Alaska and British Columbia
Large Whale Unusual Mortality Event
Summary Report

Photo courtesy B. Witteveen

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Executive Summary

Between May 22 and June 17, 2015, 12 finback whales (*Balaenoptera physalus*) were observed stranded around Kodiak Island and the western Gulf of Alaska. The atypical nature of these strandings, i.e. high number of mortalities in a relatively short period of time and small space, was sufficient to characterize the cluster as an Unusual Mortality Event (UME). Demographic, epidemiologic, pathologic and laboratory findings from an increase in large whale strandings in British Columbia (BC) between April 2015 and April 2016 were added to the UME investigation to help understand possible stranding causes. Data were compiled from: 1. 2015 and 2016 stranding reports and photographs and, 2. a partial necropsy of one of the 2015 Alaskan fin whales and necropsies of eight of the BC whales. Necropsy results of 2016 Alaskan (AK) fin and humpback whales were also assessed relative to the UME. The total number of whale cases investigated was 52, including from AK 34 in 2015 (12 fin; 22 humpback); 6 humpback whales in 2016; and from BC 11 in 2015 (5 fin; 6 humpback) and 1 humpback whale in 2016. Differential stranding causes included sonar/seismic testing, radiation, ship strike, infectious disease, predation, and oceanographic changes leading to algal toxin exposure or starvation due to shifts in prey species/distribution. Analysis of the data did not reveal a definitive cause of the UME but we determined that sonar/seismic testing, radiation, and predation likely did not contribute to the UME. Because the strandings were concurrent with anomalous physical and biological shifts in the 2015 Alaskan marine environment, and accompanying mass mortalities of avian species and northern sea otters, the UME was likely one of a many indicators of broader, complex and dynamic ecologic change and therefore these ecologic changes were most likely a contributory factor to the UME. Consequently, while the event was not repeated in 2016, post-UME monitoring over the next few years will include continued surveillance of both large whale health and ecology, including field observations of body condition, necropsy findings, population shifts, unusual strandings etc. in a larger environmental context, as well as finalizing results.

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I. Introduction

Fin whales and humpback whales are two of the most common cetacean species sighted in the Gulf of Alaska (GOA) (Rone et al 2017). For both fin whales and humpback whales, specific locations within the GOA have been designated as Biologically Important Areas (Fig. 1), defined as reproductive areas, feeding areas, migratory corridors and areas in which small and resident populations are concentrated (Ferguson et al. 2015).

Between May 22 and June 17 of 2015, a cluster of fin whale strandings near Kodiak Island prompted Alaska Stranding Network members to petition for the strandings to be considered an Unusual Mortality Event (UME). The petition included reports from Kodiak Island, Afognak Island, Chirikof Island, the Semidi Islands and the southern shoreline of the Alaska Peninsula, all areas where fin whales have historically been observed (Zerbini et al. 2006). While fin whales were focal in the UME petition, other large whale species stranded in the area were also added, including nine humpback whales, one gray whale, and two unidentified cetaceans. On August 4, the Working Group on Marine Mammal Unusual Mortality Events (Working Group) unanimously voted to consider the large whale strandings in the western GOA as a UME under Criteria #1: a marked increase in the magnitude or a marked change in the nature of morbidity, mortality or strandings when compared with prior records with the UME boundary described as including the Gulf of Alaska from Kodiak Island, Afognak Island, Chirikof Island, the Semidi Islands, and the southern shoreline of the Alaska Peninsula. Beginning on April 23, 2015 coastal British Columbia (BC), from the northern tip of Haida Gwaii to southern Vancouver Island, also experienced an increase in the number of large whale strandings. Due to the similarity in atypical strandings, events in Alaska and BC were investigated together.

Throughout the remainder of 2015, reports of all dead large whales observed within the general UME boundaries were compiled. By the end of 2015, Alaskan reports of 12 fin whales, 22 humpback whales, 2 gray whales and 4 unidentified whales had been received. In BC, the 2015 total was 12 animals, including 5 fin whales, 6 humpback whales and 1 sperm whale. In Alaska, only a partial necropsy of one fin whale was completed. Data from all other Alaskan animals were compiled from information in reports and photographs. To eliminate as much subjectivity as possible in photo interpretation, a group of marine mammal biologists, including some with extensive large whale necropsy expertise, independently evaluated the carcass photos for condition code, age, gender and possible cause of death. Results of the evaluations were compiled, compared and summarized into final scores that served as the basis for most of the Alaskan data. In BC, eight of the animals were necropsied.

A cause of death (COD) was not apparent for the majority of stranded animals. The large number of animals with no apparent COD is attributed to the small numbers of animals examined, impeded in part by limited access, delayed reporting and loss of carcasses, advanced level of decomposition, and other factors. However, because the UME was one of many anomalous physical and biological events that occurred in 2015, one of the primary differentials included toxicity or starvation associated with altered food chain events as a result of changing oceanographic conditions. Because conditions were predicted to be similar in 2016, much of the UME work in 2016 focused on preparing for a possible repeated mortality event. A workshop was convened for expert discussion on physical and biological shifts in the Alaskan marine environment. Public service announcements were made in Kodiak requesting public vigilance and prompt reporting for large whale carcass observations. A series of four aerial carcass surveys were completed along the southern Kodiak coastline. A necropsy lead was always available for rapid response. In 2016, necropsy findings of two fin whale and five humpback whale strandings from other locations around Alaska were assessed relative to the UME. While the UME was not repeated in 2016, other indications of environmental shifts persisted, although these indications were not as evident as in 2016.

On October 8, 2016, during a meeting with the UME Working Group, the Large Whale UME Core Team recommended closing the UME based on the analysis to date, pending outstanding results and the input of the larger investigative team.

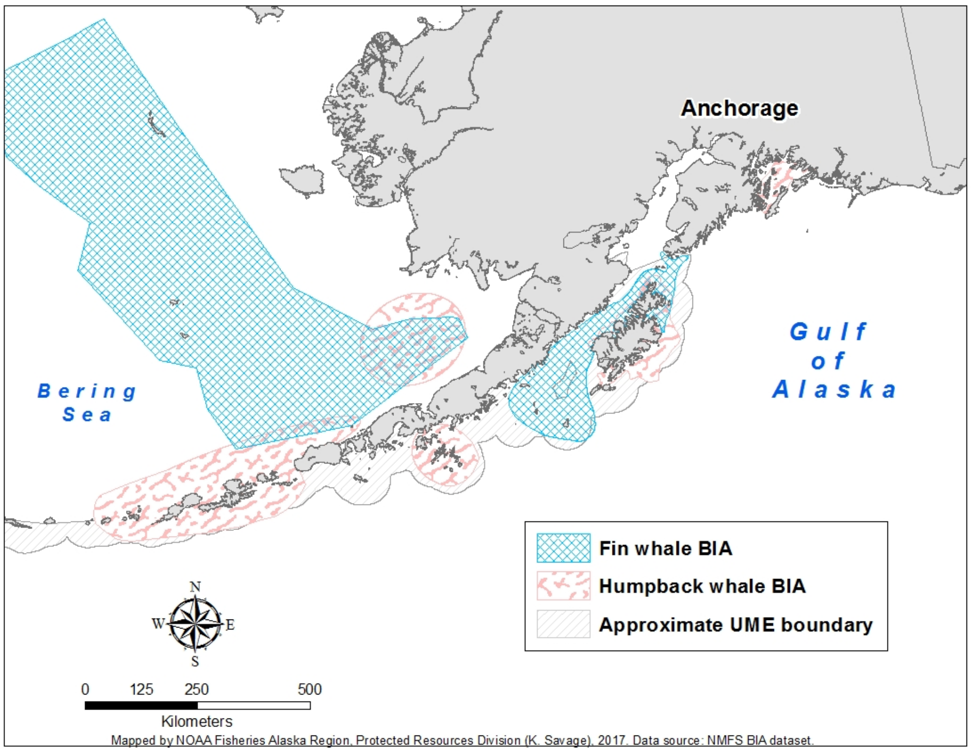

Figure 1. Biologically Important Areas (BIA) for fin whales and humpback whales in the Gulf of Alaska (NMFS 2017) and the spatial boundary of the Unusual Mortality Event (UME).

II. Summary of Reports

A. AK Fin Whales

2000-2014

While fin whales are one of the most common cetacean species in the Gulf of Alaska (GOA)(Rone 2017), with an average abundance estimate of 1652 animals and a suggested annual population increase of 4.8% (Zerbini 2006), fin whale strandings are not commonly observed. Between 2000 and 2014, a total of 9 fin whales were reported stranded, averaging less than 1% of all regional annual strandings (range: 0 to 1.9% per year, regional strandings including all confirmed stranding reports of NMFS marine mammal trust species) with never more than two fin whales reported stranded in any given year (Fig. 2). Due to the remoteness of beach cast animals, climatic conditions (wind storms) and sparse human population, these observed carcasses represent a minimum estimate of regional mortality within the population.

The nine reports were from three subareas in the region; five from the GOA, two from Southcentral Alaska and two from the Bering Sea (Fig. 3). No reports were received from the Arctic or from inside waters of Southeast Alaska. Reports of stranded whales extended from early spring to early fall, with one each in March, April, May and June, two in July, two in August, and one in September. Three animals were female, one was male and five were of undetermined gender (Fig. 4). Three were subadults, two were adults, and the remainder were of unknown age (Fig. 5).

Four of the nine fin whale reports were associated with ship strike, with either a carcass observed on the bulbous bow of a large ship or a carcass having injuries consistent with ship strike noted on necropsy (Fig. 6).

2015 and 2016

In 2015, 14 dead fin whales were reported stranded in the Alaska Region, comprising over 4% of all regional stranding reports for the year. The first reported carcass was observed in February along the shore of St. Paul Island in the Bering Sea. The animal was not necropsied and COD was not apparent. Between May 22 and June 17, twelve fin whale carcasses were observed either floating off the coast of Kodiak Island or in waters to the west of Kodiak. The last fin whale in 2015 was observed on September 27, brought in to the Port of Anchorage (POA) on the bulbous bow of a freighter. The first whale (St. Paul) was an adult female. The last whale (POA) was of unknown age and gender. Of the remaining twelve GOA animals, six were female, three were male, and three were of unknown gender. Nine were adults, one was a calf and two were of unknown age. Cause of death was not determined in any of the carcasses except for the presumed POA ship strike. Limited necropsies were performed on the St. Paul animal and one of the Code 3 GOA animals.

In 2016, 3 fin whales were reported stranded in the Alaska Region, compromising 1% of all stranding reports for the year. The first carcass was observed in February along the shore of St. George Island in the Bering Sea, the second carcass came into the Seward harbor on the bulbous bow of a cruise ship in May, and the third carcass was first observed as a live stranding in the tidal flats of upper Cook Inlet on June 21and found dead a few days later. Gender and age were not identified for the St. George animal, the Seward animal was a subadult male and the Cook Inlet animal was an adult male. A full necropsy on the fresh Seward animal determined ship strike to be the COD. Cause of death for the other two animals was not determined, with only minimal samples collected from the Cook Inlet stranding.

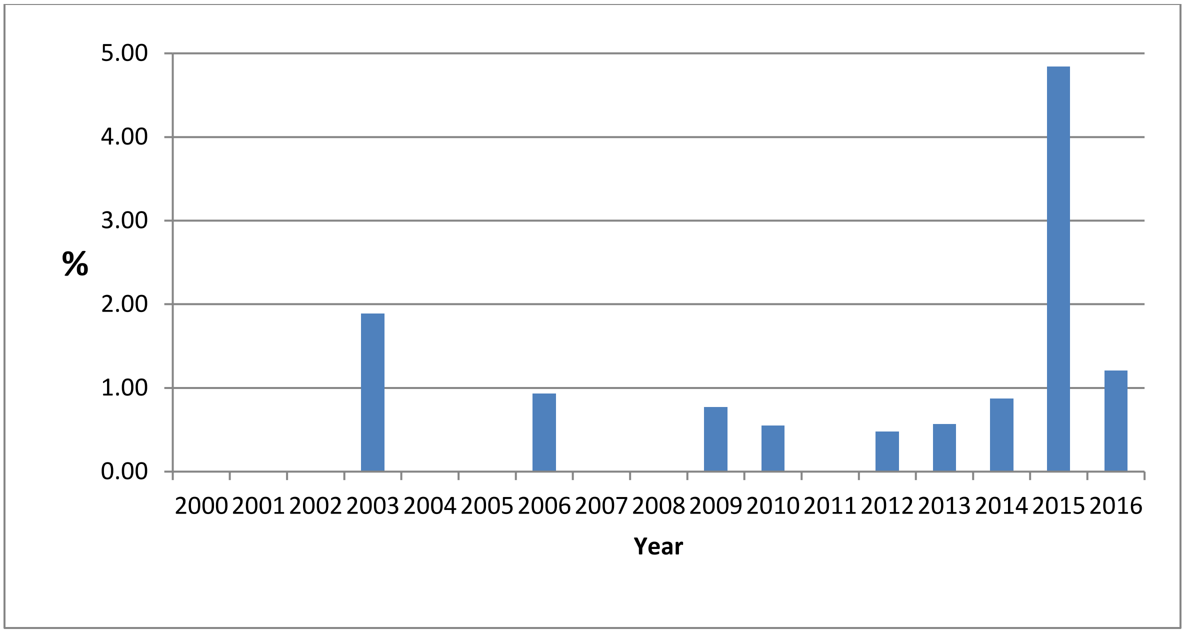

Figure 2. Number of dead AK fin whale stranding reports as a percent of total marine mammal stranding reports by year, 2000-2016.

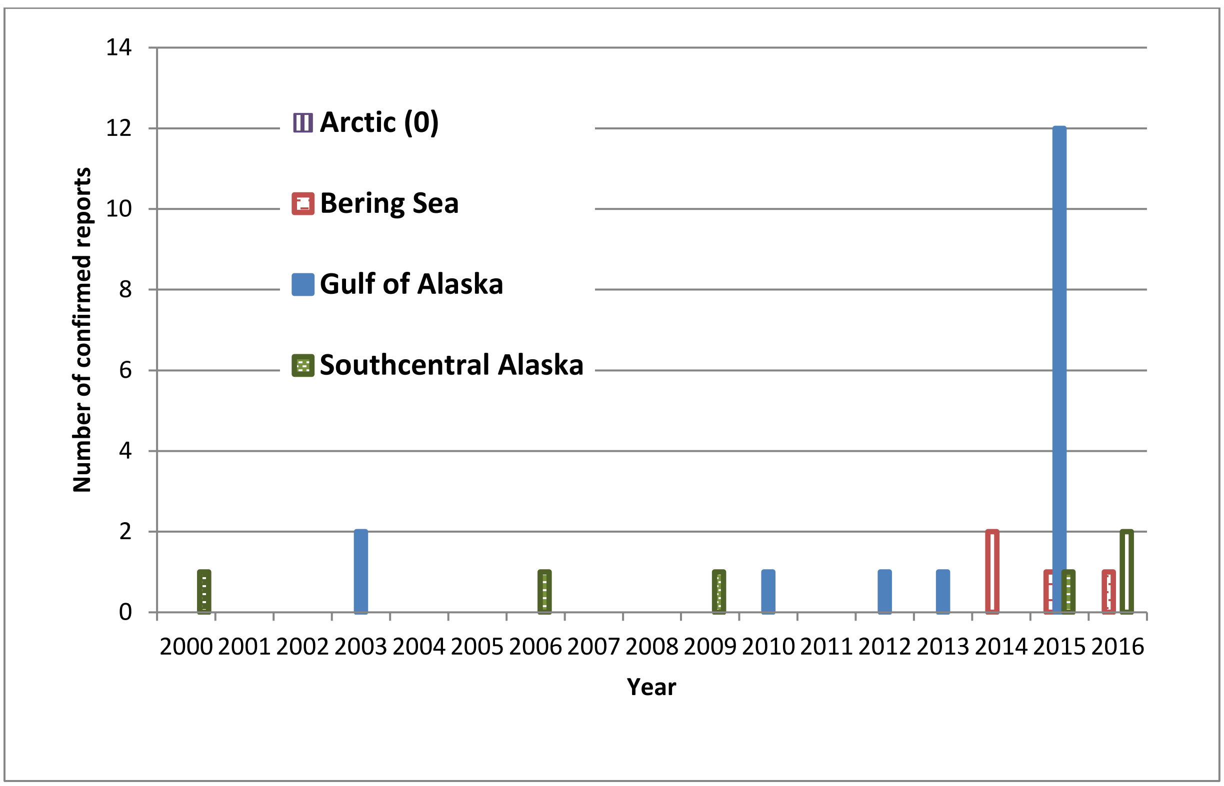

Figure 3. Number of confirmed reports of dead AK fin whales by regional subarea.

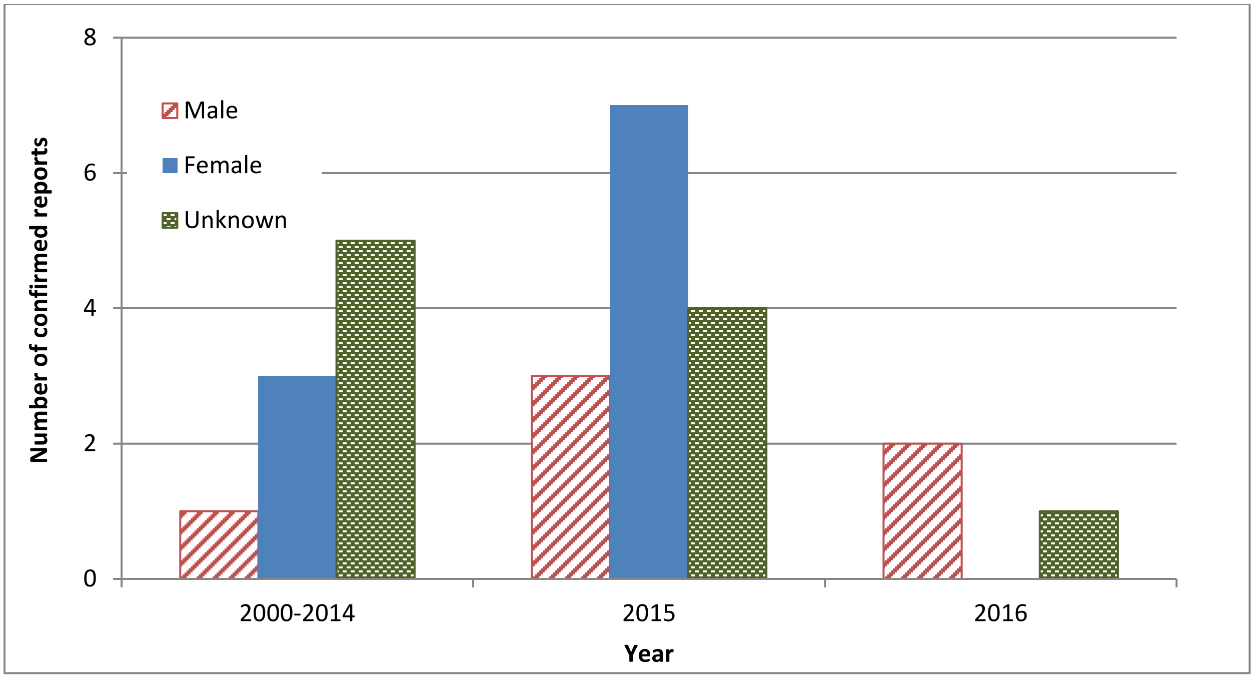

Figure 4. Gender of stranded AK fin whales by year.

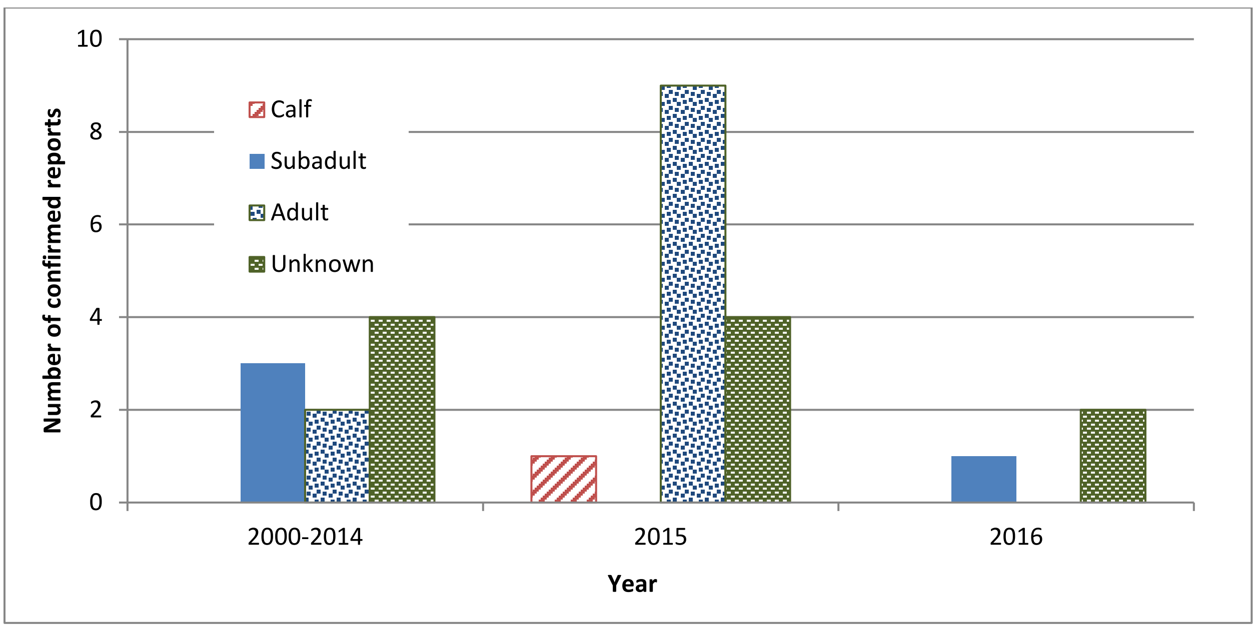

Figure 5. Age of stranded AK fin whales by year.

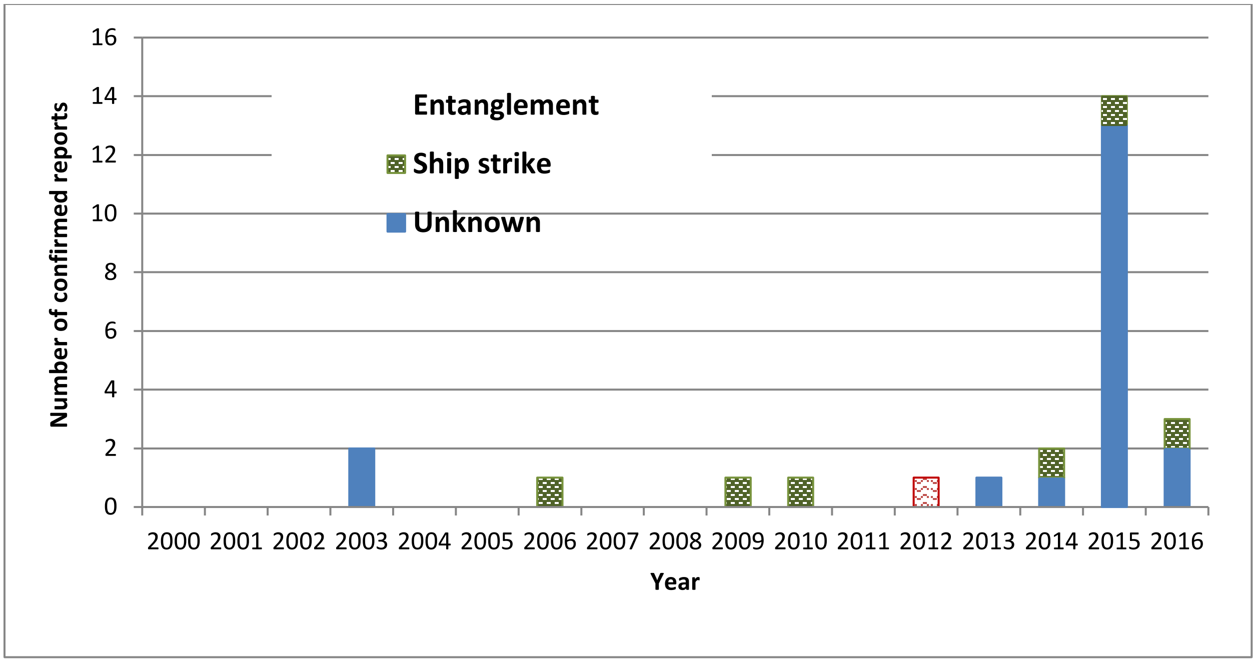

Figure 6. Cause of death of stranded AK fin whales by year.

B. AK Humpback Whales

Humpback whales (*Megaptera novaeangliae)* are one of the most common marine mammal species reported stranded in the Alaska Region, and the most common large cetacean species.

Between 2010 and 2014, an average of 13 dead humpback whales were reported stranded per year averaging 3-8% of all stranding reports per year. In 2015, 31 dead humpback whales were reported in the Alaska region, comprising 11% of all confirmed marine mammal strandings for the year. In 2016, there were a total of 19 dead humpback whales reported stranded in the region, or 8% of all confirmed marine mammal strandings for the year (Fig. 7).

Approximately 61% of the 2010 – 2014 humpback whale reports were from carcasses observed in the GOA (range 50 – 75%). In 2015, 25 humpback whales or about 80% of all dead humpback whales were reported from the GOA, which decreased to 9 whales, or 47%, in 2016 (Fig. 8).

Of the 63 dead humpback whales reported between 2010 and 2014, 21 (33%) had a specific COD identified. Five whales (8%), were reported as ship struck, either when a carcass was observed on the bulbous bow of a large ship or a carcass had injuries consistent with ship strike. The death of two animals (3%), was due to entanglement in fishing gear. Killer whale predation was also considered as a COD. In examining photos of dead humpback whales in the GOA between 2010 and 2014, 56% (29-80%) had indications of killer whale predation such as rake marks or bite wounds, missing mandible or tongue (Fig. 9).

Of the 25 GOA carcasses in 2015, 12 (48%) had lesions sufficiently severe to account for death (COD). One whale appears to have died from human interaction, either fishery interaction or ship strike. Killer whale predation, with a bias towards subadults, was evident in 11 (60%) of the animals. Either photos were not available or there was no indication of COD in the remainder of the reports. In 2016, COD was not apparent for most dead floating or beach cast animals. One of the nine animals showed evidence of ship strike injury on necropsy and 4 of 8 (50%) dead humpbacks reported in the GOA featured photographic evidence of fatal killer whale attack.

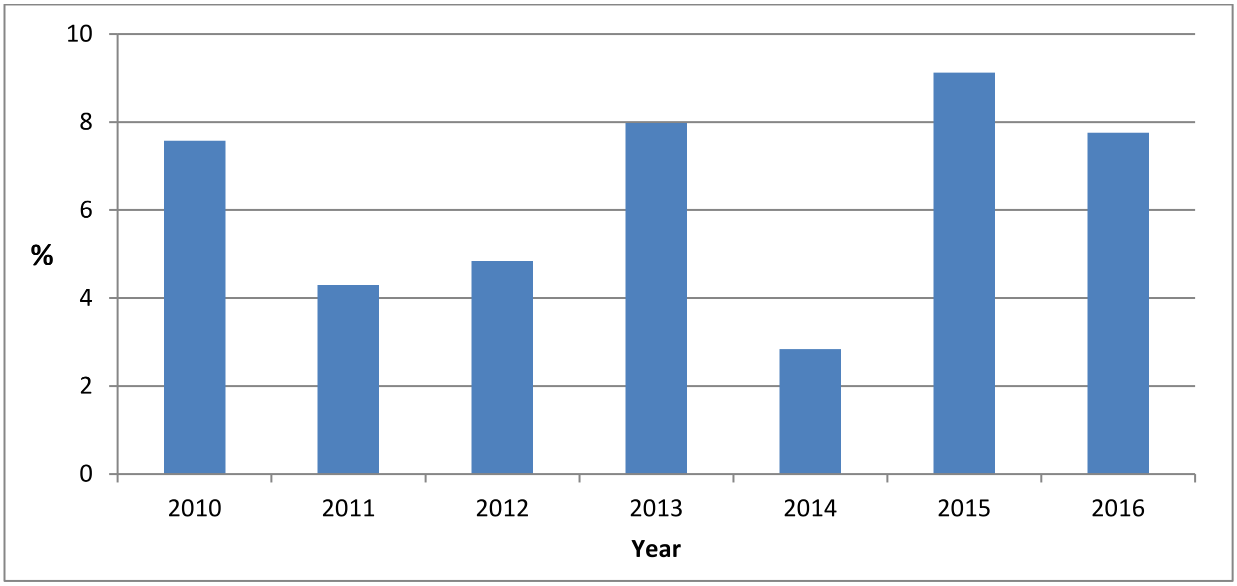

Figure 7. Number of dead AK humpback whale stranding reports relative to total annual number of marine mammal stranding reports, 2010-2016.

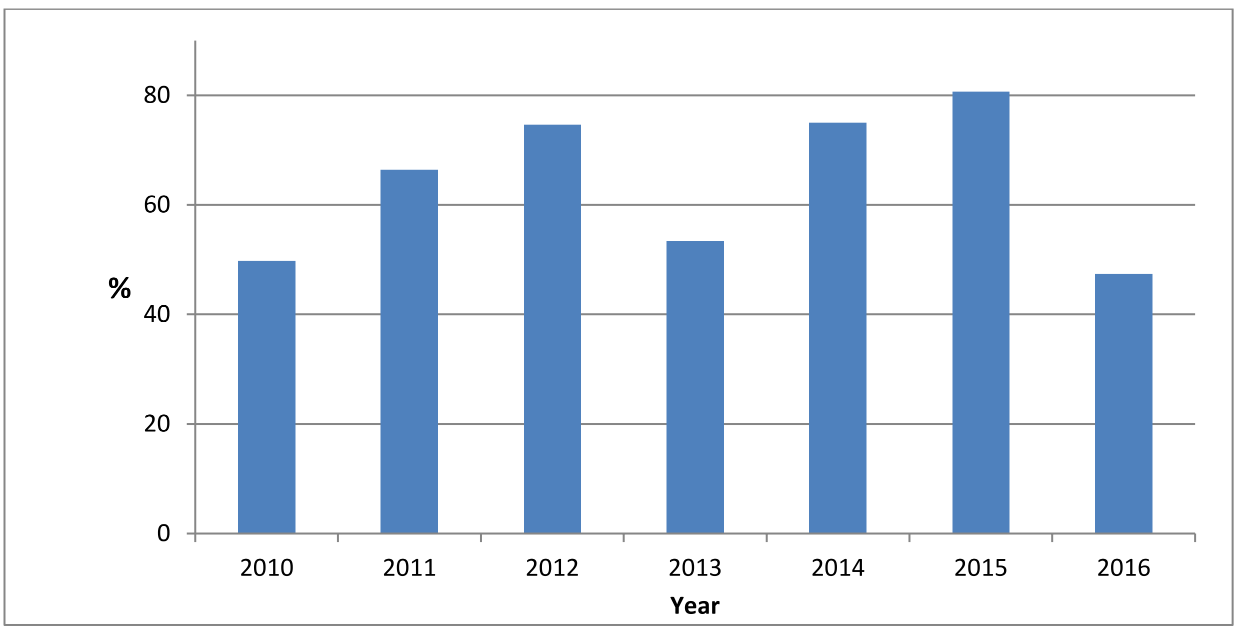

Figure 8. Number of dead humpback whale stranding reports from the GOA relative to total number of dead humpback whale stranding reports, 2010-2016.

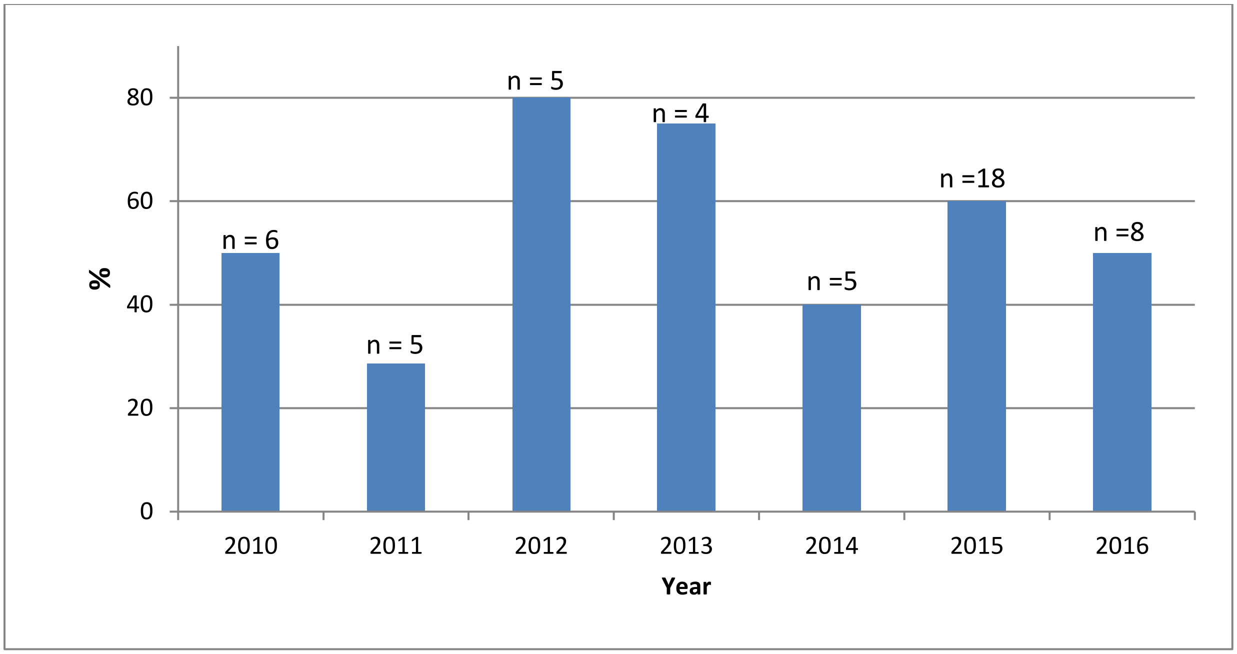

Figure 9. The percent of dead humpback whales in the GOA that had photographic evidence of injuries consistent with killer whale predation by year.

C. AK Gray Whales and Unidentified Whales

Gray Whales 2010-2016

Between 2010 and 2016, the number of dead gray whales (*Eschrichtius robustus*) in Alaska varied from 9 to 23, with 17 animals reported in both 2015 and 2016. In 2015 and 2016, dead gray whales represented 6% and 7% of all marine mammal strandings compared to a 14 year average of about 7% (6 - 11%) (Fig. 10). Between 2010 and 2014, an average of 17% of all dead gray whale reports were from the GOA (range 0-40%) compared to 18% in 2015 and 29% in 2016. (Fig. 11). No necropsies were performed on gray whales.

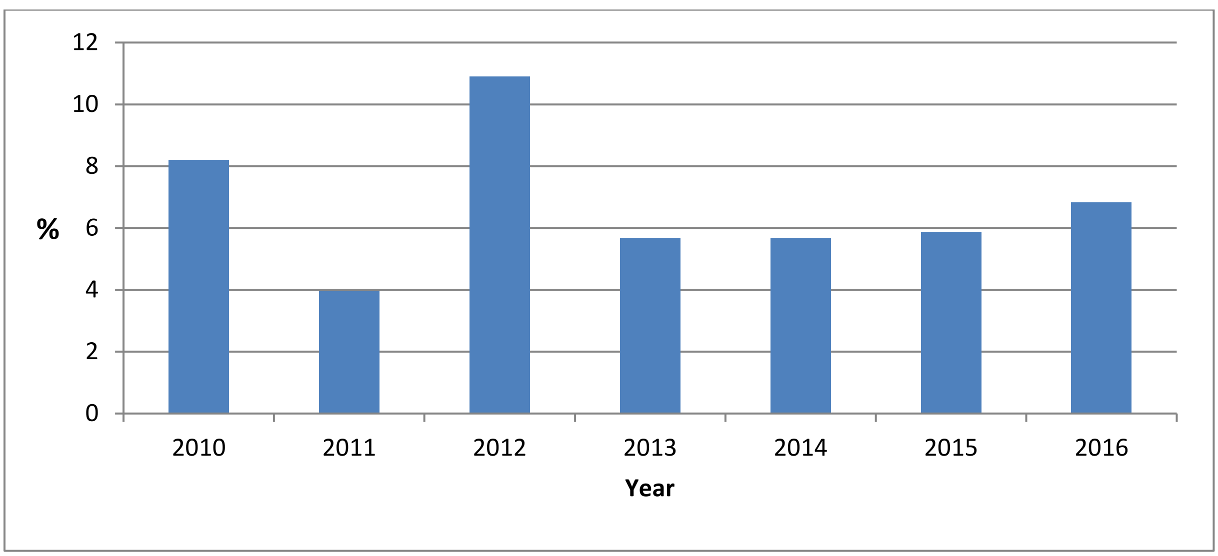

Figure10. Number of AK dead gray whale stranding reports relative to total annual number of marine mammal stranding reports, 2010-2016.

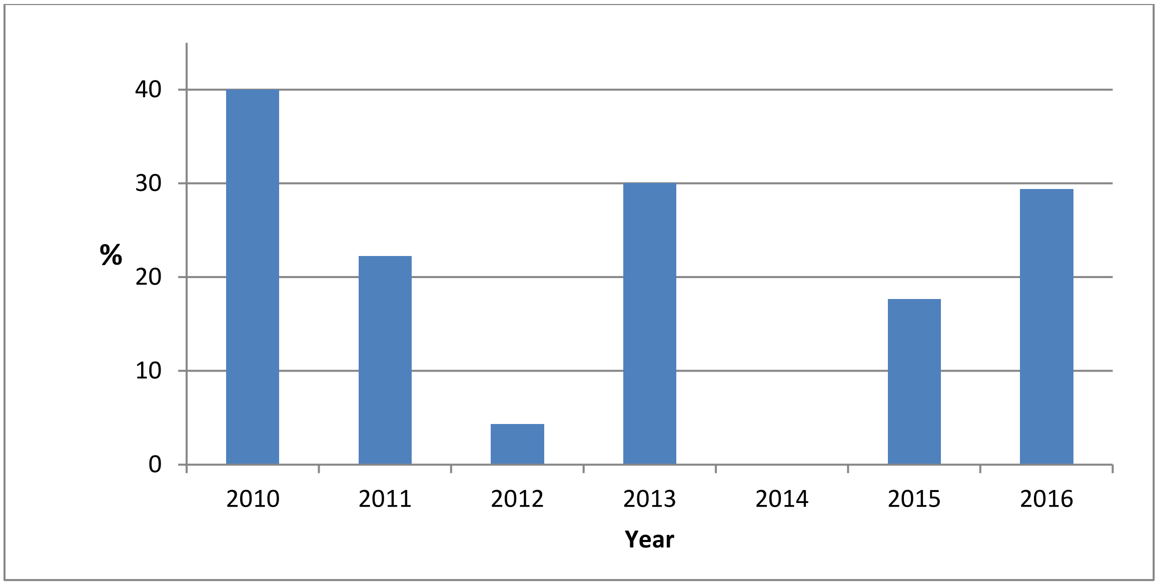

Figure 11. Percent of dead gray whales reported from the Gulf of Alaska relative to the total annual number of dead gray whale stranding reports, 2010-2016.

Unidentified Large Cetaceans, 2010 – 2016

Between 2010 and 2014, the average number of dead unidentified large whales in the region was 13 animals or 7% of all stranding reports (2 – 13%). In 2015 and 2016, 22 unidentified whales were reported stranded, or 8% and 9% of all reports respectively (Fig. 12). Between 2010 and 2014, an average of approximately 27% of all dead unidentified large whales were reported from the GOA (14 - 56%). In 2015 and 2016, 36% and 23% of dead unidentified large whale reports were from the GOA (Fig. 13). The number of unidentified whales likely reflects the state of postmortem decomposition, quality of submitted photographs, or the difficulty conducting field observations during inclement weather.

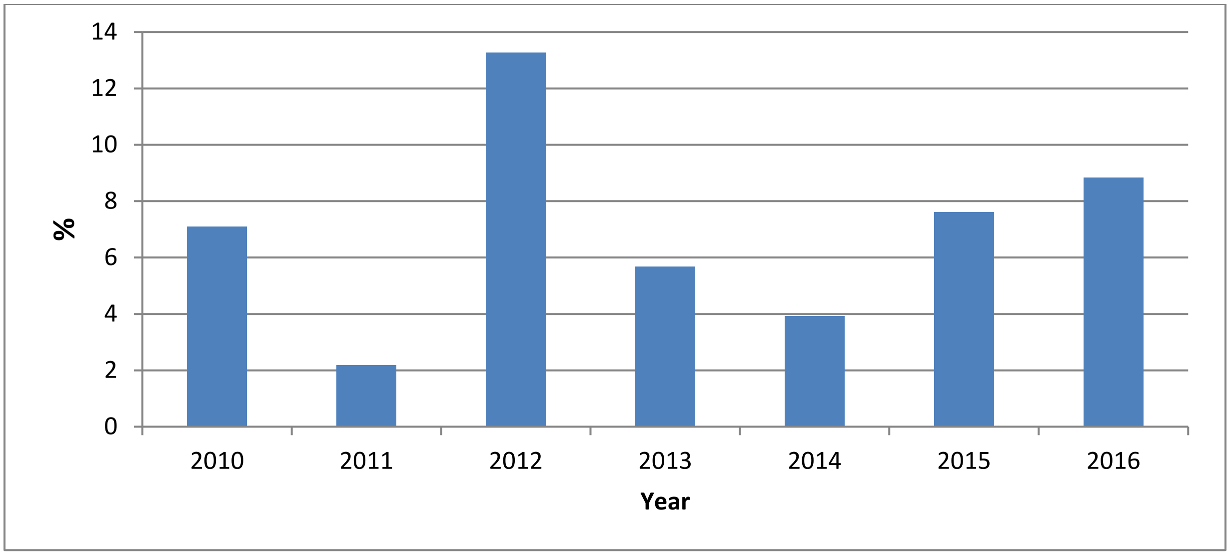

Figure 12. Number of AK unidentified large whale stranding reports relative to total annual number of marine mammal stranding reports, 2010-2016.

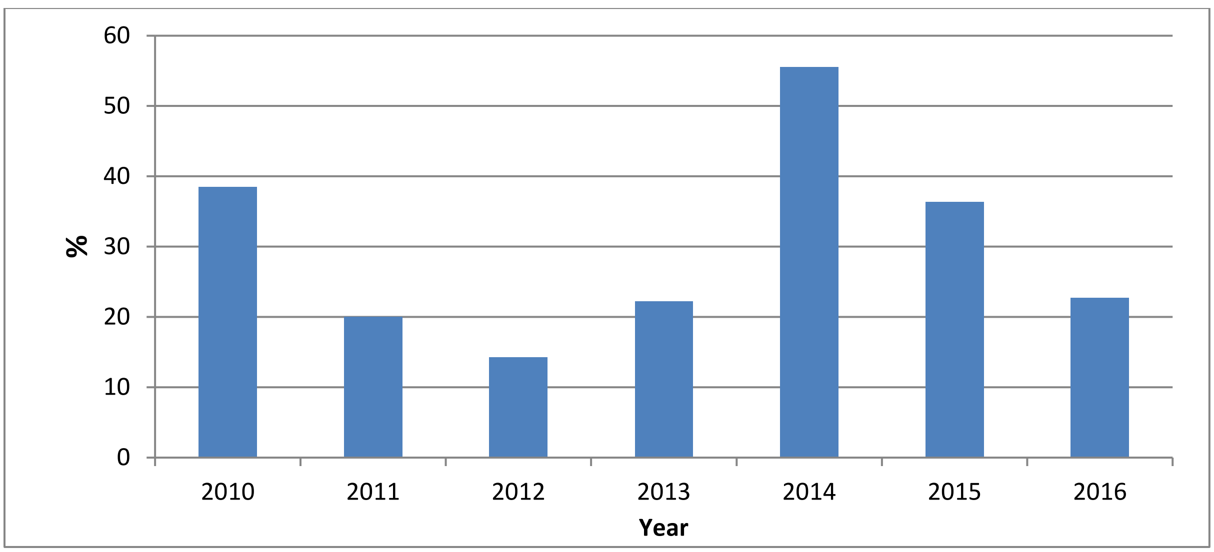

Figure 13. Percent of dead unidentified large whale strandings reported from the Gulf of Alaska relative to the total annual number of unidentified large whale stranding reports, 2010-2016.

D. BC Large Whales

Between April 23, 2015 and April 16, 2016, 17 large whale strandings were reported to the Department of Fisheries and Oceans (DFO) along coastal British Columbia, from the southern tip of Vancouver Island to the northern tip of Haida Gwaii (Fig. 14). These 17 animals accounted for over twice the 2010-2014 average of 8.4 whales per year and included 7 humpback whales, 5 fin whales, 3 gray whales, 1 minke whale and 1 sperm whale (Figs. 15 and 16). Fin whale strandings, which averaged less than 1 stranding per year over the past five years, increased to 5 reported carcasses in 2015. Humpback whale strandings also increased slightly with six in 2012 and 2013, five in

2014, and seven in 2015. Sperm, minke and unidentified whales appeared consistent at one to two per year, and 2015 gray whale strandings were below the five year average.

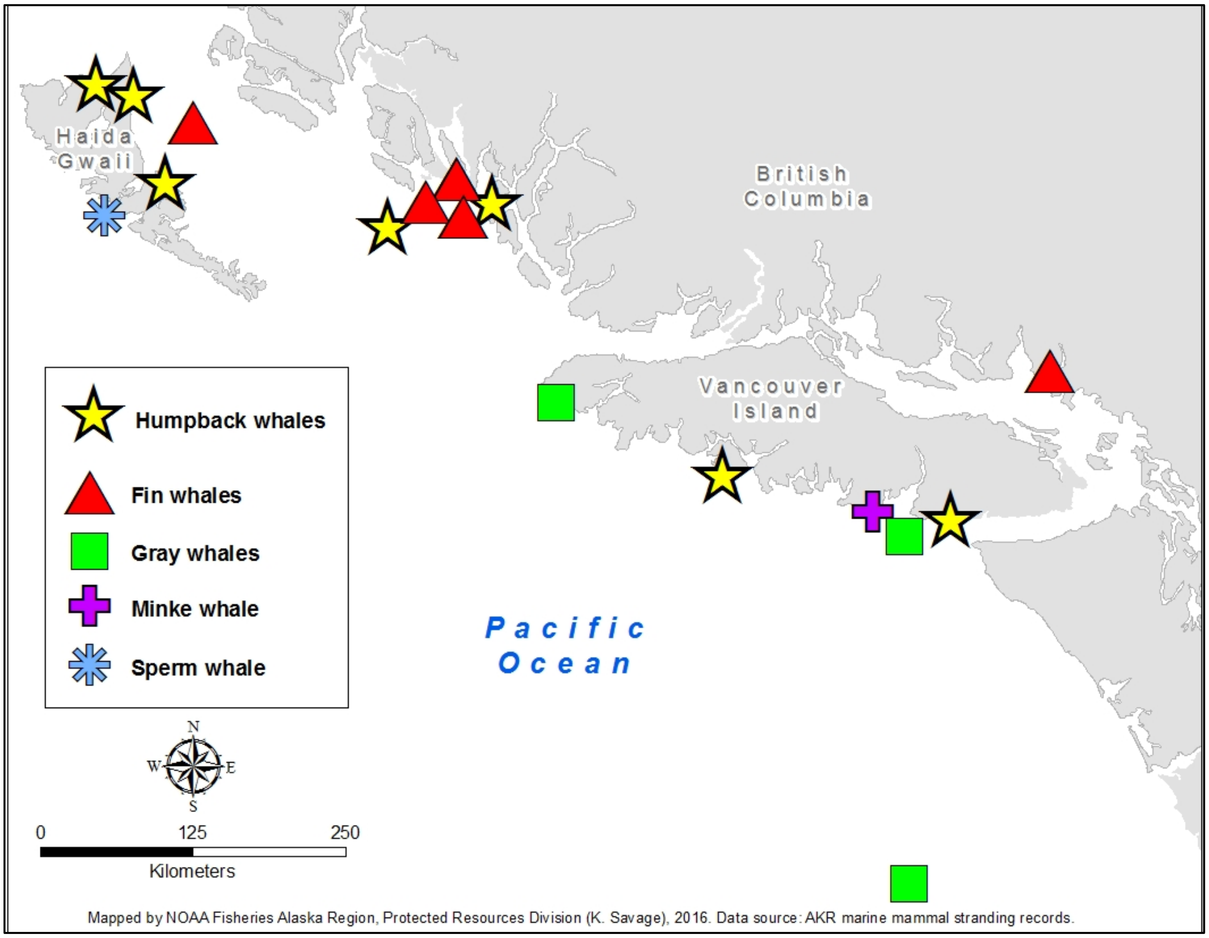

Figure 14. Location of BC large whale strandings, April 2015-2016.

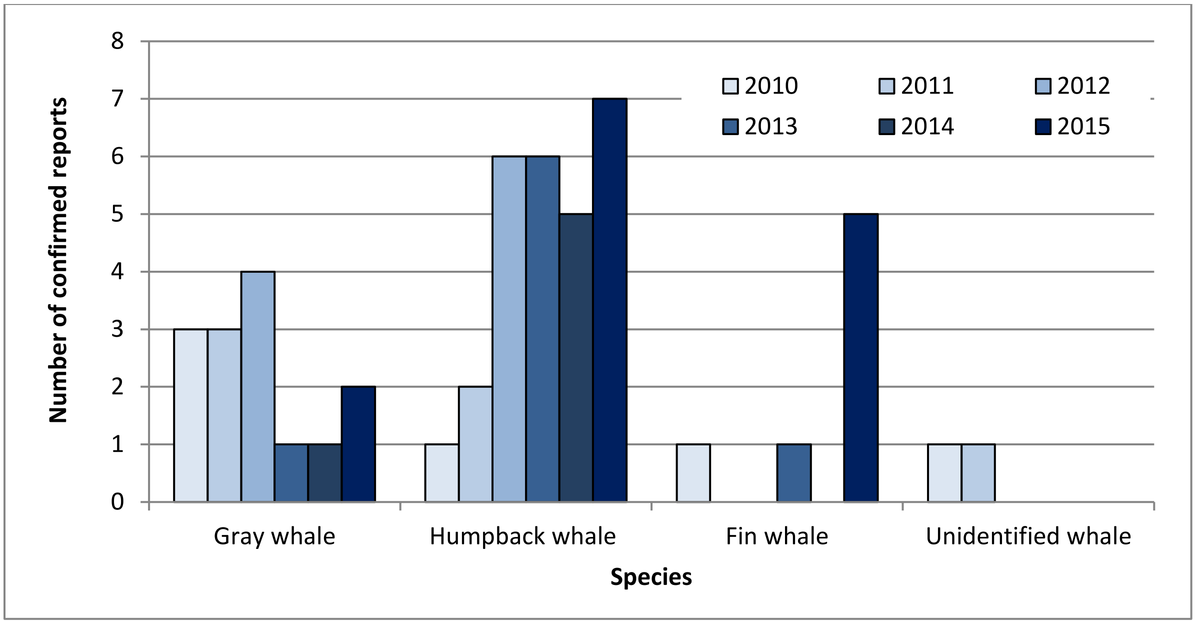

Figure 15. Number of BC gray, humpback, fin and unidentified whale strandings, 2010-2015.

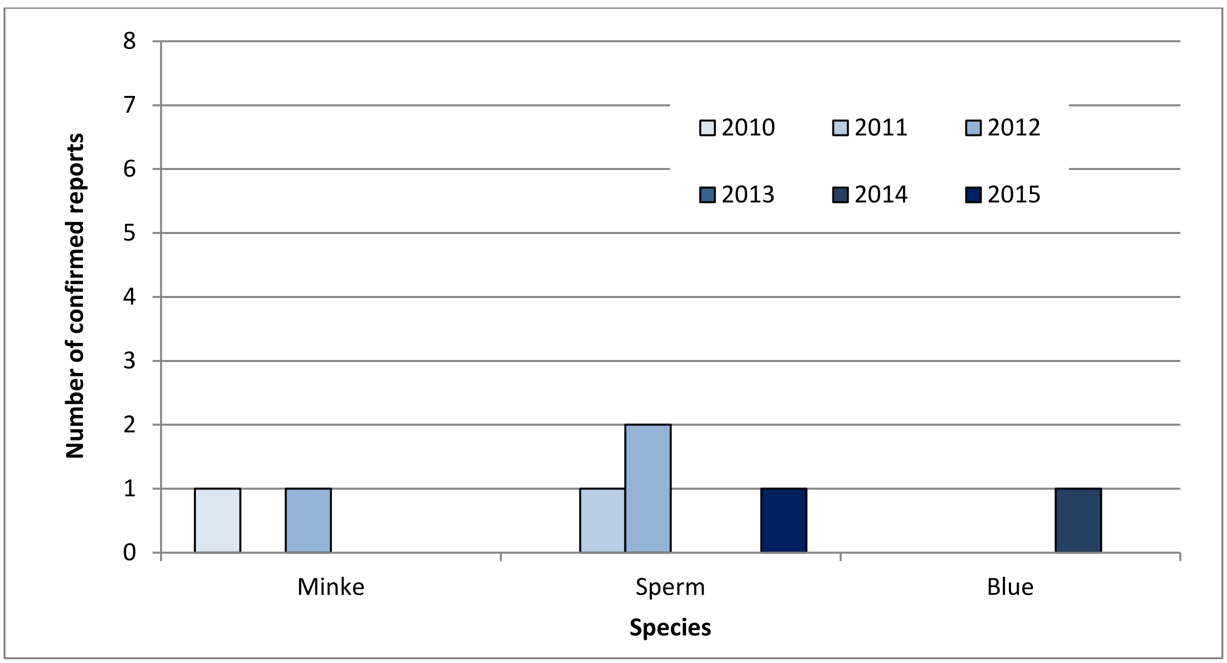

Figure 16. Number of BC minke, sperm and blue whale strandings, 2010-2015.

III. Analysis of Reports and Findings

A. Species, Condition Code, Gender and Age

Species

Reported fin whale mortalities were significantly elevated in 2015. Some added reports of mortality might be expected with heightened public awareness, field effort and an increasing population trend. Survey data did not support the presence of increased numbers of whales: the number of fin whale sightings around Kodiak, during August – September surveys in 2015, was 25% of fin whale sightings in 2013. These data do not support an increased mortality due to increased population, however these data would have been more compelling if the surveys had been conducted in June 2015 when the bulk of the strandings occurred.

In 2015, Alaskan fin whale strandings were unusual not only in the elevated number of mortalities, but also in the temporal and spatial shifts in stranding patterns. Figure 17 illustrates fin whale strandings by day of the year from 2000 through 2016. Except for 2015, all years show strandings that are dispersed over several months. In contrast, for 2015, 12 of 14 strandings were within a 3 week period.

Fin whale strandings in 2015 were also unusually clustered geographically. Figure 18 shows the location of fin whale reports from 2000-2014. These reports were spread between three of the five subareas in Alaska. In the rare years when two fin whales were reported stranded, they were never close in both time and space, e.g. of the two fin whales that stranded in the GOA in 2013, the first carcass was found in a state of advanced decomposition on May 28 and the second found moderately decomposed 90 miles away and two months later. Figure 19 illustrates the relative close proximity of the UME animals in 2015.

The two 2015 reports outside the temporal spring cluster were more in keeping with typical fin whale stranding patterns. One whale stranded in St. Paul in February and the other whale came into the Port of Anchorage on a bulbous bow in September.

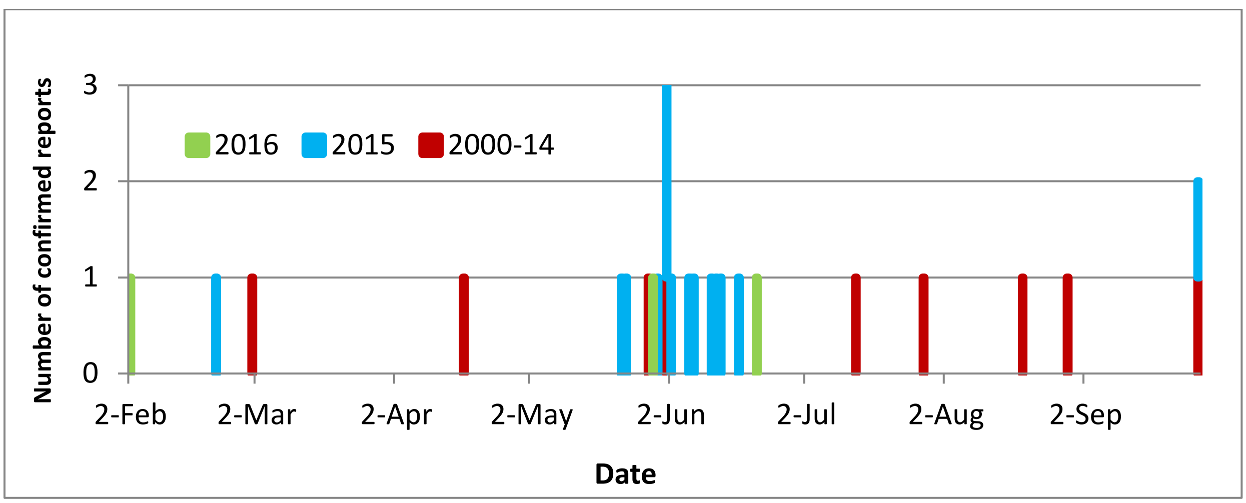

Figure 17. Relative date of AK fin whale strandings, 2000-2014, 2015 and 2016.

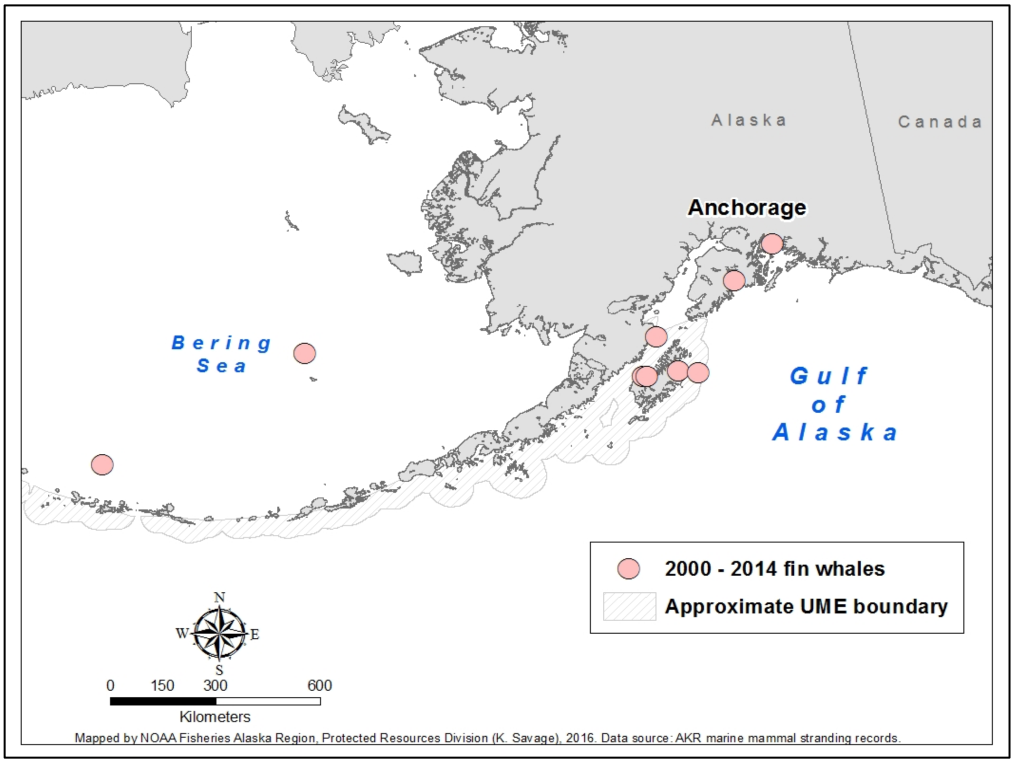

Figure 18. Location of AK fin whale strandings, 2000-2014.

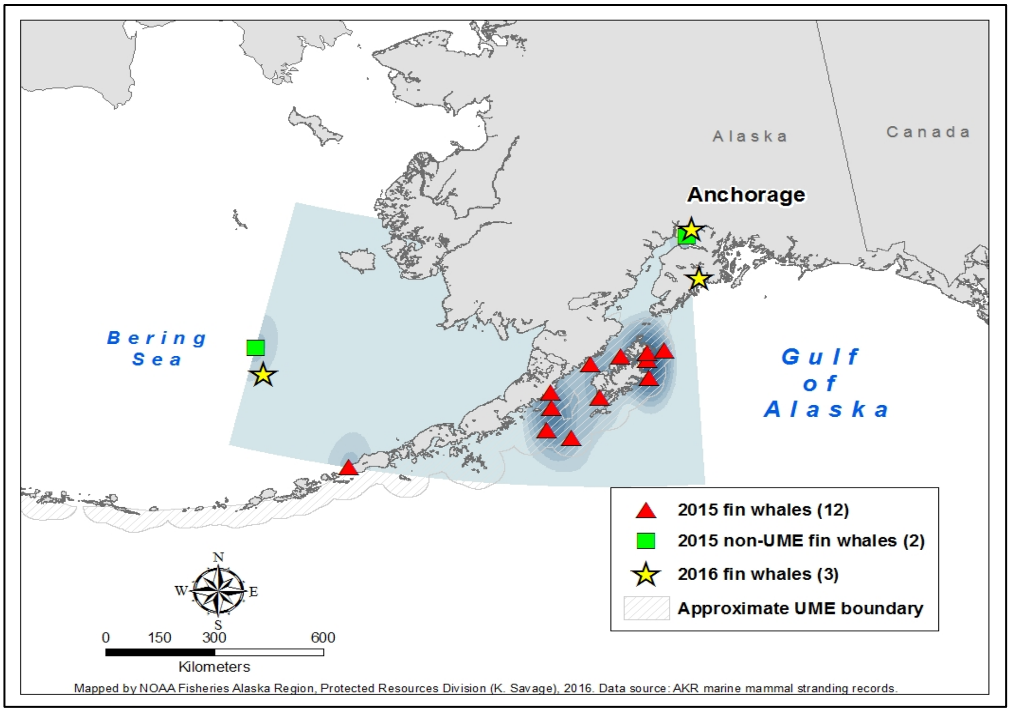

Figure 19. Location of AK fin whale strandings, 2015 and 2016.

Fin whale strandings in BC followed a similar stranding pattern of discrete mortality pulses (Fig. 20). The two earliest reports on May 15 and August 23, 2015 both had evidence of ship strike as a COD. The last three reports included a cluster of three subadult males that were reported stranded at the same time and in the same area, all of which exhibited some degree of emaciation.

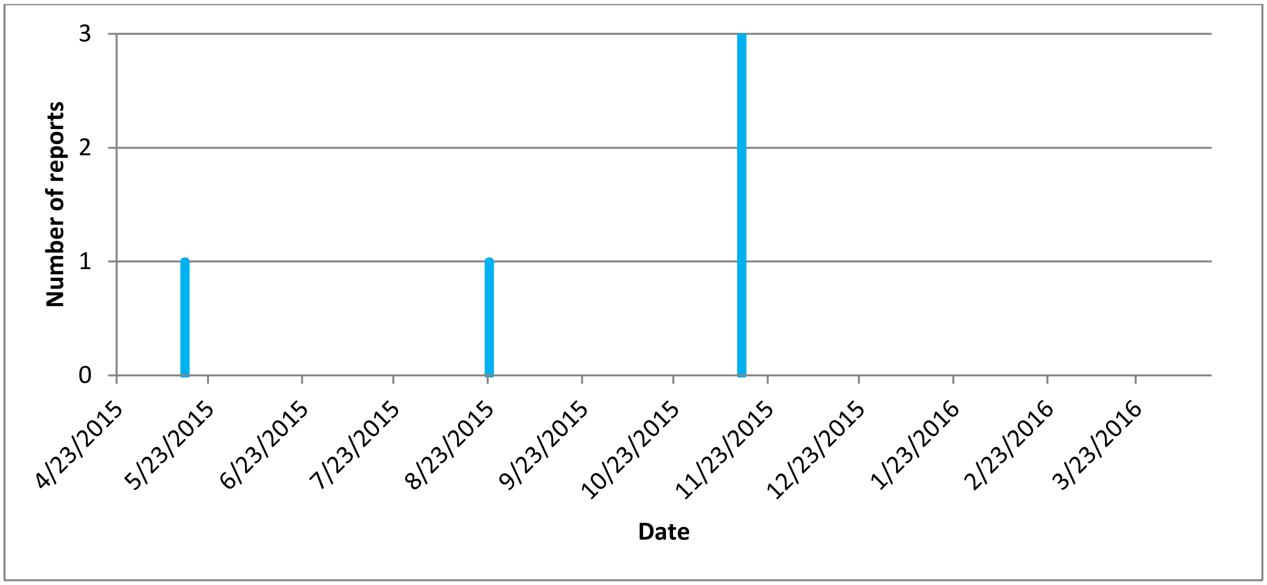

Figure 20. BC fin whale strandings by date.

In 2015, the number of dead humpback whales reported and the number of dead humpbacks relative to the number of total strandings in Alaska were above average. The percentage of annual dead humpback whales reported specifically from the GOA in 2015 (80%) was also marginally above the 2014 value of 75%. These increases may have been due to a number of reasons unrelated to unusual mortality, including mortality proportional to a possible increase in GOA humpback presence in 2015 relative to other surveyed years (Rone et al. 2017), concomitant with a population growth of about 7% per year for the Alaskan Peninsula and Aleutian Islands based on 2001-2003 data (Zerbini et al. 2010). The increased mortality did not appear to be due to killer whale predation, which was not significant in either 2015 or 2016. While the number of dead humpbacks reported from the GOA was high in 2015, neither the temporal nor spatial pattern of strandings were clustered like they were for fin whales.

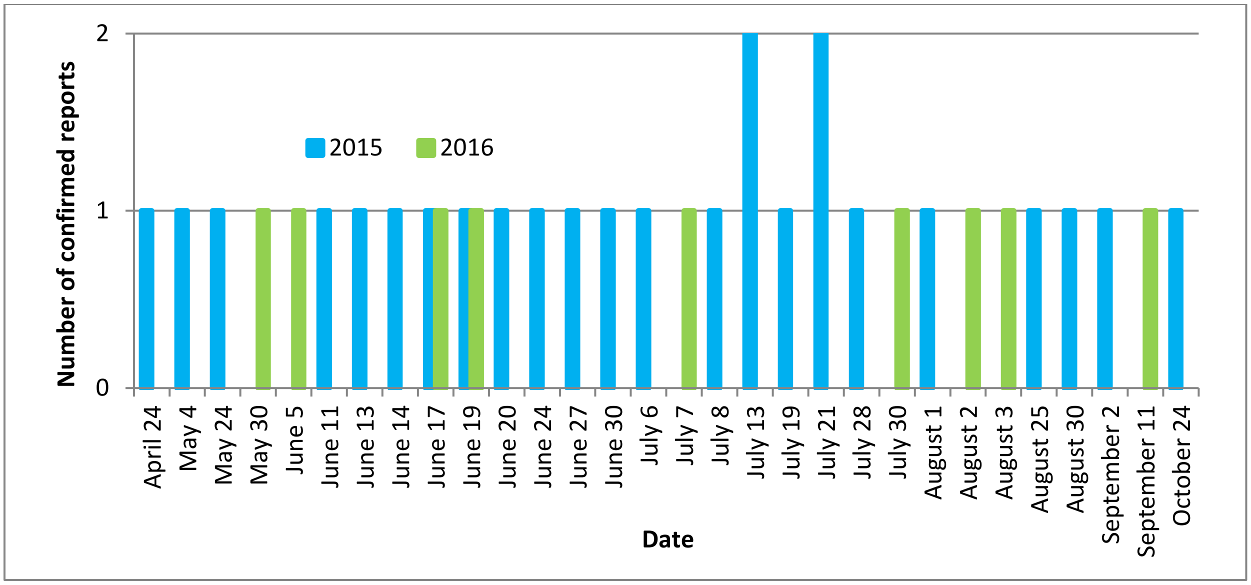

Figure 21. Relative date of AK humpback whale strandings, 2015 and 2016.

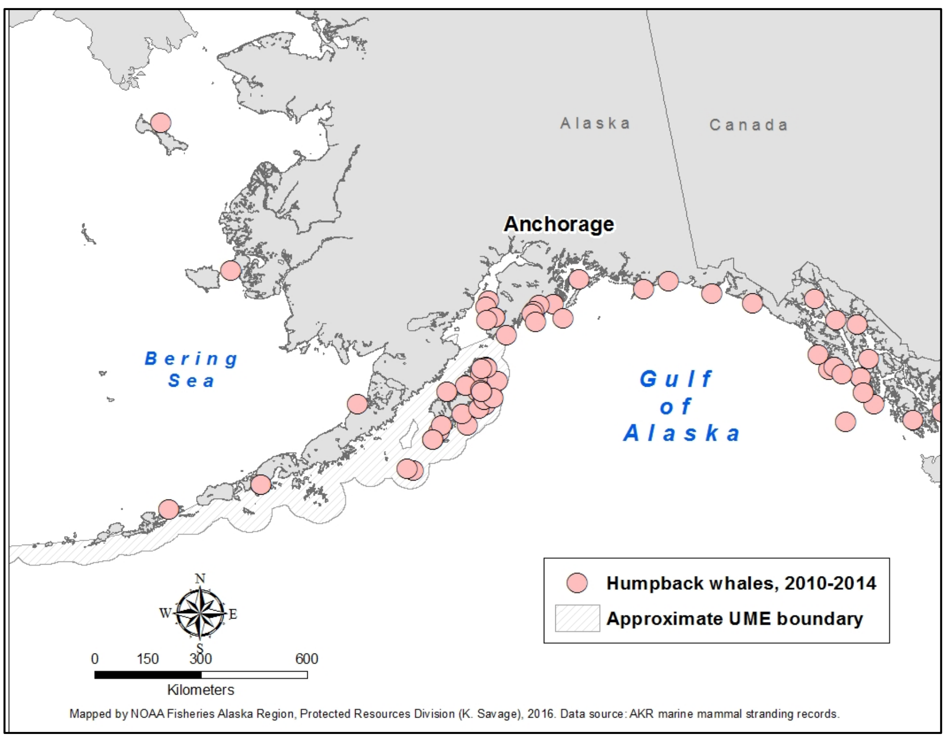

Figure 22. Location of dead AK humpback whale strandings, 2000-2014.

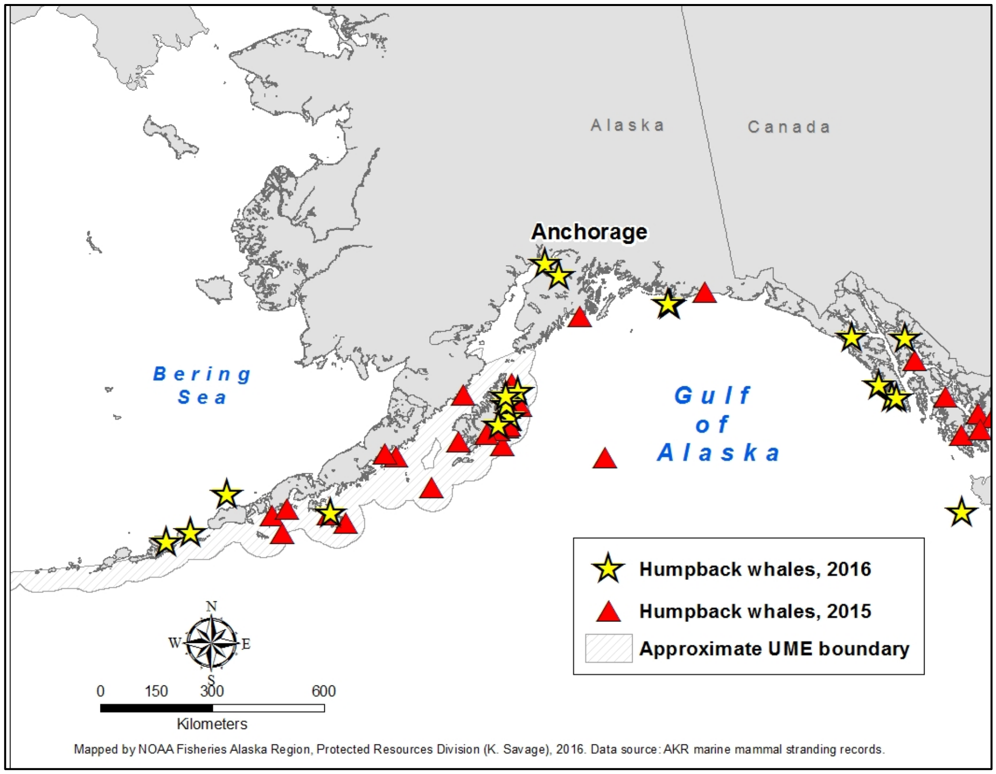

Figure 23. Location of dead AK humpback whale strandings, 2015 and 2016.

Increased humpback strandings in BC were similar to AK. Five of the seven animals stranded within a relatively narrow time interval between July 31 and August 23, with the COD of two of the animals attributed to ship strike/human interaction. The temporal cluster occurred over a broad geographic range.

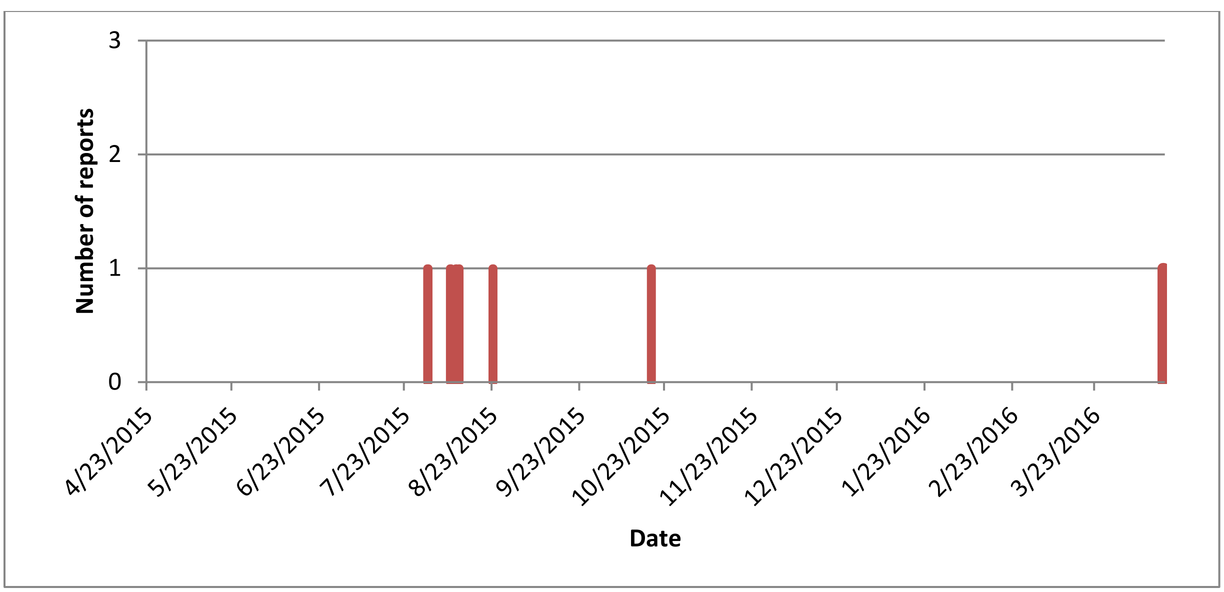

Figure 24. BC humpback whale strandings by date

In both 2015 and 2016, the number of gray whales and unidentified whales in Alaska relative to total strandings was within the 7 year historical range. The number of dead gray whales and unknown cetacean reports from the GOA relative to other subareas in 2015 and 2016 were also within the 7 year historical range. Observations of dead gray whales in the GOA were spread from May through September and did not appear to be localized geographically (Fig. 21). Of the eight unidentified animals stranded in the GOA, four were reported from within the general UME boundary (Fig. 21) with initial observations made between May 31 and July 14. In BC, gray whales, sperm whales and minke whale strandings appeared within normal limits.

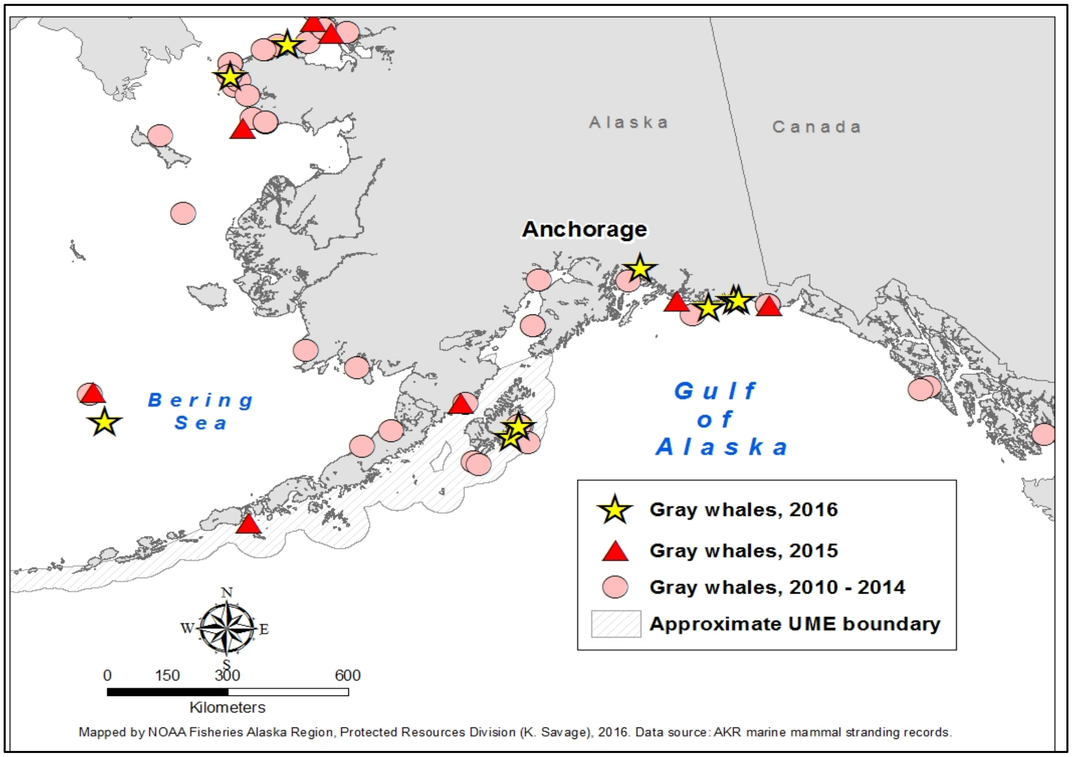

Figure 25. Location of dead AK gray whale strandings, 2010 - 2016.

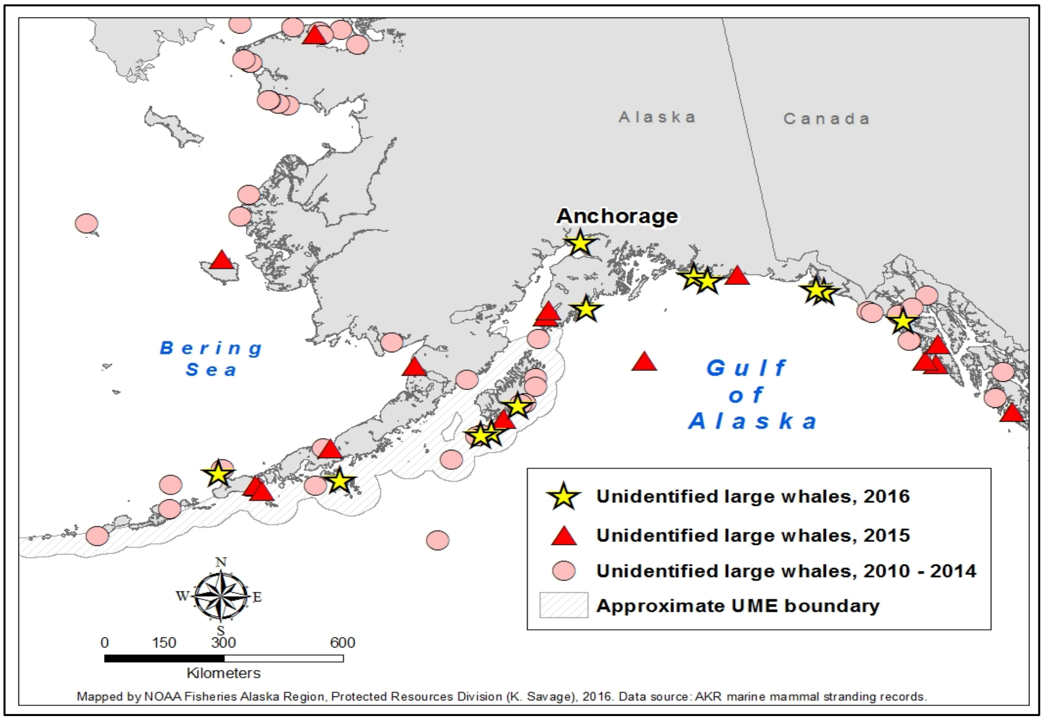

Figure 26. Location of dead AK unidentified large whale strandings, 2010 - 2016.

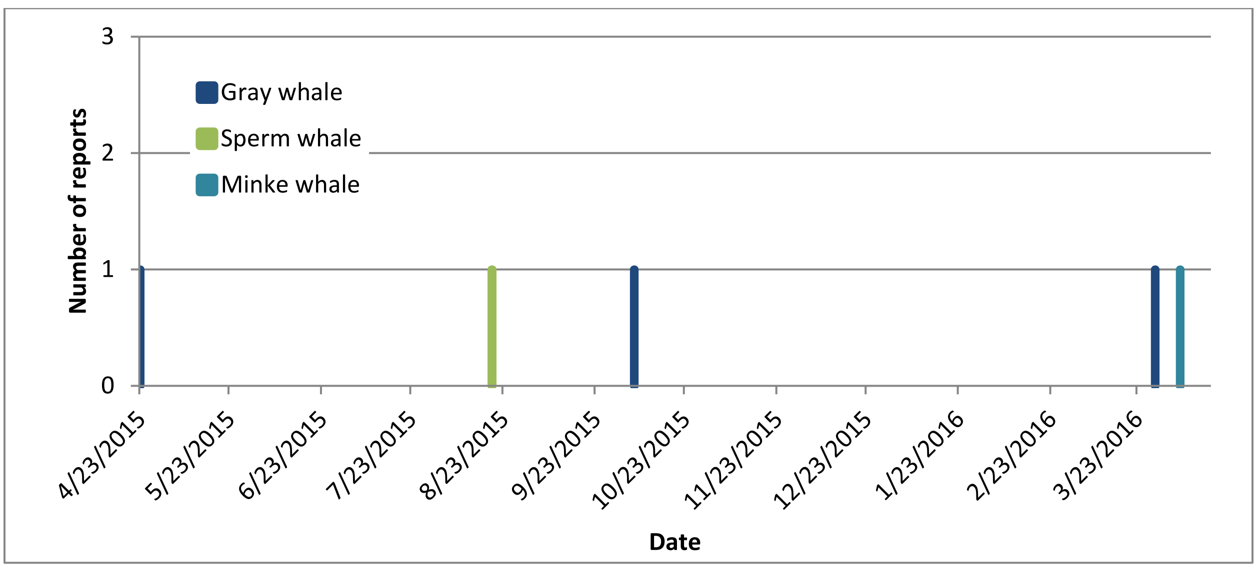

Figure 27. BC gray, sperm and minke whale strandings by date

Condition Code

Condition codes are quantitative assessments of carcass decomposition, based on characteristics such as bloating, skin sloughing, odor etc. Levels include: Code 2 – fresh dead, Code 3 – moderate decomposition, Code 4 – advanced decomposition and Code 5 – mummified or skeletal. Because almost all of the Alaskan fin whales in 2015 were inaccessible for necropsy, most of the data were based on vetted photographs and information included in stranding reports. Evaluators assigned condition code scores to carcass photographs, which were then tallied, compared and finalized.

While uncertainty in data requires loose interpretation, condition codes of the clustered fin whales appear to indicate these animals were involved in a discrete temporal event (Fig. 28), with an overall pattern of less to more decomposed carcasses reported with time. Humpback whales did not appear to follow the same pattern (Fig. 29).

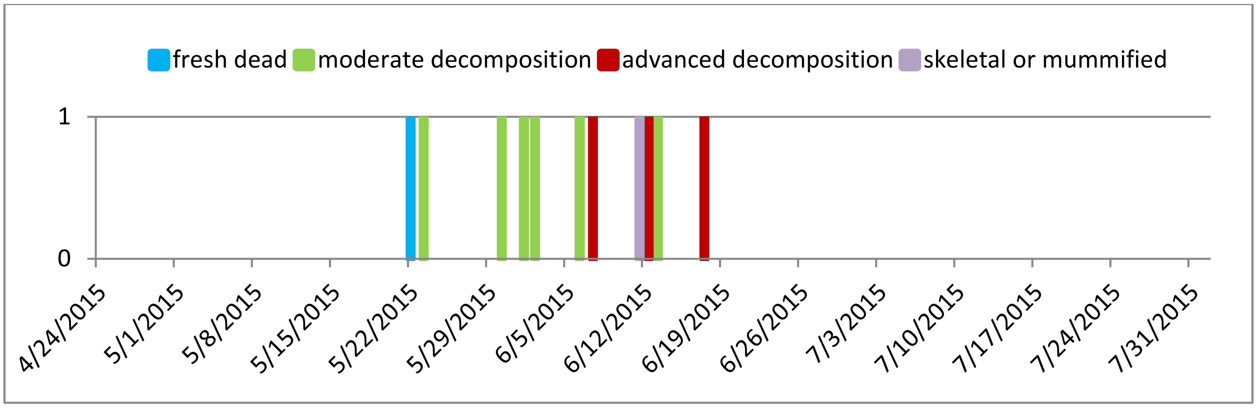

Figure 28. Condition Codes of stranded AK fin whales by date.

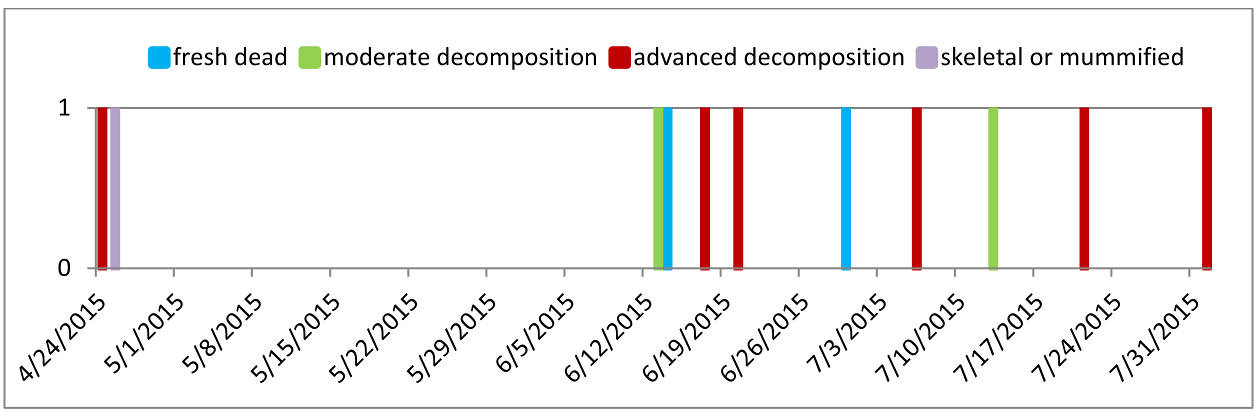

Figure 29. Condition Codes of stranded AK humpback whales by date.

Gender and Age

Between 2000 and 2014, the female to male ratio of fin whale strandings in Alaska was 3:1. In 2015, the female to male ratio of fin whale strandings in Alaska was 7:3. Conversely, four of the BC fin whales were male and 1 of unknown gender. There were no apparent field observations or diagnostic findings which may account for these regional differences. Females maybe over-represented in 2015 and this may be due to reproductive status, stage of fetal development, prey availability or other factors.

Between 2000 and 2014, the age ratio of stranded fin whales (subadult to adult) in Alaska was 3:2. In 2015, aside from a single calf, all nine animals of estimated age were considered adults. There were more adults than other age classes which may be due to the reproductive cycle, loss of younger animals in remote areas, or sinking of calves and perinates. BC animals included one adult and 4 juvenile/subadults.

B. 2016 Necropsies

In 2016, necropsy findings of two fin whale and five humpback whale strandings from other locations around Alaska were assessed relative to the UME. See Appendix A, Table 4.

Cause of death for one of the fin whales was determined to be ship strike. The other fin whale was first observed as a live stranding in upper Cook Inlet and later died. Necropsy results did not indicate significant pathogens or HABs. The analysis of samples to describe feeding ecology and nutritional status, including stable isotopes and thiamine levels, is pending.

Of the five humpback whale carcasses outside the UME boundaries that were necropsied, two appeared to be in poor body condition, although cause of death was not determined. One of the DA of 1249 ng/ml, which was substantially higher than the values in stranded humpback whales tested opportunistically in Alaska between 2007 and 2011 (n=8) (Lefebvre et al. 2016).

C. Differentials

1. Navy sonar testing

Per NMFS and U.S. Navy Gulf of Alaska Stranding and Communication Plans, the Navy is required to send a pre-event notification to NMFS, which includes the dates when activities are expected to be conducted. The 2015 Navy Major Training Exercise, titled "Northern Edge 2015" was conducted between June 15 and June 26, 2015, after the pulse of fin whale strandings and there was no indication of a pulse of reported strandings after completion of the exercises on June 26th, 2015.

2. Radiation

Concern about radiation in the marine environment followed the Japanese Fukushima nuclear reactor leak in 2011. The level of Cs-134 in the Alaskan fin whale aqueous humor was below minimum detectable levels. The level of Cs-137 was 0.2 Bq/kg WW, far below the FDA Derived Intervention Level of 1200 Bq/kg[1]. The observed Cs-137 concentration was also less than that measured in fin whale muscle tissue samples collected in the North Pacific (Arctic) in 1964 and North Atlantic in 1968 (Samuels et al. 1969; Schithananthan et al. 1965). Similar radioisotope levels below detection limits were identified in 3 BC fin whales (15-6258, 15-6259 and 15-6269) examined June, 2016. There is currently no evidence to indicate that radioactive contamination from the Fukushima event is affecting the health of marine mammals in Alaska. Radionuclide testing in northern fur seals in 2014 also revealed very low levels of the radionuclides (Ruedig et al. 2016).

3. Ship strike

While only a few of the carcasses (2 AK fins; 2 AK humpbacks; 2 Canadian fins; 2 Canadian humpbacks) displayed injuries consistent with ship strike, ship strike still requires consideration as a cause because:

- Fin whales are prone to ship strike, both in Alaska as previously described, and in general reviews of human interactions. In an assessment of 1975 -2002 large whale ship strike data, fin whales were the most commonly struck of eleven large whale species (Jensen and Silber, 2003).
- Ship strikes may cause mortality without external evidence of injury (Moore et al 2005: Glass et al. 2009)

- A comprehensive examination/necropsy was not possible for most of the UME carcasses. While all five BC fin whales were necropsied (two with evidence of ship strike), only one of the 12 AK fin whales was partially necropsied.

Multiple ship strikes would require significantly more contact between ships and whales. The most probable scenarios would include increased fin whale foraging/presence in shipping channels, increased shipping traffic or changes in shipping patterns. During the 2015 Aug-Sept GOA cetacean surveys, fin whales were found throughout the survey area (Fig. 30), including an aggregation in the "Historical High Catch" area about 300 km to the south of the continental shelf. The location of fin whale aggregation in mid-May when UME carcasses were initially reported is unknown. However, at least one location may be estimated through a post-hoc drift analysis. To accomplish this analysis, the US Coast Guard SAROPS Search and Rescue Optimal Planning System (SAROPS) software was used to retrospectively

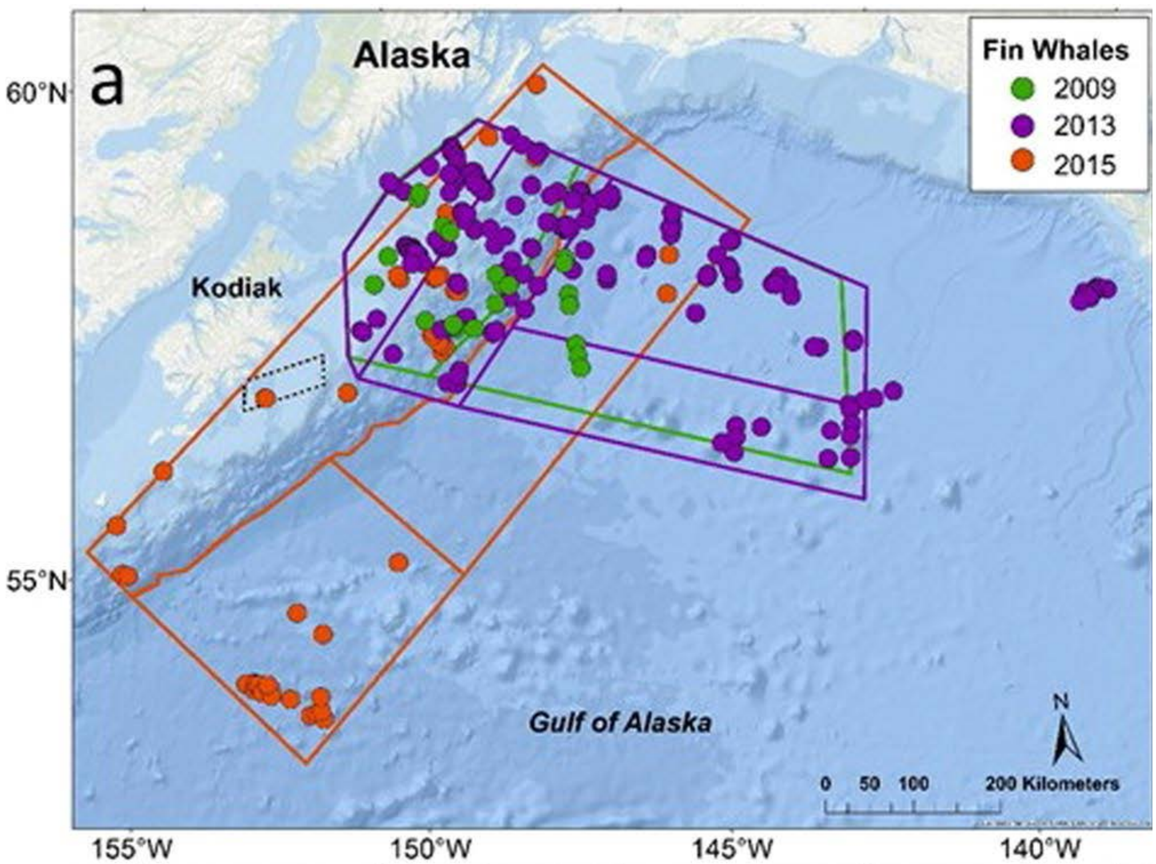

Figure 30. Locations of fin whale sightings during GOA cetacean surveys by year (Rone et al. 2017).

trace the original stranding location of two of the freshest Alaskan animals, NMFS# 2015038 and NMFS# 2015033. Expert opinion of the two animals, with previously vetted Condition Codes averaging 2.3 and 2.7, estimated 2015038 to have died 2-4 days before the initial observation on May 22 and 2015033 to have died 4-6 days before the initial observation on May 23. Figures 31 and 32 show the probability of location on May 18 with the caveat that the weather modeling data, including wind and currents, for the time period and location of the two animals were sparse resulting in additional uncertainty. Nonetheless, the epicenter of both animals near Marmot Bay on May 18, has been recorded historically as a fin whale foraging location (Zerbini 2006).

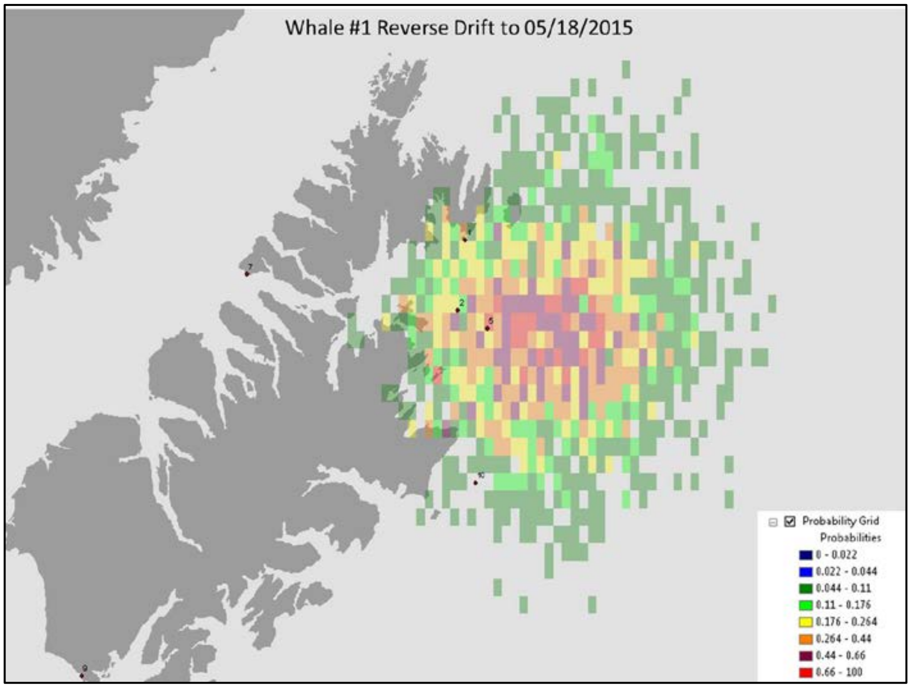

Figure 31. Reverse drift analysis of fin whale #2015038.

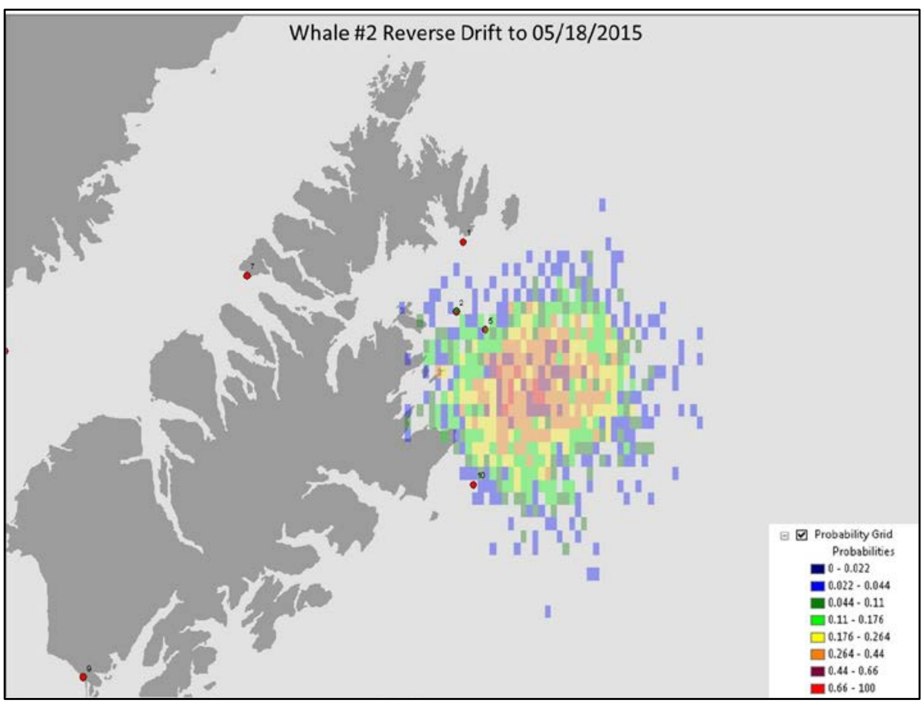

Figure 32. Reverse drift analysis of fin whale#2015033.

If ship strike was the COD for the two animals in Marmot Bay, it was most probably from vessels entering or departing the Kodiak Harbor. The Kodiak port facilities receive vessels up to 800ft, including military, NOAA, State ferries, cruise ships and container ships. While the city does not track vessels coming and going from the harbor, vessel traffic entering and departing the Port of Kodiak was not observed to be higher in 2015 than in other years (L. White, Kodiak Port and Harbor Director, personal communication, Feb.7, 2017). The Automatic Identification System (AIS) is a mandatory program implemented by the US Coast Guard to track specific vessels such as fishing industry vessels, self-propelled commercial vessels greater than 65 ft in length, self-propelled vessels carrying more than 150 passengers and commercial towing vessels greater than 26 feet. Figure 33 includes track lines of vessels transmitting data, collected between May 16 and May 23, 2014 around Kodiak and along the southern coast of the Alaska Peninsula, relative to the 2015 fin whale strandings. Figure 34 includes the same data relative to the general area where whales 1 and 2 were estimated to have died and started drifting. Data from 2015 is pending.

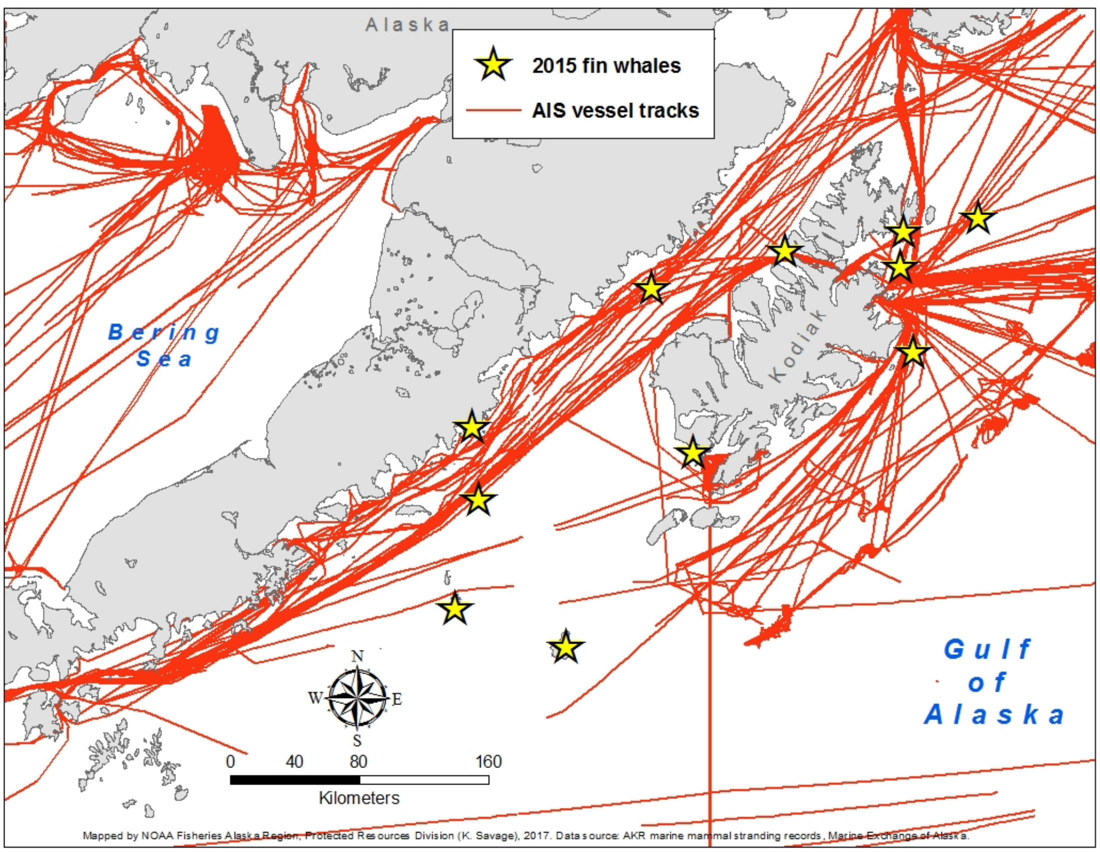

Figure 33. 2014 tracklines of AIS vessels relative to 2015 stranded fin whales.

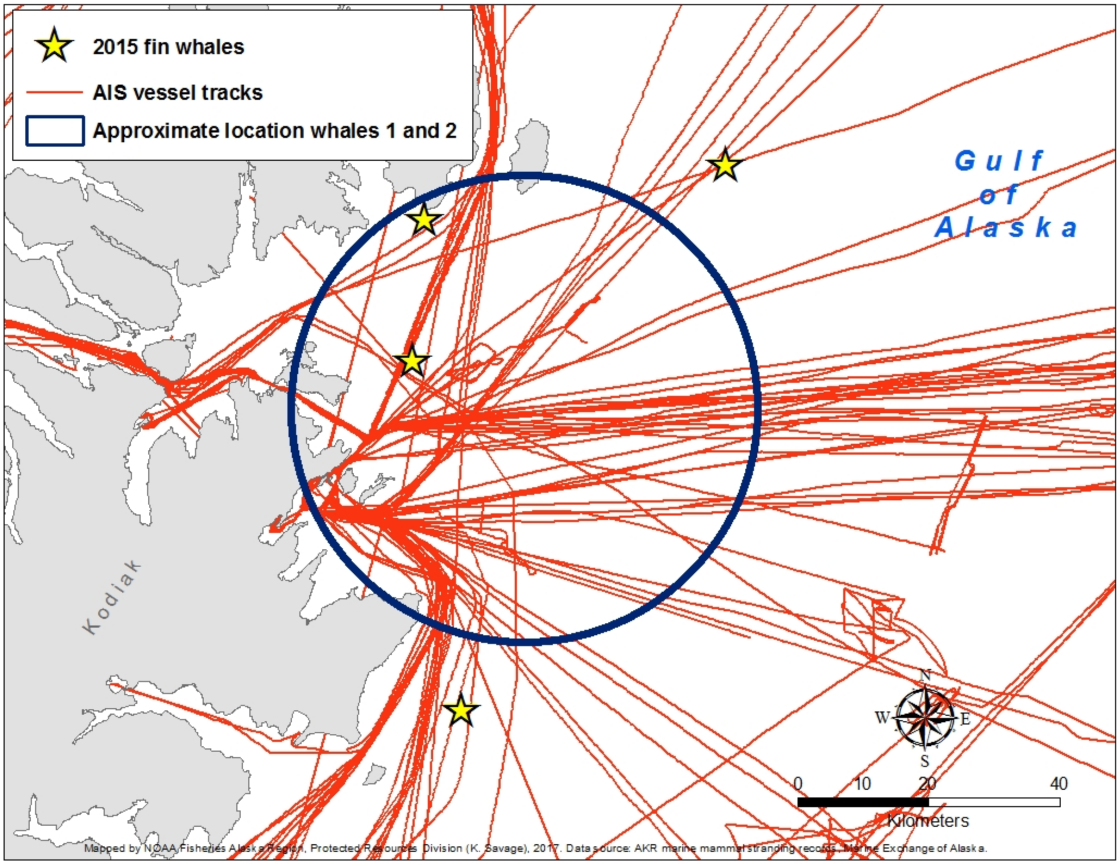

Figure 34. 2014 tracklines of AIS vessels relative to 2015 stranded fin whales.

It is apparent from this example that the minimum vessel traffic over an 8 day period moving around Kodiak and the western Gulf as well as vessel traffic moving in and out of Kodiak Harbor might result in multiple ship strikes, although the probability cannot be calculated with existing data. The likelihood of mass ship strike might increase if the animals were debilitated by algal toxin exposure. Of the six fin whales in AK considered victims of ship strike between 2006 and 2016, four were reported on the bulbous bow of a vessel and two had injuries consistent with ship strike on necropsy. None were diagnosed solely on external injury.

4. Infectious Disease

Samples from one Alaskan whale and eight Canadian whales were tested for a variety of bacterial and viral pathogens, with no evidence of infectious disease present. Refer to Appendix A, Tables 2 and 3.

5. Predation

While there was evidence of killer whale predation associated with a historically consistent number of humpback carcasses, predation did not appear to be involved in any fin whale mortality. All of the fin whale carcasses appeared intact, aside from changes expected with decomposition or injuries associated with ship strike.

6. Oceanographic changes leading to shifts in prey distribution or HAB exposure

It is possible that the event was part of a larger, climate-driven process affecting a range of species. To further define this possibility, a workshop was convened in January 2016 to share information and foster collaboration concerning physical and biological anomalies that occurred throughout the GOA in 2015. The following changes were observed in 2015.

Oceanographic/climatic conditions:

- "The Blob"– changing centers of surface heat anomalies in the North Pacific and the Bering Sea
- 2015/16 El Nino among the strongest
- Decreasing ice extent in the Bering Sea
- AK second warmest year (air temperature) since record keeping began in 1925
- Deep heat: 200 m or more below the surface

Biological conditions throughout food web:

- The Blob may be an offshore incubator for toxic cells. Increase in number of phytoplankton species associated with toxicity, e.g. pseudo-nitzchia, as well as increase in phytoplankton growth rate. More warm-water zooplankton species in 2014 and 2015
- Largest domoic acid bloom along the Pacific west coast on record
- Increased algal toxins in shellfish
- Spatial and temporal changes in fish distribution as well as condition and density of fish species
- Seabird die-offs – mainly murres – largest geographic extent recorded in Alaska. Consistent finding is emaciation and starvation.
- Northern sea otter mortalities – mainly in lower Cook Inlet. Mimics 2006-2010 UME except higher mortality and occurring later in the year. Cause of death considered Streptococcal viral encephalitis and meningoencephalitis.

Of these conditions, the unusual presence and intensity of phytoplankton species associated with harmful algal blooms (HABs) and toxins entering the food chain is a possible source of whale mortality. Mass mortality of large whales as a result of ingestion of neurotoxins has been recorded historically. In 1987, the death of 14 humpback whales in Cape Cod Bay was attributed to the animals ingesting prey species containing saxitoxin (STX), a neurotoxin produced by *Alexandrium*, a dinoflagellate algae. While there was no temporal or geographic pattern to the distribution of Cape Cod Bay dead whales, the fact that multiple animals died acutely, including one that was observed behaving normally 90 minutes before death, and food fish and whale tissues tested positive for STX, was presented as evidence that STX had accumulated and transferred through prey species in sufficient concentrations to cause death (Geraci et al. 1989).

Alaskan and Canadian UME animals were tested for two of algal neurotoxins, including domoic acid (DA), produced by *Pseudo-nitzschia* algae, and STX. Both were present in variable amounts in tested samples (Appendix A, Tables 2 and 3). Aqueous humor from the AK fin whale was negative for DA and STX. Four of five BC fin whales tested between 0 – 120.3 ng/ml DA and 5.8 – 144.5 ng/g STX. Two of the BC humpback whales also tested positive for both DA (0-612.8 ng/ml) and STX (2.5 – 238 ng/g). All of these values were in the realm of those found in West Coast pinnipeds exhibiting clinical signs of toxicity as well as within the range of values found in a study of DA concentations in 13 Alaskan marine mammal species (not including fin whales) (Lefebvre et al. 2016). However, both the DA concentration of 612.8 ng/ml and the STX concentration of 238 ng/g were significantly higher than the maximum concentration of 51 ng/ml and 62 ng/g, respectively, in the AK humpback whales tested in the that study. Unfortunately, interpretation is challenging for a number of reasons. Toxin concentrations are not related to exposure (Lefebvre et al. 2016). Variables that can affect interpretation of toxin concentrations include time before death and testing, decomposition, undetermined specific pathology associated with toxicity in cetaceans, and possible synergies or comorbidities between exposure and behaviors that may indirectly lead to mortality such as lack of vessel avoidance.

There is some indication that humpback whales may change their foraging behavior in response to ecosystem shifts (Fleming et al. 2015), and their primary prey in 2015 is unknown. The level of overlap between humpback and fin whale foraging is also unclear, although zooplankton are likely common prey. Zerbini (2006) suggested habitat partitioning involving some of the same prey, but with different depth or patch characteristics, occurred between fin and humpback whales in the GOA, with fin whales foraging for euphausiids and humpbacks more broadly targeting schooling fish and euphausiids. Based on dive behavior and acoustics, Witteveen et al. (2015) suggested the two species may target different prey, but cited the greatest potential for overlap when zooplankton density is very high. In 2015, a moderate level of euphausiids were available as prey around Kodiak and the western GOA (Zador 2015). There were also documented algal blooms of both *Pseudo-nitzschia* species and *Alexandrium* species in a number of areas around Kodiak Island in the spring and early summer of 2015 (J. Matweyou, AK Sea Grant Marine Advisory Program, personal communication, Feb. 7, 2017). It is possible that mortality was caused by more than one etiology. For example, animals exposed to sublethal levels of algal toxins may have been more prone to ship strike. The 2015 BC humpback whale and 2016 AK humpback whale with the highest levels of STX and DA, respectively, were both considered ship strikes. The emaciated BC fin whales may have succumbed to malnutrition, either from decreased availability to prey or decreased ability to forage with toxin exposure. Because the AK fin whale mortalities occurred in localized and discrete space and time, it is also possible that mortality occurred acutely and solely from direct exposure to HAB toxins in prey species, akin to the Cape Cod Bay humpback whales.

IV. Conclusion

Fin whale strandings were focal in both the AK and BC portions of the UME during 2015, with an increased number of strandings through limited time and space in both locations. Involvement of humpback whales was less clear due to a larger temporal and spatial spread in the strandings. There was no evidence to indicate other cetacean species were a part of the UME.

Data were limited to reports, photographs, and results from a single partial necropsy of an Alaskan fin whale and eight necropsies of Canadian animals. Differentials included navy sonar testing, radiation, ship strike, infectious disease, predation, and oceanographic changes leading to shifts in prey distribution or HAB exposure. After analyzing these differentials relative to available data, Navy sonar, radiation, and predation can be ruled out. The most likely etiology involves one or more consequences of shifting environmental conditions such as exposure to algal toxins or lack of prey although ship strike and infectious disease cannot be ruled out.

Therefore, based upon the investigation as described, the UME is preliminarily defined with peak occurrence from May 1 to November 30, 2015, involving 18 fin whales total that stranded in the GOA (13) and BC (5) with a primary cause likely attributed to ecological factors.

V. Post-UME monitoring

While the events of 2015 were not replicated in 2016, indications of ongoing trophic level changes were noted, e.g. poor body condition in some stranded fin and humpback whales, strandings in unusual locations. Consequently, post-UME monitoring will continue to monitor trophic level changes and associated environmental shifts. Expected steps include:

Current Data Analyses:

- Finish analyzing all samples from 2015 and 2016 samples from fin and humpback whales throughout Alaskan waters, including the interpretation of stable isotopes and thiamine.

- Monitor other of indicators of feeding ecology, including stable isotopes, a commonly used tool to investigate foraging patterns in many species, and thiamine, possibly decreased and nutritionally deficient if significant thiaminase activity is in forage fish species.

Reponse to Future Strandings:

- When feasible conduct necropsies and sample collection on future large whale strandings

- Conduct HABs testing of future whale samples to attempt to correlate morbidity and mortality and associated pathology qualitatively and quantitatively with algal toxins.

- Continue to look for unusual stranding patterns in future years – numbers, location and timing

- When feasible, investigate anecdotal accounts of changing or new large whale behavior/presence.

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VII. Appendix A

Year	Number of Confirmed Reports by Species			
	Fin whale	Humpback whale	Gray whale	Unidentified whale
2000	0	2	45 (?)	5
2001	0	8	5	1
2002	0	1	0	4
2003	2	1	4	3
2004	0	2	1	6
2005	0	13	5	4
2006	1	5	8	7
2007	0	2	2	6
2008	0	19	6	8
2009	1	3	10	14
2010	1	16	15	13
2011	0	12	9	5
2012	1	12	23	28
2013	1	15	10	10
2014	2	8	13	9
2015	14	31	17	22
2016	3	19	17	22

Table 1. Number of confirmed reports of dead fin, humpback, gray and unidentified large whales in the Alaska Region by year.

Table 2. Necropsy results of AK fin whale., 2015.

Date Collected, NMFS No.	Species	Sex	Age	CC	Location	DA (ng/ml)	STX/PST (ng/g)	Pathogens	Cs-134 (Bq/kg)	Cs-137 (Bq/kg)	Other
6/5/2015 2015033	fin whale	F	A	3.5	Kodiak	NEG (NWFSC)	<10.1 (EHL)	Neg - morbillivirus, influenza A	<MDA*	0.2	Aqueous humor

CC = Condition Code 1 = alive 2=fresh dead 3=moderate decomposition 4=advanced decomposition
5=skeletal/mummified F=female, M = male A = adult, S = subadult, J = juvenile, C = calf DA = domoic acid
PSP/PST (paralytic shellfish poisoning) = saxitoxin

Table 3. Necropsy results of BC fin and humpback whales, 2015.

Date Collected	Species	Sex	Age	CC	Location	DA (ng/ml)	PSP (ng/g)	Tissues tested for HABs	Pathogens	Parasites	Other
5/15/2015	Fin Whale	M	J	3	Vancouver Harbor	120.3 (colon)	134.7 (colon)	Colonic contents	Neg - Salmonella, Brucella, Morbillivirus	Pos - Apicomplexa	Possible ship strike. Bloated, left throat missing, left pec flipper dried up at tip. Extensive bruising dorsally and at abdomen
7/31/2015	Humpback whale	NA	NA	4	Tofino, Estavan	612.8	2.5	Stomach contents	Neg - Salmonella, Brucella, Morbillivirus, Mollicutes, Canine Distemper	Neg - Apicomplexa	Too decomposed, no photos, inaccessible, algal toxin screen - domoic acid and SXT
8/6/2015	Humpback whale	F	A	2.5	Bella Bella	Neg	238 (colon); 232 (intestinal)	Colonic and intestinal contents	Neg - Salmonella, Brucella, Morbillivirus	Pos - Apicomplexa	Possible ship strike.
8/23/2015	Fin Whale	NA	A	2.5	Bamfield, Hecate Strait	28.5	144.5	Colonic contents	Neg - Brucella, Herpesvirus	Neg - Apicomplexa	Ship strike. Amputated peduncle
8/23/2015	Humpback whale	NA	J	2.5	Carmanah	NA	NA		NA	Neg - Apicomplexa	NSF, entangled in kelp

						DA (ng/ml)	PSP (ng/g)	Tissues tested for HABs	Pathogens	Parasites	Other
11/14/2015	Fin Whale	M	S	4	Bella Bella	0	5.8	Colonic contents	Neg - Salmonella, Brucella, Morbillivirus, Mollicutres; Neg - Fecal Yersinia or Campylobacter	Pending - Apicomplexa	Emaciation
11/14/2015	Fin Whale	M	S	3.5	Bella Bella	6	14.2	Intestinal contents	Neg - Salmonella, Brucella, Morbillivirus, Mollicutres; Neg - Fecal Yersinia or Campylobacter	Pending - Apicomplexa	Emaciation, moderate amounts feed in stomach and proximate small intestine
11/14/2015	Fin Whale	M	S	3.5	Bella Bella	26.9	55	Colonic contents	Neg - Fecal Salmonella, Yersinia or Campylobacter	NA	Emaciation, moderate amounts feed in stomach and proximate small intestine

Table 3. Necropsy results of BC fin and humpback whales, 2015 – continued.

Date Collected NMFS No.	Species	Sex	Age	CC	Location	DA (ng/ml)	PSP (ng/g)	Tissues tested for HABs	Pathogens	Parasites	Other
4/26/16 2016029	Humpback whale	F	J	3	Cook Inlet, Little Su	pending (feces)	4.9 (stomach), pending (feces)	Stomach contents, feces	Fecal pathogens –Neg- Campylobacter, Salmonella, Vibrio, E. Clostridium difficile; Small number- Enterococcus faecalis, E. coli, Clostridium perfringens	Neg	Stomach empty
5/29/16 2016053	Fin Whale	M	J	2	Seward	3.7 (peritoneal fluid)	4.99 (stomach), 7.36 (feces)	Aqueous humor, stomach contents, peritoneal fluid, feces, urine	No significant systemic or fecal pathogens; Neg- Brucella, Morbillivirus, Influenza A/B; Neg- Salmonella, Vibrio, E. Clostridium difficile, Clostridium perfringens; Small number - Edwardsiella tarda, Sreptococcus Sp., E. coli, Campylobacter sp.	*Crassicauda boopis* in kidney	Ship strike. Thiamine - variable. Pigmentary nephrosis, Myoglobin - neg
6/21/16 2016076	Fin Whale	M	A	2	Cook Inlet, Knik Arm	21.1 (feces)	Neg	Aqueous humor, feces	Neg - Campylobacter, Salmonella, Vibrio, E. Clostridium difficile; Small number - Enterococcus faecalis, E. coli, Clostridium perfringens; Neg viral culture of blood and aqueous humor	NA	Stable isotopes - pending

Table 4. Necropsy results of AK fin and humpback whales, 2016.

Date Collected NMFS No	Sp.	Sex	Age	CC	Location	DA (ng/ml)	PSP (ng/g)	Tissues tested for HABs	Pathogens	Parasites	Other
6/28/16 2016094	Hump back whale	M	A Aging - estimated 66 years	2	Icy Strait	2.7	Neg	urine	Neg - Brucella, morbillivirus; Moderate - Edwardsiella tarda - light, Lactobacillus curvatus; Heavy - enterococcus faecalis	Heavy infestation of cyamids	Poor body condition. Enlarged lymph nodes. Thiamine - variable. Stable isotopes - pending.
7/7/16 2016105	Hump back whale	F	A	3-4	Sitka, Whale Bay	Neg	Neg	Aqueous humor, stomach contents, feces	Pending	Heavy infestation.*C yamus boopis, Crassicauda boopis*	Poor body condition, possible enteritis, chronic nephritis. Stable isotopes - pending.
9/17/16 2016222	Hump back whale	M	A Aging – estimated 62 years	3	Sitka, Low Island	1,248.9 (feces), 3.6 (stomach contents), 3.2 (urine)	100.5 (feces)	Stomach contents, feces	NA	NA	Ship strike. Moderate to good body condition. Stable isotopes - pending.
6/29/16 2016096	Hump back whale	M	A	2	Cook Inlet, Hope	396.1 (feces)	Neg	Stomach contents, feces	Neg - Salmonella, Vibrio, E. Clostridium difficile, Clostridium perfringens, Campylobacter sp., E. coli; Small numbers - Enterococcus sp - moderate, E. faecalis	NA	NA

Table 4. Necropsy results of AK fin and humpback whales, 2016 – continued.