Photo-identification of Beluga Whales in Upper Cook Inlet, Alaska

Final Report of Field Activities and Belugas Re-sighted in 2010

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ConocoPhillips Alaska, Inc.

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EXECUTIVE SUMMARY

Introduction

Alaska's Cook Inlet beluga whale (CIBW) population (*Delphinapterus leucas*) was listed as endangered in 2008 under the Endangered Species Act (ESA). As a result of the ESA listing, NMFS was required to designate critical habitat (i.e., habitat deemed necessary for the survival and recovery of the population) and to develop a Recovery Plan for CIBW. More information on annual abundance estimates of age-specific cohorts, habitat preferences, life history characteristics associated with population growth (births, calving intervals, age at sexual maturity, etc.), and sources of stress and mortality (natural and human-induced) is needed to promote recovery and conservation of the CIBW population. Data describing CIBW residency and movement patterns, habitat use by mothers and calves, and assessment of behavior will aid in the identification of movement corridors and locations of grounds for feeding, calving, and rearing of young.

The CIBW photo-identification study has been ongoing since 2005, and has demonstrated that a large number of beluga whales in Upper Cook Inlet possess distinct natural marks that persist across years, and that these marks can be effectively identified and re-sighted with digital photography. The photo-identification catalog and associated surveys from six field seasons (2005-2010) provide information about the distribution, movement patterns, and life-history characteristics of dozens of individually identified beluga whales, including mothers with calves.

The original objectives of this study were to:

1. assess the feasibility and utility of photo-identification for studying CIBWs,
2. build a photo-identification catalog of distinctively marked individuals, describing re-sight rates and discoveries of new individuals over time,
3. describe population characteristics of beluga whales in Cook Inlet, including age-class distribution, residency/movement patterns, behavior, and social group structure, and
4. develop abundance estimates of CIBWs using mark-recapture models.

A fifth objective, added in 2007, was to:

5. determine CIBW life history characteristics, such as calving frequency, calving interval, period of maternal care/association, survival rates of calves, and survival rates of identified individuals.

This report summarizes field effort during photo-identification surveys from the 2010 field season, and presents results from analyses of photos of whales encountered and identified in 2005-2010, including sighting rates, distribution, movement patterns, group compositions, entanglements, and reproductive information.

Methods

Dedicated surveys and opportunistic sampling of Upper Cook Inlet, Alaska were conducted from a small vessel and from shore from May through October 2010. Surveys varied according to those combinations of season, location, and tide that provided the greatest likelihood of detecting whales. All vessel surveys were conducted under NMFS MMPA/ESA Research Permit # 14210.

Standardized data forms were used to record beluga whale sightings and environmental conditions. Whales were photographed with a digital camera and zoom lens. Locations of beluga whale sightings and survey routes were mapped and figures were prepared showing survey routes, group location, group size, and group color composition for each survey conducted in 2010.

Photographs were sorted according to image quality using ACDSee photo software. Photographs of belugas in a group were cropped to include a single whale, and were separated into images of the left and right sides of the whales. Images of the left sides of belugas were archived. Daily right-side photo samples (i.e., all cropped photos taken on a single survey day) were sorted into temporary folders. Each temporary folder contained all of the cropped photos taken of the same individual beluga on a single day, and was comprised of one to many images. Temporary folders were then examined to determine if there was a match to photographic records of individual belugas identified within that year or in previous years. If a match was made to a previous year, the new photos were entered into the catalog. Whale profiles were divided into 11 sections along the right half of the whale. Profile completeness was determined by the number of sections with high quality images; a profile set was considered complete if it contained high quality images of all five sections of the dorsal half of the whale, beginning just behind the blowhole to the base of the tail. Whales with complete profile sets are considered to be individuals in the catalog.

Sighting histories (i.e., dates and locations of sightings) of a subset of the catalog, consisting of all sightings of belugas that were identified in all six years of the study (2005-2010), and whales bearing scars from previous satellite tags, were presented graphically. Locations of cataloged beluga whale sightings were mapped in ArcGIS™ Version 10 (http://www.esri.com). The study area was divided into sub-areas and occurrence and movements of identified belugas among sub-areas was examined. Mothers and calves were identified in photographs, and sighting histories were compiled for all cataloged mothers with calves.

Results

Whales in 54 groups were counted and photographed during 35 survey days in 2010. Maximum group size was 173. The largest groups per month were seen in the following locations: Susitna River Delta in May, June, July, and August; and Knik Arm in September and October. The field work completed in 2010 brings the project total to 209 photo-identification surveys conducted over six consecutive annual field seasons. From 2005 through 2010, a total of 135,646 photographs were taken of whales sighted in 425 groups.

Mean group size in 2010 was 26.7 whales. Calves were seen throughout the months when beluga groups were encountered during the 2010 field season. Neonates were not observed until 16 July and were last observed 8 October. Calves and neonates were seen in all areas of Upper Cook Inlet where beluga groups were encountered during photo-identification surveys in 2010, although groups were more likely to contain neonates in Knik Arm than in other areas.

Revisions to the right-side catalog continued through the addition of photographs from the 2010 field season. Of the belugas photographed in 2010, 89 were previously identified as individual whales in the 2005-2009 catalog, and 8 newly-identified individuals were added to the catalog. The 2005-2010 right-side catalog currently contains records for 270 individual whales.

Fifteen belugas were identified in all six years of the study (2005-2010), and their individual sighting histories and photographs are presented in Appendix B. Of the 15 individually identified belugas sighted in each year, none were observed exclusively in one survey area. All 15 belugas were photographed in both Knik Arm and the Susitna River Delta. Twenty percent of these belugas were also seen in Turnagain Arm.

Twenty-five identified belugas were photographed with calves in 2010. One hundred and twenty-nine identified belugas were presumed to be reproductive adult females; this presumption was based on photographs taken of these females from 2005 through 2010 in which they were closely accompanied by calves. Fifty-five identified belugas were photographed with calves in more than one year. Thirty-one identified belugas were seen in more than one year with maturing calves (i.e., if a presumed mother was seen with a calf in multiple years, and the calf appeared larger every year, it was presumed to be the same calf maturing). Eight identified belugas were each first seen with a larger calf, then one to four years later, were seen with a much smaller calf (assumed to be a new calf). Twelve calves were individually identified between 2005 and 2009.

Seven photo-identified belugas have unique scars from holes used by NMFS to affix satellite tags in 1999-2002. Five previously tagged belugas were photographed with calves, and one of these was photographed with a calf in more than one year. Individual sighting histories and photographs of previously tagged belugas are presented in Appendix C.

Dead belugas were not encountered by LGL biologists in 2010. A live beluga entangled in a rope was encountered and photographed throughout the 2010 field season, and NMFS and the Alaska Marine Mammal Stranding Network were notified.

Discussion

Whales were photographed in the Susitna River Delta in the summer and in Knik Arm and Turnagain Arm in the late summer and fall, which was consistent with seasonal whale distribution patterns found in previous years of this study. The maximum number of beluga whales encountered in a single survey day was never more than 173, which indicated that some of the population was elsewhere (NMFS estimated the population at 321 in 2010; www.fakr.noaa.gov/newsreleases/2009/cibeluga100609.htm). The largest

beluga groups were found in the Susitna River Delta, which was consistent with patterns reported by NMFS from aerial surveys.

Whale groups did not appear to be stratified by color or age-class, and most of the groups encountered contained both white and gray whales. All of the groups seen in Knik Arm and 82% of the groups seen in the Susitna River Delta contained white and gray whales. Color composition was more difficult to determine in Turnagain Arm, where whales were generally far from land-based observers. Environmental conditions and photographic settings (most notably ambient light and camera exposure settings) influenced where whales were classified on the gray-to-white scale, and therefore the color assigned to a whale during a field survey may not match the color assigned to the photograph once the photograph was cataloged.

Our observations indicated that calving for CIBWs began in mid-to late July/early August and the first neonates of the season were seen at the Susitna River Delta. We did not detect localized areas for calf rearing, as calves were seen in all locations surveyed. Groups seen in Knik Arm were more likely to contain calves and neonates compared to groups seen in other areas.

The largest groups during each field season were recorded mid-July/early August along the Susitna River Delta. These large groups were observed travelling, socializing, and were suspected to be feeding.

Identified whales did not display fidelity to any single area of Upper Cook Inlet. Distribution and movement patterns were examined for whales sighted in all six years of the study and for whales identified by satellite tag scars (i.e., the subset of whales most likely to have a consistently high probability of being recognized if present because significant mark loss had not occurred). Individual sighting histories indicated that all of these whales moved between different areas of Upper Cook Inlet. All of these whales were photographed in Knik Arm and the Susitna River Delta, and some were also photographed in Turnagain Arm and Chickaloon Bay/Southeast Fire Island. This same pattern of frequent occurrence in the Susitna River Delta and in Knik Arm, with less-frequent occurrence in Turnagain Arm, also held true for the whales identified by scars from satellite tags. Beluga whales were rarely observed traveling between areas, but were instead encountered in distinct areas (i.e., along the Susitna River Delta, in Eagle Bay in Knik Arm, or traveling up and down Turnagain Arm).

Additional years of photo-identification effort are needed to determine how long calves remain with their mothers, if variation in length of mother/calf bonds exists, and how often females give birth to new calves. Although several mothers were photographed with neonates, calving interval cannot be determined until these same mothers are photographed with new neonates. With the exception of a few whales first photographed as young-of-the-year calves, the ages of most of the whales in the catalog are unknown.

Eighteen Cook Inlet belugas were tagged with satellite tags by NMFS between 1999 and 2002 (Hobbs et al. 2005). Seven identified belugas have marks on their right sides caused by satellite tags; although the satellite tags are no longer present, we are still able to photographically track and obtain survivorship data from these individuals 3-11 years later. Knowledge of the years in which the satellite tags were applied helps in

assigning a relative age to re-sightings of these previously-tagged whales; we know that none of the whales were calves at the time of tagging.

To date, the photo-identification study has not found evidence that beluga groups in Upper Cook Inlet are highly structured in terms of individual association patterns, color, age-class, location, or sex. Although results are preliminary, all re-sighting information so far indicates the portion of the population we have identified is homogenous. Future studies will examine whether subgroups exist on a seasonal scale.

In 2010 and 2011, project results from 2005-2010 were presented as talks and posters at scientific and public meetings, including posters at the Alaska Marine Science Symposium, talks to the Anchorage School District, the Cook Inlet Beluga Recovery Team, Oregon State University, and ConocoPhillips (Anchorage and Kenai Offices), and an invited talk and four poster presentations at the NMFS Cook Inlet Beluga Whale Research Symposium. Project results are presented in reports that are available publically at http://www.fakr.noaa.gov/protectedresources/whales/beluga/research.htm#ci.

Conclusion

The strength and utility of the photo-identification project grows with the proportion of the CIBW population that is photographed and identified. Photo-identification surveys from the existing six years of uninterrupted effort will continue to provide information about the distribution, habitat associations, behavior, color, and age-class compositions of CIBW groups, while identification of whales photographed during the surveys will continue to provide information about movement patterns, social structure, and life history characteristics of individually identified beluga whales. Continuation of a long-term data-set that provides insight into the population dynamics and life history of Cook Inlet beluga whales will help with the identification of appropriate conservation measures to recover and preserve the population.

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INTRODUCTION

Alaska's Cook Inlet beluga whale (CIBW) population (*Delphinapterus leucas*) is considered a distinct population segment (DPS) by the National Marine Fisheries Service (NMFS) due to geographic and genetic isolation. A dramatic decline in the CIBW population occurred in the late 1990s, and the population was designated as depleted in 2000 under the Marine Mammal Protection Act (MMPA). After finding little evidence to demonstrate the population was recovering, in October 2008 NMFS listed the CIBW population as endangered under the Endangered Species Act (ESA; NMFS 2008a). As a result of the ESA listing, NMFS was required to designate critical habitat (i.e., habitat deemed necessary for the survival and recovery of the population) and to develop a Recovery Plan for CIBW.

Many information gaps and uncertainties are associated with the current understanding of the CIBW population (NMFS 2008b). More information on annual abundance estimates of age-specific cohorts, habitat preferences, life history characteristics associated with population growth (births, calving intervals, age at sexual maturity, etc.), and sources of stress and mortality (natural and human-induced) is needed to promote recovery and conservation of the CIBW population. Data describing CIBW residency and movement patterns, habitat use by mothers and calves, and assessment of behavior will aid in the identification movement corridors and locations of grounds for feeding, calving, and rearing of young.

Available sources of information used to identify and characterize critical habitat include the distribution of beluga whales sighted from annual aerial surveys, tidal flow models, and movement data from 15 satellite-tagged individuals from 1999 to 2002 (Rugh et al. 2000, 2004, 2005, 2006; Hobbs et al. 2005, 2008; Goetz et al. 2007; NMFS 2008a; Shelden et al. 2008, 2009a&b, 2010). This information plays a key role in characterizing and understanding habitat needs, as does information on beluga movement and residency patterns obtained from land-based observational studies of CIBWs in Upper Cook Inlet (Funk et al. 2005, Prevel-Ramos et al. 2006, Markowitz and McGuire 2007, Markowitz et al. 2007, Nemeth et al. 2007). Land- and vessel-based photo-identification surveys (McGuire et al. 2008, 2009, 2011; McGuire and Kaplan 2009) are also used to characterize distribution and movement patterns of individual beluga whales, and results of these surveys complement information from aerial surveys and tagging-tracking studies conducted by NMFS. In the 2008 Conservation Plan for CIBWs, NMFS endorsed photo-identification as a method of establishing a long-term data set to monitor the CIBW population (NMFS 2008b).

The CIBW photo-identification study has been ongoing since 2005, and has demonstrated that a large number of beluga whales in Upper Cook Inlet possess distinct natural marks that persist across years, and that these marks can be effectively identified and re-sighted with digital photography. The photo-identification catalog and associated surveys from six field seasons (2005-2010) have provided information about the distribution, movement patterns, and life-history characteristics of dozens of individually identified beluga whales, including mothers with calves (McGuire et al. 2008, 2009, 2011; McGuire and Kaplan 2009).

The original objectives of this study were to:

1. assess the feasibility and utility of photo-identification for studying CIBWs,
2. build a photo-identification catalog of distinctively marked individuals, describing re-sight rates and discoveries of new individuals over time,
3. describe population characteristics of beluga whales in Cook Inlet, including age-class distribution, residency/movement patterns, behavior, and social group structure, and
4. develop abundance estimates of CIBWs using mark-recapture models.

A fifth objective, added in 2007, was to:

5. determine CIBW life history characteristics, such as calving frequency, calving interval, period of maternal care/association, survival rates of calves, and survival rates of identified individuals.

This report summarizes field effort and photo-identification surveys from the 2010 field season, and presents results from analyses of photos of whales encountered and identified in 2005-2010, including sighting rates, distribution, movement patterns, group composition, and reproductive information.

METHODS

Field Surveys

Survey effort

Dedicated surveys and opportunistic sampling of portions of Upper Cook Inlet, Alaska (Figures 1 and 2) were conducted from a small vessel and from shore in 2010. Survey schedules varied according to those combinations of season, location, and tide that provided the greatest likelihood of detecting whales. These combinations were determined by results from NMFS aerial surveys (Hobbs et al. 2008) and other studies of CIBWs (Funk et al. 2005, Markowitz et al. 2007, Markowitz and McGuire 2007, McGuire et al. 2008, Nemeth et al. 2007, Prevel-Ramos et al. 2006). General routes were followed for each area, although deviations were made to each route depending on where beluga groups were encountered. The Susitna River Delta (Figure 2) was surveyed in late spring and summer (May-August) during low tide. Knik Arm (Figure 2) was surveyed primarily in late summer/fall (August-October) during low tide. Turnagain Arm (Figure 2) was surveyed from the Seward Highway in late summer/fall (August-October) during high tide. Vessel-based surveys of Chickaloon Bay (Figure 2) were not made in 2010 as wind conditions were deemed unsafe for boating. The Port of Anchorage was surveyed during all vessel-based surveys because the survey vessel was always launched from the small boat ramp at the Port of Anchorage.

Vessel surveys

Most photographs were taken from vessels. Vessel surveys were conducted from the *R/V Leucas*, a 4.9 m (16 ft) inflatable Proman 9 Zodiak powered by a 4-stroke 50 hp Yamaha motor. The *Leucas* usually carried one skipper and one crew member. Vessel position was recorded at 2-minute intervals with a Garmin™ GPS (Global Positioning System) Map 76C. Survey routes were determined by tidal stage, water depth, and navigational hazards, and were designed to maximize the probability of encountering whales. Surveys were not appropriate for line-transect methodology designed to estimate abundance. Whale groups were approached once per survey and followed in the manner described by Würsig and Jefferson (1990). The research vessel approached slowly, parallel to the group, and matched group speed and heading in order to obtain images of lateral sides of individuals while minimizing disruption of the group. Researchers noted the position of whales relative to the vessel and GPS-logged tracks were used to estimate approximate whale group positions. Vessel-based surveys were suspended during NMFS aerial surveys. All vessel surveys were conducted under NMFS MMPA/ESA Research Permit # 14210.

Land-based surveys

Photographs were also taken from shore. A single observer drove south and east from Anchorage along the Seward Highway, generally beginning three hours before high tide. The observer, while stopping at pullouts along the highway, searched with binoculars and the naked eye for marine mammals. When beluga whales were seen, the observer attempted to follow them along Turnagain Arm as they moved with the tide. Most photographs were taken from sites between Bird Point and Girdwood (Figure 2) because whales approached closest to shore here, and because of easy highway access to these sites. Although the majority of photographs from shore were taken along Turnagain Arm, on a few occasions photographs of whales were taken from shore near Ship Creek at the Port of Anchorage. These whales had been sighted while observers were preparing to launch the survey vessel, and photos were taken from shore rather than from the vessel in order to minimize possible disturbance to the whales.

Field data (vessel- and land-based surveys)

Standardized data forms were used to record beluga whale sightings and environmental conditions. For each beluga whale group sighting, observers recorded: time of day, group size, GPS position of the vessel, magnetic compass bearing to the group, estimated distance of the vessel from the group (distance at first detection, and minimum distance to individual whales), water depth (under the vessel), group formation, direction of travel, movement patterns, average distance between individuals, and any human activities near the sighting. For groups with multiple records on a single day, the best record was selected at the end of the survey, which was either the highest count (for groups that merged), or the count considered by both observers to be the most accurate. Group size was usually difficult to determine and counts provided estimates rather than actual number of whales in the group. Behavioral data were collected using focal group sampling (Mann 2000) and behavior was classified into primary and secondary activities.

Primary activities were behaviors that appeared to be the dominant behavior of the group, and secondary activities were behaviors that occurred sporadically during primary activities. Behavioral activities were defined as follows:

Travel – directed movement in a linear or near-linear direction, transiting through an area, usually at a relatively high speed.

Dive – movement directed downward through the water column.

Feeding Suspected – chasing or apparently chasing prey, as evidenced by bursts of speed, lunges, and/or focused diving in a particular location, or by fish jumping out of the water near belugas.

Rest – little or no movement, body of animal visible at or near the surface.

Mill – non-linear, weaving or circular movement within an area.

Socialize – interactions among whales indicated by physical contact observed at the surface, or by audible vocalizing.

Body color and relative size of whales in the group were recorded as "white", "gray", "calf", and "neonate". Calves were usually dark gray, relatively small (i.e., <2/3 the total length of adult belugas), and usually swimming within one body length of an adult-sized beluga. Observers noted if any calves appeared to be neonates (i.e., newborns, estimated to be hours to days old) based on extremely small size (1.5 m [5 ft]), a wrinkled appearance due to the presence of fetal folds, and uncoordinated swimming and surfacing patterns.

Environmental data were collected hourly or when conditions changed. Environmental variables recorded included Beaufort sea state, swell height, cloud cover, visibility, wind speed and direction, air temperature, water temperature at the surface, water depth, and habitat type (e.g., mudflat, bay, mid-channel, river mouth, depositional bank, erosional bank, island, and shoal).

Digital photographs of beluga whales were collected using a Nikon D300, 12.3 megapixel digital SLR camera with a Nikkor 70-400 mm zoom telephoto auto focus lens. Typical settings included shutter speed priority, dynamic auto-focus, 800 ISO, and shutter speed of 1,000 or greater. Photographs were taken in RAW (not compressed) format and stored on compact flash memory cards.

Analyses of Data from Field Surveys

Locations of beluga whale sightings and survey routes were mapped in ArcGIS™ Version 10 (http://www.esri.com) and figures were prepared showing survey routes, group location, group size, and group color composition for each survey conducted in 2010. Primary and secondary behaviors of beluga whale groups, group size and color composition, and presence of calves and neonates were compared among the Susitna River Delta, Turnagain Arm, Knik Arm, and Chickaloon Bay.

Processing of Photographs

All RAW format photographs were downloaded from the camera's compact flash memory card onto a computer hard drive and archived to DVDs to preserve the original data before any further processing. Copies of photographs were then reformatted into JPEGs (JPEG files are smaller than RAW files) for more-efficient processing. Photographs were sorted according to image quality using ACDSee photo software (http://www.acdsee.com). Photographs of unsuitable quality for identification (e.g., poor focus, whale obscured by splash or too distant) were noted and archived, but not used for subsequent analyses. If distinguishing features of marks were obvious even in poor quality photographs, the photo was considered for inclusion in the catalog.

When original field photographs contained two or more whales, each whale was cropped individually and given a separate file name. Cropped images were separated into left and right sides of whales. Images of the left sides of belugas were archived. In order to conserve project funds, only photographs of the right sides of the whales were further processed.

Daily photo samples (i.e., all cropped photos taken on a single survey day) were sorted into temporary folders. Each temporary folder contained all of the cropped images taken of the same individual beluga on a single day, and was comprised of one to many images. Images within a temporary folder may have been taken seconds or hours apart, and often showed different sections of the body as the beluga surfaced and submerged. Temporary folders were then examined to determine if there was a match to photographic records of individual belugas identified within that year or in previous years. If a match was made to a previous year, the new photos were entered into the catalog. If no match was made, the new photos were put into a newly created "potential whale" folder (potential whales are discussed in more detail below).

Cataloging of Photographs

As a beluga surfaced and submerged, different portions of its body were available to photograph. Side-profile photographs were most useful for matching marks used to identify individual whales. Profile images were divided into 11 sections along the right half of the whale (Figure 3). Sections containing the head, tail and ventral half of the whale were less commonly captured in photographs and were therefore less likely to provide identifying marks. "Profile completeness" was determined by the number of sections with high quality images; a side profile set was considered complete if it contained high quality images of all five sections of the dorsal half of the whale, beginning just behind the blowhole to the base of the tail. Whales with complete profile sets were considered to be individuals in the catalog. Another criterion that allowed for the acceptance of a whale into the catalog was if two temporary whale folders that spanned two or more years were matched.

Mark-type categories were created in order to facilitate cataloging. Locations of all visible marks were assigned to sections of the body. This was done for each individual within the catalog. Computer software specialized for this species was

developed to allow for computer-aided filtering of the database according to mark type and location.

Sighting Histories

Sighting histories (i.e., dates and locations of sightings) were compiled for all cataloged belugas in order to examine residency and movement patterns. Sighting histories of a subset of the catalog, consisting of all sightings of belugas that were photographed in all six years of the study (2005-2010) and of all sightings of whales bearing scars from previous satellite tags, were presented graphically. Locations of cataloged beluga whale sightings were mapped in ArcGIS™ Version 10 (http://www.esri.com). The study area was divided into sub-areas (Figure 2), and occurrence and movements of identified belugas among sub-areas were examined.

Classification of Mothers and Calves in Photographs

Identified belugas were classified as mothers in photographs if they appeared in the same cropped photo-frame with a calf or neonate alongside. Belugas were classified as calves in photographs if they were dark gray (although light-gray calves were also observed), relatively small (i.e., <2/3 the total length of adult belugas), and photographed swimming and surfacing in synchrony alongside a larger beluga. Neonates were distinguished in photographs by visible fetal folds and often a "peanut-shaped" head. Sighting histories (i.e., dates and locations of sightings) were compiled for all cataloged mothers and calves. Sighting records for mothers included information on when the mother was photographed with and without a calf, as well as information on the relative size of the calf.

Additional Information Provided by the Study

Many photographs of Cook Inlet belugas in the catalog contain marks indicative of disease and injury (LGL 2009). Using the cataloging tools within the database application, marks were labeled according to mark type and body segment in which they occurred in a photograph (Figure 3).

Database Development

We continued to work with a database specialist to consolidate all photo-identification data (2005-2010) into a single, comprehensive, and integrated database, and to aid in management of photos during the cataloging process. Data from surveys included the survey route, environmental conditions, and group size, color, and behavior. Data associated with each photograph included the "metadata", such as the original camera settings, the time the original photograph was taken, and the lighting conditions. Finally, data included the number of photos in the catalog, the dates and locations when photos were taken, the number of individual whales represented in the catalog, the

number of temporary files yet to be matched, and the number of photos of whales with few or no visible markings.

RESULTS

Surveys

Survey effort and number of whales and whale groups encountered in 2010

Fifty-four beluga whale groups were counted and photographed during 35 survey days in 2010 (Table 1). Mean group encounter rates were higher in Turnagain Arm and the Susitna River Delta than in Knik Arm (Chickaloon Bay was not surveyed in 2010). Across all areas a mean of 1.5 groups per survey was observed. Survey effort was unequal among locations and seasons (Table 2). Survey effort was highest in Turnagain Arm and lowest in Chickaloon Bay. Duration of surveys depended on hours of daylight, tidal conditions, if whale groups were encountered, and size and behavior of whale groups; vessel-based surveys generally lasted six hours and land-based surveys generally lasted three hours. The number of whales sighted per survey was variable, even after stratifying by month and location (Tables 3 - 5). Total number of belugas sighted per survey varied between 0 and 173. The largest groups per month were recorded in the Susitna River Delta in May, June, July, and August, and in Knik Arm in September and October (Tables 3 - 5). Maps of whale group sighting locations and survey routes from the vessel and from land in 2010 are presented in Appendix A.

The field work completed in 2010 brings the project total to 209 photo-identification surveys conducted over six annual field seasons (Table 6), with 135,646 photographs of whales sighted in 425 groups.

Group size, color composition, and age class of groups encountered during surveys

Whales were most often seen in groups of twelve or fewer individuals, and maximum group size was 173 (Figure 4). Mean group size was 26.7 whales (Table 1). Fifty-three percent of all beluga sightings in 2010 were of white belugas, 28% were of gray belugas, 7.5% were of calves, 2% were neonates, and 9.5 % were of unknown color and relative size (Table 7). Relative color and age-class composition of groups varied with location, season, and survey method (Tables 3 - 5 and 7). Color composition and age class were determined for almost all groups seen in Knik Arm and in the Susitna River Delta, while slightly more than half of the whales seen in Turnagain Arm were of unknown color and size.

Calves were seen throughout all months when beluga groups were encountered during the 2010 field season (Tables 3 - 5). Neonates were not observed until 16 July and were last observed 8 October. Calves and neonates were seen in all areas of Upper Cook Inlet where beluga groups were encountered during photo-identification surveys (in 2010 and throughout the six-year study), although more neonates per group were seen in Knik Arm than in other areas (Tables 3 - 5 and 7, Figures 5 - 6). The percentage of each group composed of calves and neonates varied according to location, as did the percentage of

groups containing calves and neonates. Twenty-seven percent of groups encountered in Turnagain Arm contained calves, whereas 77% and 70% of groups encountered in the Susitna River Delta and Knik Arm, respectively, contained calves (Tables 3 - 5). Neonates were found in 80% of the groups seen in Knik Arm and in 41% of the groups in the Susitna River Delta. Only 4.5% of groups in Turnagain Arm contained neonates.

Behavior of whale groups

Traveling was the most-frequently observed primary group activity, regardless of area. Suspected feeding activity was seen more often in the Susitna River Delta than it was in other areas (Table 8).

Catalog Development and Current Status

As is typical for a maturing photo-identification catalog, revisions to the right-side catalog continued through the addition of photographs from the 2010 field season. Of the belugas photographed in 2010, 89 were previously identified as individual whales in the 2005-2009 catalog, and 8 newly-identified individuals were added to the catalog (Figure 7). The 2005-2010 right-side catalog currently contains records for 270 individual whales.

Sighting Histories

Sighting histories of belugas 2005-2010

Fifteen belugas were identified in all six years of the study (2005-2010), and their individual sighting histories and photographs are presented in Appendix B. In addition, 27 belugas were identified in five years of the study, 35 belugas were identified in four years of the study, 53 belugas in three years of the study, 72 belugas in two years of the study, and 68 individual belugas were identified in only a single year.

Of the 15 individually identified belugas sighted in each year of the study (Table 9) none were observed exclusively in one survey area. All 15 belugas were photographed in both Knik Arm and the Susitna River Delta. Twenty percent of these belugas were also seen in Turnagain Arm. The highest total encounter rate (number of sightings for all years combined) during the course of the study was for one identified beluga sighted on 24 different days during 2005-2010 (Figure 8). Nine percent of belugas identified from 2005 to 2010 were sighted once, and 91% were sighted on multiple days. Identified belugas were rarely photographed in more than one group per survey day, and were never photographed in more than two groups per survey day. The identification rate (number of beluga identifications/survey) was highest in the Susitna River Delta and was lowest in Turnagain Arm (Table 10). On average, ~ 12.5% of each group was identified in Knik Arm and the Susitna River Delta, while only ~ 2% of each group was identified in Turnagain Arm.

Sighting histories of mothers and their calves

Twenty-five identified belugas were photographed with calves in 2010 (Tables 11 and 12). One hundred and twenty-nine identified belugas were presumed to be reproductive adult females; this presumption was based on photographs taken of these females from 2005 through 2010 in which they were closely accompanied by calves. The position of the calf relative to the presumed mother was either the "neonate position", in which the calf surfaced just above the mother's midline, or the "calf position" alongside the posterior half of the mother. Position descriptions were based on those described for bottlenose dolphins (*Tursiops* sp.) by Mann and Smuts (1999), and for belugas by Krasnova et al. (2009).

Fifty-five identified belugas were photographed with calves in more than one year (Table 11). The majority of calves could not be identified as individuals because they were either not marked or they were never photographed with enough of the body above water to allow marks to be seen. Twelve calves were individually identified between 2005 and 2010 (Table 12). Eleven of these calves were large calves (i.e., 2/3 the body length of an adult) and each was photographed with a larger, whiter, beluga assumed to be the mother. In several instances, these calves were later photographed closely accompanied by much smaller darker calves; whether these were their own offspring or their younger siblings could not be determined.

Thirty-one identified belugas were seen in more than one year with maturing calves (i.e., if a presumed mother was seen with a calf in multiple years, and the calf accompanying her appeared larger every year, it was presumed to be the same calf maturing; Figure 9). Eight identified belugas were each first seen with a larger calf, then one to four years later, were seen with a much smaller calf (assumed to be a new calf).

Sighting histories of belugas identified by satellite tag scars

Seven photo-identified belugas had unique right-side scars from holes used by NMFS to affix satellite tags 1999-2002. These individuals were identified based on a combination of natural marks and the tag scars to avoid mistakenly matching similar scar patterns caused by the same tag type. Five of these belugas were sighted in 2010. Five previously tagged belugas were photographed on the right-sides with calves, and one of these was photographed with a calf in more than one year (Table 13). Six previously tagged belugas were photographed in both Knik Arm and the Susitna River Delta. Four previously tagged belugas were photographed in Turnagain Arm, and also in Knik Arm and the Susitna River Delta. No previously tagged animals were photographed in Chickaloon Bay/Southeast Fire Island during the five surveys conducted in the area (2006-2009). Individual sighting histories and photographs of previously tagged belugas are presented in Appendix C.

Additional Information Provided by the Study

Dead and injured belugas encountered in 2010

Dead belugas were not encountered by LGL biologists in 2010. A live beluga entangled in a rope was encountered and photographed throughout the 2010 field season (Figures 10 and 11). This entangled beluga was photographed on 26 May, 16 July, 29 July, 12 August, and 27 August. All sightings occurred in the Susitna River Delta, and the whale was always in seen in large groups containing calves and neonates. NMFS and the Alaska Marine Mammal Stranding Network were contacted with sighting information and photographs.

DISCUSSION

Whales Encountered During Surveys

Whales were photographed in the Susitna River Delta in the summer and in Knik Arm and Turnagain Arm in the late summer and fall. The presence of whales in these areas during these time periods was consistent with seasonal whale distribution patterns found in previous years of this study (McGuire et al. 2008, 2011; McGuire and Kaplan 2009) and in other studies (Moore et al. 2000, Funk et al. 2005, Hobbs et al. 2005, Markowitz and McGuire 2007, Nemeth et al. 2007). Photo-identification survey routes and seasonal schedules in 2010 were similar to those from previous years (McGuire et al. 2008, 2009, 2011; McGuire and Kaplan 2009). The maximum number of beluga whales encountered in a single survey day was never more than 173, which indicates that some of the CIBW population was elsewhere (NMFS estimated the population at 340 in 2010; www.fakr.noaa.gov/newsreleases/2010/belugapopulation.htm). The largest beluga groups were found in the Susitna River Delta, which was consistent with patterns reported by NMFS from aerial surveys (Shelden et al. 2010).

Group sighting rates (number of groups encountered per survey) were similar among surveys conducted in 2010, 2009, and 2008 (1.5, 1.3 and 1.5, respectively), and somewhat lower in these years than in previous years (2.0 in 2007, 4.9 in 2006, and 2.4 in 2005). Although inter-observer differences in defining groups may contribute to differences in group size recorded, the LGL photo-identification research team remained the same during the 2007-2010 field seasons. Average group size during photo-identification surveys was 27 whales in 2010, 26 in 2009, 27 in 2008 and 14 in 2007. Shelden et al. (2008, 2009a) also report larger and fewer groups of beluga whales seen during aerial surveys in June 2009 and 2008 compared to June 2007.

Color and Age Composition of Groups

Whale groups did not appear to be stratified by color or age-class, and most of the groups encountered in 2010 contained both white and gray whales. Color composition

was most difficult to determine in Turnagain Arm, where whales were generally far from land-based observers. Almost half of the groups seen in Turnagain Arm did not contain gray whales, but that may have been because gray whales were harder to detect with greater sighting distance and often-rougher water. Although not quantified, observers on the survey vessel had the impression that white whales were more likely to be detected than gray whales, as gray whales tended to blend with the turbid gray waters of Cook Inlet. This suspected bias in detection towards white whales seemed greater with distance between whale and observer. Behavioral differences between white and gray belugas, however, may have resulted in an opposite bias. Observers also had the impression that gray animals were more likely to both approach the survey boat and to remain near the boat. Therefore, although white belugas were more likely to be detected at a distance, gray whales may have been more likely to be photographed from vessels, possibly resulting in better photographs of gray individuals and a higher rate of identification. Environmental conditions and photographic settings (most notably ambient light and camera exposure settings) influenced whale classification on the gray-to-white scale (McGuire et al. 2008, Blees et al. 2009), and this likely resulted in some variability in color assigned to whales.

The timing and location of beluga whale calving in Cook Inlet is not well documented in the literature (Hobbs et al. 2008). Groups of belugas in the Canadian Arctic were found to have seasonal differences in proportions of calves, juveniles, and adults (Smith et al. 1994), which were used to determine seasonality of calving. Based on the presence of calves sighted in summer aerial surveys, Calkins (1983) speculated that calving might occur between mid-June and mid-July in the larger estuaries of upper western Cook Inlet. Our observations indicate that calving for CIBWs begins in mid-late July/early August; neonates were first seen on 16 July 2010, 1 August 2009, 24 July 2008 and 27 July 2007. The first year we sub-classified calves as neonates was 2007. The "calf" category used during field surveys 2005-2006 did not differentiate newborn calves from those now known to be one- and two-year old calves (determined photographically by sighting histories of calves of identified mothers; McGuire et al. 2008), which suggested that any peak in newborn calf numbers may not have been captured in the data recorded during these field surveys.

During 2007-2010, the first neonates of the season were seen at the Susitna River Delta. We did not detect localized areas for neonate and calf rearing, as calves and neonates were seen in all locations surveyed (Figure 6). Groups seen in Knik Arm were more likely to contain neonates compared to groups seen in other areas. Seasonal differences in survey location may confound patterns among years, locations, season, and occurrence of neonates. For example, groups seen in the Susitna River Delta were more likely to contain calves than groups in other areas in 2010 and 2008, but not in 2007 or 2009.

Sighting distance between observer and beluga groups may have had an effect on observer ability to detect neonates in a group. For example, compared to other locations, fewer groups in Turnagain Arm contained neonates and mean sighting distances were greater. It is likely that some calves and neonates in Turnagain Arm were not detected by observers due to the greater sightings distances and rougher waters.

Behavior

Traveling was the predominant group behavior regardless of area. The distinction among behavioral categories was somewhat artificial as the terms only described behaviors seen when the whales were briefly at the surface. In reality, whales were often probably simultaneously feeding, diving, and traveling as they pursued and captured prey. The largest group recorded during the study (2005-2010) was of 173 whales seen 16 July 2010; this audibly vocal group was travelling and suspected to be feeding (whales were seen making waves against the shore and in shallow water, which may have been caused by pursuing prey at high speed in short bursts). The second largest group ever encountered during photo- identification surveys was of 121 beluga whales encountered on 29 July 2008, seen traveling and socializing along the Susitna River Delta. Observers noted that the whales in this group seemed exceptionally vocal and playful with one another and the survey boat. In 2007, the largest group (74 whales) was encountered on 27 July, diving, traveling, and feeding along the Susitna River Delta. This large group was presumed to be pursuing salmonids, based on observations of fish jumping out of the water near the whales.

On several occasions in late August and September, whales traveling rapidly south-east along Turnagain Arm with the incoming tide were observed to suddenly circle near the north shore rip-rap approximately 1 km (0.6 mi) east of Bird Point (presumably in pursuit of fish) and then continue traveling rapidly eastward.

Whales were much easier to photograph when feeding or traveling than when diving. Feeding and traveling animals remained at the surface longer, had higher surfacing profiles, and exhibited less response (attraction or avoidance) to the survey vessel, whereas diving animals often remained submerged for long periods of time and were unpredictable in their surfacing locations and patterns.

Sighting Histories and Movement Patterns

The photo-identification catalog and associated surveys from six continuous years of effort provide information about the distribution and movement patterns of individually identified CIBW. The strength and utility of the catalog grows over time as the proportion of the population that is identified grows. Results of continued photo-identification efforts will help to fill gaps in current knowledge about the life history of the CIBW population.

Identified whales did not display fidelity to any single area of Upper Cook Inlet. Distribution and movement patterns were examined for whales sighted in all six years of the study and for whales identified by satellite tag scars. This subset of whales (i.e., whales seen in six years and whales with satellite-tag marks) was the most likely group to have a consistently high probably of being recognized if present because significant mark loss had not occurred. Individual sighting histories of the 15 beluga whales photographed in all six years of the study indicated that all of these whales moved among different areas of Upper Cook Inlet. All of these whales were photographed in Knik Arm and the Susitna River Delta, and some were also photographed in Turnagain Arm (none were photographed in Chickaloon Bay/SE Fire Island, but this may have been due to low

survey effort in this area). This same pattern of frequent occurrence in the Susitna River Delta and in Knik Arm, with less-frequent occurrence in Turnagain Arm, held true for the whales identified by scars from satellite tags. Beluga whales were rarely observed traveling between areas, but were instead encountered in distinct areas (i.e., along the Susitna River Delta, in Eagle Bay in Knik Arm, or traveling up and down Turnagain Arm). Similar patterns of localized aggregations and rapid and directed travel between areas of localized aggregations have been reported for satellite-tagged Cook Inlet beluga whales (Hobbs et al. 2005) and beluga whales in Norway (Lydersen et al. 2001).

Overall sampling effort has been lower in Turnagain Arm and Chickaloon Bay/Southeast Fire Island than in the Susitna River Delta or in Knik Arm. In addition, group encounters in Turnagain Arm typically yielded a much lower percentage of identified whales than did groups encountered in other areas, likely a result of greater sighting distances in Turnagain Arm compared to other areas. Despite the limitations encountered while photographing belugas from land along Turnagain Arm, these photos have provided important evidence that belugas identified in Turnagain Arm are also seen in the Susitna River Delta and in Knik Arm, and do not appear to be a sub-population endemic to Turnagain Arm. Increased sampling effort in Turnagain Arm and Chickaloon Bay/Southeast Fire Island will be necessary to determine if only a portion of identified whales in the larger study area exhibit a preference for these areas.

When making inferences about the greater population of CIBW based on sighting histories of individually identified whales, it is important to consider the results within the context of survey effort. Photo-identification surveys were not systematic relative to the entire Upper Cook Inlet. Instead, effort was focused in certain areas during particular times of the year that would maximize the probability of encountering whales. The maximum numbers of beluga whales noted in a single survey day (2005-2010) was never more than 173 which indicated that most of the population was elsewhere (the highest population estimate during this survey period was 375 in both 2008 and 2007; www.fakr.noaa.gov/newsreleases/2009/cibeluga100609.htm; Hobbs et al. 2008). In addition, sighting histories that were obtained from cataloged whales were a function of which whales within a group were photographed and which of these had marks that could be reliably identified through time.

Life History

The development of long-term sighting histories of identified mothers and calves can provide data necessary for the determination of several aspects of life history, including calving interval (minimum time period between calving events), calving frequency (how often females give birth), period of maternal care/association, and survival rates of calves. It will be important to monitor these life history parameters over time, because a decline in population abundance is sometimes associated with a decrease in female age at maturity and a decrease in calving interval (Fowler 1984).

Of the 129 belugas presumed to be mothers, 31 were photographed with calves maturing over two or more field seasons, and one identified mother was photographed with a maturing calf during five field seasons. Additional years of photo-identification effort are needed to determine how long calves remain with their mothers, if variation

exists among individual mothers, and how often identified mothers give birth to new calves. Although several mothers were photographed with neonates, calving interval cannot be determined until these same mothers are photographed with new neonates. Eight mothers seen with relatively large calves in one year were photographed with smaller calves in subsequent years, but because none of the original calves was photographed as a neonate, the number of years between births cannot be determined at the present time.

Twelve calves have been identified by their own marks rather than those of their mothers, which allow them to be tracked independently of their mothers. The mothers of most of these calves have not yet been identified. A project goal is to be able to calculate coefficients of association (COAs) between identified mothers and identified calves, but this can only be done when both mother and calf have been identified. Evidence of decreasing COAs over time between a mother-calf pair has been used to quantify the weakening of the mother-calf bond and to help to define the period of maternal care and association. For example, COAs between bottlenose dolphin mothers and calves were near 1.0 for calves in the first three years of life, but declined in most cases when the mother became pregnant again (Connor et al. 2000). Future efforts will also compare how often an identified calf is photographed with an identified mother to how often the mother and calf are photographed in the same group but are not in close physical proximity (i.e., seen in the same group, but not photographed together). The current method of defining mother-calf pairs at the level of the photo frame limits our ability to detect mothers with older calves, because the distance between cetacean mothers and offspring increases with increasing age of the calf (Mann 1997, Krasnova et al. 2006). We use the term "presumed mother" because we can only make informed guesses about maternity based on reasonable evidence (in this case, physical proximity and behavior). In the future, combined photo-identification and genetic sampling from remote-biopsy would allow us to test our assumptions of maternity.

With the exception of a few whales first photographed as young-of-the-year calves, the ages of most of the whales in the catalog are unknown. Eighteen Cook Inlet belugas were satellite tagged by NMFS between 1999 and 2002 (Hobbs et al. 2005). Seven identified belugas have marks on their right sides caused by satellite tags; although the satellite tags are no longer present, we are still able to photographically track and obtain survivorship data from these individuals 3-11 years later. Knowledge of the years in which the satellite tags were applied helps in assigning a relative age to re-sightings of these previously-tagged whales; we know that none of the whales were calves at the time of tagging. Details from the time of capture/tagging such as total length and girth may provide more information about the relative age of these whales. Satellite tag type and attachment method varied among years (Rod Hobbs and Barbara Mahoney, NMFS, personal communication) and it may be possible to assign a capture/tagging date based on scar type, which in turn would provide information on survivorship, wound healing, and longevity of these types of marks.

Social Structure

To date, the photo-identification study has not found evidence that beluga groups in Upper Cook Inlet are highly structured in terms of association patterns among individuals, color, age-class, location, or sex. Although results are preliminary, all re-sighting information so far indicates the portion of the population we have identified is homogenous. While some of the whales identified in all years of the study and some of the previously-tagged whales were more likely to be seen with certain individuals, these patterns were not widespread or consistent enough to allow the population to be divided into subgroups (McGuire et al. 2011). Future studies will attempt to determine if subgroups exist on a seasonal scale (e.g., do the large groups seen in the summers in the Susitna River Delta break into smaller subgroups during other seasons and in other locations?).

Groups encountered during surveys were rarely exclusively comprised of white or gray animals, but generally had both colors present. Identified whales seen in five consecutive years (2005-2009) of the study had roughly equal rates of occurrence in groups with calves, and none were found in groups of exclusively white adult animals, groups of solely mother-calf pairs, or groups of only small gray animals (McGuire et al. 2011). Groups containing calves and neonates were seen in all parts of the study area.

It is unknown if groups of CIBWs are sexually segregated for all or even part of the year. Association patterns within a single season will be examined in the future. We have not been able to identify any belugas as male, and have only been able to infer a beluga was female if it was accompanied by a calf. Smith et al. (1994) identified adult males by their "large size and heavy lateral musculature". We have photographed several large, white, well-muscled belugas, but at least two of these animals were closely accompanied by calves and were classified as females. Elsewhere in their range, this species segregates into groups comprised of maternal pods of adult females, calves, juveniles, and subadults, and smaller groups of adult males outside of the breeding season (Smith et al. 1994, Krasnova et al. 2009); it is unknown if this pattern also occurs in Cook Inlet belugas. If adult male belugas roam Cook Inlet as singles or in small segregated groups, the possibility exists that we are not encountering and identifying them due to a survey schedule designed to locate and photograph large conspicuous aggregations. Adult male belugas, perhaps because they were once the target of hunting, may also be more wary of vessels and may have left the area when the survey vessel approached.

Additional Information Provided by the Study

Several photographs of belugas contained marks indicative of trauma and disease. By documenting the occurrence and frequency of these marks and attempting to identify mark sources, more can be learned about the incidence of risk factors that may be preventing the recovery of the endangered CIBW population. The roped whale photographed in 2010 is an example.

Photo-identification has been used to characterize and quantify epidermal lesions on adult and young delphinids, providing information relevant to coastal environmental health (Wilson et al. 1999; Van Bressem et al. 2003, 2009; Bearzi et al. 2009). By

collaborating with other investigators, particularly those authorized to investigate mortalities (NMFS, stranding groups, and subsistence users), we could increase the utility of our documentation of skin lesions. We have created and distributed a protocol for photographing beluga mortalities (McGuire et al. 2009) that was made as a guide for stranding responders who are willing to photo-document markings on beluga mortalities. Matching of photographs of dead belugas to identified individuals in the catalog will provide information necessary for understanding survivorship and population dynamics.

Progress Made in 2010 and Dissemination of Project Results

Progress made in 2010 may be measured in terms of the number of field surveys conducted, the number of groups of whales photographed, the number of whales identified, and improvements in survey and data processing techniques. Project results are presented in reports that are available publically at http://www.fakr.noaa.gov/protectedresources/whales/beluga/research.htm#ci.

In 2010 and early 2011, project results from 2005-2010 were presented as talks and posters at scientific and public meetings, including posters at the Alaska Marine Science Symposium, and invited talks to the Anchorage School District, the Cook Inlet Beluga Recovery Team, ConocoPhillips (Anchorage and Kenai Offices), a seminar at Hatfield Marine Science Center at Oregon State University, and an invited talk and four poster presentations at the NMFS Cook Inlet Beluga Whale Research Symposium.

Communication of project results and collaboration with colleagues grow more productive with each continuing year of the project. Examples of existing partnerships we plan to maintain and expand in the future include: the exchange of information with NMFS about beluga locations during aerial (NMFS) and vessel (LGL) surveys during the field season; informing NMFS-AK of dead belugas (in some cases securing the carcass until NMFS is able to respond) and assisting with necropsies; informing the NMFS Office of Law Enforcement of suspected cases of beluga poaching and harassment; circulating photographs of injured or infected belugas to the Alaska Marine Mammal Stranding Network for expert opinion; exchange of whale sighting reports, photographs, and sighting history with wildlife biologists employed by the U.S. Army at Fort Richardson (now the DOD Joint Base); pairing our visual observations of CIBWs with acoustic recordings of belugas collected by the Alaska SeaLife Center, the National Marine Mammal Laboratory, the Alaska Department of Fish and Game, and the University of Hawaii; and sharing our beluga observation, data recording, and observer training expertise with the Friends of the Anchorage Coastal Refuge and Defenders of Wildlife's "Anchorage Coastal Beluga Survey Citizen Science Project".

Project Status and Future Work

Fieldwork from 2010 was completed 15 October. Cataloging of photographs from 2010 was completed 1 August 2011, and results are presented in the current report. Additional photo-identification surveys were conducted May-October 2011 and cataloging of those photographs is underway. Plans for 2012 include an increase in the

scope of photo-identification survey effort with a more-even distribution of survey effort throughout different locations. Increased sampling in those areas (Turnagain Arm, Chickaloon Bay/Southeast Fire Island, Middle Cook Inlet) and in those seasons which have had patchy survey effort in the past will provide the sample sizes necessary to rigorously test patterns that are beginning to emerge but have not been tested statistically.

Conclusion

The strength and utility of the photo-identification project grows with the proportion of the CIBW population that is photographed and identified. Photo-identification surveys from the existing six years of uninterrupted effort will continue to provide information about the distribution, habitat associations, behavior, color, and age-class compositions of CIBW groups, while identification of whales photographed during the surveys will continue to provide information about movement patterns, social structure, and life history characteristics of individually identified beluga whales. Continuation of a long-term data-set that provides insight into the population dynamics and life history of Cook Inlet beluga whales will help with the identification of appropriate conservation measures to recover and preserve the population.

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Table 1. Photo-identification survey effort and beluga whale groups encountered in 2010 in Upper Cook Inlet, Alaska. More than one location was occasionally surveyed during a single survey, therefore total surveys are not additive across the number of survey locations. (na = not applicable)

2010	Susitna River Delta	Knik Arm	Turnagain Arm	Chickaloon Bay/SE Fire Island	*Total for All Locations*
Number of Surveys	14	10	15	0	*35*
Total Number of Beluga Whale Groups	22	10	22	na	*54*
Total Number of Beluga Whale Sightings	973	214	254	na	*1441*
Mean Number of Groups per Survey	1.6	1.0	1.5	na	*1.5*
Mean Number of Whales per Survey	69.5	21.4	16.9	na	*41.2*
Mean Number of Whales per Group	44.2	21.4	11.5	na	*26.7*

Table 2. Distribution of photo-identification effort by month, week, and location in 2010 in Upper Cook Inlet, Alaska. Numbers in the table represent survey events in each area, where multiple areas were occasionally surveyed in a single day.

Month	Week	Susitna River Delta	Knik Arm	Turnagain Arm	Chickaloon Bay/SE Fire Island
May	**1**				
	2			1	
	3				
	4	1			
June	**1**				
	2	1			
	3	1			
	4	1	1		
July	**1**				
	2	1			
	3	2			
	4	1			
August	**1**	1			
	2	1		1	
	3	1	1	1	
	4	1	2	1	
	5	2	2	1	
September	**1**			4	
	2		1		
	3		1	2	
	4		1	1	
October	**1**			1	
	2		1	1	
	3			1	
	4				

Table 3. Group size, color, composition, and total belugas sighted during vessel surveys in the Susitna River Delta in 2010. Group numbers were assigned by day and will not sum to the total number of groups. (Neonates separate from calf total. Unknown = beluga of unknown color and size.)

Date	Beluga Group #	# White	# Gray	# Calves	# Neonates	# Unknown	***Total Belugas Sighted***
26-May-2010	1	93	51	6	0	0	***150***
11-Jun-2010	1	12	9	2	0	0	***23***
11-Jun-2010	2	30	15	2	0	0	***47***
21-Jun-2010	1	7	3	1	0	0	***11***
21-Jun-2010	2	0	0	0	0	3	***3***
21-Jun-2010	3	6	4	1	0	0	***11***
21-Jun-2010	4	4	1	1	0	0	***6***
21-Jun-2010	5	2	0	0	0	0	***2***
21-Jun-2010	6	9	1	1	0	0	***11***
21-Jun-2010	7	1	0	1	0	0	***2***
29-Jun-2010	0	0	0	0	0	0	***0***
9-Jul-2010	1	4	0	0	0	0	***4***
9-Jul-2010	2	7	3	2	0	0	***12***
16-Jul-2010	1	110	50	10	3	0	***173***
21-Jul-2010	1	60	50	6	2	0	***118***
29-Jul-2010	1	60	40	15	3	0	***118***
6-Aug-2010	1	2	0	0	0	0	***2***
6-Aug-2010	2	8	4	0	1	0	***13***
6-Aug-2010	3	45	20	2	2	0	***69***
12-Aug-2010	1	60	38	10	4	0	***112***
19-Aug-2010	1	26	15	3	2	0	***46***
20-Aug-2010	2	16	6	4	2	0	***28***
27-Aug-2010	2	6	3	2	1	0	***12***
31-Aug-2010	0	0	0	0	0	0	***0***
Total	***22***	***568***	***313***	***69***	***20***	***3***	***973***

Table 4. Group size, color, composition, and total belugas sighted during vessel surveys in Knik Arm in 2010. Group numbers were assigned by day and will not sum to the total number of groups. (Neonates separate from calf total. Unknown = beluga of unknown color and size.)

Date	Beluga Group #	# White	# Gray	# Calves	# Neonates	# Unknown	***Total Belugas Sighted***
29-Jun-2010	0	0	0	0	0	0	***0***
19-Aug-2010	1	18	9	7	1	2	***37***
20-Aug-2010	1	23	21	6	2	0	***52***
26-Aug-2010	1	10	3	3	1	0	***17***
27-Aug-2010	1	1	0	0	0	0	***1***
30-Aug-2010	1	12	6	2	1	0	***21***
10-Sep-2010	1	25	20	5	2	0	***52***
23-Sep-2010	1	6	6	3	1	0	***16***
27-Sep-2010	1	5	5	1	1	0	***12***
8-Oct-2010	1	2	0	0	0	0	***2***
8-Oct-2010	2	2	1	0	1	0	***4***
Total	***10***	***104***	***71***	***27***	***10***	***2***	***214***

Table 5. Group size, color, composition, and total belugas sighted during land and vessel surveys in Turnagain Arm in 2010. Group numbers were assigned by day and will not sum to the total number of groups. (Neonates separate from calf total. Unknown = beluga of unknown color and size.)

Date	Beluga Group #	# White	# Gray	# Calves	# Neonates	# Unknown	***Total Belugas Sighted***
9-May-2010	0	0	0	0	0	0	***0***
15-Aug-2010	0	0	0	0	0	0	***0***
20-Aug-2010	1	5	5	5	0	0	***15***
20-Aug-2010	2	0	0	0	0	50	***50***
28-Aug-2010	1	9	3	0	0	0	***12***
28-Aug-2010	2	0	0	0	1	20	***21***
29-Aug-2010	1	14	0	0	0	0	***14***
3-Sep-2010	1	1	0	0	0	0	***1***
3-Sep-2010	2	4	0	0	0	0	***4***
4-Sep-2010	1	8	3	2	0	0	***13***
5-Sep-2010	1	1	0	0	0	0	***1***
5-Sep-2010	2	2	0	0	0	0	***2***
5-Sep-2010	3	20	2	1	0	0	***23***
6-Sep-2010	1	1	0	0	0	0	***1***
6-Sep-2010	2	0	0	0	0	20	***20***
17-Sep-2010	1	0	0	0	0	10	***10***
19-Sep-2010	1	0	1	1	0	10	***12***
19-Sep-2010	2	0	0	0	0	20	***20***
26-Sep-2010	1	5	3	0	0	0	***8***
26-Sep-2010	2	2	2	1	0	0	***5***
4-Oct-2010	1	3	0	2	0	0	***5***
14-Oct-2010	1	3	0	0	0	0	***3***
15-Oct-2010	1	6	0	0	0	0	***6***
15-Oct-2010	2	8	0	0	0	0	***8***
Total	***22***	***92***	***19***	***12***	***1***	***130***	***254***

Table 6. Total project survey effort and beluga whale group encounters 2005-2010, Upper Cook Inlet, Alaska. (Chickaloon Bay = Chickaloon Bay/Southeast Fire Island)

	2005	2006	2007	2008	2009	2010	*Total*
Number Photo-identification Survey Days	49	38	23	32	32	35	***209***
Number Photos Taken	44,878	21,244	4,193	13,222	20,817	31,292	***135,646***
Number Groups Encountered	140	96	42	50	43	54	***425***
Range of Surveys	14 Apr-21 Oct	12 May-5 Oct	28 Jun-27 Oct	21 May-28 Oct	19 Jun-24 Oct	9 May-15 Oct	
Season Survey Span (Months)	6	5	4	5	4	5	
Areas Surveyed	Knik Arm, Susitna River Delta, Turnagain Arm	Chickaloon Bay, Knik Arm, Susitna River Delta, Turnagain Arm	Chickaloon Bay, Knik Arm, Susitna River Delta, Turnagain Arm	Chickaloon Bay, Knik Arm, Susitna River Delta, Turnagain Arm	Chickaloon Bay, Knik Arm, Susitna River Delta, Turnagain Arm	Knik Arm, Susitna River Delta, Turnagain Arm	

Table 7. Percent color composition of beluga whale sightings from surveys conducted in 2010 from vessels and land in Upper Cook Inlet, Alaska, according to location surveyed. (Chickaloon Bay = Chickaloon Bay/Southeast Fire Island)

Area	Survey Method	# Beluga Sightings	% White	% Gray	% Calves	% Neonates	% Unknown
Susitna River Delta	vessel	973	58	32	7	2	<1
Knik Arm	vessel	214	49	33	13	5	<1
Chickaloon Bay	vessel	0	N/A	N/A	N/A	N/A	N/A
Turnagain Arm	vessel and land	254	36	7	5	<1	52
All Areas 2010		***1441***	***53***	***28***	***7.5***	***2***	***9.5***

Table 8. Summary of primary and secondary activities of beluga groups encountered in 2010 during vessel and land surveys in Upper Cook Inlet. Surveys were not conducted in Chickaloon Bay/Southeast Fire Island in 2010.

		Percent of all Group Activity Recorded per Area				
Area	Group Activity	% Traveling	% Milling	% Suspected Feeding	% Diving	% Unknown
Knik Arm	Primary	50	20	0	30	0
Susitna River Delta	Primary	42	21	21	16	0
Turnagain Arm	Primary	73	4	4	14	4
Knik Arm	Secondary	43	14	14	29	0
Susitna River Delta	Secondary	17	12	59	12	0
Turnagain Arm	Secondary	20	20	40	20	0

Table 9. Sighting records of 15 individual belugas identified and cataloged each year from 2005 to 2010, according to year and location. (P = photographed)

	Knik Arm						Susitna River Delta						Turnagain Arm						Chickaloon Bay/ SE Fire Island					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
	# of Surveys						# of Surveys						# of Surveys						# of Surveys					
WHALE ID	32	15	10	12	12	10	17	21	4	8	15	14	1	6	8	12	12	15	0	1	1	2	1	0
R3	P	P	P	P	P			P	P	P	P	P												
R4	P	P		P				P	P		P	P												
R11	P	P	P	P		P	P		P	P	P	P												
R70	P	P			P			P	P	P	P	P		P				P						
R100	P	P			P				P	P	P	P												
R103	P	P	P	P		P	P	P		P	P	P				P								
R106	P		P	P				P		P	P	P												
R109	P	P	P						P	P	P	P												
R110	P	P	P	P	P		P	P		P	P	P												
R115	P		P	P	P		P		P	P	P	P		P	P			P						
R118		P		P			P	P	P	P	P	P												
R150	P	P	P	P			P	P		P	P	P												
R206	P				P			P	P	P	P	P												
R225	P				P			P	P	P		P												
R245	P	P		P	P			P	P		P	P												

Table 10. Mean percent of the group cataloged, mean group size, and number of surveys per area in 2010 in Upper Cook Inlet, Alaska.

Area	Mean # Cataloged Belugas/Survey	Mean % of Group Cataloged	Mean Group Size	# of Surveys
Susitna River Delta	9.0	12	44.2	14
Knik Arm	3.4	13	21.4	10
Turnagain Arm	0.5	2	11.4	15

Table 11. Yearly sighting records of 129 individual beluga whales assumed to be mothers based on the close accompaniment of a calf at least once during 2005-2010. (C = photographed with a calf, P = photographed without a calf)

	2005	2006	2007	2008	2009	2010	# Years seen with a calf	Calf Age Information Inferred from Individuals seen with Calves >1 year (CBD=could not be determined)
	# of Surveys							
WHALE ID	**49**	**38**	**23**	**32**	**32**	**35**		
R100	C	C	C	C	C	P	5	maturing calf
R109	C	C	P	C	C	P	4	CBD
R224	C	C	P	P	C	C	4	CBD 2005/2006; smaller calf in 2009/maturing 2010
R206	P	C	P	P	C	C	3	CBD
R11	C	P	P	C	C	P	3	CBD
R34	C	P	P	C	C		3	smaller calf in 2008 than 2005; maturing 2009
R51	C	C		P	C	P	3	cbd 2005/2006; maturing 2006/ 2009
R52	P	C	C	P	C		3	cbd 2006/2007; maturing 2007/2009
R68	C			C	C	P	3	cbd 2005/2008; maturing 2008/2009
R75	P	C		P	C	C	3	CBD
R84		C		C	C		3	CBD
R90	P	C		C	C		3	CBD 2006/2008; maturing 2008/2009
R101	P	C		C	P	C	3	CBD 2006/2008; large and small calf in 2008; new calf 2010?
R110	P	C	P	C	C	P	3	maturing calf 2006/2008/2009
R112	P	C		C	C	P	3	maturing 2006/2008; large and small calf in 2009
R157	C		P	C	C		3	CBD (died Oct 2009 while pregnant)
R219	P	C	C	C	P		3	maturing calf
R530		C	C	P	C		3	CBD2006/2007; 2007/2009 maturing
R4	C	C	P	P	P	P	2	CBD
R6	P	P			C	C	2	CBD
R18	P				C	C	2	maturing calf 2009/2010
R23	C	P	C				2	CBD
R25	C	P		C	P	P	2	CBD
R26	P		P	P	C	C	2	maturing calf
R35	P	C		P	C		2	maturing calf (neonate in 2006)
R38	P	C		P	C	P	2	2009 calf smaller
R44	C	P	P	P	C		2	CBD
R53	P			C	C		2	maturing calf
R60	P		C	C	P		2	CBD
R66	C	P	C	P	P		2	maturing calf
R67	C		P	C			2	CBD
R72	P	C	P	P	C		2	CBD
R86	P	C	P	C			2	maturing calf
R96		P	P	C	P	C	2	maturing calf
R102	C	P	P	P	C		2	CBD
R103	P	P	C	C	P	P	2	maturing calf
R106	C	P	P	P	P	C	2	CBD
R125	P	P			C	C	2	maturing calf 2009/2010, plus new calf 2010
R128	P	P		C		C	2	maturing 2008/2010, big calf and small calf 2010
R137	P			C	C		2	maturing calf

Table 11. Continued.

	2005	2006	2007	2008	2009	2010	# Years seen with a calf	Calf Age Information Inferred from Individuals seen with Calves >1 year (CBD=could not be determined)
	# of Surveys							
WHALE ID	**49**	**38**	**23**	**32**	**32**	**35**		
R158	P	P		C	P	C	2	CBD
R198	P	P	P	C	C	P	2	maturing calf
R200	P				C	C	2	maturing calf
R220	P		C	C	P		2	maturing calf
R245	P	C	P	C	P	P	2	CBD
R521		P		P	C	C	2	maturing calf
R545		C		P		C	2	new calf in 2010
R1014				C	C		2	CBD
R1086		P		C	C		2	maturing calf
R1220				C	C	P	2	maturing calf
R1268				C	C		2	CBD
R1365				C	C		2	maturing calf
R1368				C	P	C	2	CBD
R3029					C	C	2	CBD
R3	P	C	P	C	P	P	2	maturing calf
R8	C	P				P	1	
R9	P		P	P	C		1	
R12	C						1	
R15	P	P	P	C			1	
R16	C	P	P				1	
R17	P			C	P	P	1	
R19	P	P		C			1	
R37	C				P	P	1	
R47	P			P	C		1	
R48	C	P					1	
R49	P	P		C		P	1	
R50	P	P	P	C			1	
R56	P	P	C				1	
R61	P			C			1	
R62	C						1	
R63		C		P			1	
R82	C	P					1	
R85	C	P		P	P		1	
R87	P	P		C	P		1	
R92		P	P	P	C		1	
R97		P		C			1	
R104	P		P		P	C	1	
R108	P	P				C	1	
R111	P		P	P	C	P	1	
R115	P	P	P	C	P	P	1	
R122	P	P		C	P	P	1	
R123	C						1	
R134	P		C		P	P	1	
R143	P		P	P	P	C	1	
R152	P	C		P			1	
R156	P		C				1	
R165	P	P	P	C			1	
R166	P			C			1	
R176	C	P		P	P		1	
R180	P	P		P	C	P	1	
R195	P			C			1	
R225	P	P	P	C	P	P	1	

Table 11. Continued.

	2005	2006	2007	2008	2009	2010	# Years seen with a calf	Calf Age Information Inferred from Individuals seen with Calves >1 year (CBD=could not be determined)
	# of Surveys							
WHALE ID	**49**	**38**	**23**	**32**	**32**	**35**		
R232		P		C			1	
R515		P		P	C		1	
R519			C	P		P	1	
R522		C		P			1	
R523		C		P			1	
R527			C		P	P	1	
R529		C					1	
R536		P		C			1	
R538		C					1	
R540		C		P	P		1	
R544		C					1	
R549		C					1	
R594			P	C	P	P	1	
R624			P		C		1	
R651		P	C				1	
R800	P				C		1	
R808	P				C	P	1	
R875				P	C		1	
R1048				C	P		1	
R1128				P	P	C	1	
R1137				P	C	P	1	
R1168				P	C		1	
R1238				P	C	P	1	
R1358				C	P	P	1	
R1416		P	C				1	
R2904					C		1	
R3121					C		1	
R3138					C		1	
R3203					P	C	1	
R3229					C		1	
R3305				P	C		1	
R3399					C		1	
R3400					C		1	
R3470					P	C	1	
R4108						C	1	
R177	P	P		P	C		1	
R1106			P	P	C		1	

Table 12. Yearly sighting records of 12 individual beluga whales assumed to be calves based on the close proximity of a larger, whiter beluga at least once during 2005-2010. (P = photographed without a calf, C = photographed with a calf)

	2005	2006	2007	2008	2009	2010	
	# of Surveys						
WHALE ID	49	38	23	32	32	35	Size Estimates/Comments
R177	P	P		P	C		Was the calf in 2005/6; seen with own calf in 2009
R206	P	C	P	P	C	C	Large calf of R92; seen with own calf in 2006 & 2009 & 2010
R519			P	P		P	Large calf (=2/3 length of associated adult)
R534		P		P	P		Large calf (=2/3 length of associated adult)
R1081				C	C	P	Large calf (=2/3 length of associated adult), may be calf of R109; small calf in 2008/9 is either calf of R1081 or younger sibling
R1187				P	P	P	Large calf (=2/3 length of associated adult)
R1228				P			Skin disease/injury; mother is R67
R1293			P	P		P	Large calf (=2/3 length of associated adult)
R1318				P	P		Large calf (=2/3 length of associated adult)
R1319				P	P		Large calf (=2/3 length of associated adult); might be calf of R103
R3390					C		Large calf (=2/3 length of associated adult); has an adult and small calf or younger sibling next to it
R1438				P		P	Large calf (=2/3 length of associated adult)

Table 13. Sighting records of seven individual belugas that were identified by scars from satellite tags applied by NMFS between 1999 and 2002, according to year and location in 2005-2010. (P = photographed, C = photographed with a calf)

	Knik Arm						Susitna River Delta						Turnagain Arm						Chickaloon Bay/ SE Fire Island					
	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010	2005	2006	2007	2008	2009	2010
	# of Surveys						# of Surveys						# of Surveys						# of Surveys					
WHALE ID	32	15	10	12	12	10	17	21	4	8	15	14	1	6	8	12	12	15	0	1	1	2	1	0
R96			P	P				P	P	P	P	C		P										
R103	P	P	C	C		P	P	P	P	P	P	P				P								
R114	P		P				P		P							P								
R115	P		P	P	P		P		P	C	P	P		P	P			P						
R549		C																						
R243	P		P				P			P	P	P												
R111	P				P		P		P	P	C	P												

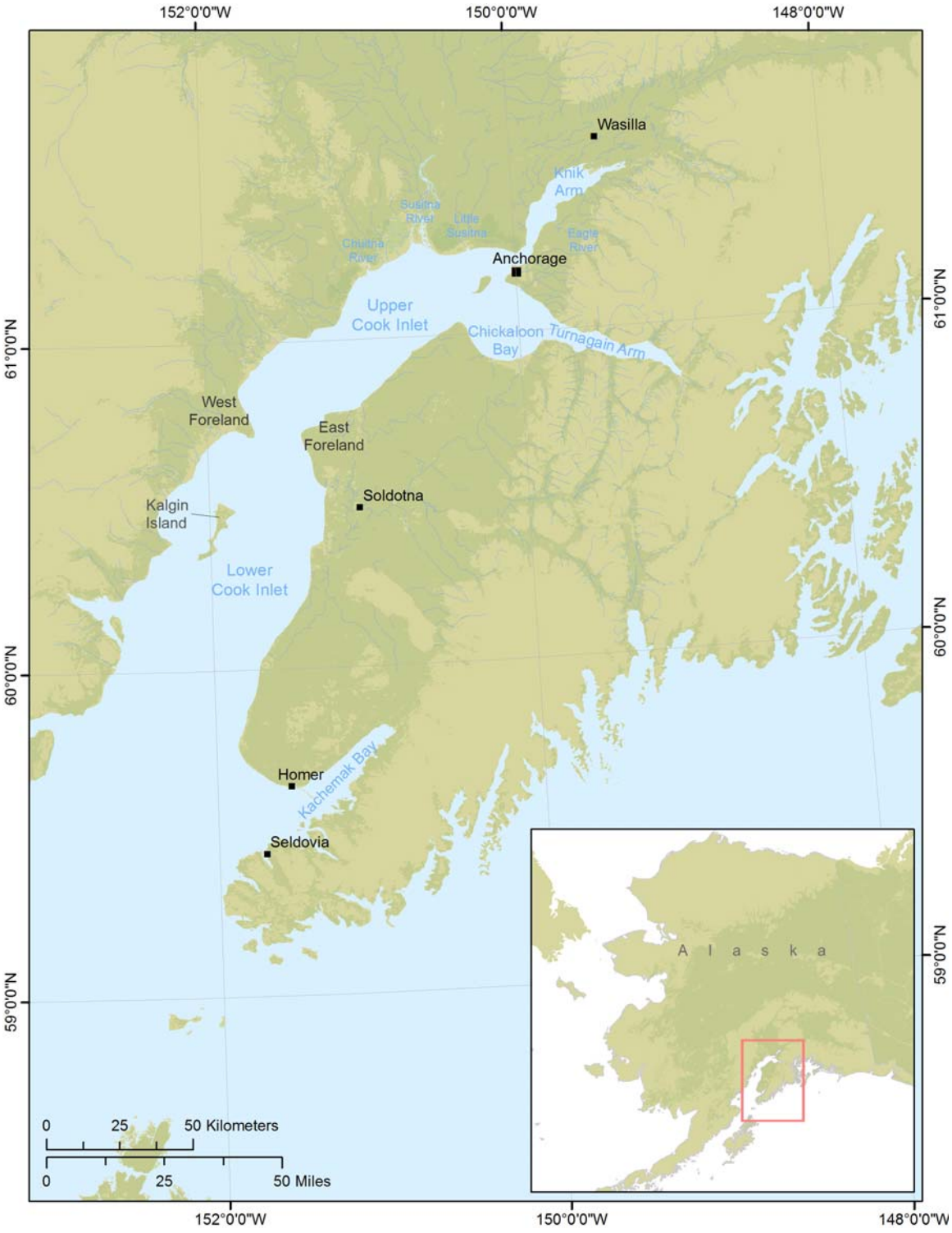

Figure 1. Map of Cook Inlet, Alaska, showing major features discussed in text.

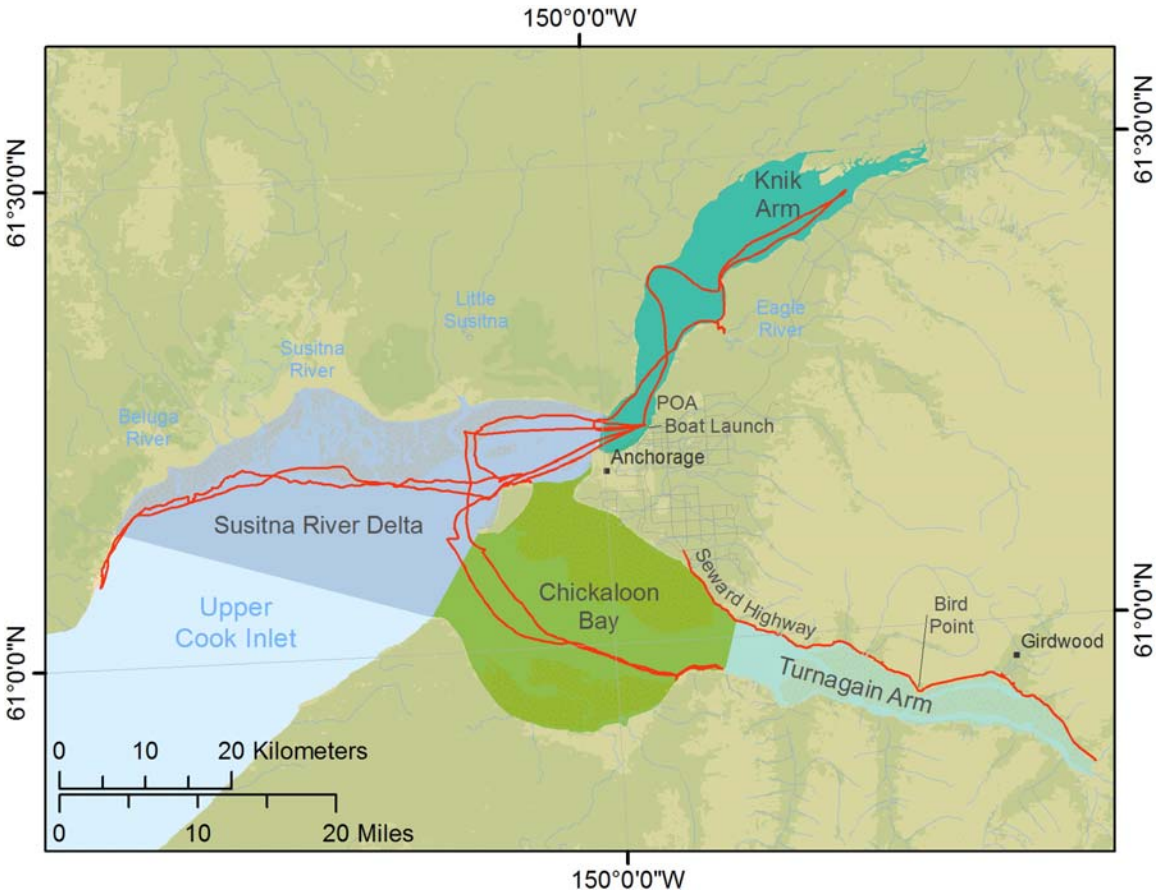

Figure 2. Map of Upper Cook Inlet, Alaska, showing boundaries of four sub-areas within the study area and the vessel- and land-based survey routes used during 2005-2010. Chickaloon Bay was not surveyed in 2010.

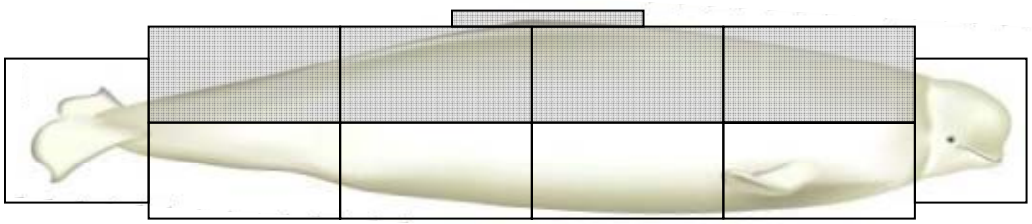

Figure 3. Diagram showing the various segments used when cataloging. The five shaded areas were the critical sections used in matching marks. Beluga illustration courtesy of Uko Gorter.

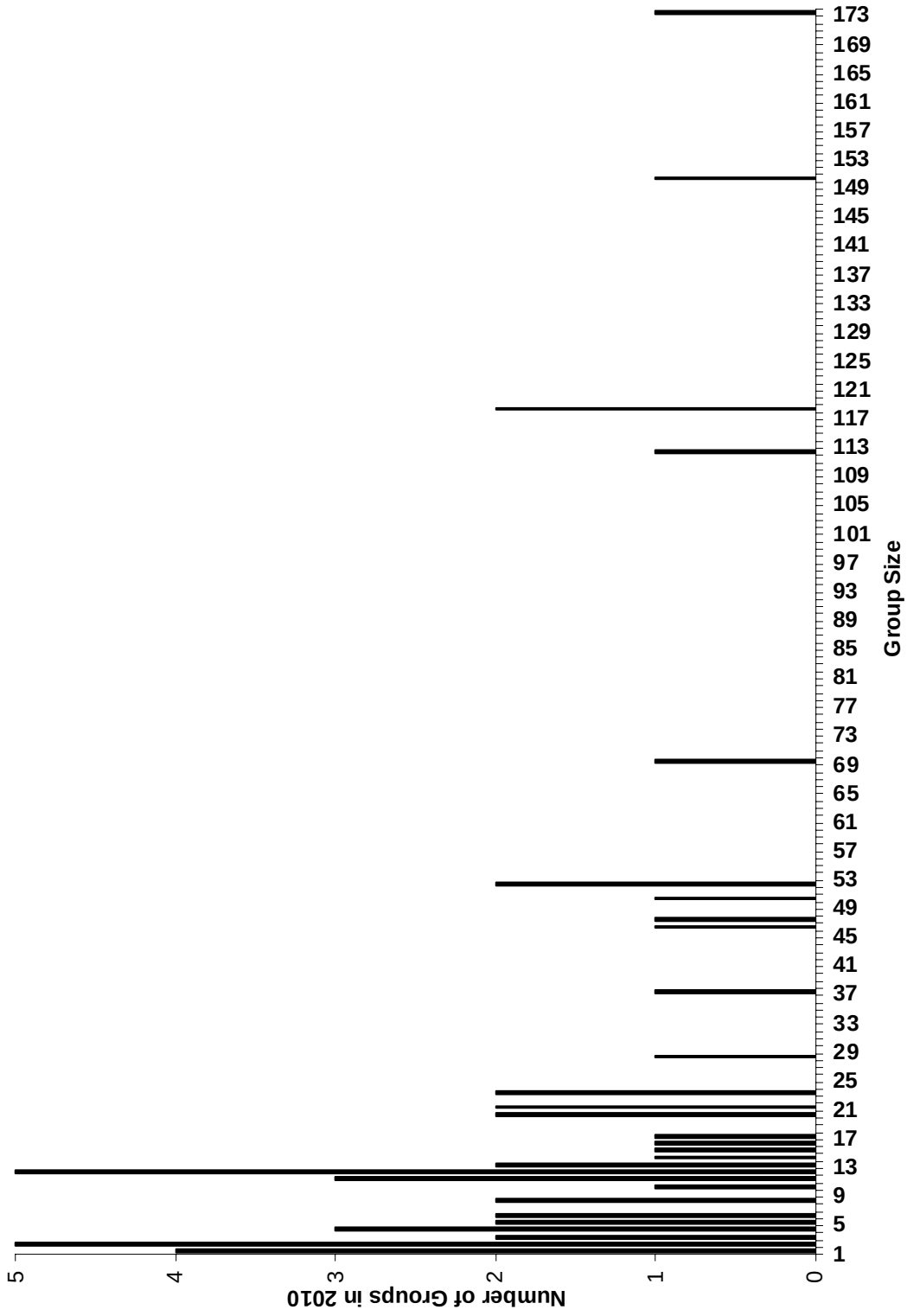

Figure 4. Group-size frequency distribution of beluga whales encountered during photo-identification surveys of Upper Cook Inlet conducted from land and vessels in 2010 (n = 54 groups).

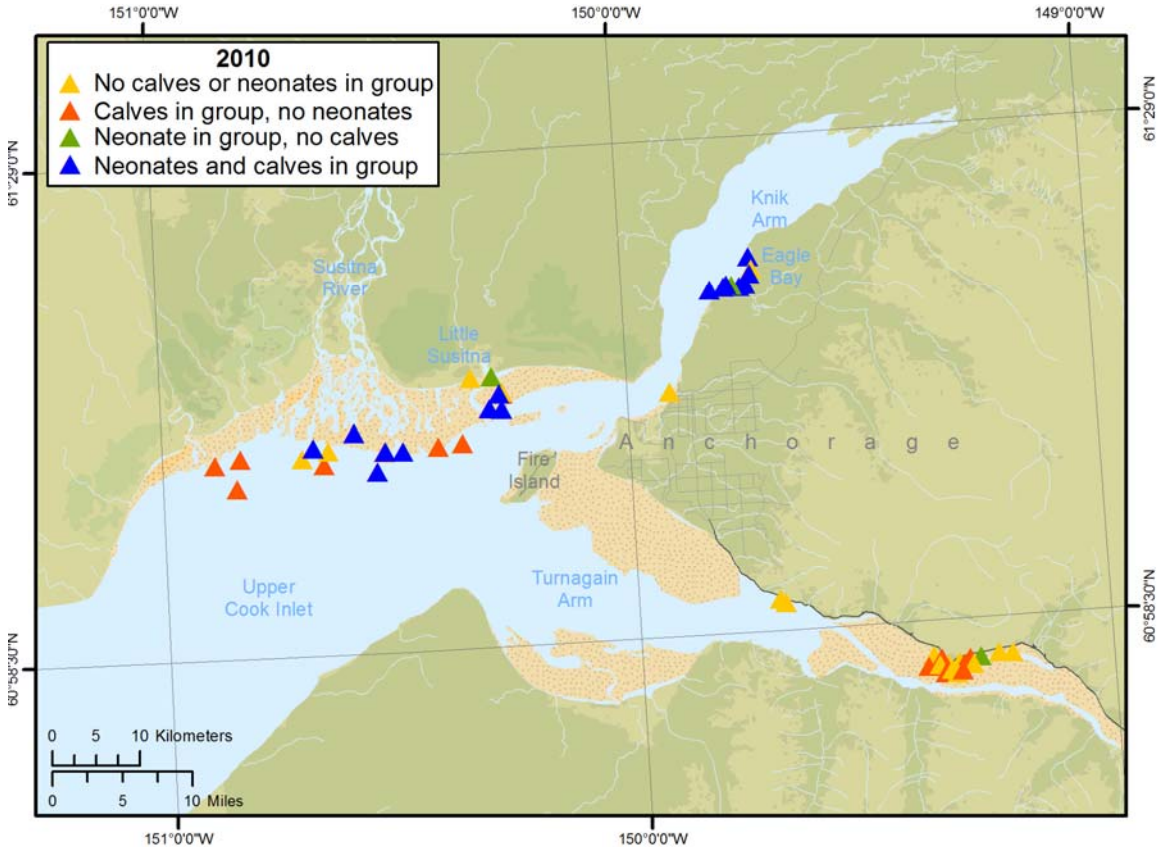

Figure 5. Location of groups with and without calves and neonates encountered during land- and vessel-based photo-identification surveys of Upper Cook Inlet, Alaska in 2010.

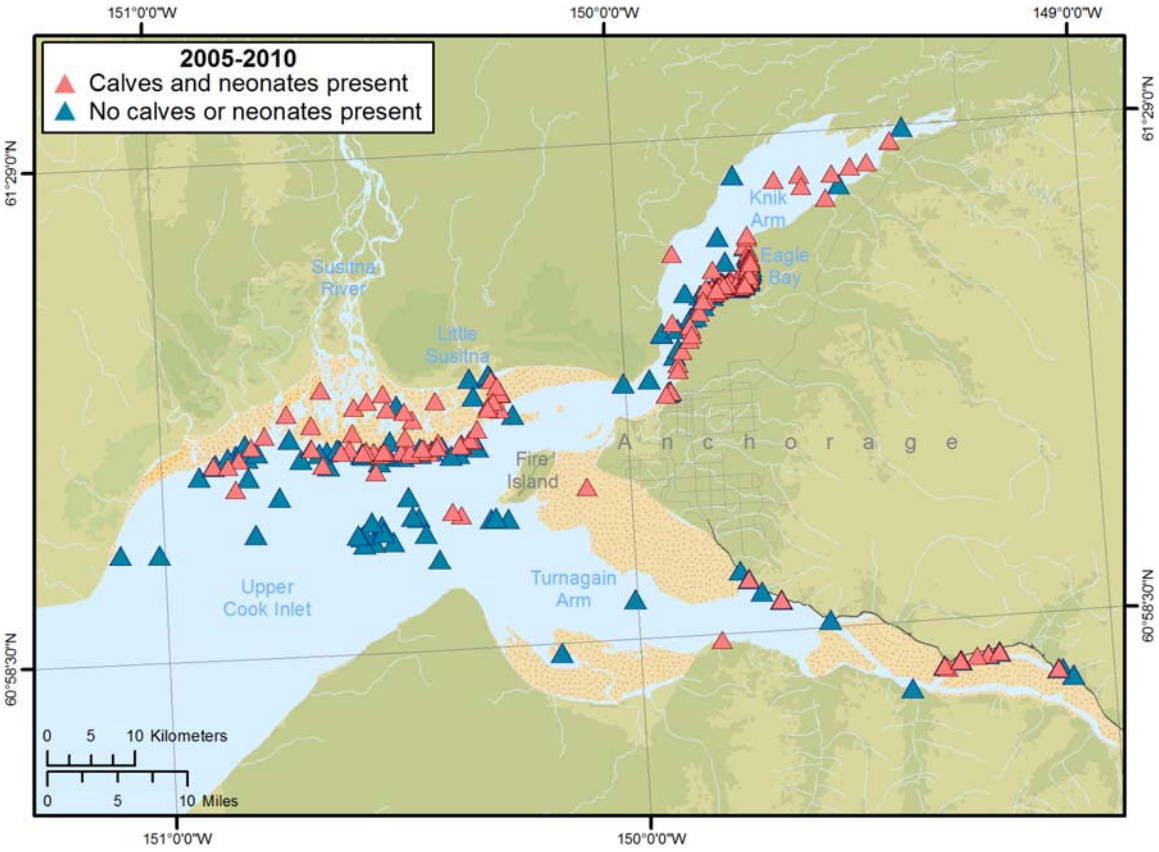

Figure 6. Location of all groups with and without calves and neonates encountered during land-and vessel-based photo-identification surveys of Upper Cook Inlet, Alaska 2005-2010.

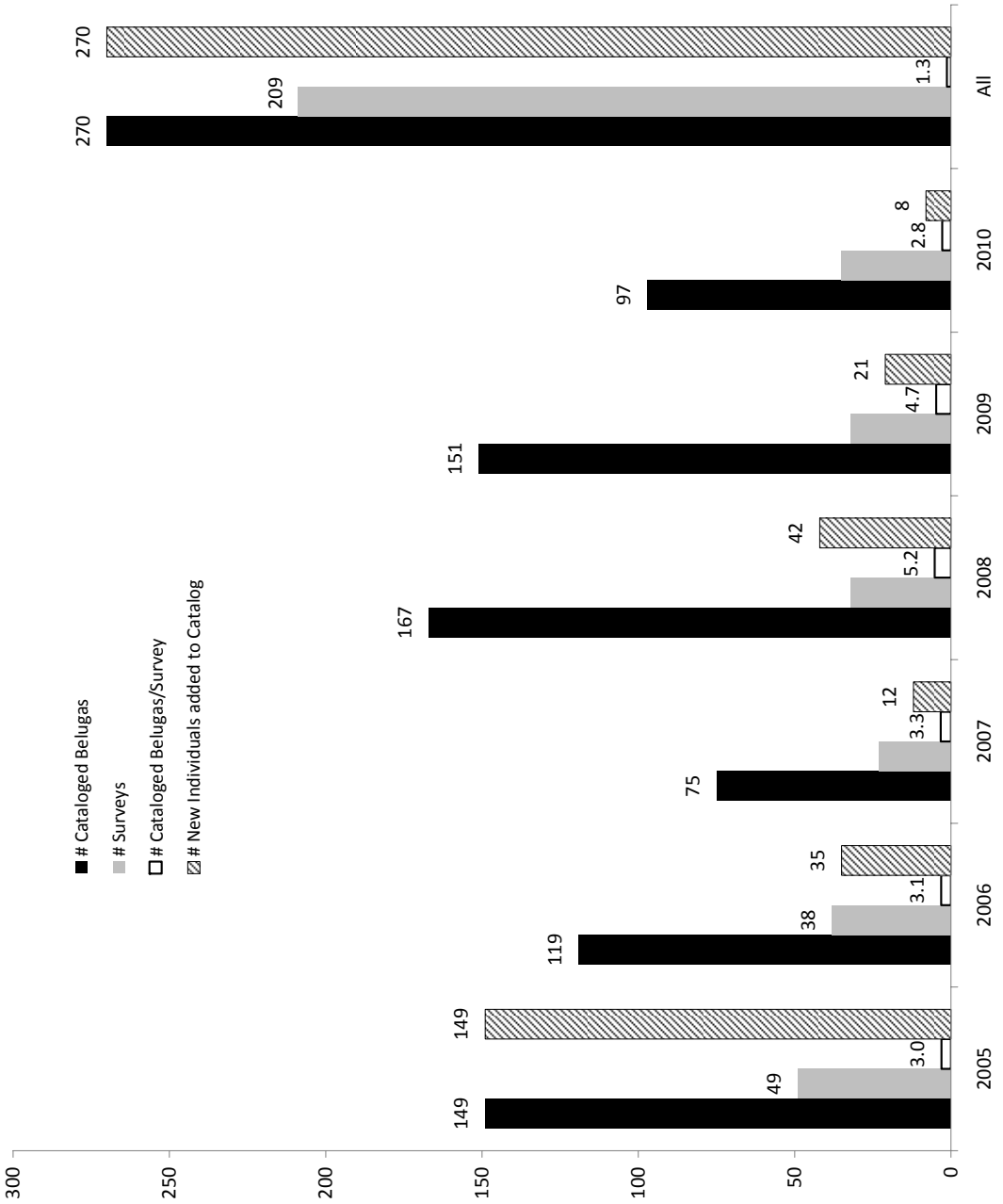

Figure 7. Number of belugas cataloged per year and yearly survey effort, 2005-2010.

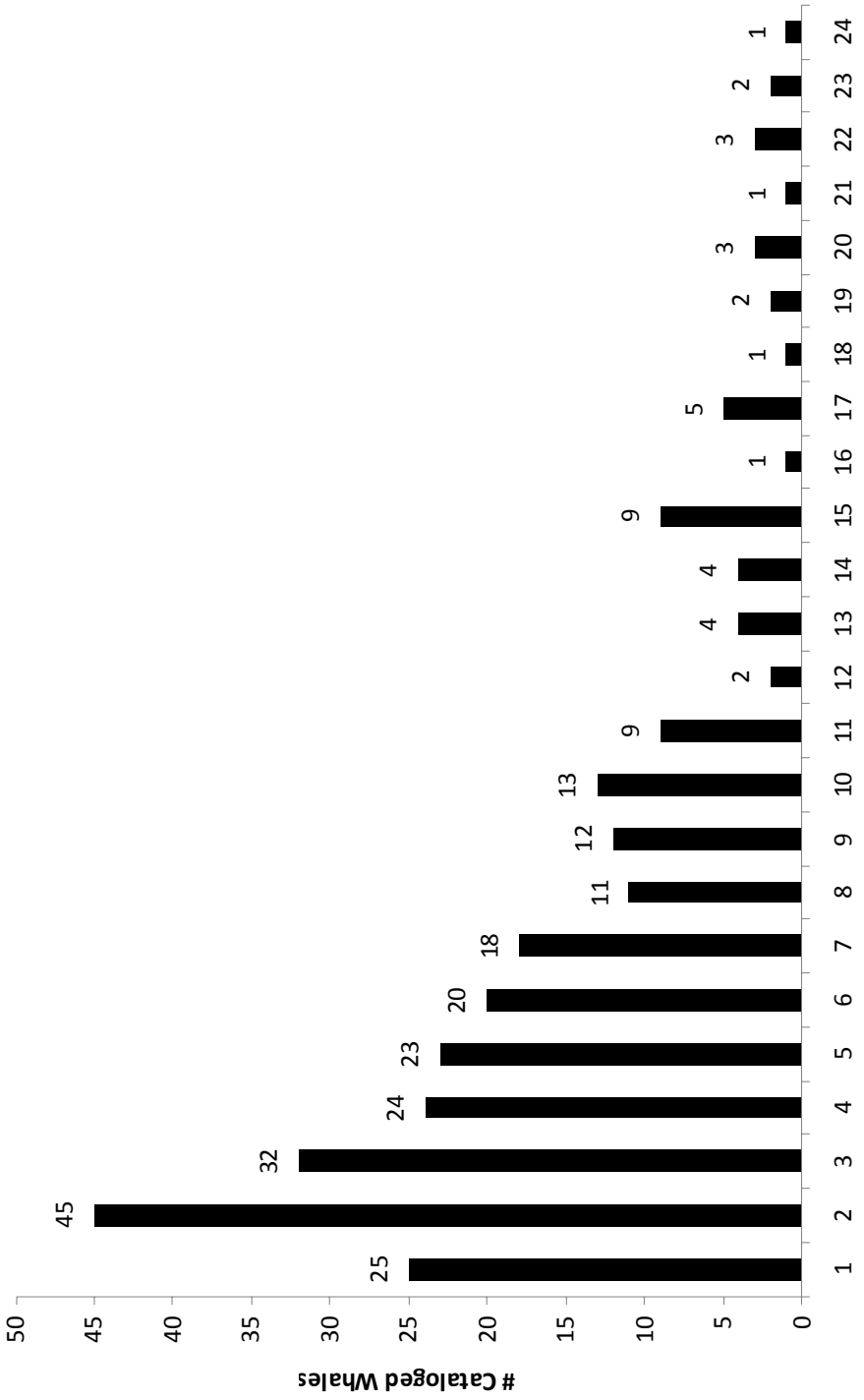

Figure 8. The number of days cataloged whales were re-sighted from 2005-2010.

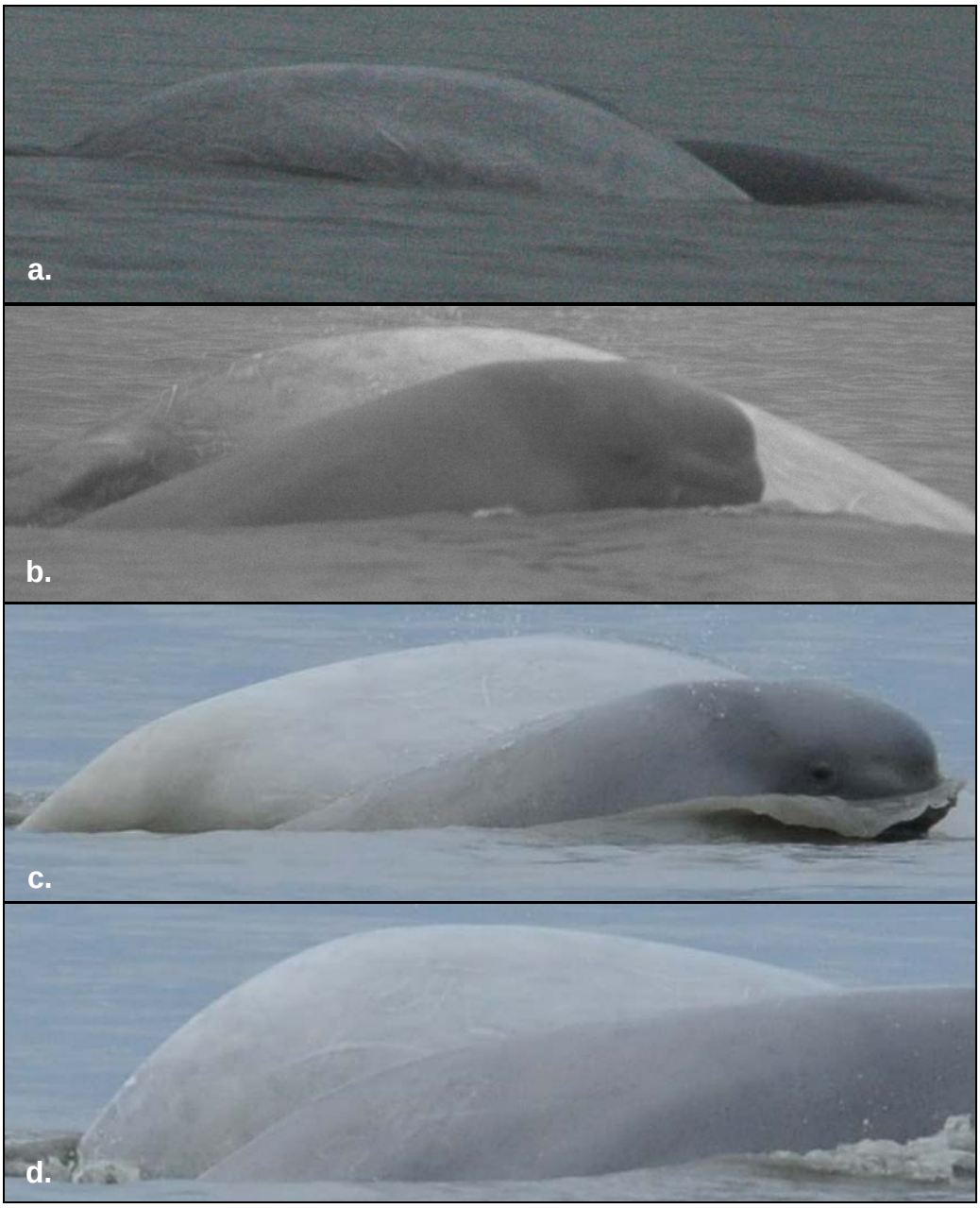

Figure 9. Adult beluga R90 accompanied by a calf in 2006 (a), 2008 (b), and 2009 (c and d). Size/age difference of calf between 2006 and 2008 cannot be determined. Calf appears to be maturing between 2008 and 2009.

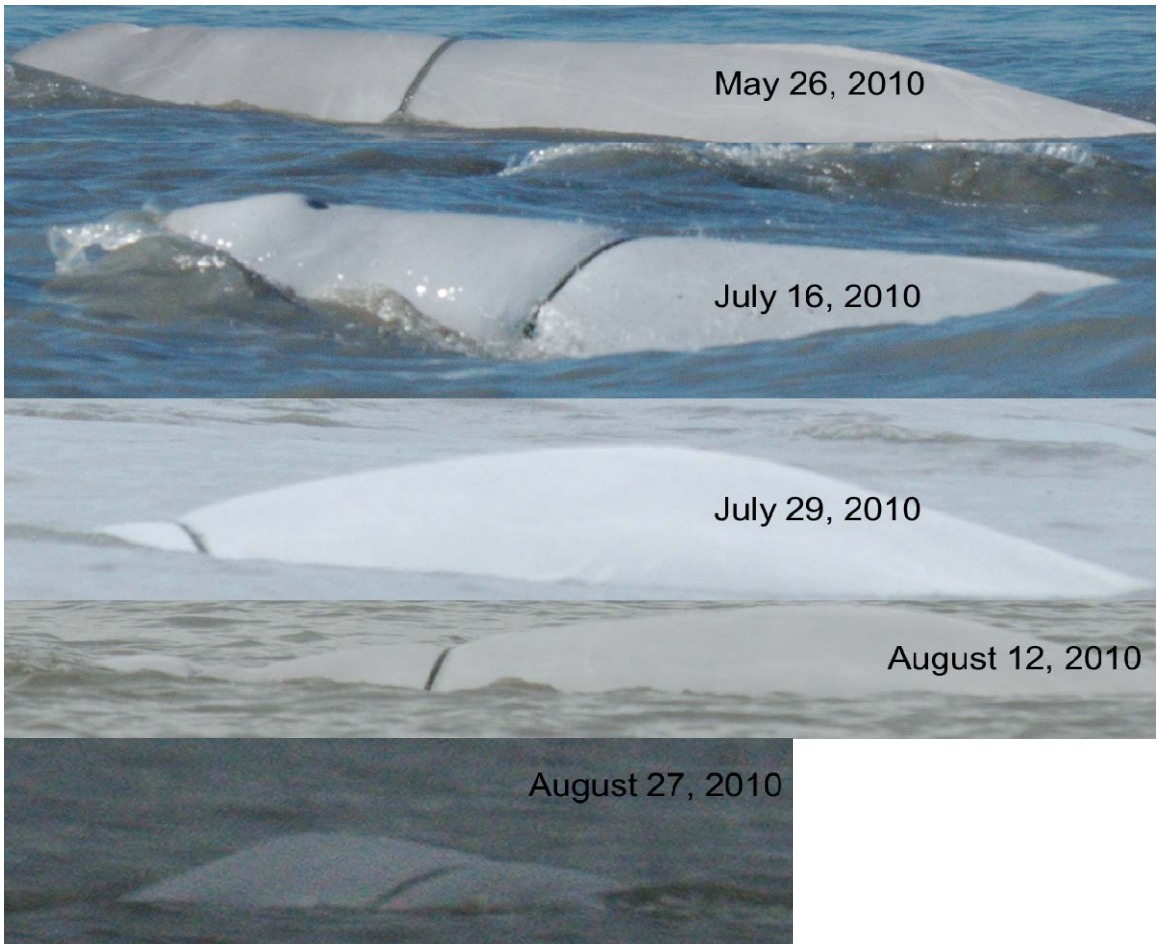

Figure 10. Sightings during the 2010 field season of an entangled beluga. Natural marks were used to identify this animal as the same individual. The top four images are of the left side of the body, and the bottom image is of the right side of the body.

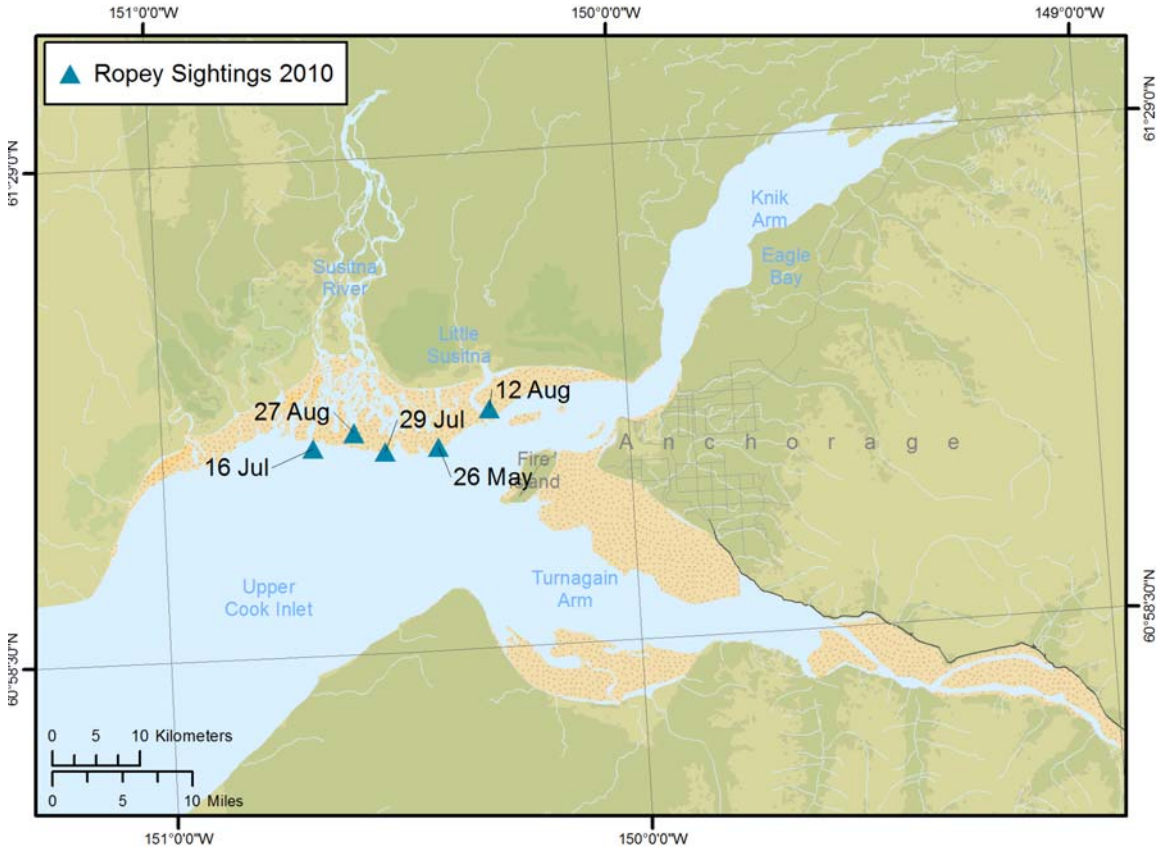

Figure 11. Sighting history of entangled whale during the 2010 field season in Upper Cook Inlet.

APPENDIX A

BELUGA WHALE GROUPS ENCOUNTERED DURING LAND- AND VESSEL-BASED SURVEYS CONDUCTED IN UPPER COOK INLET, ALASKA.

DAILY SURVEY TRACKS AND LOCATIONS OF WHALES, 2010 FIELD SEASON

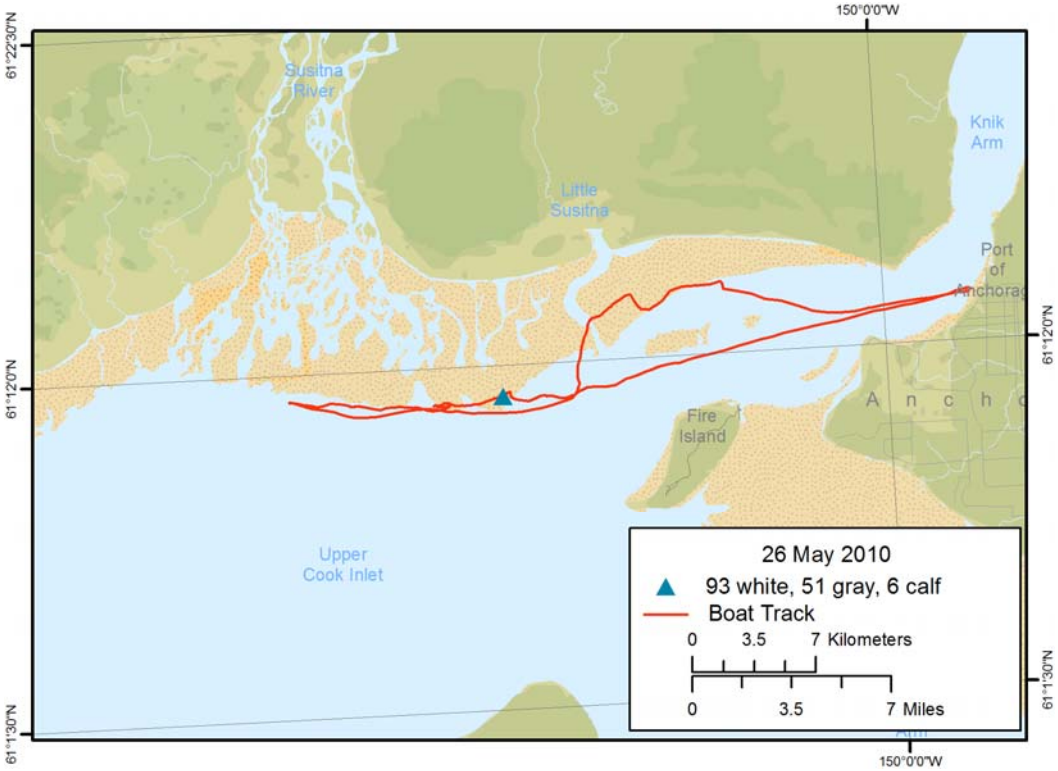

Figure A1. Route and beluga whale group(s) encountered during the vessel-based survey route of 26 May 2010 in Upper Cook Inlet, Alaska.

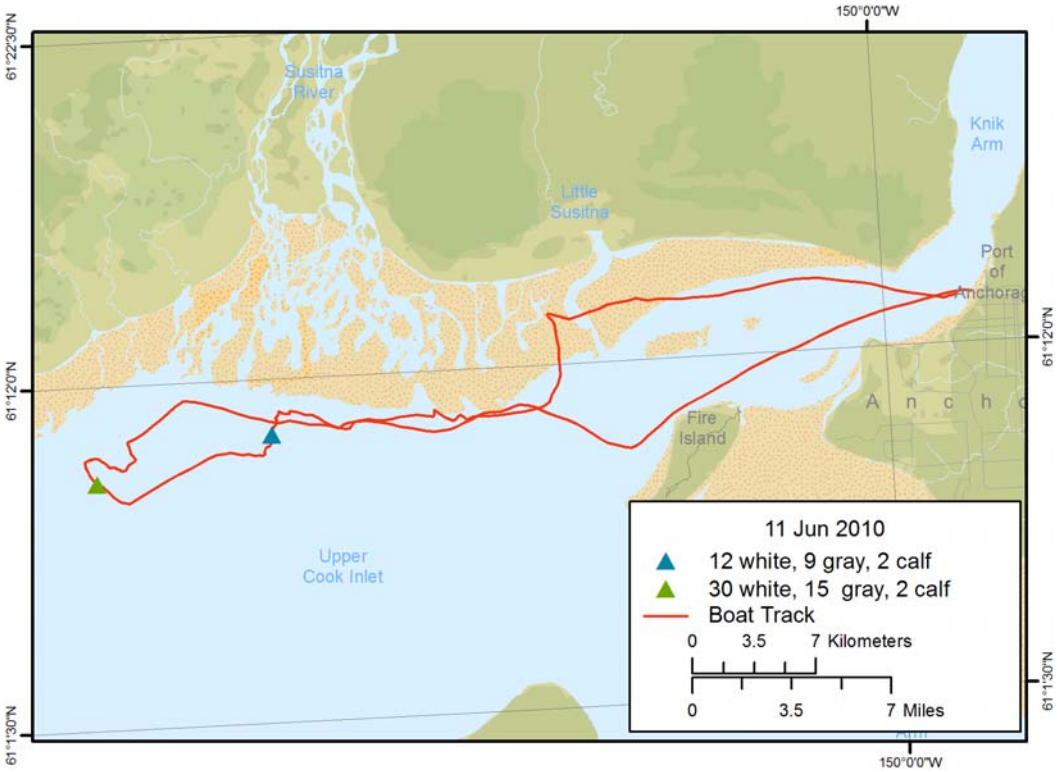

Figure A2. Route and beluga whale group(s) encountered during the vessel-based survey route of 11 June 2010 in Upper Cook Inlet, Alaska.

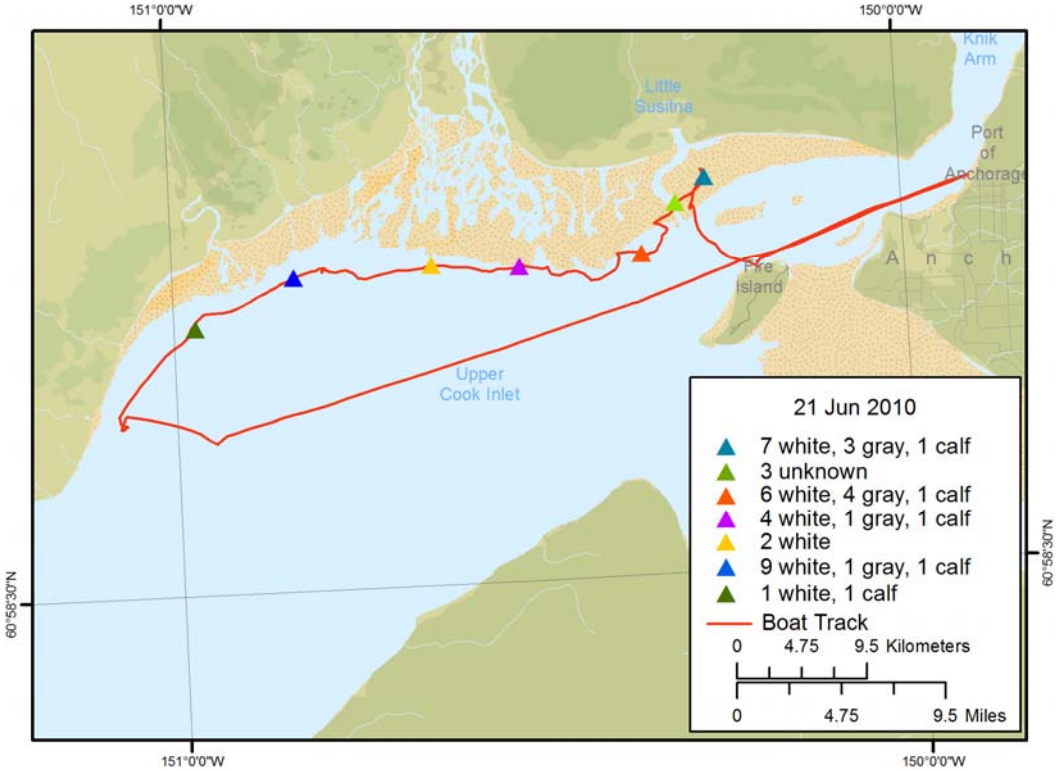

Figure A3. Route and beluga whale group(s) encountered during the vessel-based survey route of 21 June 2010 in Upper Cook Inlet, Alaska.

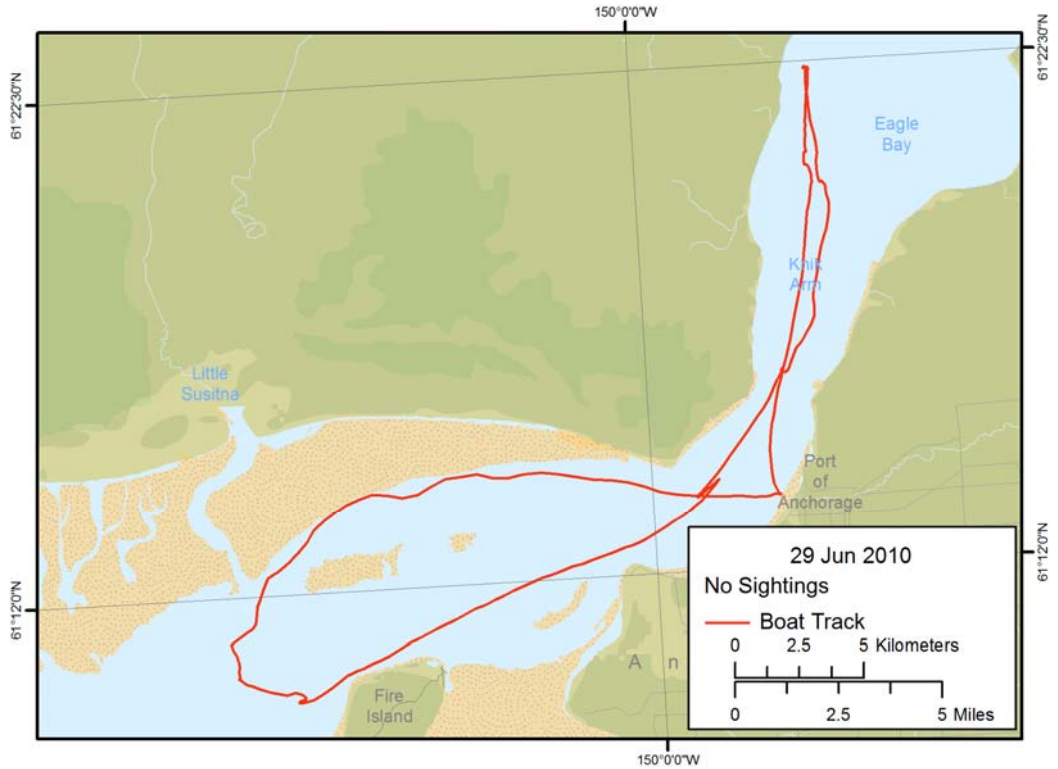

Figure A4. Route and beluga whale group(s) encountered during the vessel-based survey route of 29 June 2010 in Upper Cook Inlet, Alaska. No belugas were encountered during this survey.

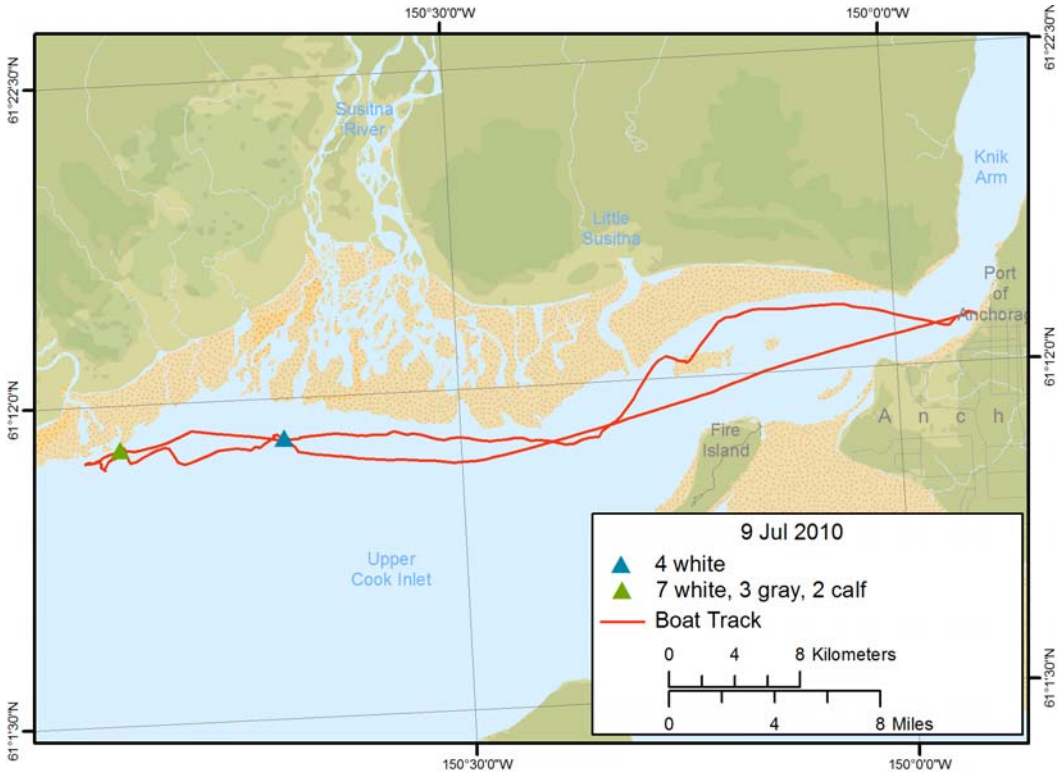

Figure A5. Route and beluga whale group(s) encountered during the vessel-based survey route of 9 July 2010 in Upper Cook Inlet, Alaska.

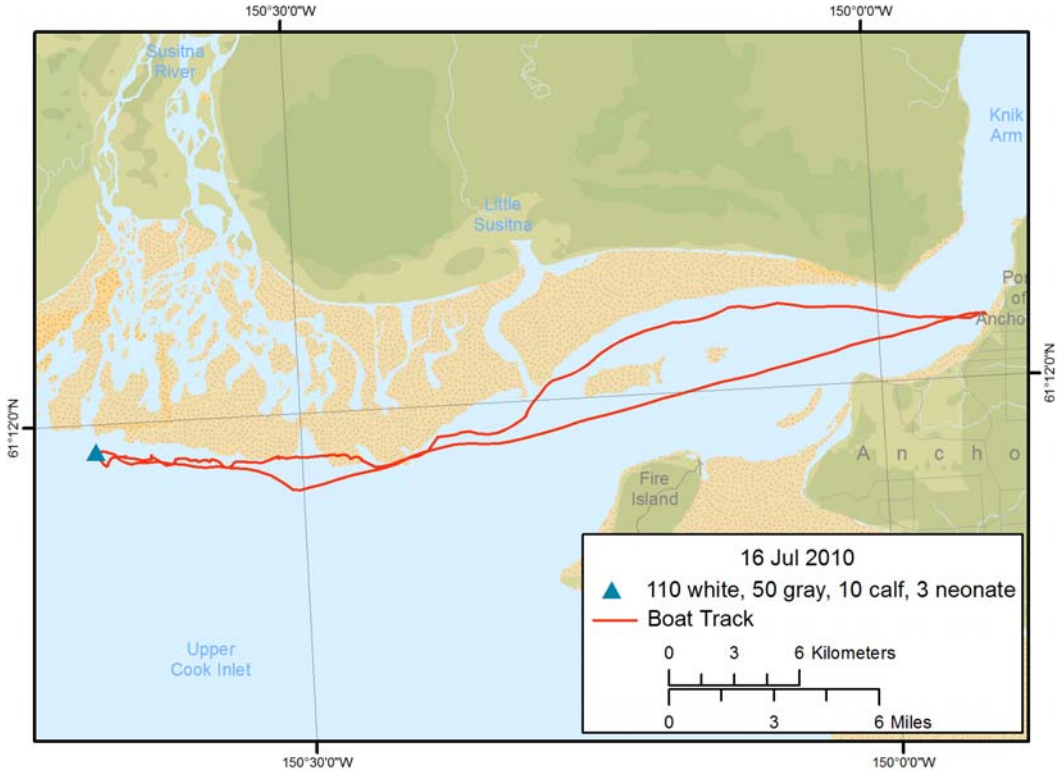

Figure A6. Route and beluga whale group(s) encountered during the vessel-based survey route of 16 July 2010 in Upper Cook Inlet, Alaska.

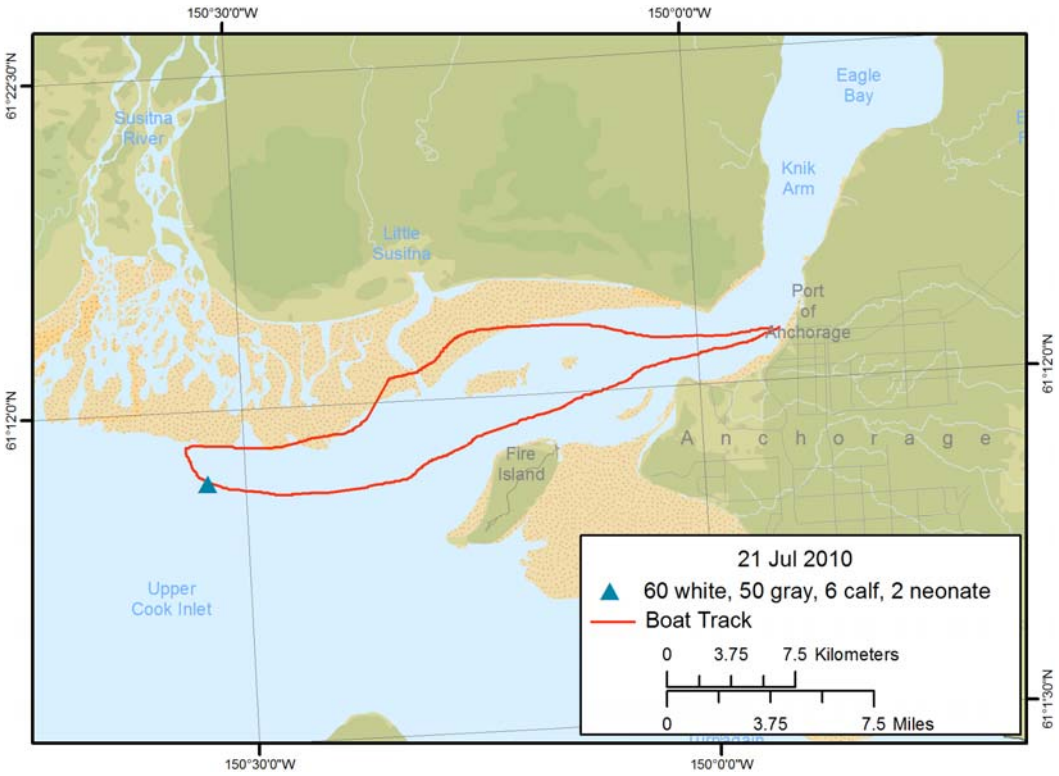

Figure A7. Route and beluga whale group(s) encountered during the vessel-based survey route of 21 July 2010 in Upper Cook Inlet, Alaska.

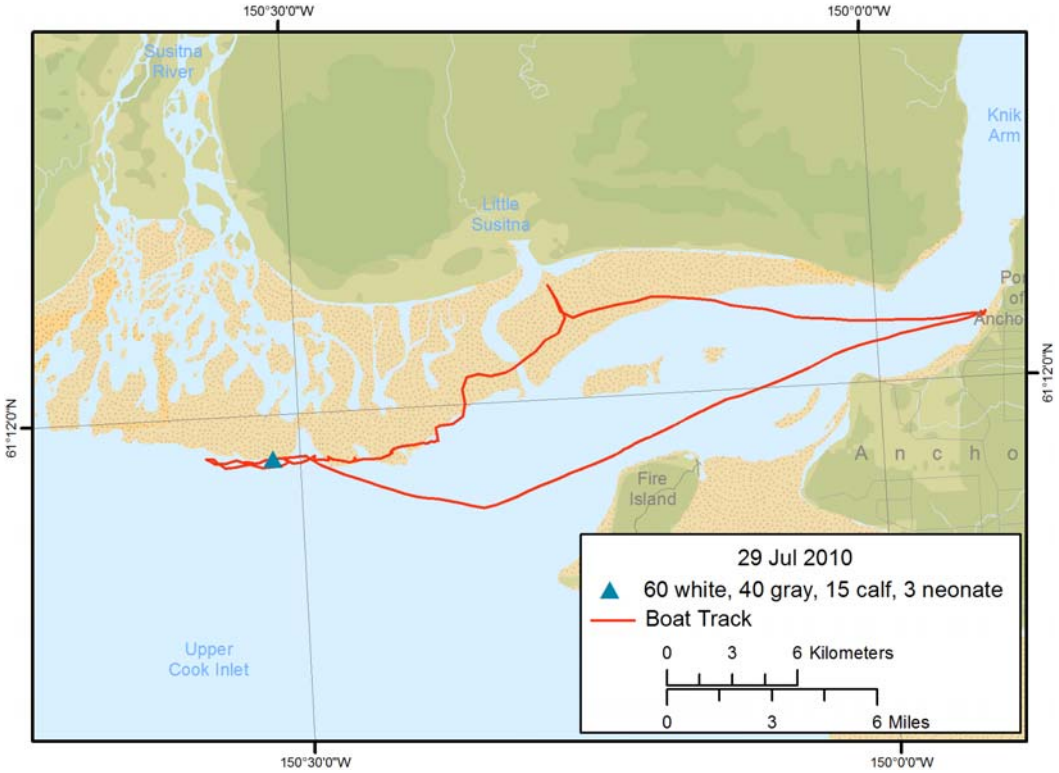

Figure A8. Route and beluga whale group(s) encountered during the vessel-based survey route of 29 July 2010 in Upper Cook Inlet, Alaska.

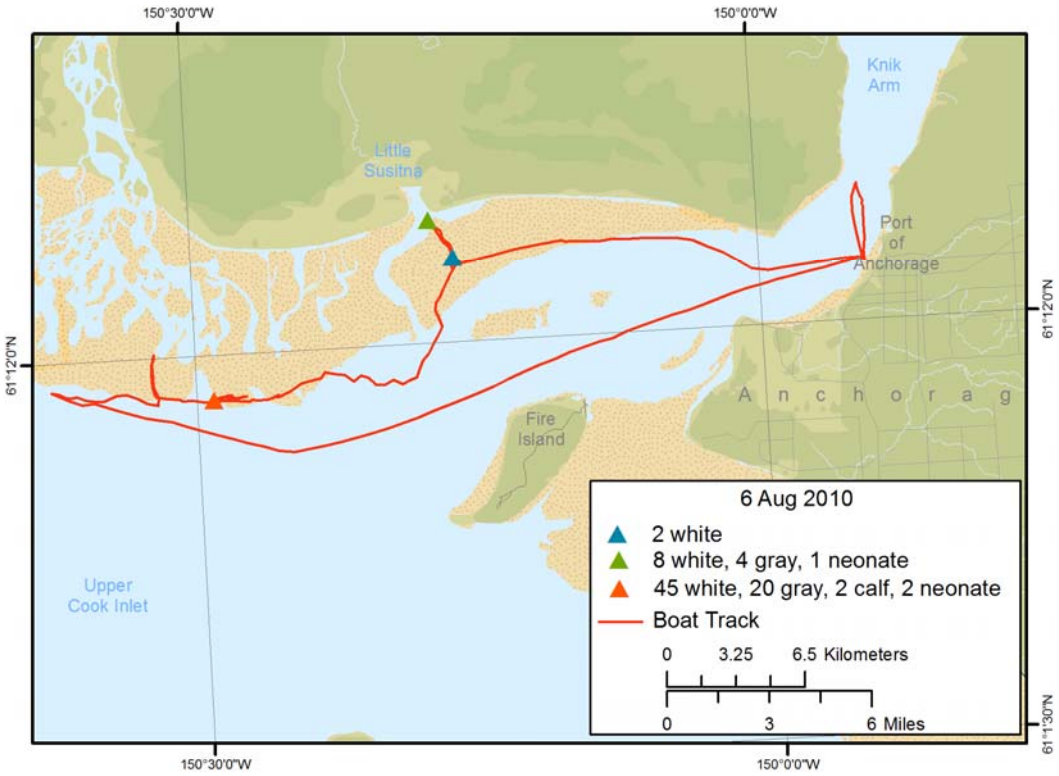

Figure A9. Route and beluga whale group(s) encountered during the vessel-based survey route of 6 August 2010 in Upper Cook Inlet, Alaska.

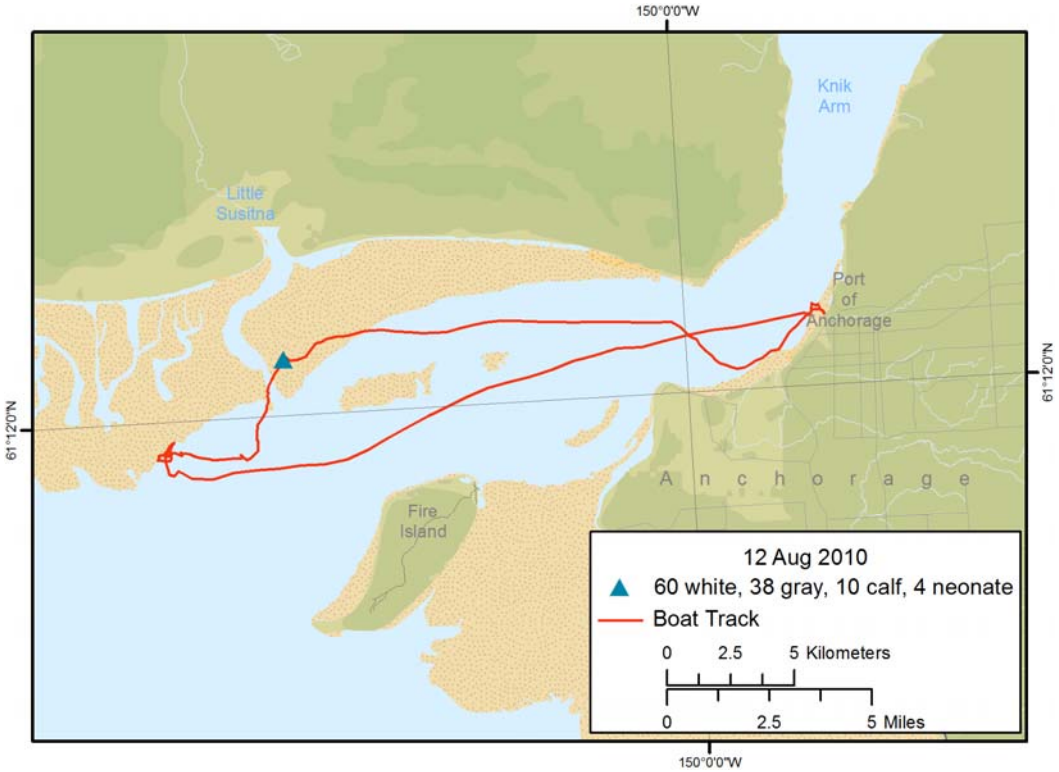

Figure A10. Route of the vessel-based survey route of 12 August 2010 in Upper Cook Inlet, Alaska.

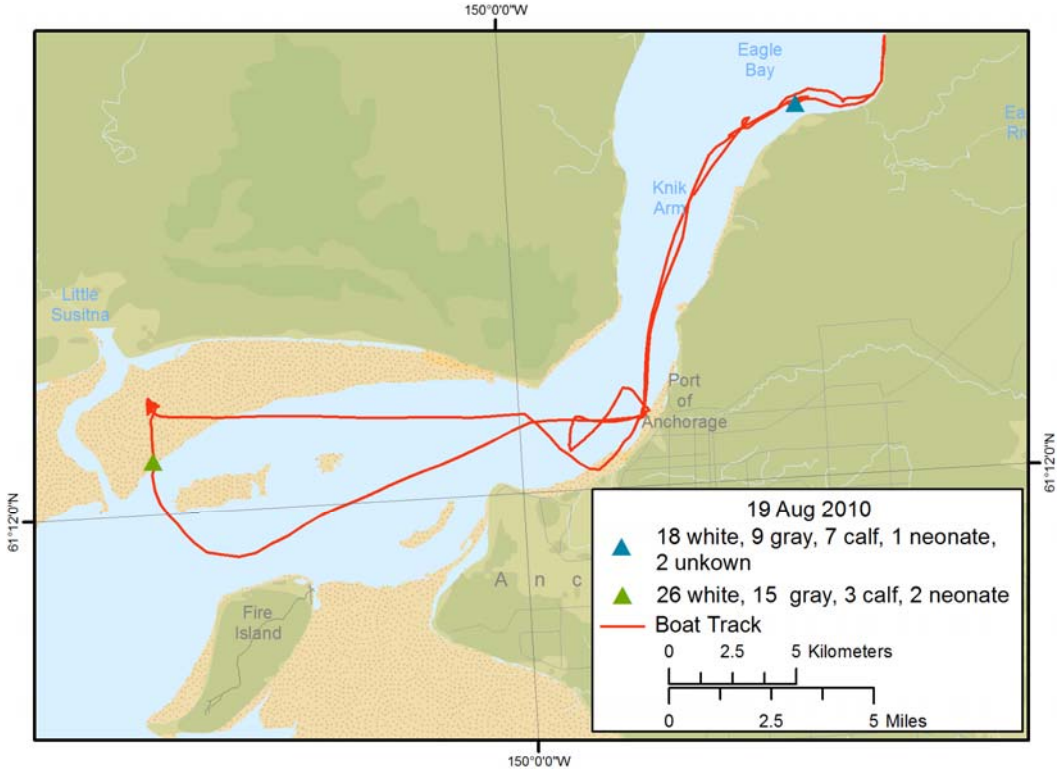

Figure A11. Route and beluga whale group(s) encountered during the vessel-based survey route of 19 August 2010 in Upper Cook Inlet, Alaska.

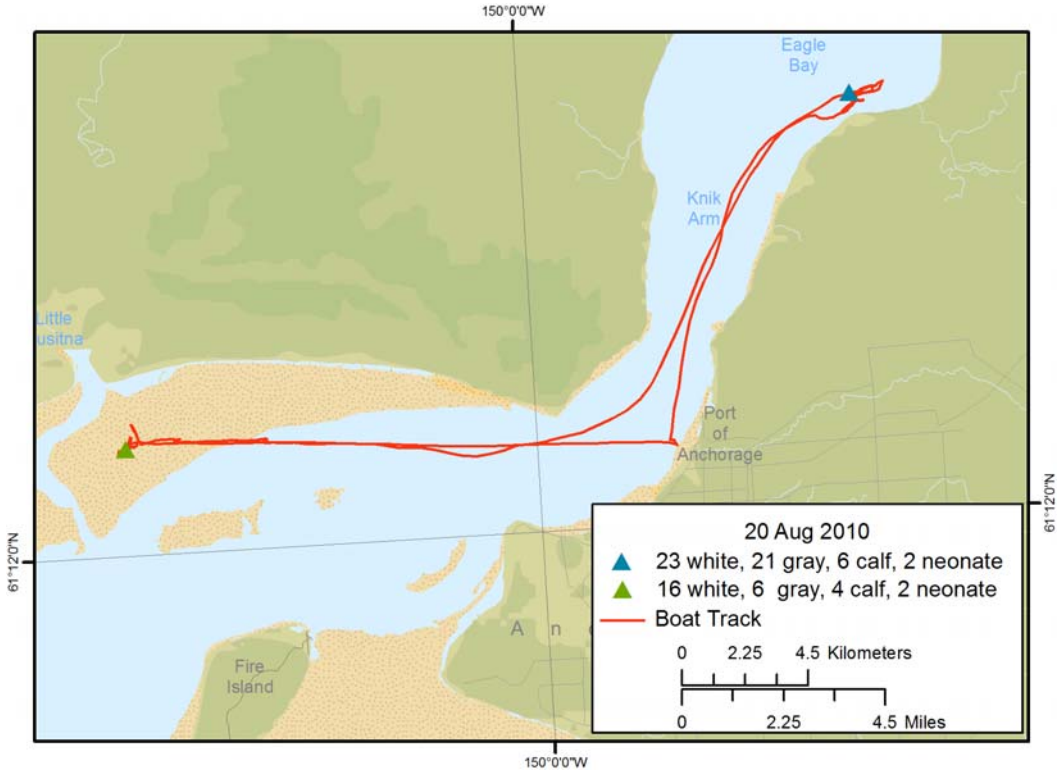

Figure A12. Route and beluga whale group(s) encountered during the vessel-based survey route of 20 August 2010 in Upper Cook Inlet, Alaska.

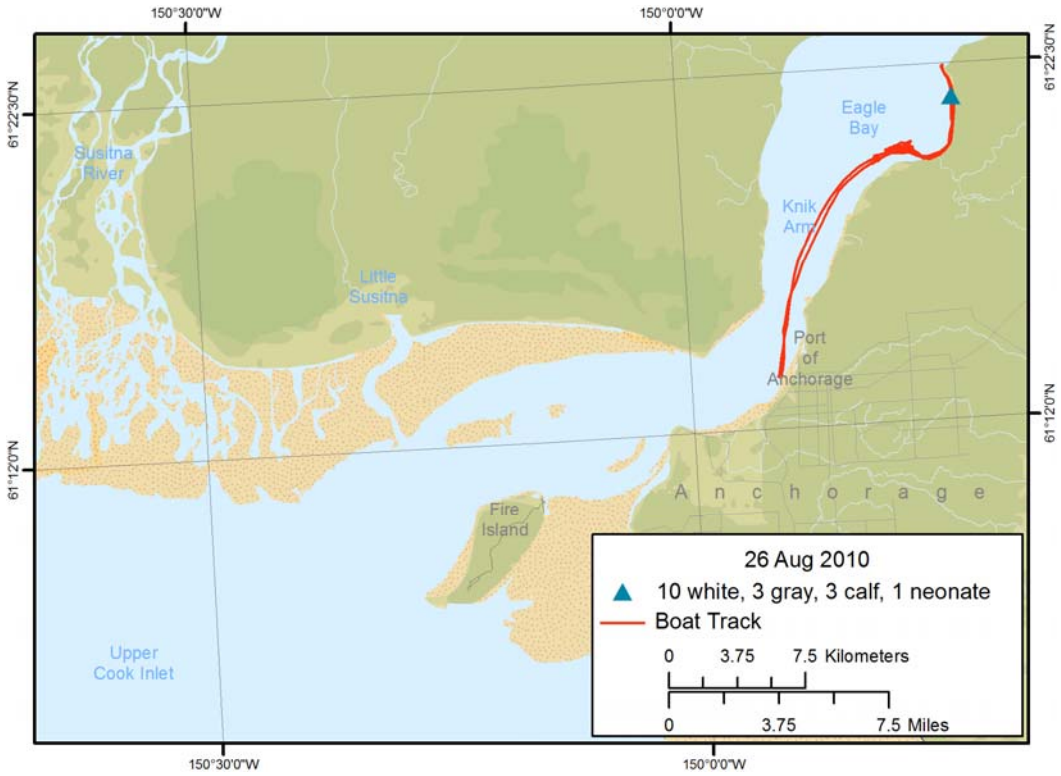

Figure A13. Route and beluga whale group(s) encountered during the vessel-based survey route of 26 August 2010 in Upper Cook Inlet, Alaska.

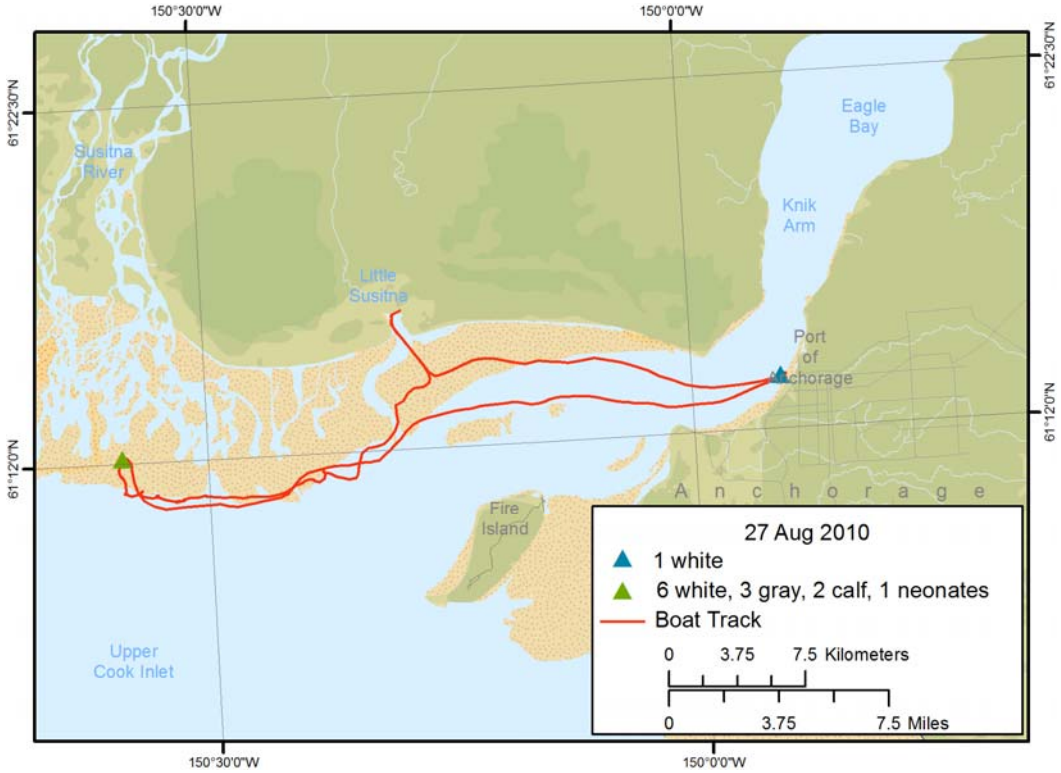

Figure A14. Route and beluga whale group(s) encountered during the vessel-based survey route of 27 August 2010 in Upper Cook Inlet, Alaska.

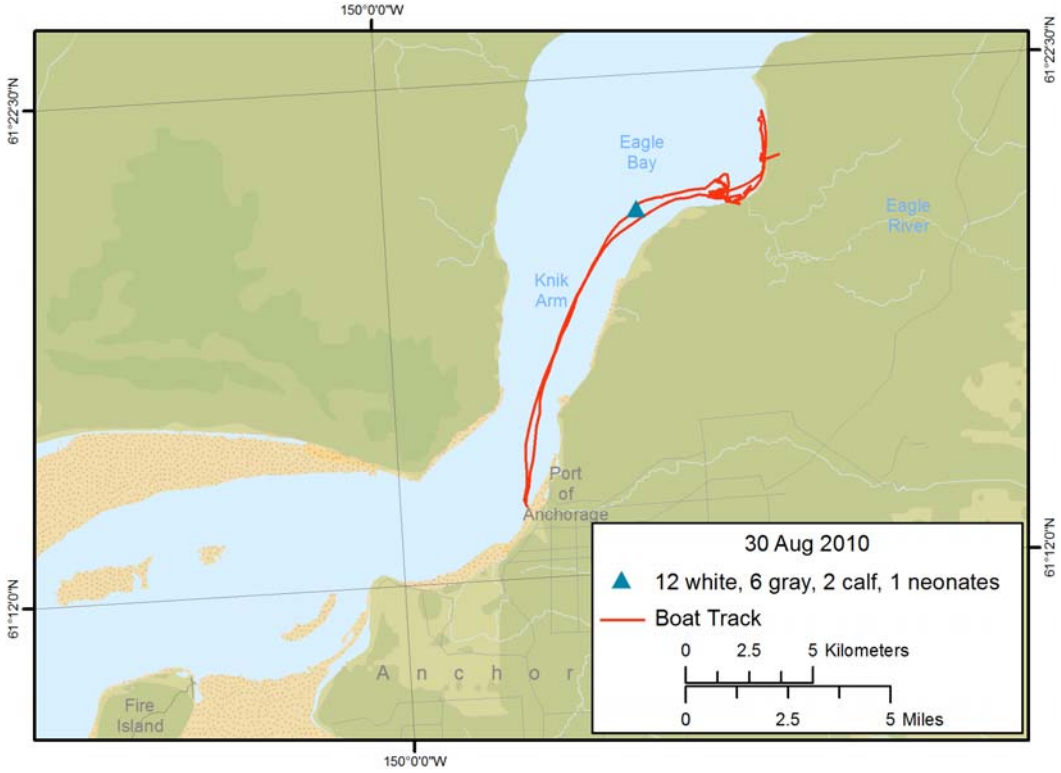

Figure A15. Route of the vessel-based survey route of 30 August 2010 in Upper Cook Inlet, Alaska.

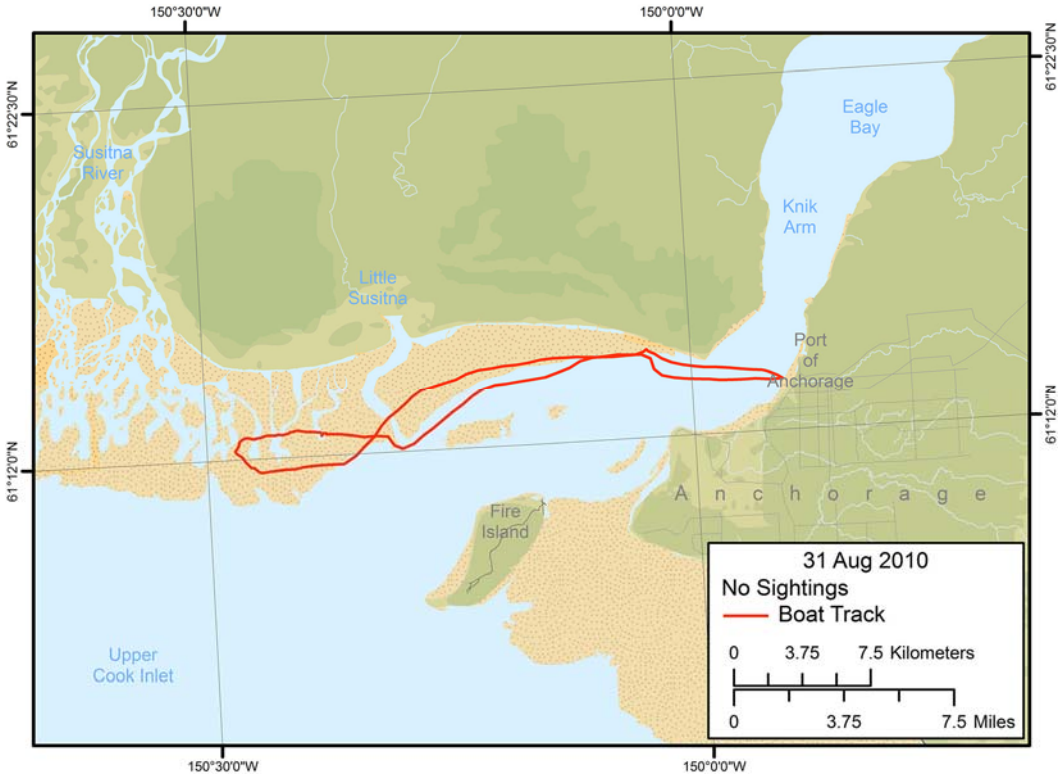

Figure A16. Route of the vessel-based survey route of 31 August 2010 in Upper Cook Inlet, Alaska. No belugas were encountered during this survey.

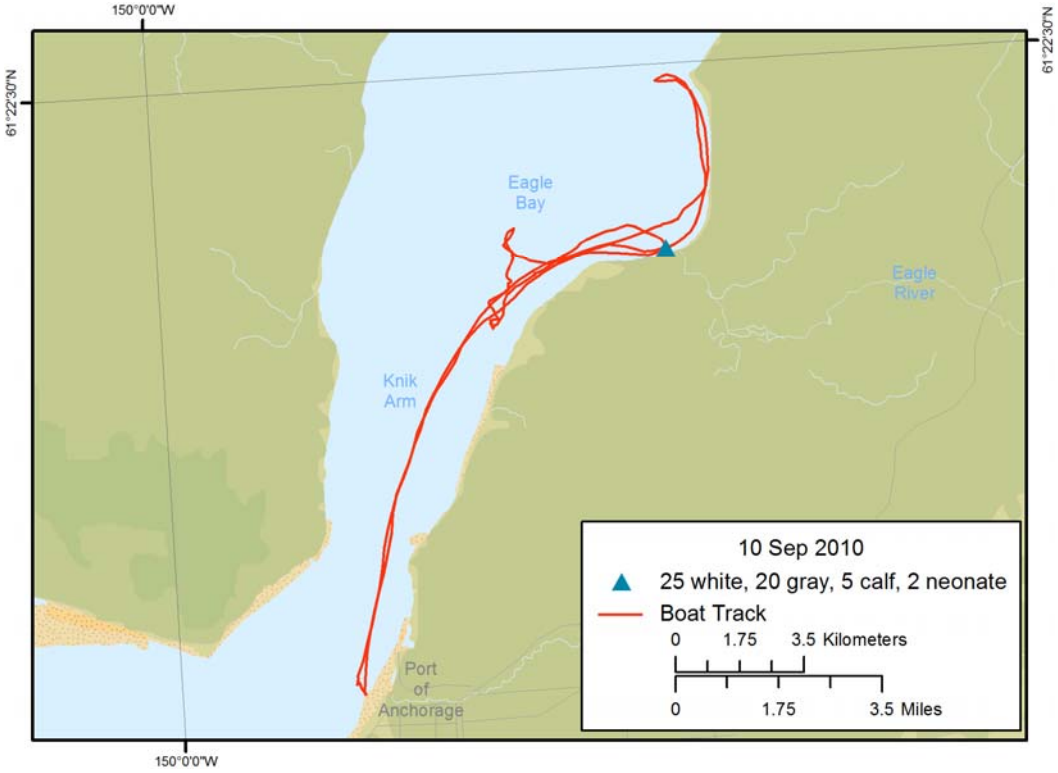

Figure A17. Route and beluga whale group(s) encountered during the vessel-based survey route of 10 September 2010 in Upper Cook Inlet, Alaska.

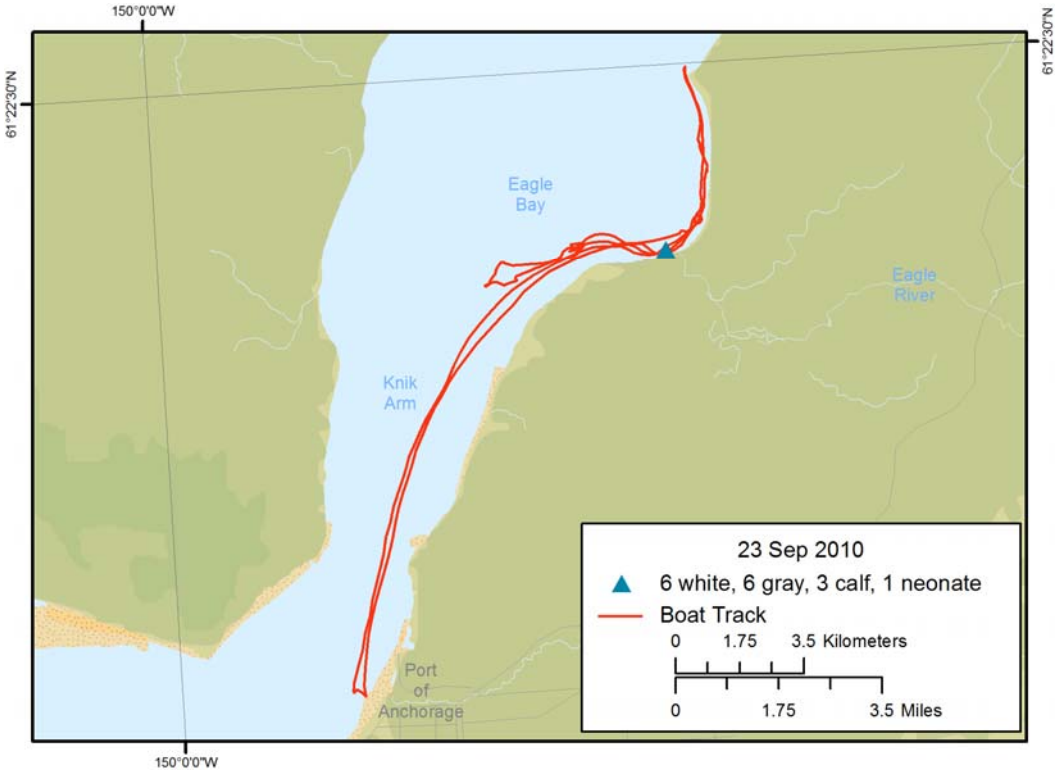

Figure A18. Route and beluga whale group(s) encountered during the vessel-based survey route of 23 September 2010 in Upper Cook Inlet, Alaska.

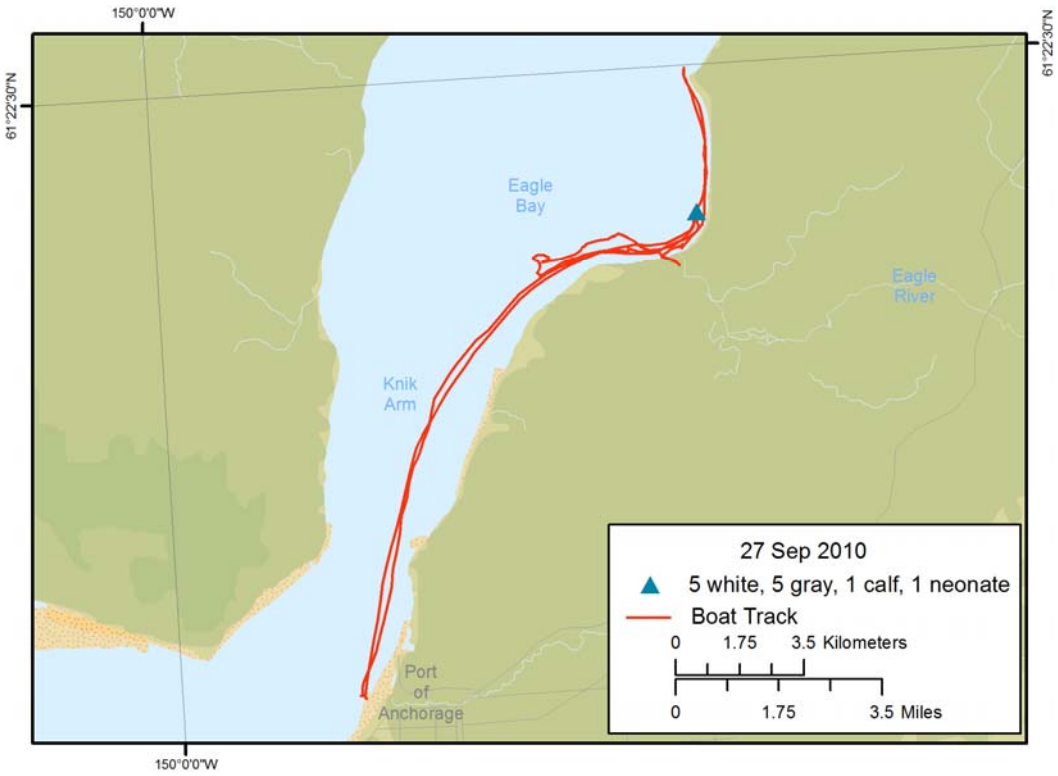

Figure A19. Route and beluga whale group(s) encountered during the vessel-based survey route of 27 September 2010 in Upper Cook Inlet, Alaska.

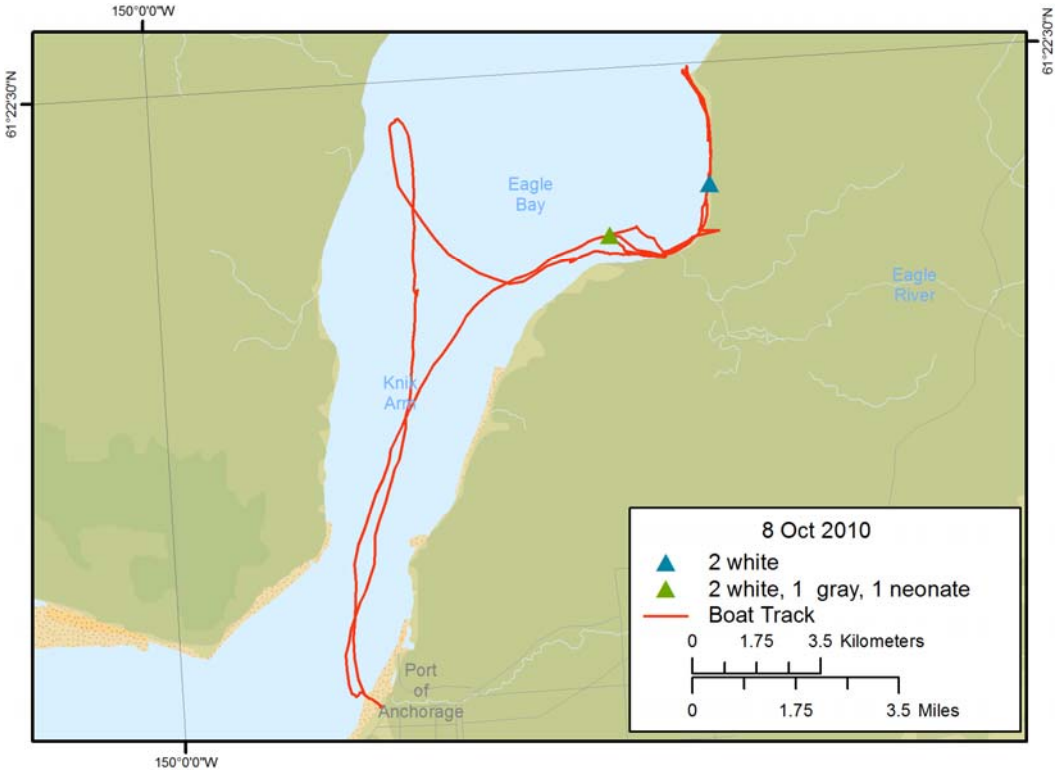

Figure A20. Route and beluga whale group(s) encountered during the vessel-based survey route of 8 October 2010 in Upper Cook Inlet, Alaska.

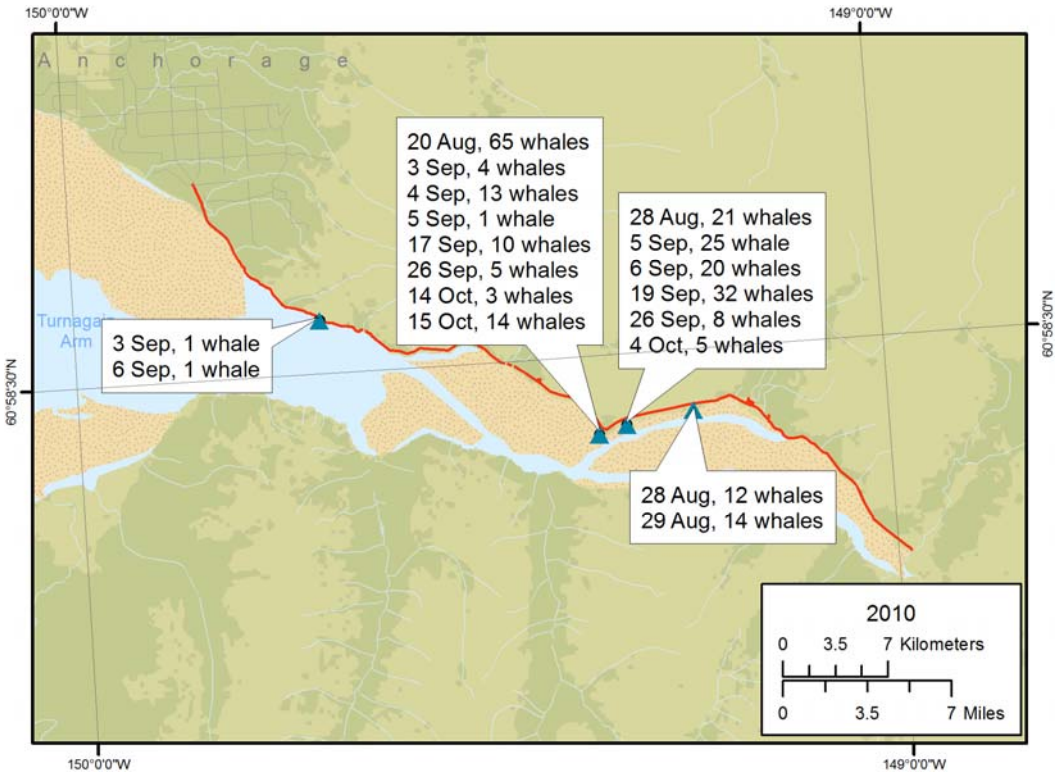

Figure A21. Beluga whale groups encountered and general survey route of all 2010 land-based surveys along Turnagain Arm, Upper Cook Inlet, Alaska.

APPENDIX B

INDIVIDUAL SIGHTING-HISTORY MAPS AND RIGHT SIDE PHOTOGRAPHS OF CATALOGED WHALES SEEN IN ALL SIX YEARS OF THE STUDY (2005-2010).

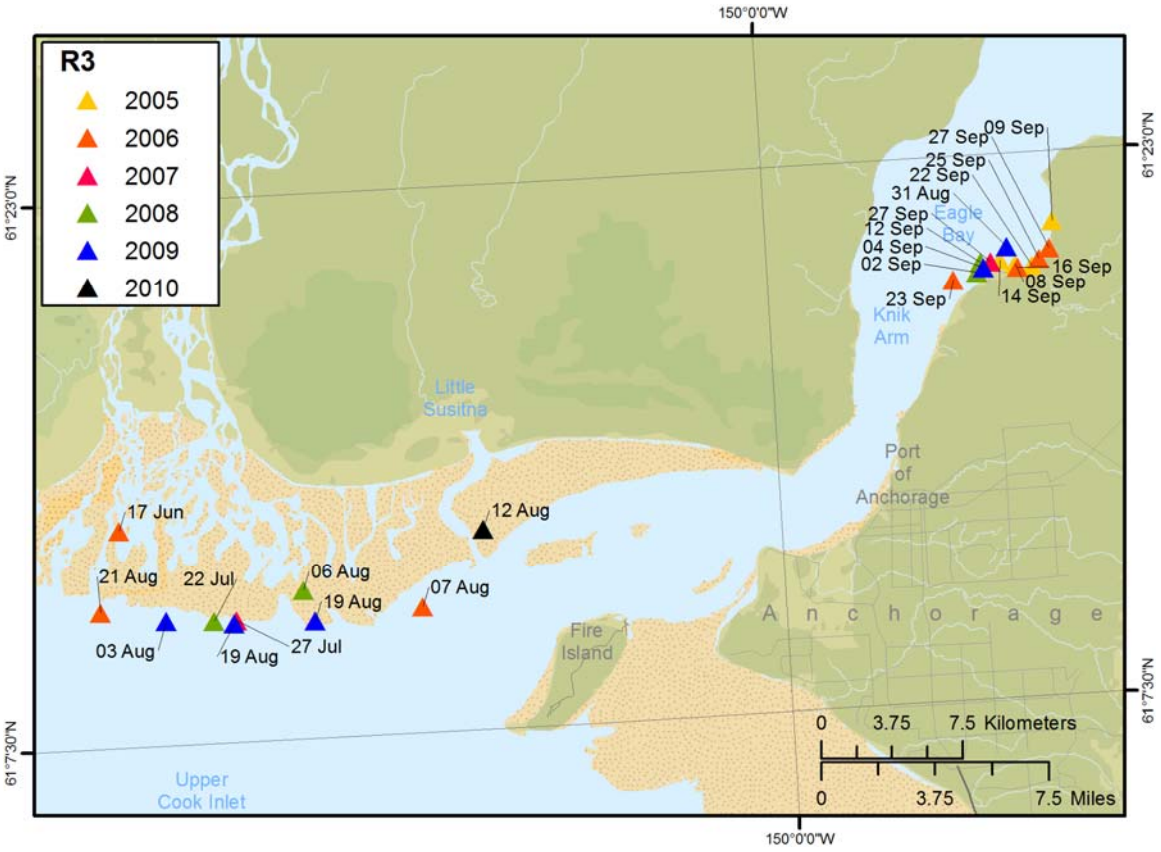

Figure B1. Sighting history and photograph of beluga R3. This beluga is a presumed mother based on photographs with an accompanying calf.

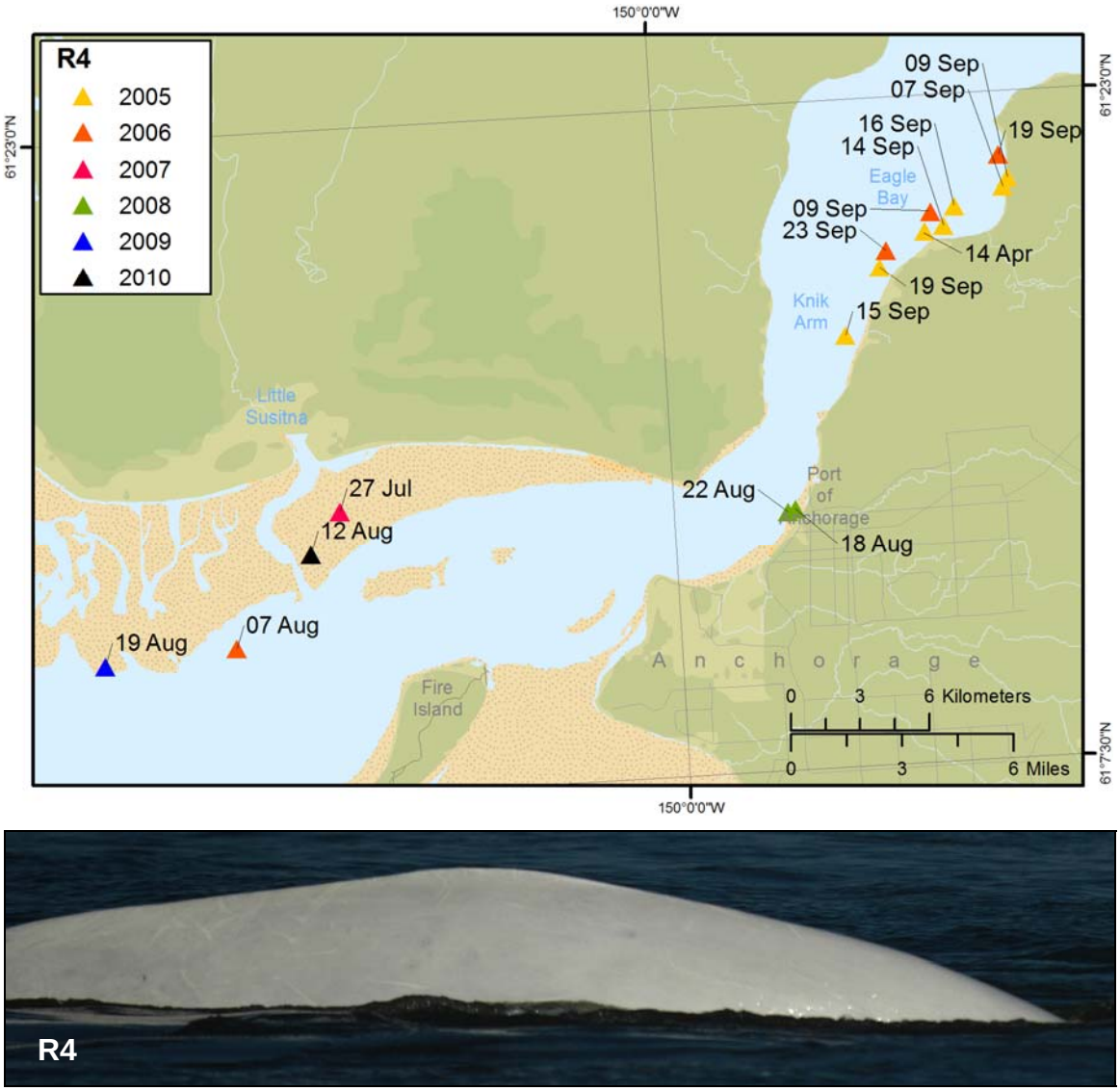

Figure B2. Sighting history and photograph of beluga R4. This beluga is a presumed mother based on photographs with an accompanying calf.

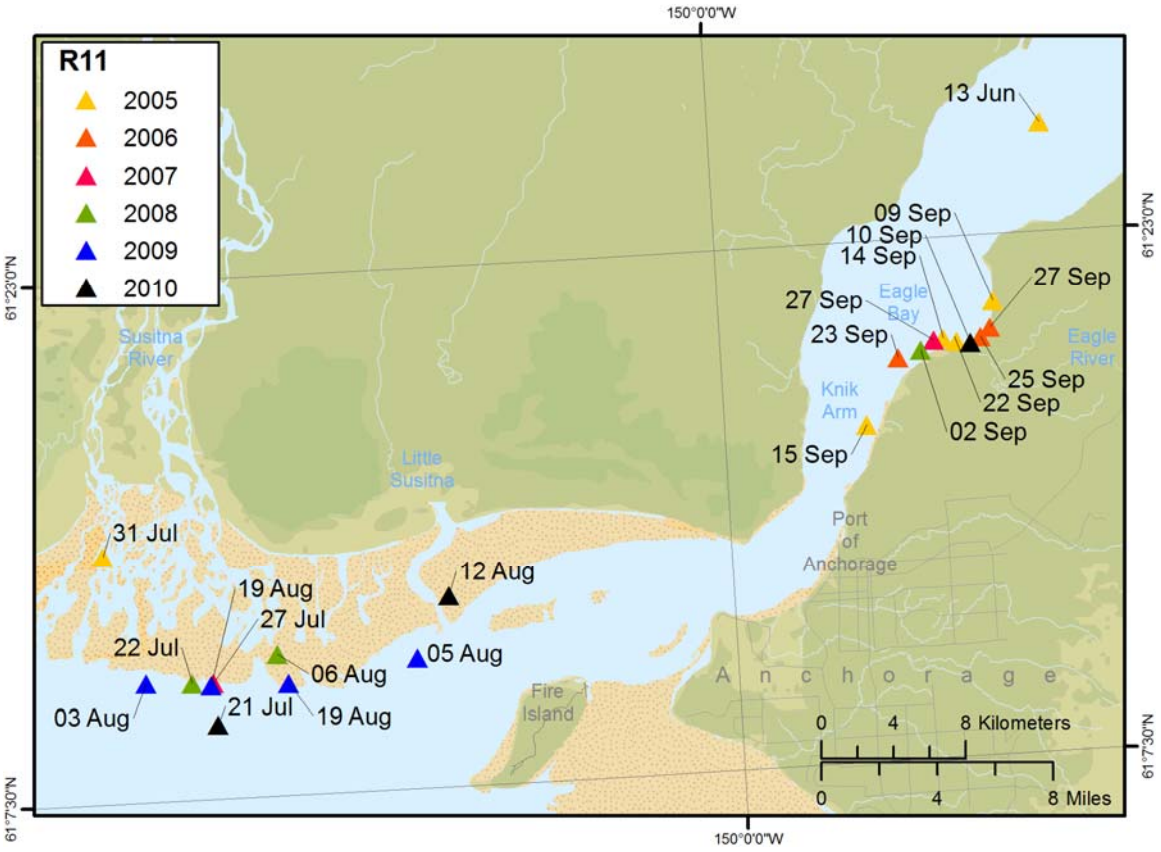

Figure B3. Sighting history and photograph of beluga R11. This beluga is a presumed mother based on photographs with an accompanying calf.

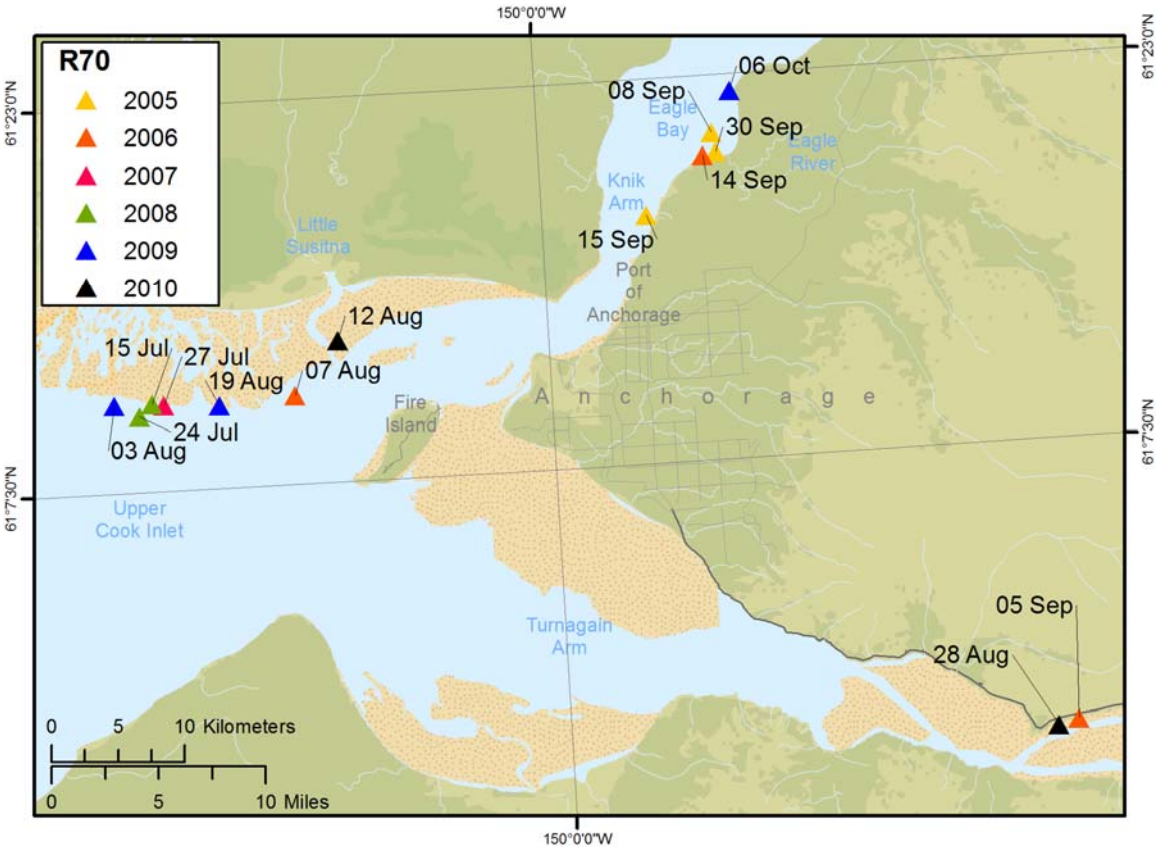

Figure B4. Sighting history and photograph of beluga R70.

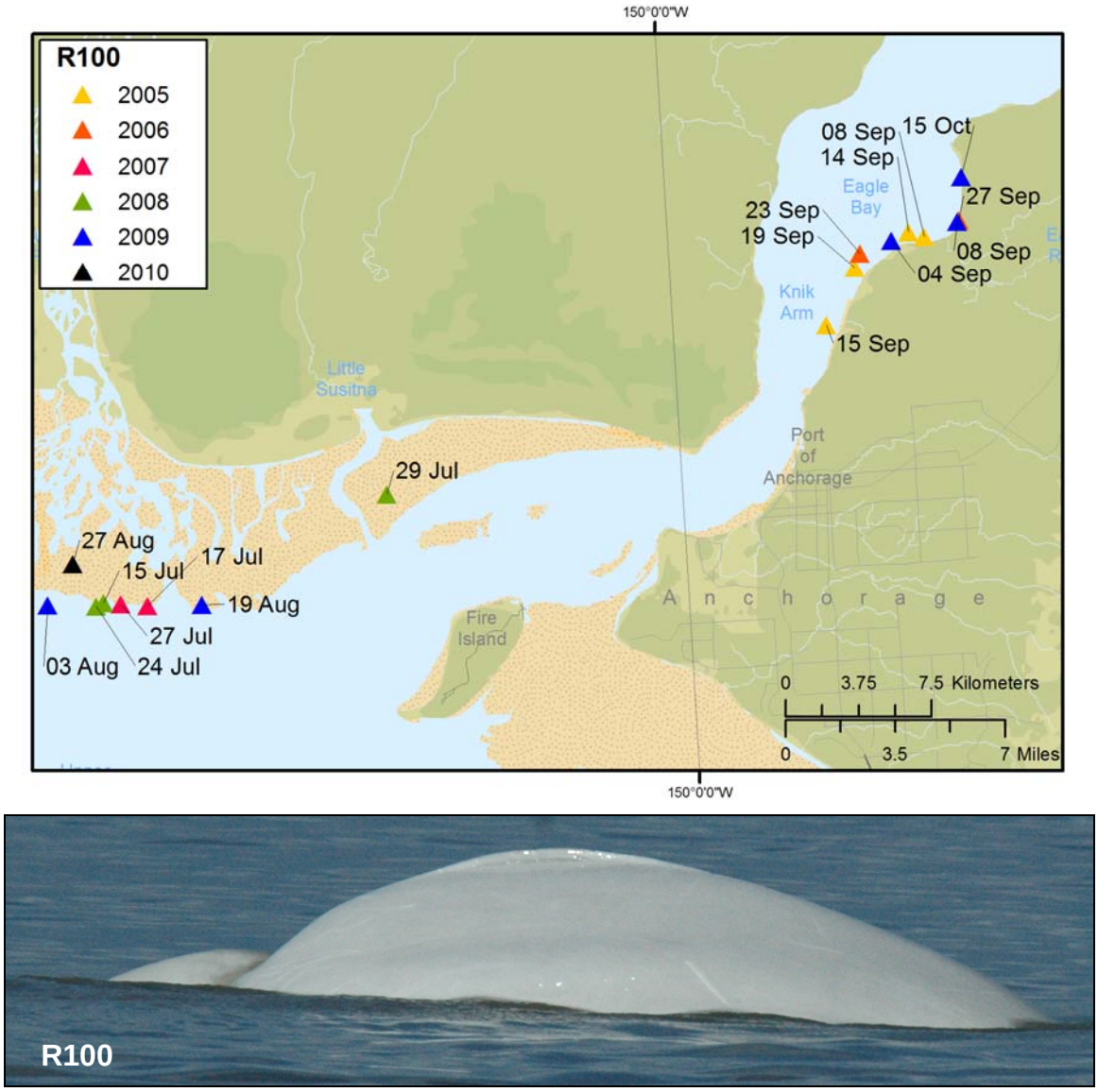

Figure B5. Sighting history and photograph of beluga R100. This beluga is a presumed mother based on photographs with an accompanying calf.

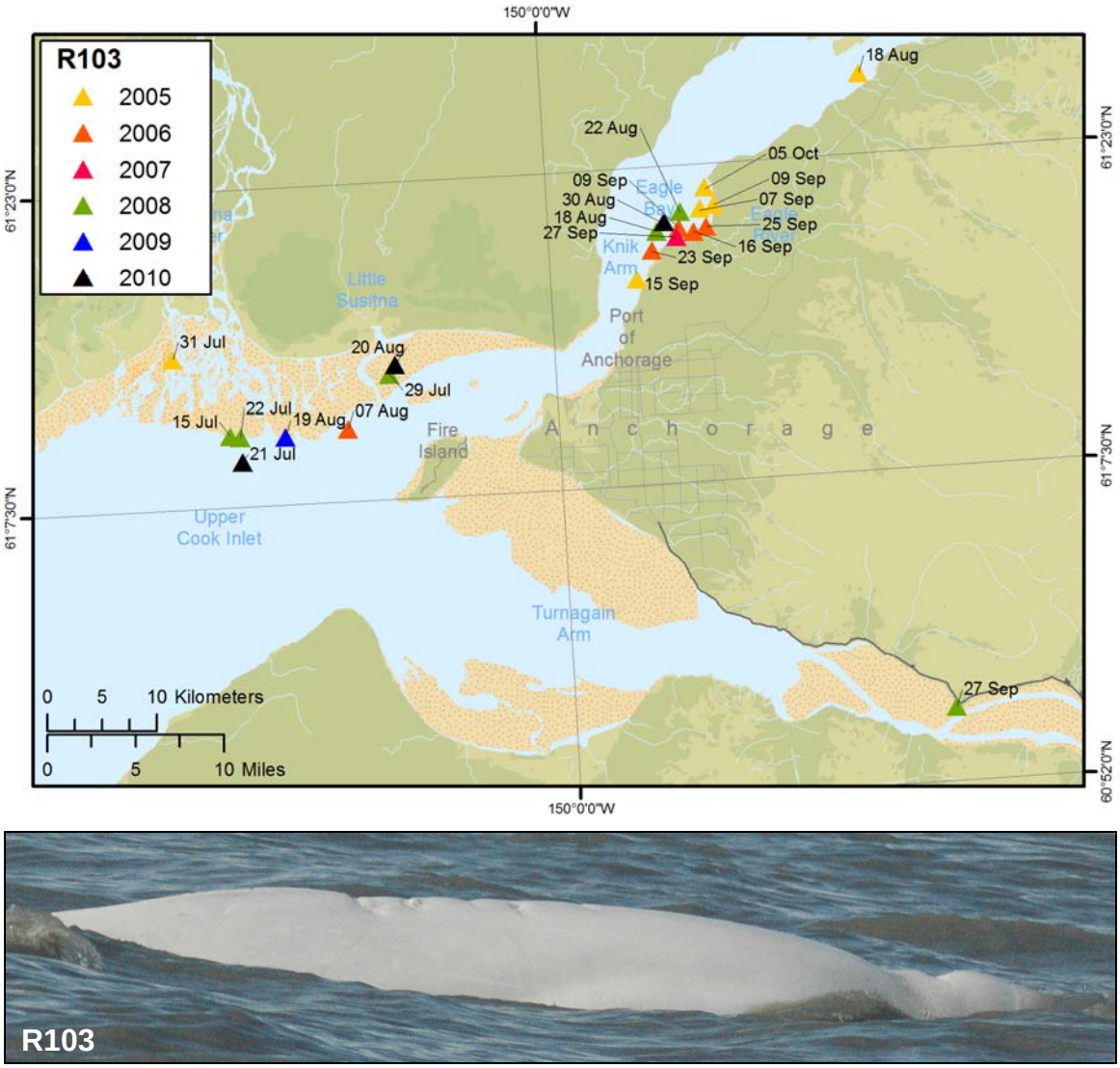

Figure B6. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R103. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

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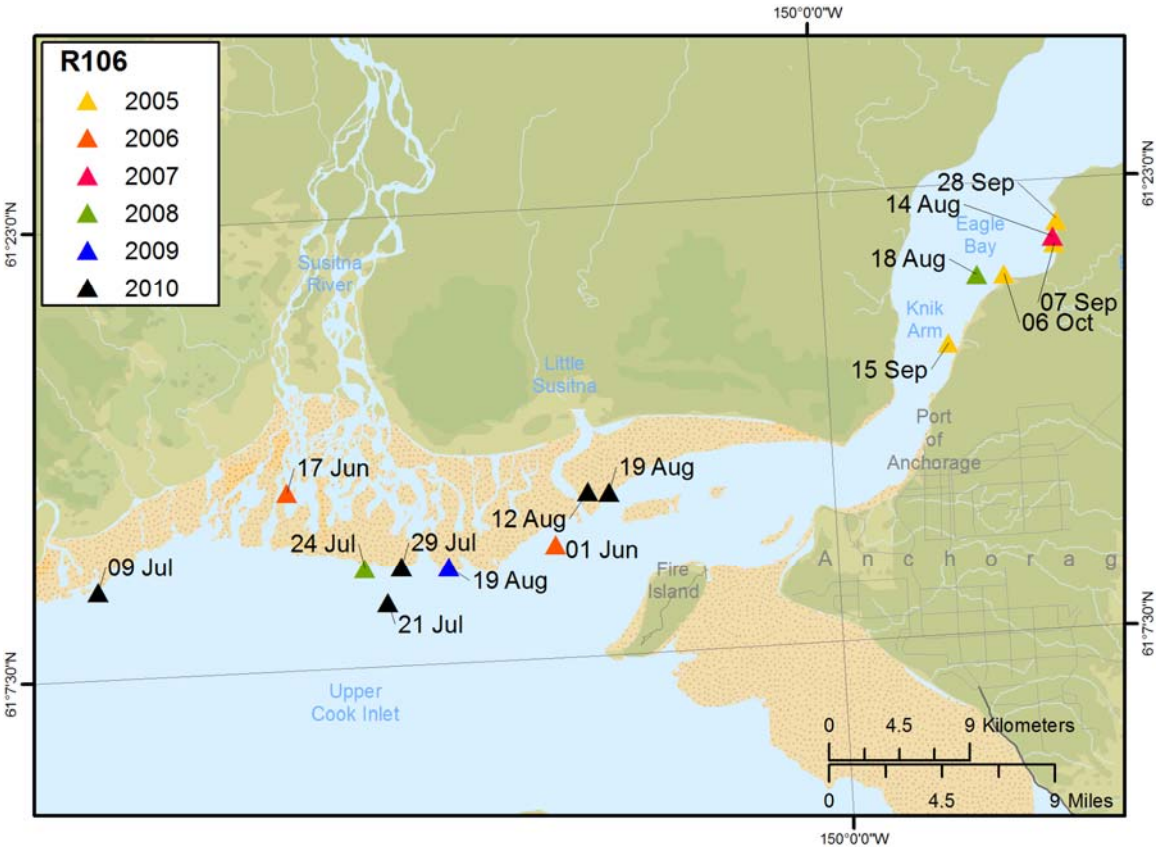

Figure B7. Sighting history and photograph of beluga R106. This beluga is a presumed mother based on photographs with an accompanying calf.

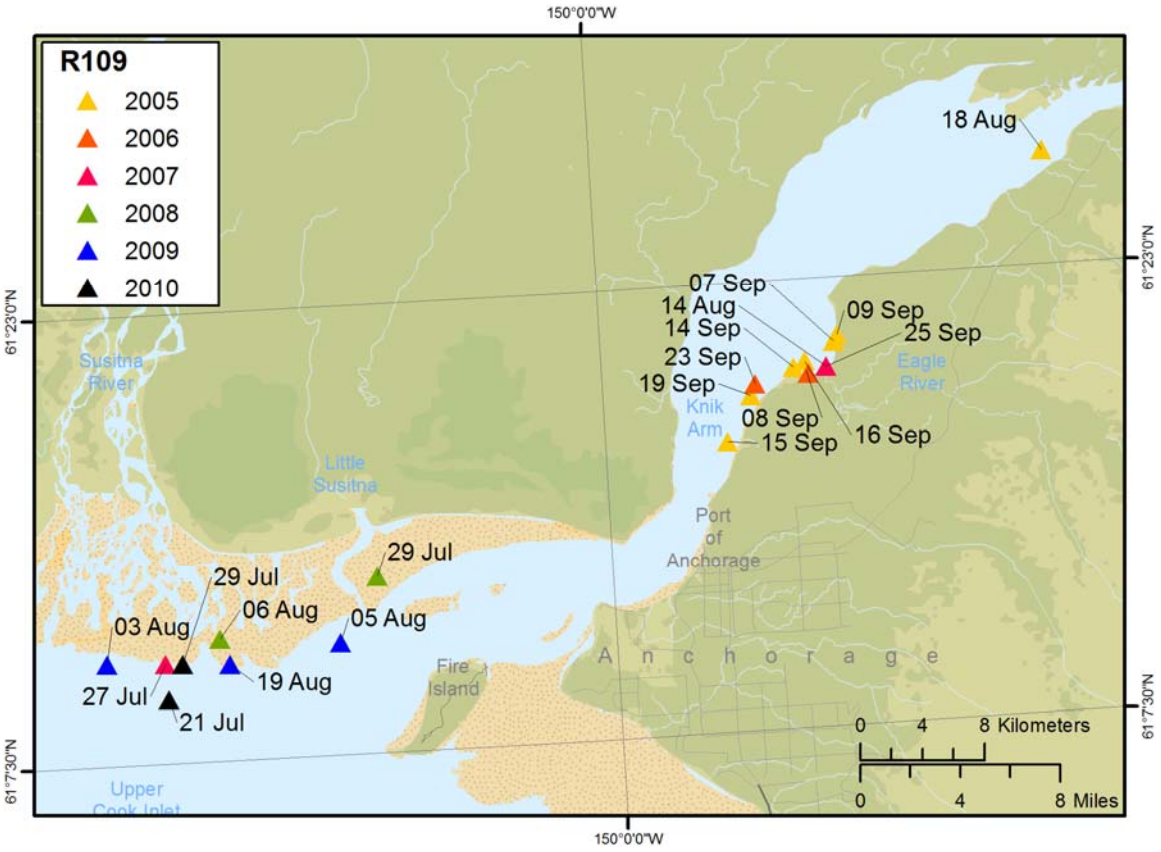

Figure B8. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R109. This beluga is a presumed mother based on photographs with an accompanying calf.

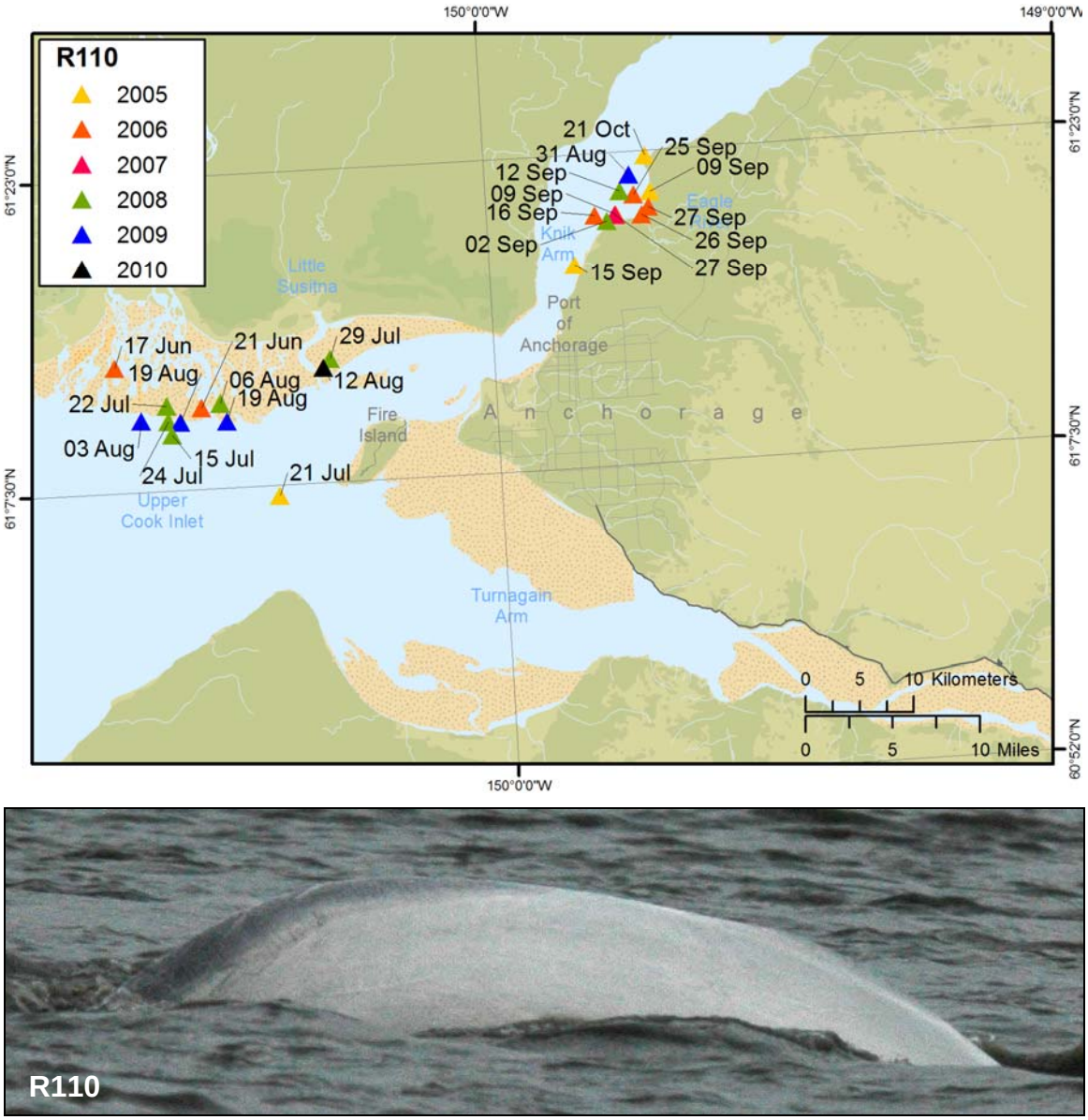

Figure B9. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R110. This beluga is a presumed mother based on photographs with an accompanying calf.

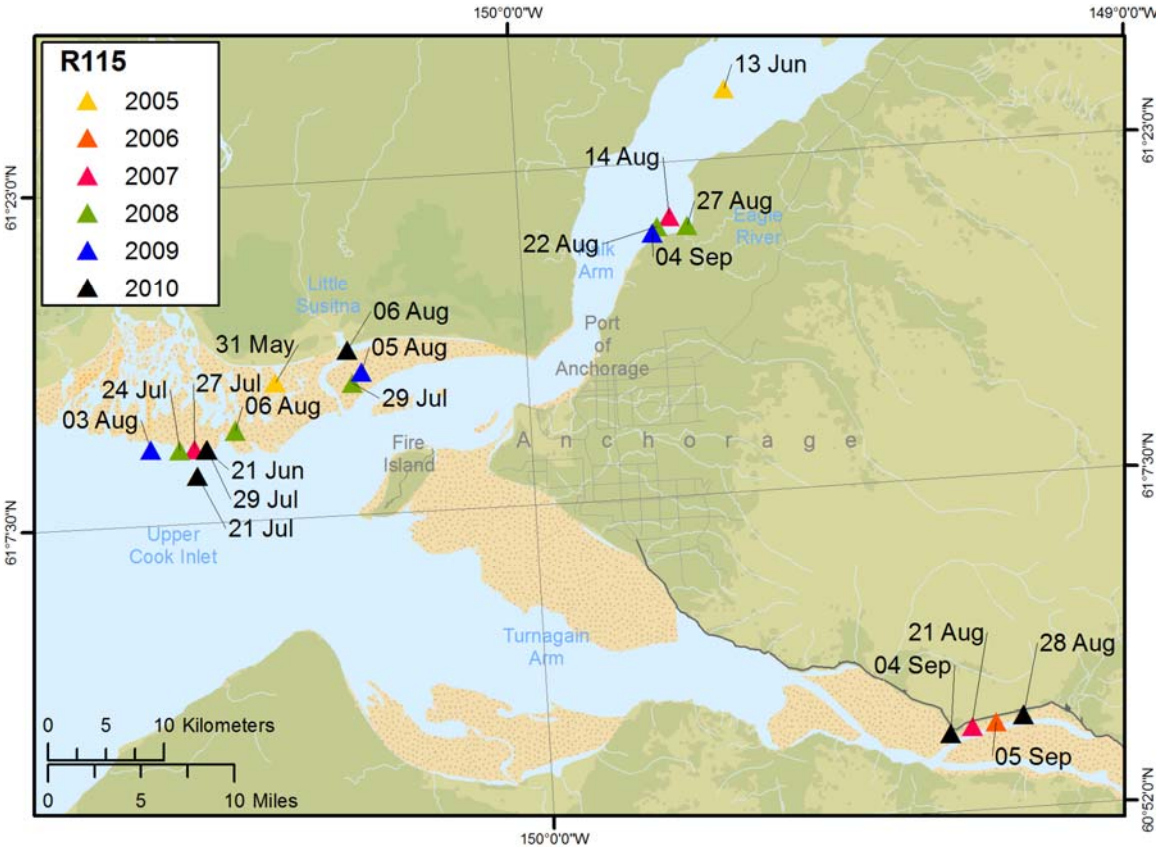

Figure B10. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R115. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

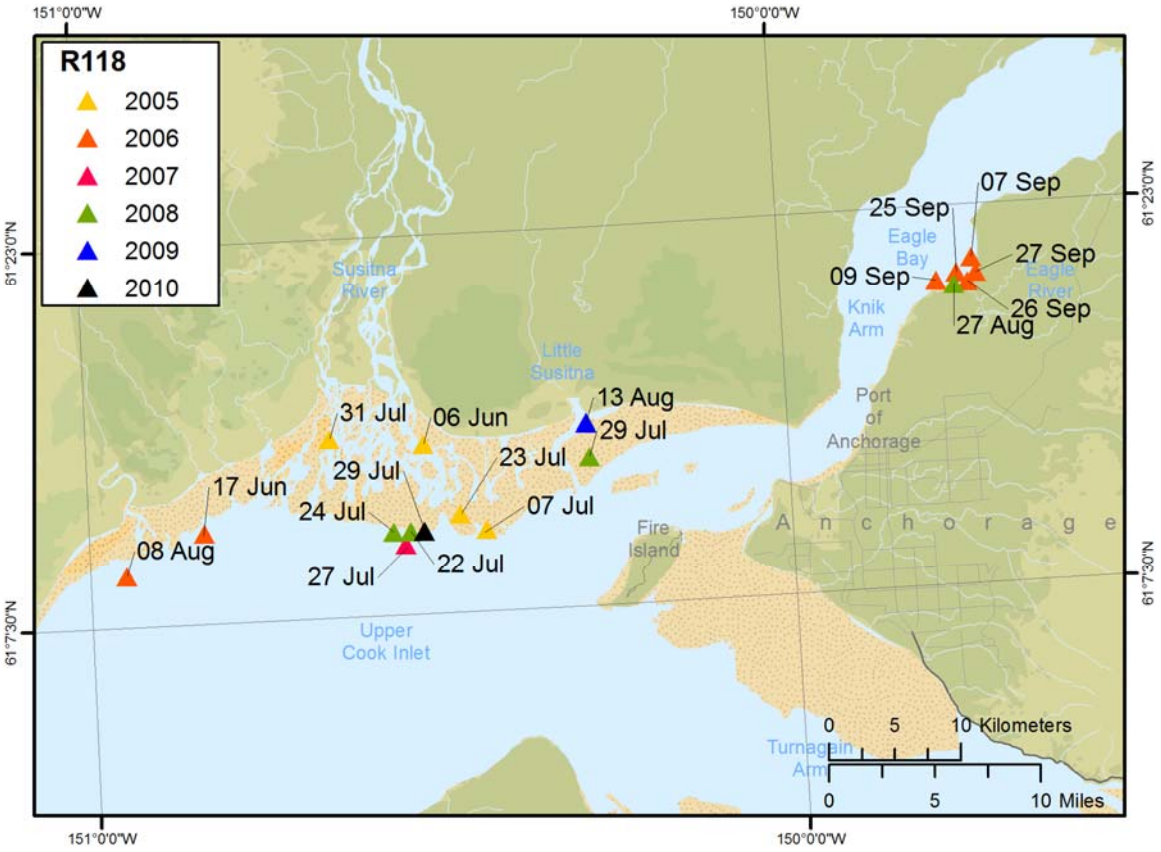

Figure B11. Sighting history and photograph of beluga R118.

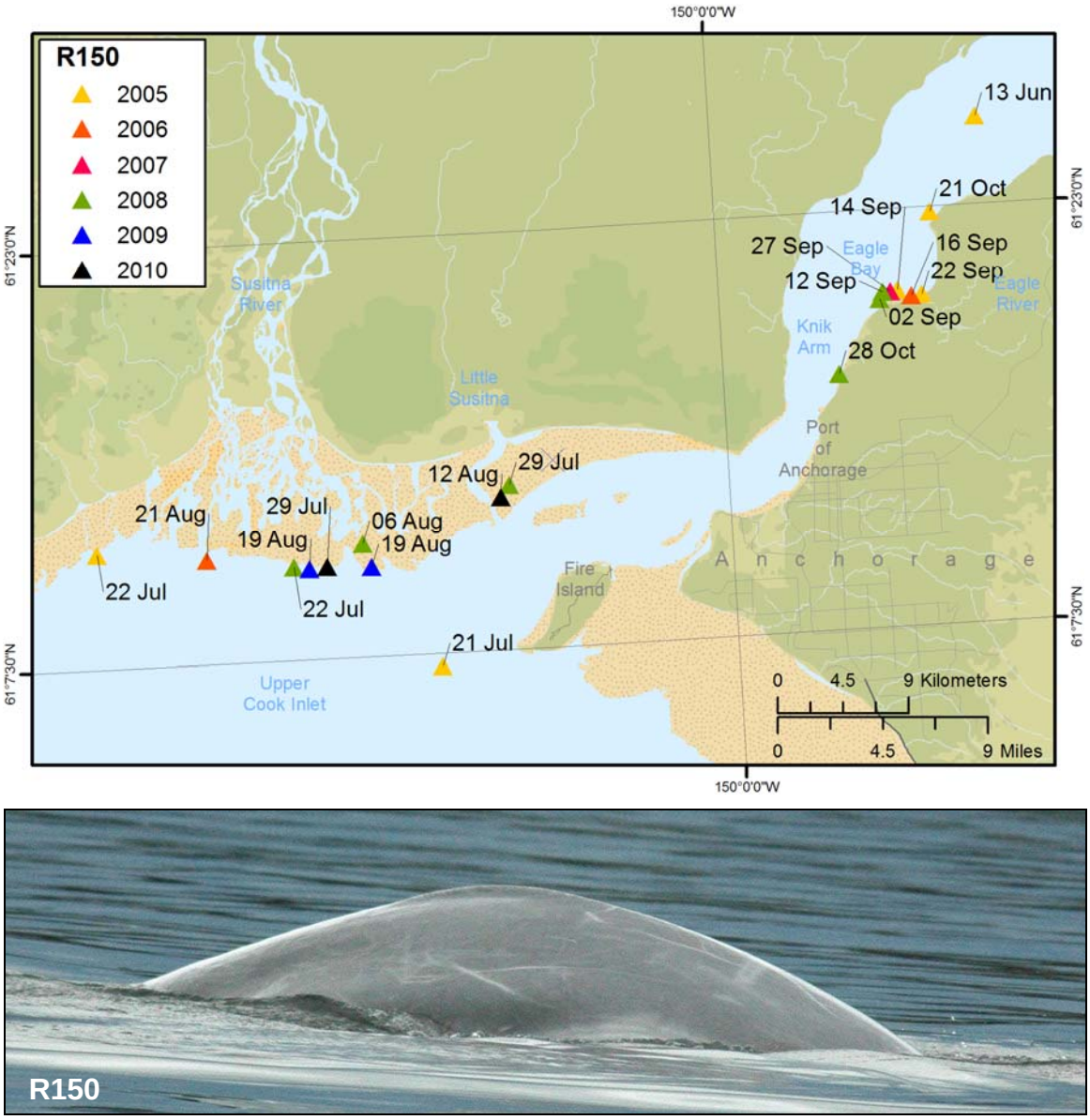

Figure B12. Sighting history and photograph of beluga R150.

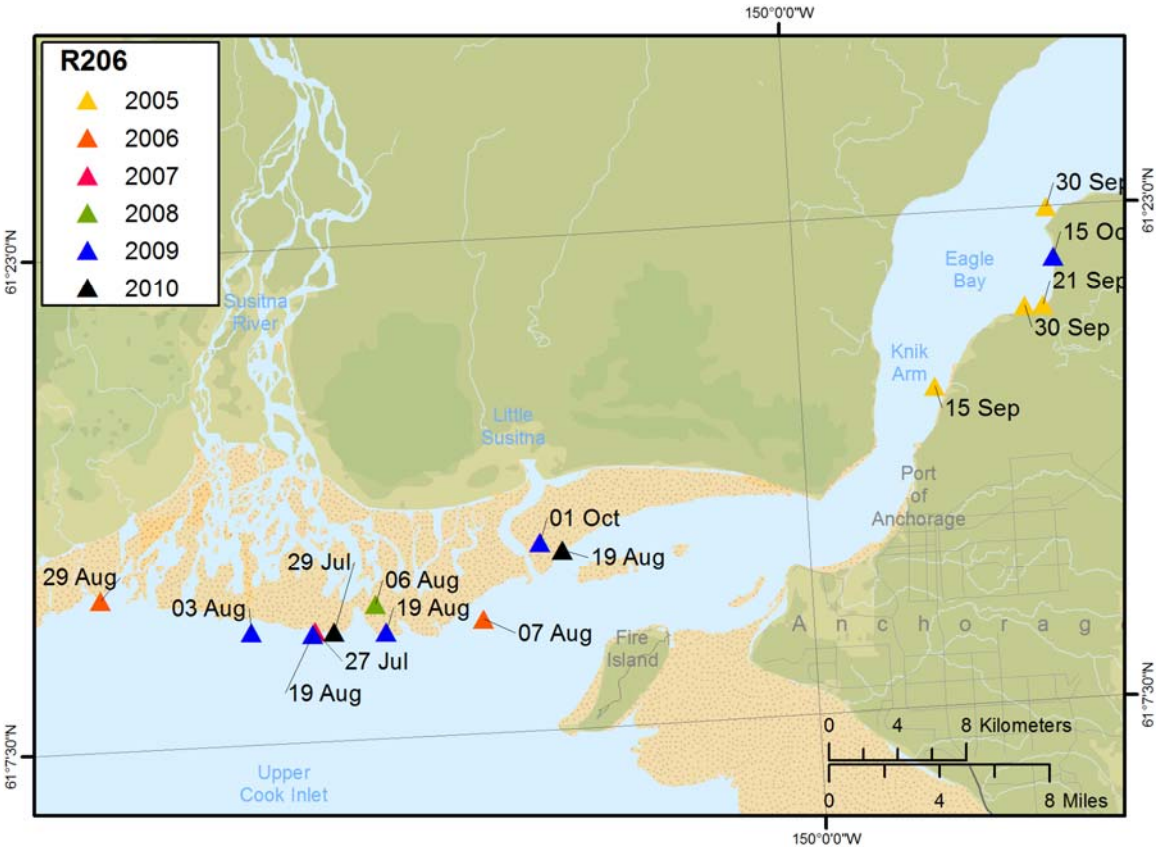

Figure B13. Sighting history and photograph of beluga R206.

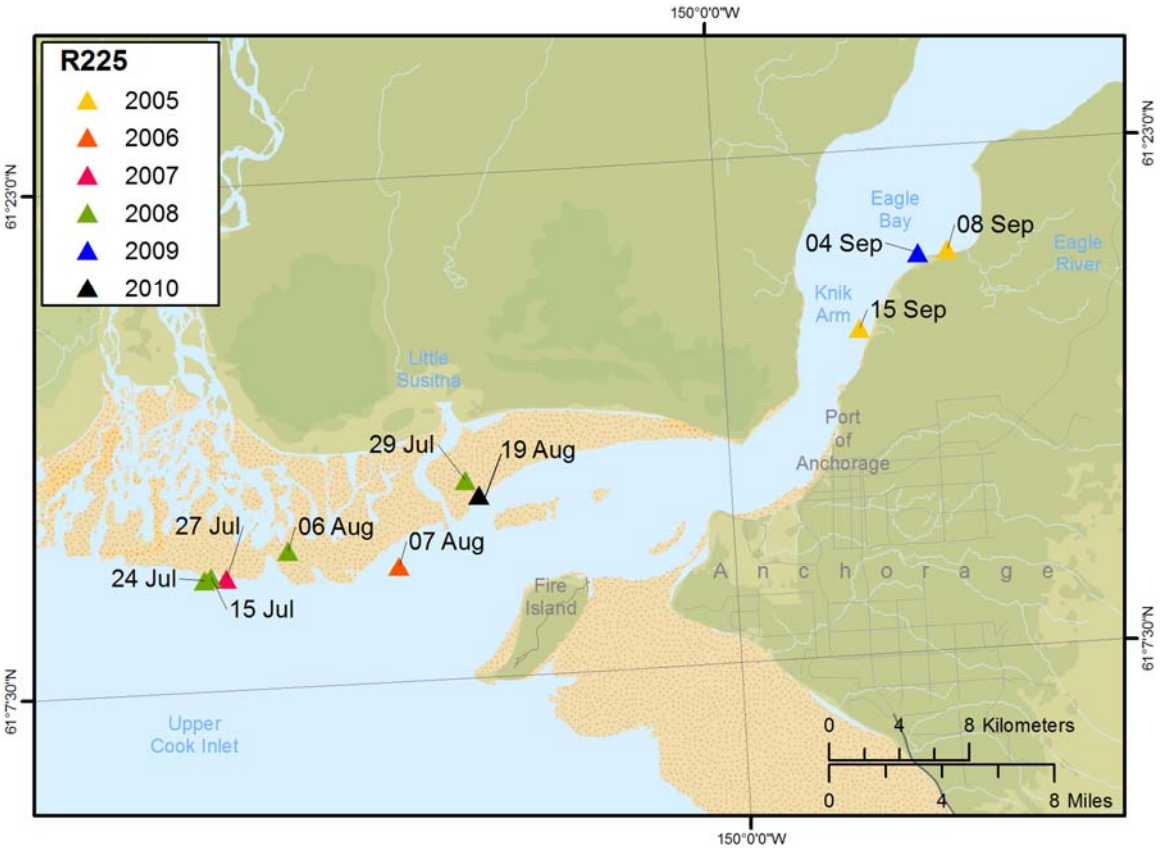

Figure B14. Sighting history and photograph of beluga R225. This beluga is a presumed mother based on photographs with an accompanying calf.

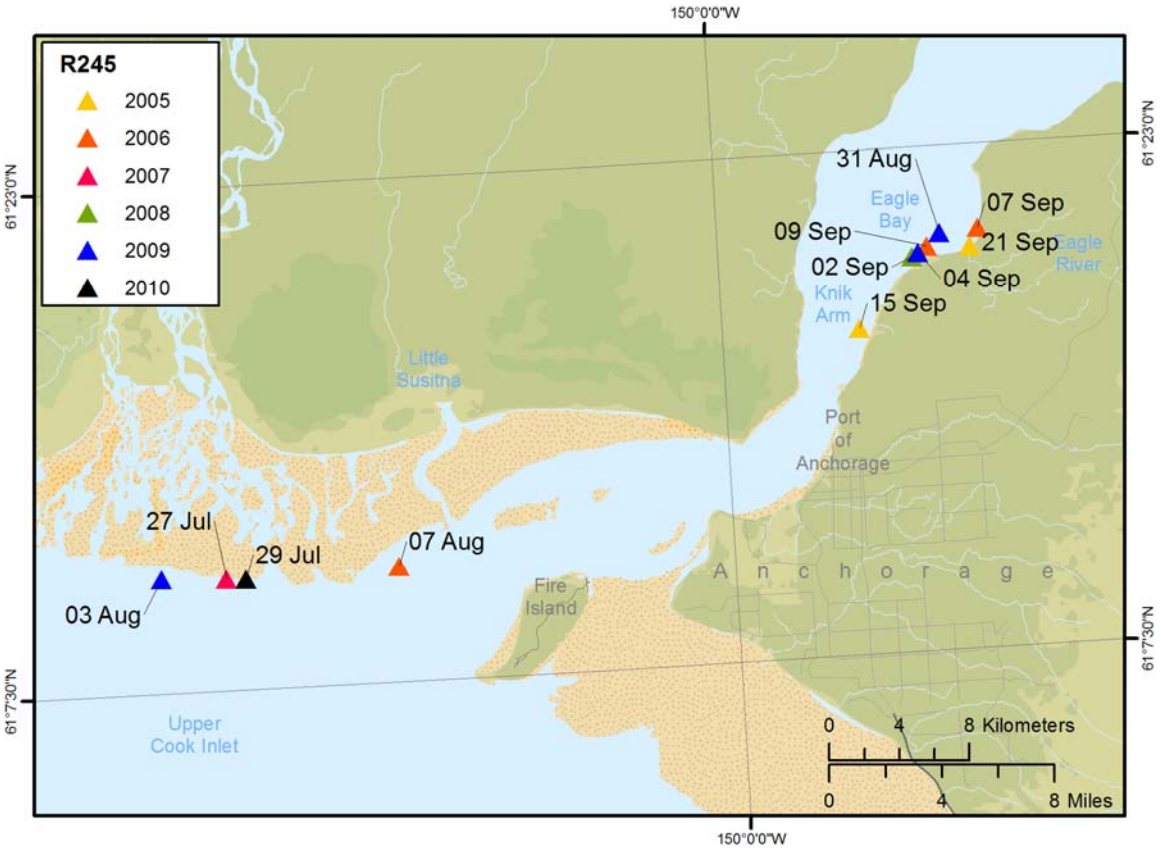

Figure B15. Sighting history and photograph of beluga R245. This beluga is a presumed mother based on photographs with an accompanying calf.

APPENDIX C

INDIVIDUAL SIGHTING-HISTORY MAPS AND RIGHT SIDE PHOTOGRAPHS OF CATALOGED WHALES IDENTIFIED 2005-2010 BY SCARS FROM SATELLITE TAGS APPLIED BY NMFS BETWEEN 1999 AND 2002.

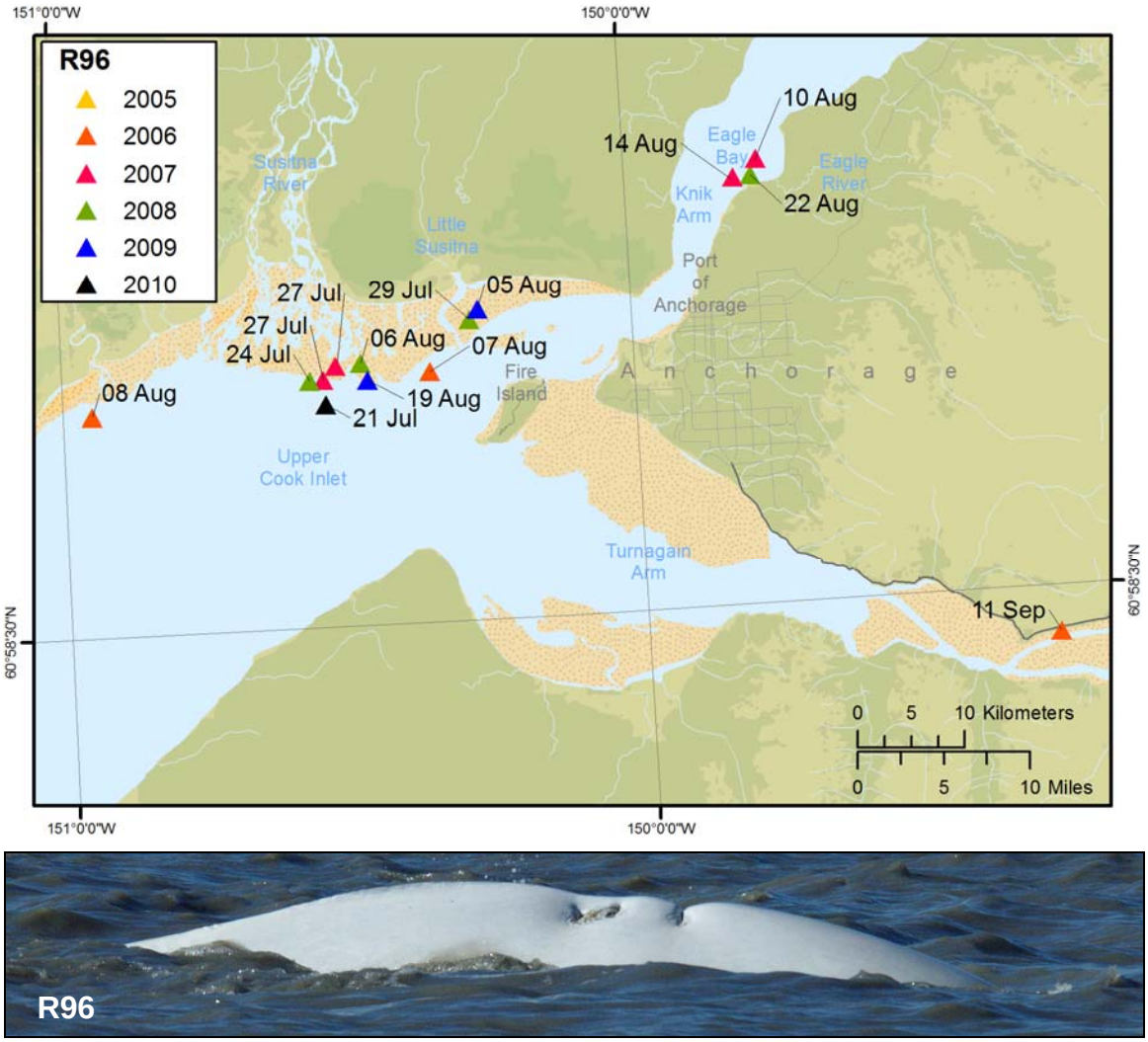

Figure C1. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R96. This beluga was tagged by NMFS sometime between 1999 and 2002.

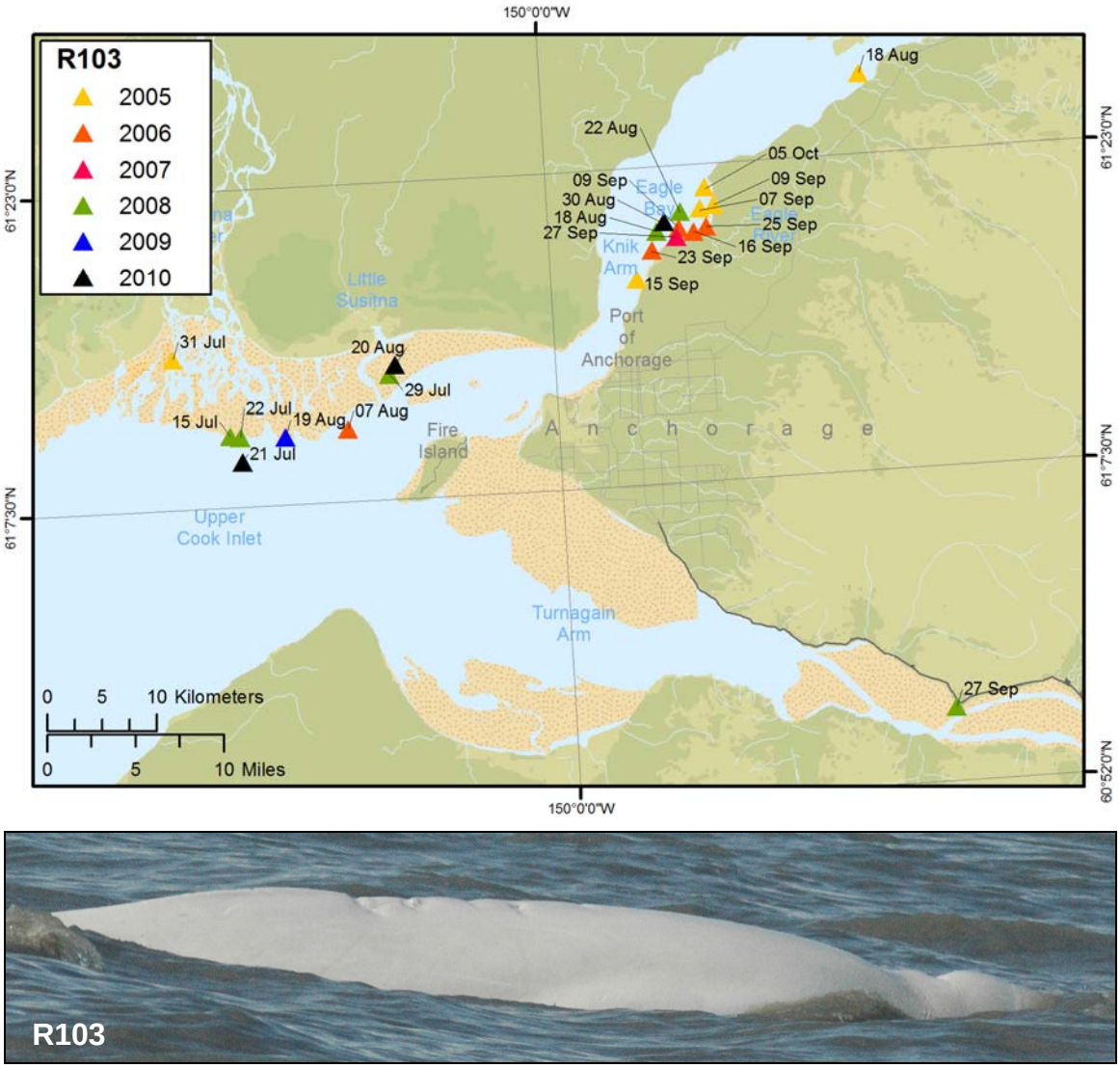

Figure C2. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R103. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

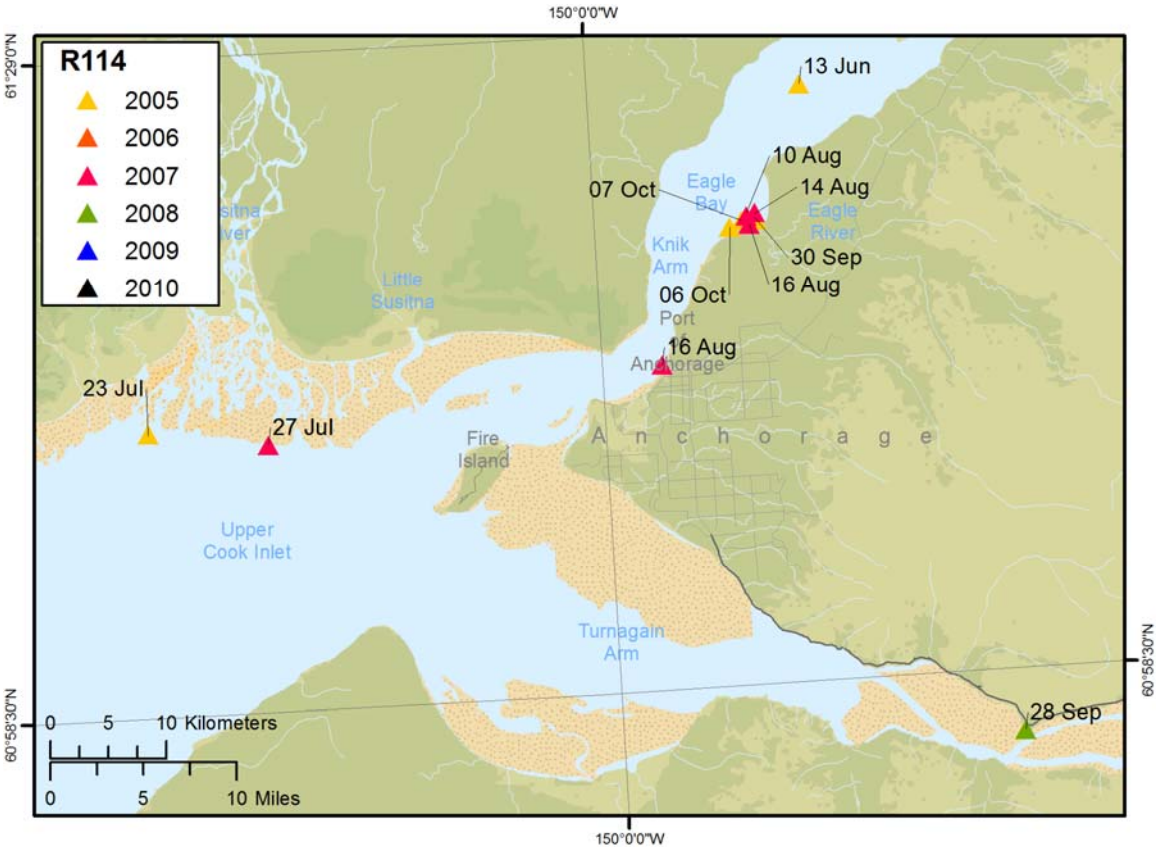

Figure C3. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R114, who was photographed in 2005 and 2007. This beluga was tagged by NMFS sometime between 1999 and 2002.

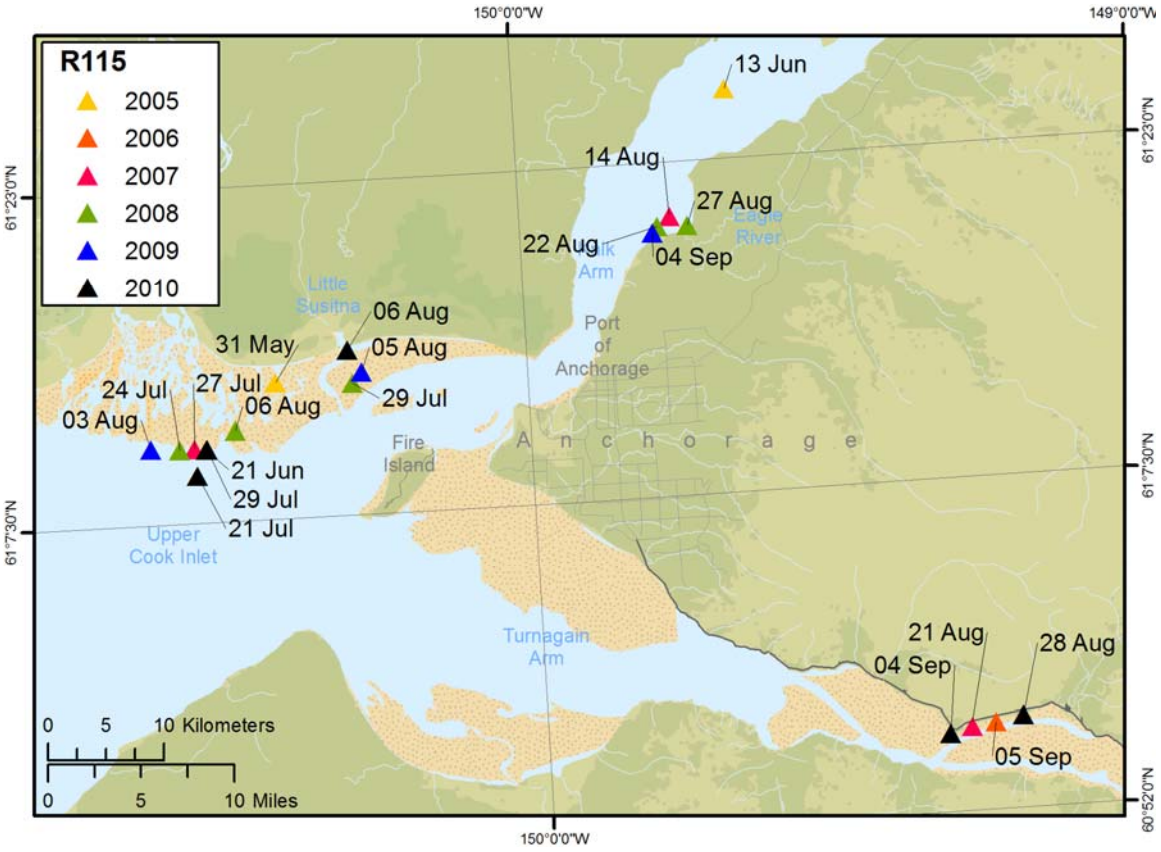

Figure C4. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga R115. This beluga was tagged by NMFS sometime between 1999 and 2002. This beluga is a presumed mother based on photographs with an accompanying calf.

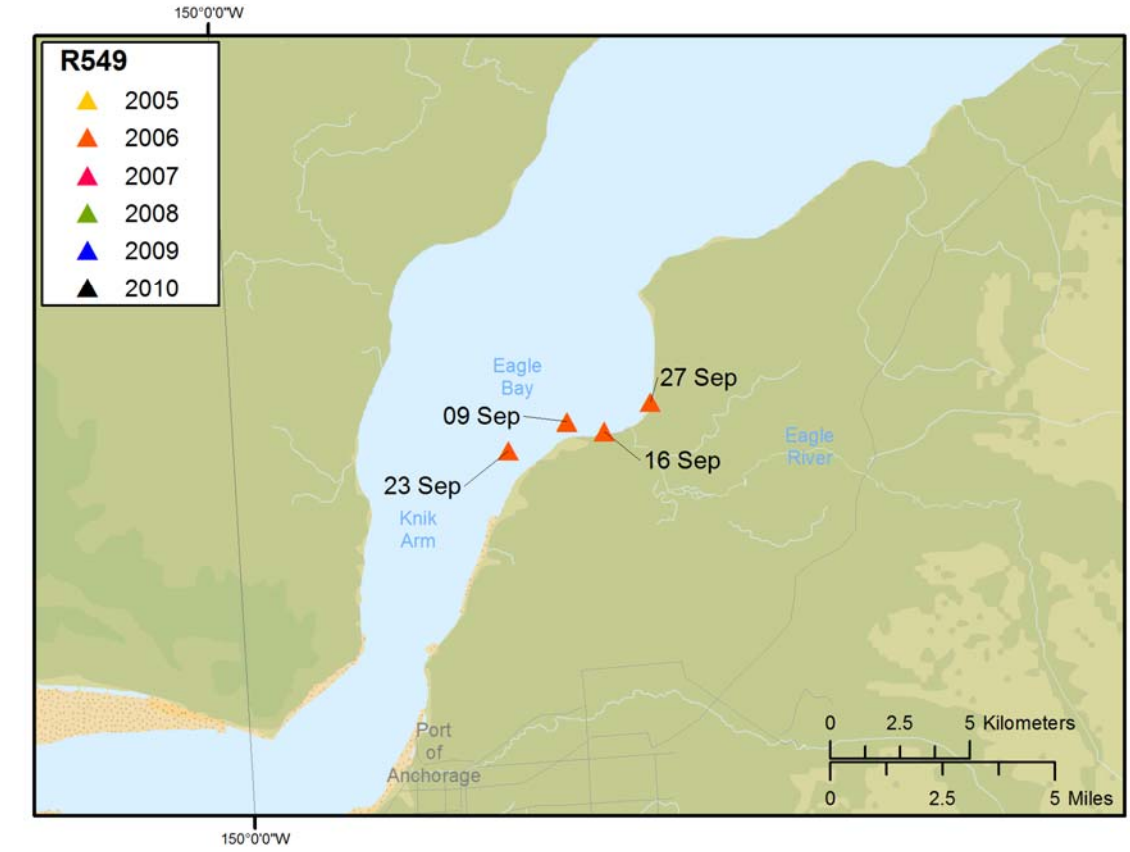

Figure C5. Sighting and photograph of beluga R549, who was photographed from its right side during 2006. This beluga was tagged by NMFS sometime between 1999 and 2002. This beluga is a presumed mother based on photographs with an accompanying calf.

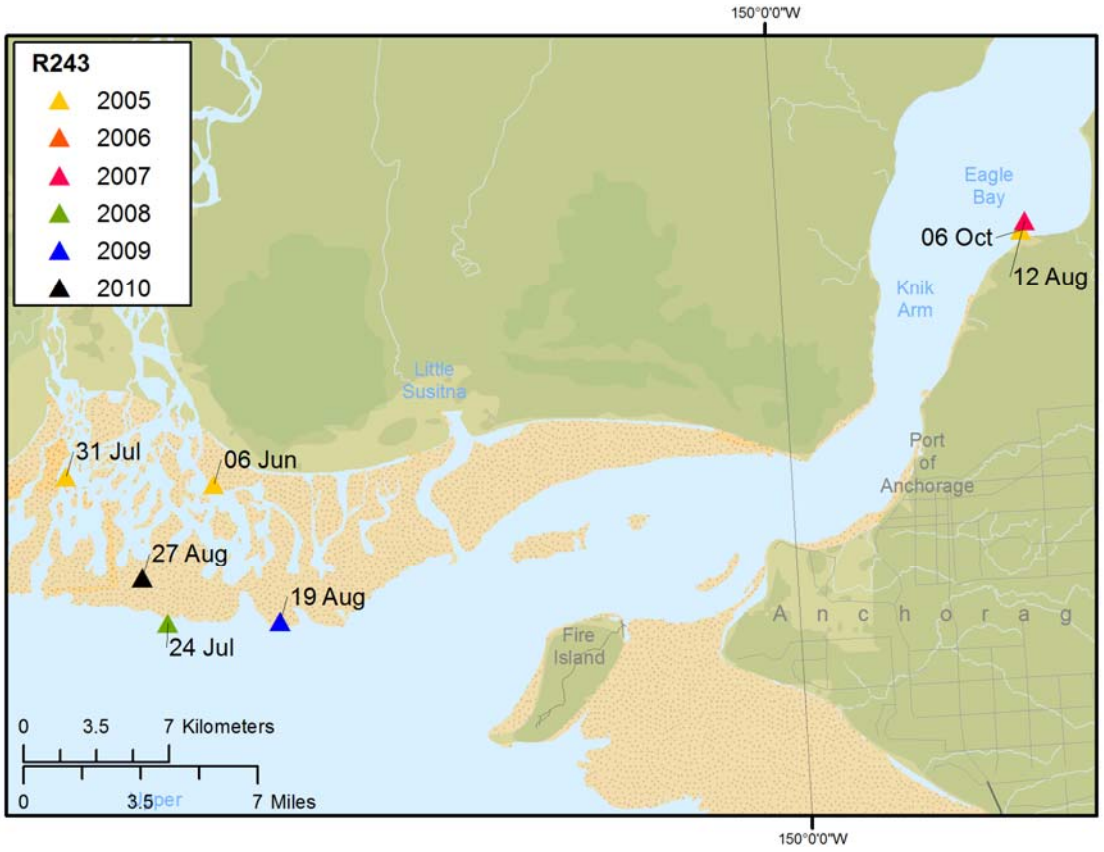

Figure C6. Sighting and photograph of beluga R243. This beluga was tagged by NMFS sometime between 1999 and 2002.

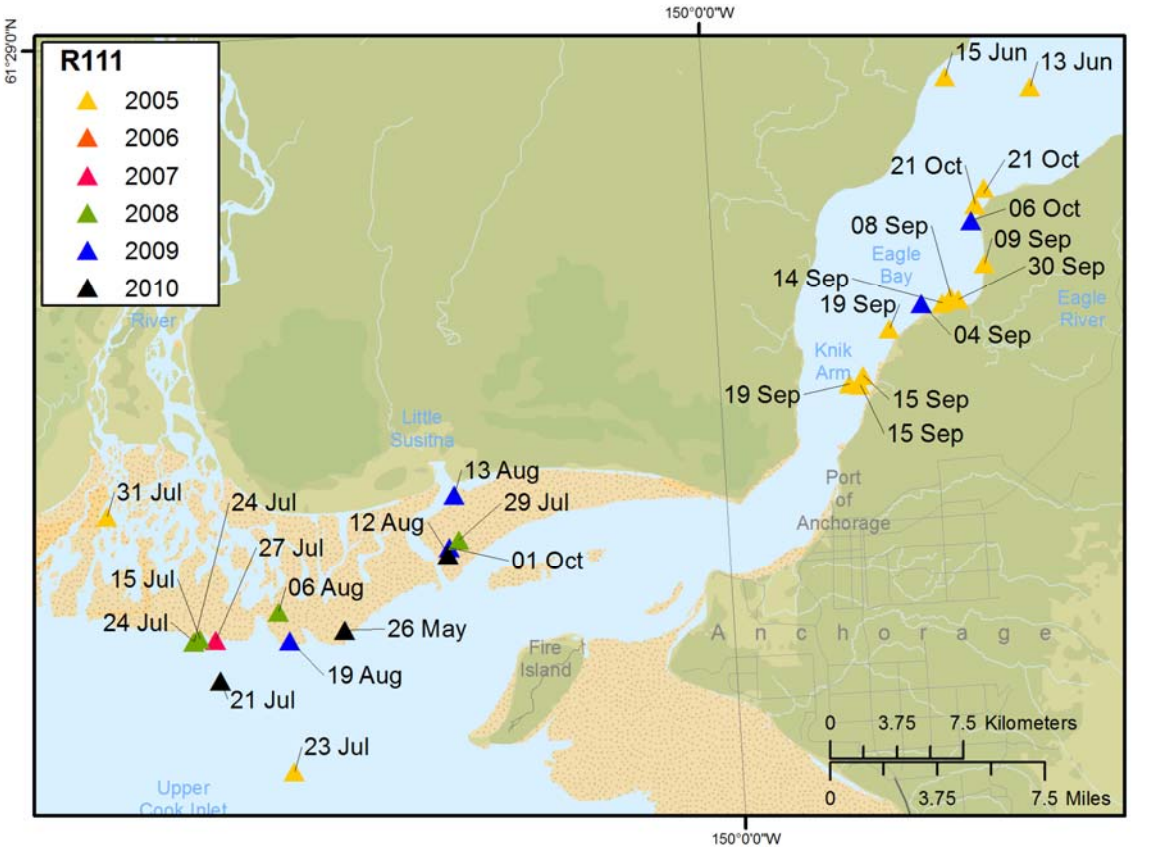

Figure C7. Sighting and photograph of beluga R111. This beluga was tagged by NMFS sometime between 1999 and 2002.