently recognized as a single stock (Carretta et al., 2014), however high resighting rates of individuals off of O‘ahu and Hawai‘i suggest small island-associated populations (McSweeney et al., 2009). Because of high rates of site fidelity, it is suggested that pygmy killer whales may be especially vulnerable to fisheries interactions (McSweeney et. al. 2009). Although no formal fisheries interactions with pygmy killer whales have been documented in Hawaiʻi, one dead stranded individual did have hook and line marks around its mouth, suggesting problematic interactions may be occurring (Schofield 2007).

In Hawaiʻi the commercial longline fishery consists of a shallow-set fishery, which targets swordfish, and a deep-set fishery targeting tuna. In 2004, 100% observer coverage on the shallow-set fishery and ~20% coverage on the deep-set fishery was implemented due to concern over sea turtle bycatch (Forney and Kobayashi, 2007). However, there are a large number of small-scale commercial fisheries operating around the main Hawaiian Islands that have no observer coverage, including the troll, handline, shortline, kaka-line fisheries, as well as the numerous recreational fishermen. These fisheries account for 3,000 to 3,200 (over 80%) of the Commercial Marine Licenses (CML) issued in Hawaiʻi from 2010 to 2013 (Baird et al., 2014).

There are no known studies that use mouthline injuries to assess fisheries interactions in false killer whales, pygmy killer whales, or any cetaceans in the main Hawaiian Islands. However there are a number of studies from other areas that assess other aspects of mouthline injuries. A study by Wells et al. (2008) assessed survivorship of Florida resident common bottlenose dolphins after being hooked in the mouthline or ingesting fishing gear, and found that ingestion of gear had a high probability of eventually lead to mortality. Another study by McLellan et al. (2014) tested how commercial longline hooks behave when hooked in the mouths of dead odontocete specimens.

The current research attention on fisheries interactions in Hawai‘i has prompted research attempting to quantify fisheries-related injuries due to direct interactions. Baird et al. (2014) evaluated Hawaiian false killer whale fin injury rates, and found differences in injury rates between populations and social clusters. This analysis prompted a study of mouthline injuries visible on the gape as a method of assessing direct injuries that occur from being hooked in the mouth, rather than secondary fin injuries that occur when whales struggle against a line while hooked. False killer whales are a species of conservation concern due to high interaction rates with fisheries, and a small island-associated resident population of Pygmy killer whales exhibits site fidelity and may be more susceptible to interactions with fisheries. Therefore these species were prioritized for mouthline injury assessment in this study.

Methods

Field Methods and Data Collection

Study Area

This research is based on data that was collected from 2000 to 2015 around the main Hawaiian Islands (MHI) as part of a long-term, multi-species, odontocete study by researchers from Cascadia Research Collective (CRC). The study area consists of the main Hawaiian islands, with <45% of effort concentrated in depths under 1,000m (Figure 1). The majority of photos used for this study were taken on CRC surveys from January 2000 to January 2015, in addition to volunteer photo submissions from 1986 to 2015.

Field methods for CRC surveys are outlined in Baird et al (2013), where small-vessel were primarily used for surveys.

Volunteer data: Opportunistic effort

A number of volunteers and partners submit photos of priority species to CRC to be added to each odontocete species catalog. Tour boat operators spend large amounts of time on the water and have many opportunistic odontocete sightings. Because of these established partnerships, Cascadia has been able to increase its photo database to include opportunistic odontocete encounters from throughout the year, in addition to CRC field projects. Some of these opportunistic encounters have included underwater photos, which often allow for the mouthline to be captured in an image, but tend to have lower photo quality when zoomed in.

Photographic Effort

All Cascadia photos taken after 2002 during directed efforts were taken with digital SLR cameras, using zoom lenses, while photos taken prior to 2003 were taken using film cameras. Directed research trips had anywhere from two to four photographers taking photos during each sighting. Effort was made to photograph the head/mouthline of all individuals encountered. Photos available from National Marine Fisheries (NMFS) from offshore surveys were also used. This is the same data set used in the Baird et al. (2014) fin injury study.

In directed field efforts, attempts are made to photograph both the right and left side of the dorsal, and subsequently both sides of each mouthline. Obtaining photos of mouthlines depended on several factors, including how high animals lifted their heads out of the water, reaction time by each photographer (as the head first emerges from the water), and water obscuring portions of the mouthline.

Photo-identification

Mouthline Assessment Protocol

Photos from all encounters in the CRC catalog were reviewed for each species for a mouthline assessment archive. I evaluated all photos from every CRC encounter from 2000 to 2015, and all volunteer photo submissions for each species. These photos were selected from the historical species catalog, where photos are grouped by individual, and then by each encounter where that individual was known to be present. I went through each folder for every known individual, using the photo processing software ACDSee. Each photo where a mouthline was visible was copied, labeled into a folder, and eventually scored for injury.

Each photo was analyzed visually, and if any portion of the mouthline was visible in the photo, it was added to the species' mouthline archive under a folder with the date and encounter that it was taken, using the specific file naming template YEARMONTHDAY_ENC#_ID#_mouthline (e.g.,2014JUL24_ENC1_HIPc144_mouthline). If the photo containing the mouthline injury came from an opportunistic encounter, the naming template included the contributor's name (e.g., 2015SEPT03_DeronVerbeck_HIFa313_mouthline). Each individual's folder was then entered into a Microsoft excel sheet, where date, encounter/source, area, island, and number of photos were entered, as well as which side of the mouthline was visible for this individual (Left, Right, Both, Front, Upper or Lower).

Mouthline scoring

After all photos from each species' archive were processed, mouthlines were then assessed and scored based off and adapted from a protocol developed by Baird and Gorgone (2005) for assessing fin injuries. Scoring of the mouthlines of each individual varied by species, but the same basic principles apply.

Each encounter where an individual was seen was scored separately by looking at the folder originally created under each encounter where an odontocete's mouthline was seen. First, I visually assessed the portion of the mouthline which was visible. The percentage of mouthline visible was also estimated and recorded in 5% increments. Finally, photo quality was scored numerically on a scale of 1 to 4 (1=poor, 2=fair, 3=good, 4=excellent).

For all species, number of notches in each side of the mouthline was recorded. Notches were identified visually as being a small cut or chunk taken out of the mouthline (Figure 2). Also recorded for all species was the degree of scarring in the corner of each mouthline (1=light, 2=moderate, 3=heavy) (Figure 2). When barnacles were growing on the mouthline it was classified as an injury because barnacles must adhere to a hard surface, therefore there must have been a breakage in the skin that exposed the tooth for the barnacles to adhere (Figure 2). Any evidence of fisheries interactions, or anything else unusual was noted and described qualitatively in an extra comments section. Injuries recorded were then assessed on the likelihood of being the result of an interaction with fisheries.

Certain species of odontocetes are known to re-pigment after injury or trauma. However, pygmy killer whale lips become naturally whiter with age, therefore in this species it cannot be assumed that if there is pigmentation, there is also injury. Because of this, pygmy killer whales in this study were assessed for injury based on irregular pigmentation and scarring around the mouthline. For pygmy killer whale mouthline assessments, an extra section was added for degree of natural pigmentation (on right and left sides of head), described numerically (0=no pigmentation, 1=slight pigmentation, 2= some/moderate pigmentation, 3=heavy pigmentation), and if irregular pigmentation occurred it was described in the comments. For false killer whales, any unusual pigmentation around the mouthline or elsewhere was described in the "other" or comments sections, and depending on the severity, was or was not determined an injury.

Mouthline injury assessment

After combining all mouthline photos for each individual, each individual's mouthline was scored. The individuals with any possibility of an injury (e.g., score > 0 in any category) were further assessed for an injury consistent with fisheries interactions. Photos were reassessed and divided into one of four categories- not consistent (with fisheries interaction), possibly consistent, consistent, and undeterminable. To be considered an injury consistent with fisheries interactions an individual must have a notch with broken skin or irregularity in the mouthline, any breakage in the lip where teeth were visible, any type of growth on the mouthline (which indicates a skin breakage), severe scarring in the corners of the mouthline, and/or irregular pigmentation (Figure 2). Pigmentation injury qualification differed by species- where moderate to heavy pigmentation on the lip was considered an injury consistent with fisheries interaction for false killer whales, but only irregular pigmentation was considered an injury in pygmy killer whales.

Individuals that received the classification of “no injury” included light scraping or scarring which could not confirmed as being consistent with fisheries interactions. Also in the “no injury” classification was anything that could be consistent with injuries from a prey species such as spines on a fish. The “possible injury” category was given to photos of individuals with that injuries that might be consistent with fisheries interactions, but either the injury was not large enough, the photo was not clear enough to determine, or part of the injury was obscured by water around the mouthline. Undeterminable injuries were qualified by poor photo quality or mouthlines that were obscured by water.

Analysis

For consistency and accuracy, minimum standards for photo quality and mouthline visibility were used in the final analysis. Individuals who only had photos of their mouthline rated as a quality of 1 (poor) were eliminated from the analysis because an accurate determination of injury could not be verified due to the photos being too dark, too blurry, or too grainy when zoomed in (this was the case for many underwater photos).

I also only used individuals who had ≥50% of their mouthline visible in all of their photos combined, to decrease the amount of negative injury bias in the results. Calves and juveniles were also eliminated from the analysis, since they would be less likely to have sustained fisheries related injuries both due to their diet consisting mostly of milk for the first year or more of their life, and due to a limited time period for potentially interacting with fisheries (Oftedal, 1997).

After the mouthline scoring, some individuals were labeled as having "possible injuries", due to the injury being too small to determine, part of the possible injury being obscured by water, or photo quality being too low. I did not include these animals in the analysis because of the ambiguity of whether or not they have an injury. Therefore, all animals used in the analysis were adults and subadults, with photo quality rated 2 to 4, who either were scored to have an injury or not have an injury, based on looking at ≥50% of their mouthline.

To evaluate the differences in fisheries-related mouthline scarring between species, populations, and social clusters, a Fisher's exact test was used. Data was available on the sex for 15 of the false killer whales with injuries, either through genetic analysis of biopsy samples (Chivers et al., 2010) or observational data on the presence of calves and neonates, and so I assessed sex bias in individuals with injuries. To determine if injury detection increases as the percentage of mouthline visible increases, I used Fisher's exact test. For this test, individuals with mouthlines visible were binned into two categories- those having 50%-75% of their mouthline visible, and those having 76%-100% of their mouthline visible.

Results

After sorting through over 167,000 photos, 290 individuals were found to have at least some portion of the mouthline visible. The remaining individuals were not included for the remainder of the study. After sorting these minimum photo quality, mouthline visibility, and age classs parameters, 99 individual false killer whales and 47 individual pygmy killer whales were used for analysis, making a total of 146 individuals.

False Killer Whales

For false killer whales, a total of 195 individuals had at least some portion of the mouthline visible, 144 had ≥50% of their mouthline visible and 45 had a full 100% of their mouthline visible. When constraining the data to the photo quality and % mouthline visibility determined in the methods, there were a total of 142 individuals with at least some portion of the mouthline visible, and 99 individuals with ≥50% of their mouthline visible (mean proportion of mouthline visible=58%). The MHI population of false killer whales had the greatest amount of individuals with mouthlines visible, accounting for 91 of the 142 individuals with mouthlines visible, which is more individuals than the pelagic and NWHI populations combined (Table 1).

No significant difference in injury rates for false killer whales between populations was detected (Fisher's exact test, p=0.47). The highest percentage of injuries occurred in the Main Hawaiian Islands population, with 22.2% of all individuals with ≥50% mouthline visibility having injuries (Table 2). When assessing only individuals who have 100% of the mouthline visible, injury rate increases to 30%. Although sample sizes for the pelagic and NWHI populations were notably small, 7% and 15% of the pelagic and NWHI, respectively, had injuries. Of all false killer whales with mouthlines visible, 19% had injuries (Table 2).

There was no significant difference in fisheries related mouthline injuries between the three MHI false killer whale social clusters (Fisher's exact test, p=0.39). The number of total mouthline photos was highest for cluster 1, with cluster 2 and 3 being relatively similar in number. Rates of injury were highest in cluster 2, with 31.8% of the population with ≥50% mouthlines visible having injuries. Injury rates were second-highest in cluster 1, where 20% of the individuals having injuries. Injury rates for cluster 3 were lower than cluster 1 and 2 (Table 3).

Of the animals that have injuries consistent with fisheries interactions, more females have injuries than males, although this difference was not statistically significant (Sign test p = 0.1185). Of the 19 individuals meeting the mouthline quality and visibility standards for this study, 11 were females and four were males (Figure 3). Four animals of unknown sex have either not been biopsied, or have no defining characteristics that would deem them either sex.

Pygmy Killer Whales

For pygmy killer whales, a total of 95 individuals had at least some portion of their mouthline visible, 66 had ≥50% of their mouthlines visible, and 15 had 100% of their mouthline visible. As percentage of mouthine visible increases, rate of injury also increases in both the “positive” and “possible” injury categories. Forty-seven individuals had ≥50% of their mouthline visibility and met the photo quality criteria. Of these, 34% had injuries consistent with fisheries interactions (Table 4).

When removing the individuals from Maui, individuals from O‘ahu and Hawai‘i, 31% had injuries consistent with fisheries interactions (Table 5). Although mouthline injury rates differed between Hawai‘i and O‘ahu associated individuals, there was not a significant difference between the two groups (Fisher’s exact test, p=0.11).

Mouthline assessment evaluation

When both species are combined, the probability of individuals having injuries consistent with fisheries interactions was significantly higher when a higher proportion of the mouthline is visible (Fisher’s exact test, p<0.0361; Figure 4).

Discussion

Although there are relatively few studies addressing mouthline injuries in odontocetes, this research demonstrates that mouthline injury analysis is an effective way to assess fisheries interactions in false killer whales and pygmy killer whales. By assessing the various factors that could contribute to a mouthline injury, we can better understand how injuries could be acquired. Other than fisheries interactions, a possible cause of injury to an odontocete mouthline could be injuries from prey species, for example the spines of a fish raking across the mouthline during a struggle. However, I assume that if negative prey interactions were the cause of these injuries, they would leave scars similar to the morphological features of that prey species (e.g. spine rake marks, circular suction cup wounds, etc.).

Another way that an individual could acquire an injury would be through an attack from a predator, such as a shark, however it would be highly unusual for these wounds to appear in a single specific location such as the mouthline, as scarring would be seen on the dorsal fin and body. Although there is no way to be completely certain that injuries are acquired through fisheries interactions (unless observed occurring), all injuries in this study are considered to be consistent with fisheries interactions based on the information available.

Scarring patterns for mouthline injuries in this study do not seem to be consistent with injuries from prey. The deep notches in the lip, large chunks taken out of lip tissue, jagged scarring in the corners of mouthlines, irregular pigmentation patterns, and growths adhering to teeth due to lip tissue breakages are all consistent with an animal being hooked in the mouth and struggling against a line, with the line causing the injuries on the gape. This is supported by a study by McLellan et al., (2014), where a variety of hooks were tested on the mouthlines of dead odontocetes to simulate that animal struggling against a line after being hooked. The hooks either tore or sliced through the lip tissue, and published photos are consistent with injuries we came across in this study. Therefore, we consider the scarring patterns and injuries seen in this study as being consistent with fisheries interactions.

False killer whales

Consistent with previous research (Baird et al., 2014) results show that of all Hawaiʻi populations, the MHI insular population of false killer whales have the highest rates of mouthline injury (22% of individuals assessed having injuries), supporting that individuals from this population regularly interact with fisheries. These results are congruent with fin injury analysis (Baird et al., 2014), where the MHI population showed injury rates five times higher than the pelagic and NWHI populations. Despite small sample sizes from the pelagic and NWHI populations of false killer whales, mouthline injuries were still seen in individuals.

Mouthline injuries seen in false killer whales in this study varied widely in severity and frequency, with the most commonly seen injury being large notches in the lip tissue (Figure 5). Two individuals had lip injuries so extensive that lip tissue was completely missing and teeth were visible (Individual B, Figure 5). Other injuries included irregular pigmentation around the head and lip (Figure 6).

Since only large injuries were considered for this study, it is unlikely that they could be the result of interaction with prey or normal 'wear and tear' on the mouthline. Although false killer whale prey include large pelagic fish and could conceivably cause damage on the mouthline, most injuries are more consistent with a localized severe wound rather than a struggling fish which would presumably cause injury all along the mouthline or head, rather than precise clefts of missing lip tissue more consistent with a pulling hook or line.

Although not significant, cluster 2 individuals had the highest rate of injury, with 31% having injuries consistent with fisheries interactions. This information is not consistent with previous research on cluster and fin injury analysis, where cluster 3 showed the highest rates of interaction (Baird et al., 2014). However that study differed in methodology since all members of cluster 3 were assessed, rather than a subset. Since there are differences in injury rates for these clusters, it does suggest that different social clusters may have different habits when it comes to depredation and fisheries interactions. This information validates further research in this area, as certain behaviors could be culturally taught and passed down within a social cluster, which could impact population growth within that cluster (Sargeant and Mann, 2009).

False killer whales are the most frequently recorded cetacean hooked in the Hawaiian longline fishery. The majority of false killer whales (83% of 24 individuals reported hooked in the tuna longline fishery between 2007 and 2011) had injuries that were either fatal or serious enough to cause death (Bradford and Forney, 2014). Since the overwhelming majority of false killer whales hooked in the longline fishery likely die, it is conceivable that we would never see most of these injuries. This information coupled with our research of high mouthline injury rates suggests that it is possible that false killer whales are interacting at high rates with other nearshore fisheries. Further substantiating this suggestion is the false killer whale that stranded in 2013 with 5 hooks in its stomach, 3 of which were not from the longline fishery (Baird et al., 2014). Since nearshore fisheries in Hawai‘i lack observer coverage, which fishery they may be coming into contact with most often is unknown.

Consistent with recent fin injury analysis (Baird et al., 2014), results showed a sex bias toward females having the most injuries consistent with fisheries interactions, with 11 out of 15 individuals of known sex with injuries being female (73.3%). Of the remaining 8 individuals, 4 were males and for 4 the sex was unknown. Although these results were not significant (likely due to a small sample size), a disproportionate rate of females interacting with fisheries could have implications for population growth in this species.

Pygmy killer whales

The limited information known about pygmy killer whales prey species makes it difficult to determine if mouthline injuries could be occurring in pygmy killer whales due to prey interactions. However, based on the descriptions of the mouhtline injuries evaluated in this study and what is known about pygmy killer whale diets in other parts of the world, we can assess this question. Pygmy killer whales in other areas have been documented feeding on fish and cephalopods (Leatherwood and Reeves, 1994; Zerbini and Santos, 1997). Injuries assessed in this study were unlikely to be from cephalopods, because those injuries would mimic the roundness of a suction cup. While it is possible that injuries could be occurring during feeding events with other prey items, the unusual nature of the injuries seen in this study suggests that they are more likely to be consistent with fisheries interactions.

The most common injuries seen in pygmy killer whales were large notches taken out of the mouthline, irregular pigmentation, and corner of the mouth scarring. One individual had large barnacle growths resulting from a breakage in the lip tissue. Pigmentation often occurred irregularly in corners of the mouthline and in jagged, vertical cuts going up, down, or through the lip (Figure 7). Notches (Figure 8) were commonly seen either by themselves or in conjunction with additional pigmentation surrounding the trauma sight. This is not surprising considering that pygmy killer whale scars heal white.

The results which demonstrate a high injury rate of 43% for Hawai‘i associated individuals compared to 20% of O‘ahu individuals (Table 5), combined with the knowledge of a Hawai‘i island associated population of this species (McSweeney et al., 2009) suggest that this population is interacting with nearshore fisheries.

Pygmy killer whales are considered data deficient under the International Union for the Conservation of Nature (IUCN) and are naturally rare throughout their range, therefore the high rates of injuries consistent with fisheries interactions shown in this study could have implications for this species. Island associated populations of pygmy killer whales have a high degree of site fidelity, and the west coast of Hawai‘i has been identified as a Biologically Important Area for this population (McSweeney et al., 2009; Baird et al. 2015). Having a high degree of site fidelity can increase a populations' susceptibility to anthropogenic impacts since they have evolved to live and feed in relatively small specific areas. This information coupled with an injury rate of 31% for Hawai‘i and O‘ahu individuals from this study suggests that individuals in these populations are coming in contact with fisheries. The only observer-covered fishery in Hawai‘i is the deep-set and shallow-set longline fishery, and there have been no confirmed reports of pygmy killer whales interacting with these fisheries prior to 2014

(Carretta et al., 2014). This suggests that pygmy killer whales are mistakenly reported as a species similar in appearance or the mouthline injuries in pygmy killer whales could be coming from unregulated nearshore fisheries.

Since pygmy killer whales primarily feed at night and there are few anecdotal reports of them depredating lines, this mouthline injury assessment could provide new insights into fisheries interactions for this species. Although sample sizes were relatively low, this research suggests that pygmy killer whales could be interacting with the fisheries at higher rates than previously thought.

This could have potential policy implications since there are no strong management directives in place for pygmy killer whales in Hawai‘i. Information about fisheries interactions could be an indication that more research should be directed at these species, especially because of their cryptic nature and how little is known about them in general. Since we have limited information on their feeding behaviors and prey species, we have little idea about with what fisheries they could potentially be interacting. Further research in this area could lead to information about the diet and feeding behavior of pygmy killer whales in Hawai‘i in addition to their degree of interaction with fisheries.

Mouthline assessment analysis

When considering these results, it is important to mention that interaction rates are negatively biased, because individuals scored as having “no” mouthline injury may have less than 100% of the mouthline visible, for example, individuals who have the left 50% of their mouthline visible may have an injury on the right side. The significant pvalue in the Fisher's exact test demonstrates that with increased mouthline visibility, more injuries are detected. All of this information suggests that all of the results found in this study are most likely a conservative estimate of actual injury rates.

Conclusion

The high rates of mouthline injuries described in this study suggest that certain changes should be considered for the management and conservation of these species. Evidence that the MHI false killer whale population has high rates of mouthline injury should be considered in future policy concerning this endangered species. Supported by fin injury analysis (Baird et al., 2014) and the 2013 stranding of the false killer whale from cluster 3 with three unidentified hooks in the stomach, this study furthers the need to expand the Take Reduction Plan to include nearshore fisheries. Further effort is also necessary to determine rates of fisheries interactions in the MHI social clusters. Obtaining more mouthline photos for all clusters would allow for a more accurate analysis of direct fisheries interactions. Further research of sex bias should be conducted to help understand potential for population growth in this species, and could also help understand more about behavioral feeding characteristics.

Pygmy killer whale injury results from this study indicate that there may also be a cause for concern that this species, as mouthline injury rates suggest that individuals are interacting with fisheries more than previously thought. Because pygmy killer whales are naturally rare, a population decrease may not be easily detected. Although difficult to study because of low encounter rates in the field, further research must be conducted to learn more about how pygmy killer whales interact with fisheries. One way to bolster our knowledge and obtain more photographic data on this species is to continue outreach among the local fishing and boating community. Increasing the data set is one important was to increase our understanding about this cryptic species. Having greater evidence of fisheries interactions for this species, coupled with more satellite tag data could help determine whether we should consider additional protections for this rare species.

Mouthline assessment research

Mouthline injury assessment is a relatively low-cost and affordable way to assess fisheries interactions. Other than being time-consuming, there are few drawbacks to consider. Mouthline injury assessment can be applied to an existing photo data set, and can reveal new information without having to specifically collect more photos. The effectiveness of mouthline assessment could be improved by intentional directed efforts by field photographers to capture mouthline and head photos.

Future research

Mouthline injury assessment can be a useful tool in determining fisheries interaction rates. In conjunction with analyzing strandings for evidence of hookings or hook ingestion, mouthline injury assessment can be provide further insight into fisheries interactions in populations within species as well as social clusters. Continuing mouthline assessment in a multi-species comparison for short finned pilot whales, rough toothed dolphins and melon headed whales, could yield valuable information about differences in species interaction rates. In addition, adding in “unknown individuals” to the false killer whale and pygmy killer whale mouthline assessment could increase the scope of the analysis. In order to understand more about mouthline injuries and depredation behavior, assessments of where injuries occur on the mouthline could be undertaken.

Figures

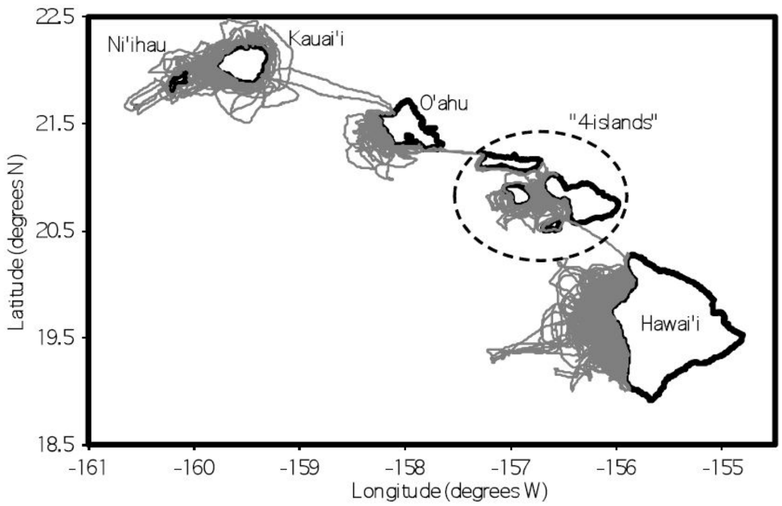


Figure 1. Tracklines showing total effort for CRC survey in Hawai‘i from 2000-2012 from Baird et al. (2013).

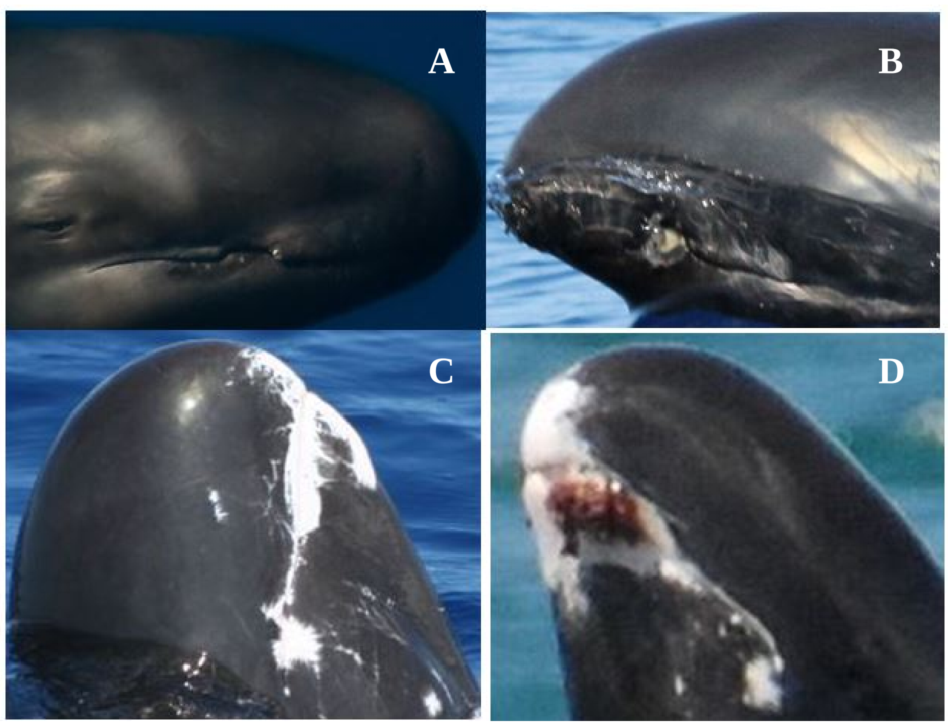


Figure 2. Examples of injuries consistent with fisheries interactions. False killer whales with notch (A) and breakage in lip tissue exposing teeth (B). Pygmy killer whale individuals with irregular pigmentation and notch (C) and growth accompanied by corner mouth scarring (D)

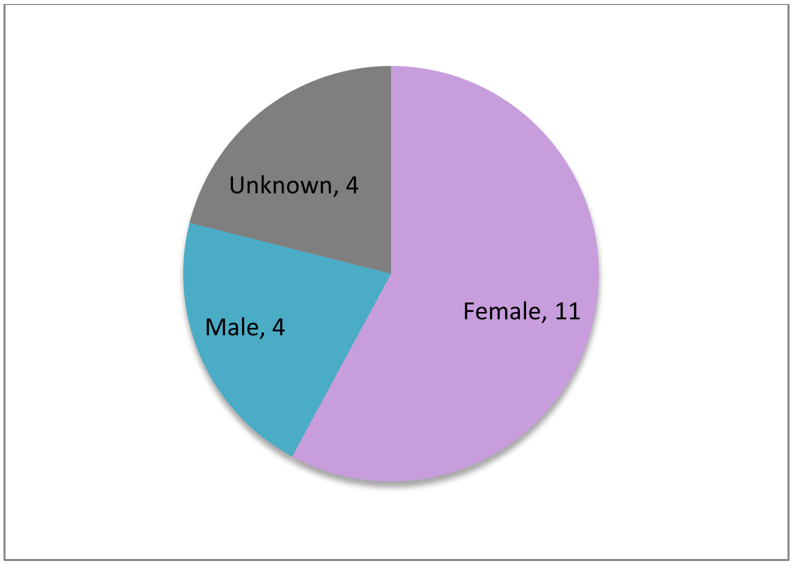
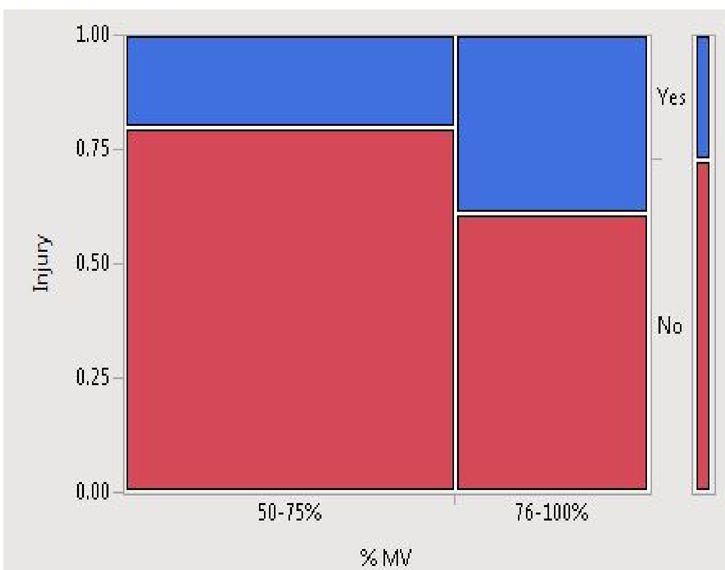


Figure 3. Sex of false killer whales with injuries consistent with fisheries interactions



% MV	Count / Total % / Col % / Row %	Injury: No	Injury: Yes	
50-75%	Count	63	16	79
	Total %	50.40	12.80	63.20
	Col %	69.23	47.06	
	Row %	79.75	20.25	
76-100%	Count	28	18	46
	Total %	22.40	14.40	36.80
	Col %	30.77	52.94	
	Row %	60.87	39.13	
	Count	91	34	125
	Total %	72.80	27.20	

Figure 4. Contingency table demonstrating that probability of injury is greater when mouthline visibility is 76-100% than 50-75%

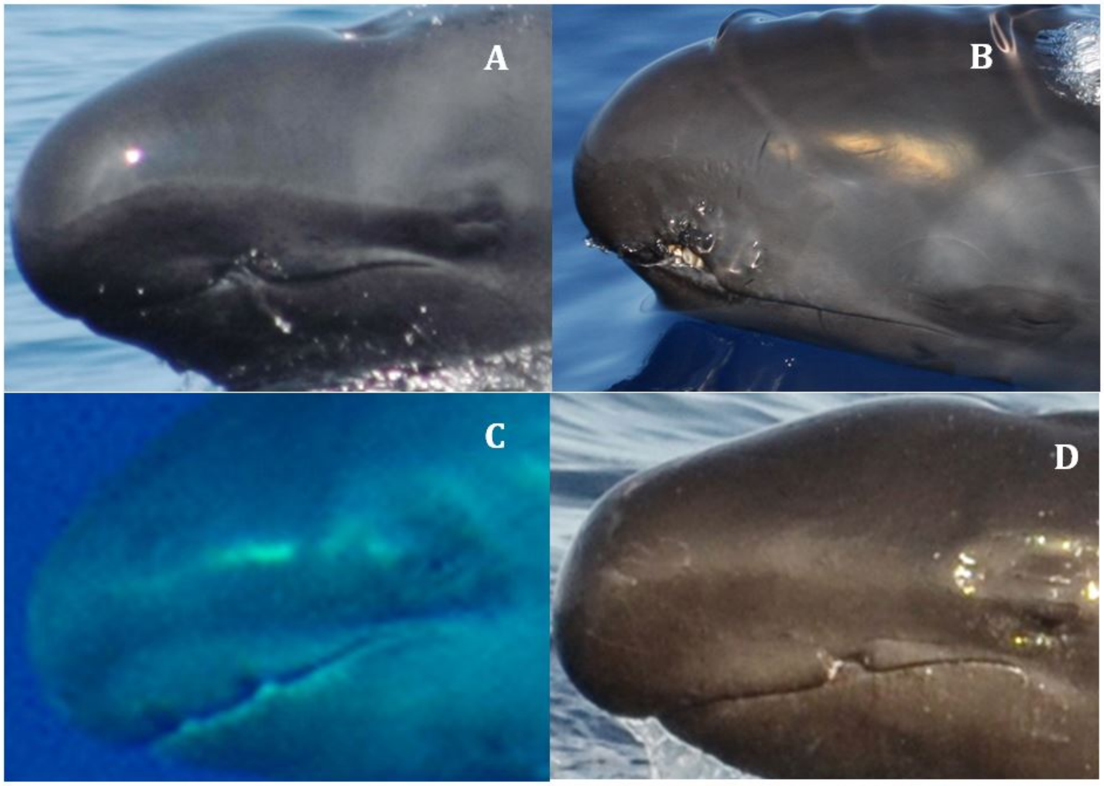


Figure 5. Examples of injuries on the mouthlines of false killer whales considered consistent with fisheries interactions. (A) HIPc210, male from cluster 1, has one large notch on the left side. This is the most commonly seen injury. (B) HIPc339, a female from cluster 2, has a large chunk taken out of the lip where the teeth are visible, placed closer to the front of the rostrum. (C) Although underwater photo quality can be low, it is still clear that this individual, HIPc222, a female from cluster 2, has two large notches in the mouthline. (D) HIPc161, an adult male from cluster 3, has a prominent notch placed mid-lip on the left side.

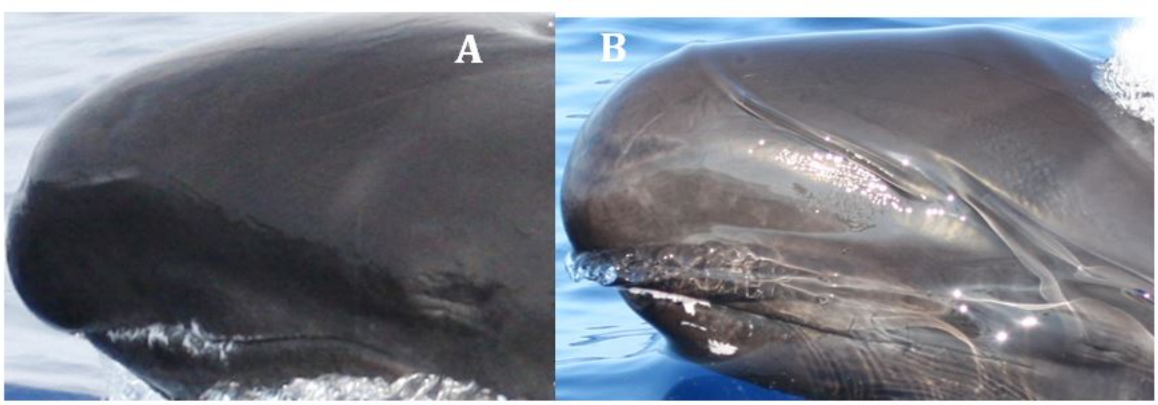


Figure 6. Examples of pigmentation in false killer whales, injuries considered to be consistent with fisheries interactions: (A) HIPc 104, an individual from cluster, 1 has pigmentation surrounding a notch in the lip; (B) HIPc230, a female from cluster 2, has pigmentation on the lower lip, towards the front of the rostrum.

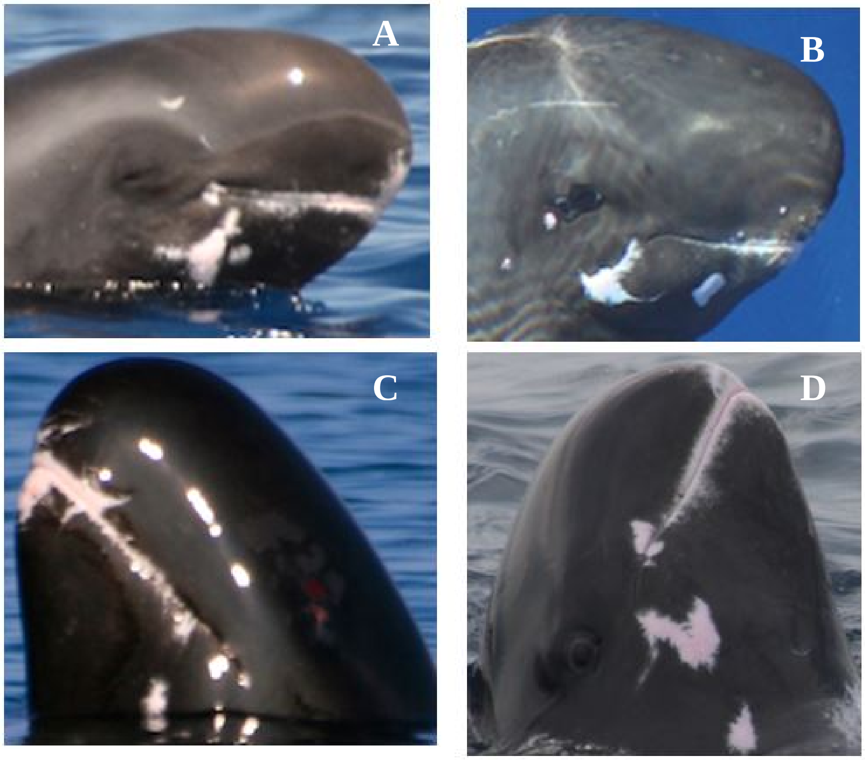


Figure 7. Examples of irregular pigmentation consistent with fisheries interactions. A, B, and C have irregular pigmentation in the corner or the mouthline. D has irregular vertical scarring going through the mouthline plus notable indentations, possibly consistent with being hooked one the mouthline

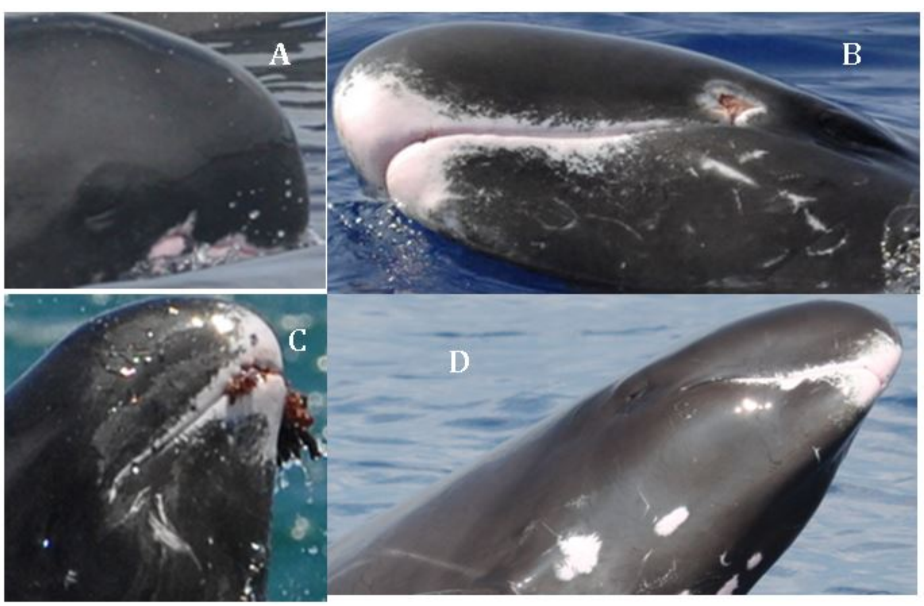


Figure 8. Examples of mouthline notches consistent with fisheries interactions: A and B have large notches in the lip. C has multiple large barnacles growing due to breakages in lip tissue. D has small equidistant nicks on the tip of rostrum, possibly created by a line.

Tables

Table 1. False killer whale mouthline visibility by population

Population	Mouthline Visibility	
MHI	Total	91
	≥50%	72
	100%	23
Pelagic	Total	33
	≥50%	14
	100%	1
NWHI	Total	18
	≥50%	13
	100%	1
All	Total	142
	≥50%	99
	100%	24

Table 2. Count and percentage of false killer whales with mouthline injuries consistent with fisheries interactions by population, for photos taken 2000-2015

Population	Mouthline Visibility		Injuries consistent with fisheries interactions	
			Count	Percentage
MHI	≥50%	72	16	22.2%
	100%	23	7	30.4%
Pelagic	≥50%	14	1	7.1%
	100%	1	0	0.0%
NWHI	≥50%	13	2	15.4%
	100%	1	0	0.0%
All	≥50%	99	19	19.2%
	100%	24	7	29.2%

Table 3. Count and percentage of mouthline injuries consistent with fisheries interactions by MHI social cluster of false killer whale

Cluster	Mouthline Visibility		Injuries consistent with fisheries interactions	
			Count	Percentage
1	≥50%	30	6	20.0%
2	≥50%	22	7	31.8%
3	≥50%	20	3	15.0%

Table 4. Count and percentage of mouthline injuries consistent with fisheries interactions in pygmy killer whales by mouthline visibility

	Mouthline Visibility		Injuries consistent with fisheries interactions	
			Count	Percentage
Pygmy Killer Whales	Total	95	17	17.9%
	>50%	68	16	23.5%
	100%	15	8	53.3%

Table 5. Count and percentage of mouthline injuries consistent with fisheries interactions in pygmy killer whales by mouthline visibility in Hawai‘i and O‘ahu associated individuals

Pygmy Killer whales	Mouthline Visibility		Injuries consistent with fisheries interactions	
			Count	Percentage
Hawai‘i	≥50%	23	10	43.5%
O‘ahu	≥50%	20	4	20.0%

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Appendix

Photo credits

Figure 2- (A) Deron Verbeck, (B) Jessica Aschettino (C) Tori Cullins (D) Russ Andrews

Figure 5- (A) Elisa A Weiss (B) Elisa A Weiss (C) Deron Verbeck (D) Russ Andrews

Figure 6- (A) Cascadia Research Collective (B) Elisa A Weiss

Figure 7- (A) Jim Ward (B) Robin W Baird (C) Tom Elliot (D) Robin W Baird

Figure 8- (A) Cascadia Research Collective (B)/(C) Russ Andrews (D) Robin W. Baird