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

Final Report of Field Activities and Belugas Re-sighted in 2009

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Prepared for:

National Fish and Wildlife Foundation
Chevron
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 is 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 five field seasons (2005-2009) have provided 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 2009 field season, and presents results from analyses of photos of whales encountered and identified in 2005-2009, including sighting rates, distribution, movement patterns, group associations, mortalities, and reproductive information.

Methods

Dedicated surveys and opportunistic sampling of Upper Cook Inlet, Alaska were conducted from a small vessel and from shore from June through October 2009. 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 2009.

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 five years of the study (2005-2009), whales seen in 2009 that were also identified by marks on the left side of their bodies, and whales bearing scars from previous satellite tags, were plotted and presented graphically. Locations of cataloged beluga whale sightings were mapped in ArcGIS™ Version 10 (http://www.esri.com). The study area was divided into subsections and occurrence and movements of identified belugas among sections was examined. Mothers and calves were identified in photographs, and sighting histories were compiled for all cataloged mothers with calves.

Coefficient of associations (COAs) were calculated for the whales cataloged in all five years of the study (2005-2009), for whales seen in 2005 and 2009 (regardless of whether they had been seen in the intervening years), and for whales identified by satellite-tag scars. A cluster analyses was performed to determine if distinct clusters or subgroups of belugas occurred within the subsets. An estimate of social differentiation was calculated to provide a measure of the variation of association patterns within a population.

Results

Whales in forty-three groups were counted and photographed during 32 survey days in 2009. Maximum group size was 152. The largest groups per month were seen in the following locations: Susitna River Delta in June, July, and August; Turnagain Arm in September, and Knik Arm in October. The field work completed in 2009 brings the project total to 174 photo-identification surveys conducted over five annual field seasons. From 2005 through 2009, a total of 104,354 photographs were taken of whales sighted in 371 groups.

Mean group size was 26 whales. Group composition ranged from 48 to 54% white belugas, 20 to 40% gray belugas, 6 to 8% calves, and 1 to 4% neonates. Calves were seen throughout the months when beluga groups were encountered during the 2009 field season. Calves (not neonates, but young animals probably born in 2008 or earlier) were first seen on 19 June (the first survey of the 2009 field season) and last seen on 15 October. Neonates were not observed until 1 August and were last observed 15 October. Calves and neonates were seen in all areas of Upper Cook Inlet where beluga groups were encountered during photo-identification surveys in 2009, although groups with neonates were seen more often (after standardizing for unequal survey effort among areas) in Knik Arm than in other areas.

Revisions to the right-side catalog continued through the addition of photographs from the 2009 field season. Of the belugas photographed in 2009, 134 were previously identified as individual whales in the 2005-2008 catalog, and 17 newly-identified individuals were added to the catalog. The 2005-2009 right-side catalog currently contains records for 255 individual whales.

Twenty-nine belugas were identified in all five years of the study (2005-2009), and their individual sighting histories and photographs are presented in Appendix B. Of the 29 individually identified belugas sighted in each year, none were observed exclusively in one survey area. All 29 belugas were photographed in both Knik Arm and the Susitna River Delta. Twenty-one percent of these belugas were also seen in Turnagain Arm and 3% were seen in the Chickaloon Bay/Southeast Fire Island area.

Fifty-one identified belugas were photographed with calves in 2009. One hundred and thirty-one identified belugas were presumed to be reproductive adult females; this presumption was based on photographs taken of these females from 2005 through 2009 in which they were closely accompanied by calves. Forty-two identified belugas were photographed with calves in more than one year. Seventeen 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 assumed to be the same calf maturing). Seven identified belugas were each first seen with a larger calf, then one or three years later, were seen with a much smaller calf (assumed to be a new calf). Seven calves were individually identified between 2005 and 2009.

Six photo-identified belugas have unique right-side scars from holes used by NMFS to affix satellite tags in 1999-2002. Three 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. Individual sighting histories and photographs of previously tagged belugas are presented in Appendix C. Fifteen whales photographed in 2009 and identified as individuals in the 2005-2009 right-side catalog were also identified in the 2005-2008 left-side catalog. Individual sighting histories and photographs of these "dual-side" whales are presented in Appendix D.

COAs were calculated for the 29 whales seen in all five years of the study (2005-2009) and for previously tagged whales, and the mean COA for each beluga was calculated. The maximum COA for a pair was 0.52, indicating that these two belugas were sighted together in 52% of the groups in which they were individually sighted. A series of cluster analyses were performed to examine if distinct clusters or subgroups of whales occurred within the population; there was no evidence that this population was divided into clusters or subgroup.

Three dead belugas were encountered by LGL biologists in 2009. In all cases, NMFS was contacted before and after LGL performed external examinations of the whales. Advanced skin decomposition prevented photo-identification of two of these whales. A third dead whale was identified as a whale already in the photo-identification catalog. The photo-identification records show this whale was accompanied by calves in 2005, 2008, and 2009; the necropsy determined that this whale was pregnant at the time of death in October 2009.

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 152, which indicated that some of the population was elsewhere (NMFS estimated the population at 321 in 2009; 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. As part of a study to compare methods, on 13 August of 2009 we conducted boat-based surveys immediately after NMFS flew aerial surveys in the same areas; group size estimates from the two methods produce similar results and that patterns seen by each team are not simply artifacts of sampling methods.

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 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 late July/early August along the Susitna River Delta. These large groups were observed travelling, socializing, and were suspected to be feeding (salmonids were seen jumping from water amidst belugas).

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 five 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 of the 29 beluga whales photographed in all five years of the study 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).

Of the 131 belugas assumed to be mothers, 17 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 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). Six 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 3-10 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 2009 and 2010, project results from 2005-2009 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, 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 five 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.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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 is 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). 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, McGuire and Kaplan 2009, McGuire et al. 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-id 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 five field seasons (2005-2009) 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, McGuire and Kaplan 2009, McGuire et al. 2009).

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This report summarizes field effort and photo-identification surveys from the 2009 field season, and presents results from analyses of photos of whales encountered and identified in 2005-2009, including sighting rates, distribution, movement patterns, group associations, mortalities, 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. 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 summer (June-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 made when wind conditions along Turnagain Arm were safe for boat activity. 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, matching 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 D70, 6.1 megapixel digital SLR camera (June-August) and a Nikon D300, 12.3 megapixel digital SLR camera (late August-October). The same Nikkor 70-400 mm zoom telephoto auto focus lens was used with each camera. 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.

A standard photographic white/gray balance card (18% gray) was photographed at least once per survey to document the variability in the camera's ability to accurately capture the true color of whales given the daily (and often hourly) variation in lighting conditions caused by changing environmental factors such as clouds, glare, ocean conditions, and fog. Beginning in early September 2009, we also used a white-constant to more accurately adjust photos of whales to their true color using Adobe® Photoshop® Lightroom® during processing. In the field, we affixed large (~2 foot squares) swatches of white tape to the pontoons of the R/V *Leucas* at four locations: bow, starboard, stern, and port and photographed the tape at the beginning of each group encounter. Because

the lighting conditions varied relative to the direction of view, we photographed the white tape frequently when the whales' position changed relative to the vessel in an attempt to capture this variability.

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 2009. 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 surfaces and submerges, different portions of its body are 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 allows for the acceptance of a whale into the catalog is 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 five years of the study (2005-2009), whales seen in 2009 that were also identified by marks on the left side of their bodies, and of all sightings of whales bearing scars from previous satellite tags, were plotted and presented graphically. The left-side catalog was created in 2009 and 2010 with a grant from the North Pacific Research Board that allowed us to catalog archived left-side photographs taken during NFWF-sponsored field surveys 2005-2008. Locations of cataloged beluga whale sightings were mapped in ArcGIS™ Version 10 (http://www.esri.com). The study area was divided into subsections (Figure 2), and occurrence and movements of identified belugas among sections was 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.

Indices of Association between Cataloged Belugas

A coefficient of association (COA) is a measure of the association between beluga A and beluga B,

$$COA=N_{ab}/N_a+N_b$$

where N_{ab} is the number of times beluga A and beluga B were found in the same group, and N_a and N_b are the total of group sightings for A and B, respectively. COAs were calculated for pairs of individuals, where a COA=0.0 indicates beluga A and B were never seen together and a COA=1.0 indicates that beluga A and B were always seen together.

COAs were calculated for the whales seen in all five years of the study (2005-2009) and for whales seen in 2005 and 2009 (regardless of whether they had been seen in the intervening years). This subset of the catalog was selected because each whale had been re-sighted for the duration of the study, thus eliminating the possibility that sightings had been missed due to mark loss or significant mark change. COAs were also calculated for those whales that were previously marked by satellite tags. Whales were considered to be associated if they were sighted in the same group on the same day. COAs and all related analyses of association were calculated with the software program SOCPROG 2.3 for MATLAB 7.4 (Whitehead 2008). COAs were calculated using a simple-ratio index (rather than a half-weight ratio index; Cairns and Schwager 1987), because association was defined as presence in the same group on the same day (Whitehead 2008).

The COA matrix for each subset was displayed in a dendrogram, in which rows represent the subset of cataloged belugas and the lines and the distances connecting the rows represents the COA between two individuals (Whitehead 2008). A cluster analyses was performed to determine if distinct clusters or subgroups of belugas occurred within the subsets. An estimate of social differentiation was calculated to provide a measure of the variation of association patterns within a social system (i.e., if a society is homogenous or well-differentiated). Because the majority of calves could not be identified independently of their mothers, COAs for mother-calf pairs were not calculated.

Additional Information Provided by the Study

Causes of markings

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 (2005-2009) 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.

Modifications were made to the database application to streamline the cataloging process. Efforts were made to update the photos cataloged before the development of the database (2005-2007) to have the same information (i.e., photos linked with vessel-tracks and sighting data) in the database as subsequent photos (2008-2009). Additional modifications included, but were not limited to, the addition of tools to create/edit/merge photos of cataloged whales within the application, the creation of a feature to view the "best photos" selected of each whale to have a quick-reference interface of cataloged whales, and a function to export detailed reports of various data listed above. Consolidation (from 96 to 38 tag categories for mark types) and renovation of tag-filters allowed for more advanced searches according to mark-types according to their position on the whale. A "view in context" feature was added to view the cropped photograph in its original, uncropped form and also in the sequence of the other photos taken on that day. This can be very helpful in the cataloging process because sequential photographs of the same whale are occasionally separated from each other.

RESULTS

Surveys

Survey effort and number of whales and whale groups encountered

Forty-three beluga whale groups were counted and photographed during 32 survey days in 2009 (Table 1). Mean group encounter rates were highest in Turnagain Arm and lowest in Knik Arm. Across all areas a mean of 1.3 groups per survey was observed. Survey effort was unequal among locations and seasons (Table 2). Survey effort was highest at the Susitna River and lowest in Chickaloon Bay. In 2009, a total of 120.3 hours was spent in vessel surveys (each vessel survey was 1.3-8.8 hours in duration, with a mean of 5.7 hours). A total of 22.3 hours was spent in land-based surveys (each land-based survey was between 0.9 and 4.3 hours in duration, with a mean of 2.0 hours). Duration of surveys depended on hours of daylight, tidal conditions, if whale groups were encountered, and size and behavior of whale groups. Mean minimum approach distance (i.e., vessel or land-based observer approaching whales) between whale groups and the photographer was 280.7 m (920.9 ft), although individual whales

often approached within 1 m of the vessel. Mean minimum approach distance was 137.1 m (449.8 ft) in the Susitna River Delta, 65.6 m (215.2 ft) in Knik Arm, and 578.1 m (1,896.7 ft) along Turnagain Arm.

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 152. The largest groups per month were recorded in the following locations: Susitna River Delta in June, July, and August; Turnagain Arm in September, and Knik Arm in October (Tables 3 - 5). Maps of whale group sighting locations and survey routes from the vessel and from land in 2009 are presented in Appendix A.

The field work completed in 2009 brings the project total to 174 photo-identification surveys conducted over five annual field seasons (Table 6). In all, a total of 104,354 photographs were taken of whales sighted in 371 groups.

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

The most-frequently encountered group sizes were three, five, or eight whales, and groups ranged from one to 152 whales (Figure 4). Mean group size was 25.5 whales (Table 1). Relative color composition of groups varied with location and survey method (Table 7). Group composition ranged between 48 and 54% white belugas, 20 and 40% gray belugas, 6 and 8% calves, and 1 and 4% neonates. Belugas of unknown color/age class comprised between 0 and 18% of groups; the highest percentage of unknowns occurred in Turnagain Arm. Color composition and age class were determined for all groups seen in Knik Arm.

Calves were seen throughout the months when beluga groups were encountered during the 2009 field season (Tables 3 - 5). Neonates were not observed until 1 August and were last observed 15 October. Calves and neonates were seen in all areas of Upper Cook Inlet where beluga groups were encountered during photo-identification surveys in 2009 (Figure 5), although groups with neonates were seen more often (after standardizing for unequal survey effort among areas) in Knik Arm than in other areas (Tables 3 - 5; Figure 5). The percentage of each group composed of calves and neonates varied according to location, as did the percentage of groups containing calves and neonates. Thirty-nine percent of groups encountered in Turnagain Arm contained calves, whereas 71and 88% of groups encountered in the Susitna River Delta and Knik Arm, respectively, contained calves (groups were not encountered in Chickaloon Bay in 2009; Tables 3 - 5). Neonates were observed in 35% of all beluga groups encountered in 2009. Neonates were found in 63% of the groups seen in Knik Arm and 47% of the groups in the Susitna River Delta. Only 11% of groups in Turnagain Arm contained neonates.

Behavior of whales

Milling was the most-frequently observed primary group activity in Knik Arm (Table 8). Travel was the most-frequently observed primary group activity in the Susitna River Delta and in Turnagain Arm. The most-frequently observed secondary group activities were suspected feeding in the Susitna River Delta and in Turnagain Arm; secondary activities in Knik Arm were equally divided among travel, milling, and suspected feeding.

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 2009 field season. Of the belugas photographed in 2009, 134 were previously identified as individual whales in the 2005-2008 catalog, and 17 newly-identified individuals were added to the catalog (Figure 6). The 2005-2009 right-side catalog currently contains records for 255 individual whales.

Sighting Histories

Sighting histories of belugas 2005-2009

Twenty-nine belugas were identified in all five years of the study (2005-2009), and their individual sighting histories and photographs are presented in Appendix B. In addition, 37 belugas were identified in four years of the study, 45 belugas in three years of the study, 89 belugas in two years of the study, and 55 individual belugas were identified in only a single year.

Of the 29 individually identified belugas sighted in each of the five years of the study (Table 9), none were observed exclusively in one survey area. All 29 belugas were photographed in both Knik Arm and the Susitna River Delta. Twenty-one percent of these belugas were also seen in Turnagain Arm and 3% were seen in the Chickaloon Bay/Southeast Fire Island area. Seventy-six percent of the belugas seen in Knik Arm and the Susitna River Delta were only seen in these two areas.

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 23 different days during 2005-2009 (Figure 7). Nine percent of belugas identified from 2005 to 2009 were sighted on one day only, 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 Knik Arm, followed by the Susitna River Delta, and was much lower in Chickaloon Bay and Turnagain Arm (Table 10). On average, ~ 29% of each group was identified in Knik Arm, while only ~ 4% of each group was identified in Turnagain Arm.

Sighting histories of mothers and their calves

Fifty-one identified belugas were photographed with calves in 2009. One hundred and thirty-one identified belugas were presumed to be reproductive adult females; this presumption was based on photographs taken of these females from 2005 to 2009 in which they were closely accompanied by calves (Table 11). 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).

Forty-two 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. Seven calves were individually identified between 2005 and 2009 (Table 12). Six 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.

Twenty-seven identified belugas were seen with calves in consecutive years. Eleven identified belugas were seen with calves in two years, but with one intervening year without a calf. Eleven identified belugas were seen with calves in two years, but with two intervening years without calves, and two identified belugas were seen with calves but with three intervening years without calves. Seventeen 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 assumed to be the same calf maturing). Seven identified belugas were each first seen with a larger calf, then one or three years later, were seen with a much smaller calf (assumed to be a new calf; Figures 8 and 9).

Sighting histories of belugas identified by satellite tag scars

Six 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. Four of these belugas were sighted in 2009. Three 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). Five 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. Individual sighting histories and photographs of previously tagged belugas are presented in Appendix C.

Sighting histories of belugas identified on both right and left sides

Fifteen whales photographed in 2009 and identified as individuals in the 2005-2009 right-side catalog were also identified as whales in the 2005-2008 left-side catalog. Individual sighting histories and photographs of these "dual-side" whales are presented in Appendix D. The left-side catalog was created in 2009 and 2010 with a grant from the North Pacific Research Board that allowed us to catalog archived left-side photographs taken during NFWF-sponsored field surveys 2005-2008.

Associations among Identified Belugas

Associations among five-year whales

COAs were calculated for 29 whales identified in all five years of the study (2005-2009), and the mean COA for each beluga was calculated by taking the mean of that beluga's 28 COAs from 28 pair-wise comparisons. Mean COAs ranged from 0.10 to 0.23. The maximum COA per beluga ranged from 0.20 to 0.52. A dendrogram was created (Figure 10) that represents the 29 cataloged belugas and the strength of the association among individuals. The maximum COA occurred between beluga RA009 and beluga RA001 and was 0.52, indicating that that these two belugas were sighted together in 52% of the groups in which they were individually sighted.

A cluster analysis was performed to examine if distinct clusters or subgroups of whales occurred within the population (in this case, the "population" is the 29 belugas identified in all five years of the study). COAs are high among individuals in the same cluster, and low among individuals in different clusters. There was no evidence that this population was divided into clusters or subgroups, because the modularity value for the cluster analysis was 0.10. Modularity values of >0.3 are considered indicative of distinct clusters (Whitehead 2008).

The estimate of social differentiation (the coefficient of variation of the true association indices) using a Poisson approximation was 0.37. This value provided a measure of the variation of association patterns within a social system (Whitehead 2008). In this case, the value indicated generally homogenous society. Values <0.3 are indicative of a homogenous society, and those >0.5 indicate evidence of a well-differentiated society (Whitehead 2008).

Associations among satellite-tagged whales

COAs were calculated for the six whales identified by satellite tag scars and natural marks on the right side of their bodies. A dendrogram of associations among these whales is presented in Figure 11. The maximum COA occurred between beluga RA139 and beluga RA160 and was 0.37, indicating that these two belugas were sighted together in 37% of groups in which they were individually sighted.

Associations among whales identified in 2005 and 2009

Eighty-four whales in the right-side catalog were identified in 2005 and in 2009 (many of these were also identified in the intervening years). Associations were examined among the 84 whales; the estimation of social differentiation was 0.00 (SE=21.86), indicating a homogenous society.

Additional Information Provided by the Study

Dead belugas encountered in 2009

Three dead belugas were encountered by LGL biologists in 2009. In all cases, NMFS was contacted before and after LGL performed external examinations of the whales. A dead male calf (teeth unerupted) was encountered by an LGL biologist on 23 September 2009 along the shore of Kincaid Park, Anchorage (Figure 12). On 15 October 2009, LGL biologists conducting a boat-based photo-identification survey encountered a dead adult beluga on the shore north of Eagle Bay in Knik Arm (Figure 13). Advanced skin decomposition prevented photo-identification of either whale. In both cases, LGL biologists secured the carcasses, photographed the whales, took skin samples for NMFS, and notified NMFS with stranding details, including GPS coordinates.

On 9 October 2009, NMFS informed LGL of a dead stranded beluga whale near Elderberry Park, Anchorage. LGL biologists photographed and secured the whale (Figure 14), which was later necropsied by Kathy Burek. The whale was identified as a whale in the photo-identification catalog (Figure 15). This whale had been seen in 2005, 2007, 2008, and 2009, and had been seen in Knik Arm and the Susitna River Delta (Figure 16). The photo-identification records show this whale was accompanied by calves in 2005, 2008, and 2009 (could not be determined from photographs if this was the same calf or different calves); the necropsy determined that this whale was pregnant at the time of death in October 2009.

Causes of markings

Types of marks that were identified and assigned to photographs included those presumed to be caused by natural sources such as disease (Figures 17 and 18), predation (Figures 19 and 20), conspecifics and anthropogenic sources such as bullets (Figures 21 and 22), ship strikes (Figures 23 and 24), and satellite tags, shown in Appendix C.

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, 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 2009 were similar to those from previous years (McGuire et al. 2008, McGuire and Kaplan 2009). The maximum number of beluga whales encountered in a single survey day was never more than 152, which indicates that some of the CIBW population was elsewhere (NMFS estimated the population at 321 in 2009; 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 (Shelden et al. 2009a).

Group sighting rates (number of groups encountered per survey) were similar between 2009 and 2008 (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-id research team remained the same during the 2007-2009 field seasons. Average group size during photo-id surveys was 26 whales in 2009, 27 whales 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. As part of a study to compare survey methods, on 13 August 2009 we conducted boat-based surveys immediately after NMFS flew aerial surveys in the same areas; group size estimates from the two methods and the two teams were very similar (Shelden et al. 2009b), increasing our confidence that data collected at different times by the two teams can be compared and that patterns seen by each team are not simply artifacts of sampling methods.

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 2009 contained both white and gray whales. All groups seen in Knik Am and 82% of groups seen in the Susitna River Delta contained white and gray whales. Color composition was most difficult to determine in Turnagain Arm, where whales were generally far from land-based observers. Slightly more than 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.

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). This resulted in some variability in color assigned to whales in the field compared to that assigned to whale photographs in the catalog.

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 late July/early August; neonates were first seen in early August 2009, and on 24 July, and 27 in 2008 and 2007, respectively. 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 2007-2009, 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. Groups seen in Knik Arm were more likely to contain calves and 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, in 2008 groups with calves (but not neonates) were seen more often in the Susitna River Delta than in Knik Arm.

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. Neonates were more likely to be found in Knik Arm than in the Susitna River Delta, and the mean sighting distances the Susitna River Delta was almost twice those in Knik Arm, although observers had the impression they would still be able to detect neonates at these distances.

Behavior

Traveling and suspected feeding were the predominant behaviors observed for groups encountered in the Susitna River Delta (surveyed during the summer) and in Turnagain Arm (surveyed primarily during the fall). Milling was the predominant activity for groups encountered in Knik Arm (surveyed in the fall). The distinction between 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 (2005-2009) was of 152 whales seen 3 August 2009; this audibly vocal group was travelling and suspected to be feeding (salmonids were seen jumping from water amidst belugas). The second largest group ever encountered during photo-id 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 near the whales.

On several occasions in 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 five 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 knowledge 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 five years of the study and for whales identified by satellite tag scars. This subset of whales (i.e., whales seen in five 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 29 beluga whales photographed in all five years of the study 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, 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 (2005-2009) was never more than 152 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 will provide the 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 131 belugas assumed to be mothers, 17 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. Seven 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.

Seven 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 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).

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). Six 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 individual 3-10 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 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. While some of the whales identified in all five 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. 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. The 29 identified whales seen in five years 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. 2009). Groups containing calves and neonates were seen in all parts of the study area, although these groups were seen with greatest frequency (after standardizing for unequal survey effort among areas) in Knik Arm.

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. By defining different mark types and recording the locations where they are found on each whale's body, we can quantify where the various types of markings are most common, which may give insight into how they occur. For example, markings may be unevenly distributed across the body depending on the source of the mark (e.g., predation, conspecifics, anthropogenic). Understanding mark characteristics is also important for determining mark-loss rates, which is required for some analyses such as population estimates. A more-detailed examination of marks, their sizes, locations, and possible causes will be presented in future reports.

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 2009 and Dissemination of Project Results

Progress made in 2009 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 2009 and 2010, project results from 2005-2009 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), 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 are 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 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 2009 was completed 24 October. Cataloging of photographs from 2009 was completed 1 August 2010, and results are presented in the current report. Additional photo-identification surveys were conducted May-October 2010 and cataloging of those photographs is underway. Plans for 2011 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 five 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 2009 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.

2009	Susitna River Delta	Knik Arm	Turnagain Arm	Chickaloon Bay/SE Fire Island	*Total for All Locations*
Number of Surveys	15	12	12	1	*32 survey days*
Total Number of Beluga Whale Groups	17	8	18	0	*43*
Total Number of Beluga Whale Sightings	648	220	228	0	*1096*
Mean Number of Groups per Survey	1.1	0.7	1.5	0	*1.3*
Mean Number of Whales per Survey	43.2	18.3	19.0	0	*34.3*
Mean Number of Whales per Group	38.1	27.5	12.7	0	*25.5*

Table 2. Distribution of photo-identification effort by month, week, and location in 2009 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
June	**1**				
	2				
	3	1			
	4	1	1		
July	**1**	1			
	2	1			1
	3				
	4	1			
August	**1**	3			
	2	1	1		
	3	1			
	4	1	1		
	5		1	1	
September	**1**	1	1	4	
	2		1	2	
	3	1	2	2	
	4			1	
October	**1**	2	2	1	
	2		1		
	3		1		
	4			1	

Table 3. Group size, color, composition, and total belugas sighted during vessel surveys in the Susitna River Delta in 2009. (Neonates separate from calf total. Unknown = beluga of unknown color and size.)

Date	Beluga Group #	# White	# Gray	# Calves	# Neonates	# Unknown	*Total Belugas Sighted*
19-Jun-2009	1	15	5	4	0	0	***24***
24-Jun-2009	1	3	0	0	0	0	***3***
24-Jun-2009	2	4	1	1	0	0	***6***
24-Jun-2009	3	5	6	2	0	0	***13***
2-Jul-2009	1	1	0	0	0	0	***1***
7-Jul-2009	0	0	0	0	0	0	***0***
23-Jul-2009	1	0	0	0	0	35	***35***
1-Aug-2009	1	55	30	5	1	0	***91***
3-Aug-2009	1	81	54	12	5	0	***152***
5-Aug-2009	1	35	22	7	4	0	***68***
5-Aug-2009	2	25	12	2	0	1	***40***
13-Aug-2009	1	28	11	2	2	0	***43***
19-Aug-2009	1	4	1	0	0	0	***5***
19-Aug-2009	2	18	12	3	1	0	***34***
19-Aug-2009	3	30	23	3	1	0	***57***
19-Aug-2009	4	3	0	1	0	0	***4***
19-Aug-2009	5	17	9	9	3	0	***38***
26-Aug-2009	0	0	0	0	0	0	***0***
18-Sep-2009	0	0	0	0	0	0	***0***
1-Oct-2009	1	16	13	3	2	0	***34***
6-Oct-2009	0	0	0	0	0	0	***0***
Total	***17***	***340***	***199***	***54***	***19***	***36***	***648***

Table 4. Group size, color, composition, and total belugas sighted during vessel surveys in Knik Arm in 2009. (Neonates separate from calf total. Unknown = beluga of unknown color and size.)

Date	Beluga Group #	# White	# Gray	# Calves	# Neonates	# Unknown	*Total Belugas Sighted*
24-Jun-2009	0	0	0	0	0	0	***0***
13-Aug-2009	1	30	11	2	2	0	***45***
26-Aug-2009	0	0	0	0	0	0	***0***
31-Aug-2009	1	7	5	1	2	0	***15***
4-Sep-2009	1	10	15	4	2	0	***31***
4-Sep-2009	2	7	5	1	0	0	***13***
8-Sep-2009	1	20	25	5	1	0	***51***
18-Sep-2009	0	0	0	0	0	0	***0***
21-Sep-2009	0	0	0	0	0	0	***0***
1-Oct-2009	0	0	0	0	0	0	***0***
6-Oct-2009	1	10	10	1	0	0	***21***
15-Oct-2009	1	21	12	4	2	0	***39***
20-Oct-2009	1	1	4	0	0	0	***5***
Total	***8***	***106***	***87***	***18***	***9***	***0***	***220***

Table 5. Group size, color, composition, and total belugas sighted during land and vessel surveys in Turnagain Arm in 2009. (Neonates separate from calf total. Unknown = beluga of unknown color and size.)

Date	Survey Type	Beluga Group #	# White	# Gray	# Calves	# Neonates	# Unknown	*Total Belugas Sighted*
30-Aug-2009	Land	1	1	2	0	0	0	***3***
1-Sep-2009	Land	1	40	20	5	2	0	***67***
2-Sep-2009	Land	1	5	1	1	0	0	***7***
6-Sep-2009	Land	1	8	0	1	0	12	***21***
7-Sep-2009	Land	1	13	8	2	0	0	***23***
11-Sep-2009	Land	1	4	2	2	0	0	***8***
11-Sep-2009	Land	2	15	0	0	0	0	***15***
13-Sep-2009	Land	1	0	0	0	0	20	***20***
13-Sep-2009	Land	2	4	2	2	0	0	***8***
15-Sep-2009	Boat	1	8	8	0	0	0	***16***
15-Sep-2009	Boat	2	2	0	0	0	0	***2***
15-Sep-2009	Boat	3	2	0	0	0	0	***2***
20-Sep-2009	Land	1	4	3	1	0	0	***8***
23-Sep-2009	Land	1	10	0	0	0	0	***10***
2-Oct-2009	Land	1	1	0	0	0	0	***1***
2-Oct-2009	Land	2	1	0	0	1	0	***2***
2-Oct-2009	Land	3	0	0	0	0	10	***10***
24-Oct-2009	Land	1	5	0	0	0	0	***5***
Total	***12***	***18***	***123***	***46***	***14***	***3***	***42***	***228***

Table 6. Total project survey effort and beluga whale group encounters 2005-2009, Upper Cook Inlet, Alaska. (Chickaloon Bay = Chickaloon Bay/Southeast Fire Island).

	2005	2006	2007	2008	2009	*Total*
Number Photo-identification survey days	49	38	23	32	32	***174***
Number Photos taken	44,878	21,244	4,193	13,222	20,817	***104,354***
Number Groups Encountered	140	96	42	50	43	***371***
Range of Surveys	14 Apr- 21 Oct	12 May-5 Oct	28 Jun-27 Oct	21 May-28 Oct	19 Jun-24 Oct	
Season Survey Span (Months)	6	5	4	5	4	
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	

Table 7. Percent color composition of beluga whale sightings from surveys conducted in 2009 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	648	52	31	8	3	6
Knik Arm	vessel	220	48	40	8	4	0
Chickaloon Bay	vessel	0	N/A	N/A	N/A	N/A	N/A
Turnagain Arm	vessel and land	228	54	20	6	1	18
	All Areas 2009	***1096***	***52***	***30***	***8***	***3***	***7***

Table 8. Summary of primary and secondary activities of beluga groups encountered in 2009 during vessel and land surveys in Upper Cook Inlet. Whales were not observed in Chickaloon Bay/Southeast Fire Island in 2009.

		Percent of all Group Activity Recorded per Area				
Area	Group Activity	% Traveling	% Milling	% Suspected Feeding	% Diving	% Unknown
Knik Arm	Primary	38	50	13	0	0
Susitna River Delta	Primary	41	12	12	23	12
Turnagain Arm	Primary	90	0	0	5	5
Knik Arm	Secondary	25	25	25	0	25
Susitna River Delta	Secondary	18	18	29	6	29
Turnagain Arm	Secondary	11	11	22	0	56

Table 9. Sighting records of 29 individual belugas identified and cataloged each year from 2005 to 2009 according to year and location. (P = photographed)

	Knik Arm					Susitna River Delta					Turnagain Arm					Chickaloon Bay/ SE Fire Island				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
	# of Surveys					# of Surveys					# of Surveys					# of Surveys				
Whale ID	32	15	10	12	12	17	21	4	8	15	1	6	8	12	12	0	1	1	2	1
RA001	P	P	P	P	P		P	P	P	P										
RA002	P	P		P			P	P		P										
RA009	P	P	P	P		P		P	P	P										
RA025	P	P				P		P	P	P										
RA036	P				P	P	P	P	P											
RA054	P	P	P			P			P	P										
RA066	P	P		P				P		P										
RA094	P	P	P	P					P	P										
RA100	P	P			P		P	P	P	P		P								
RA102	P			P			P	P	P	P			P							
RA001	P	P	P	P	P		P	P	P	P										
RA002	P	P		P			P	P		P										
RA009	P	P	P	P		P		P	P	P										
RA025	P	P				P		P	P	P										
RA036	P				P	P	P	P	P											
RA054	P	P	P			P			P	P										
RA066	P	P		P				P		P										
RA094	P	P	P	P					P	P										
RA100	P	P			P		P	P	P	P		P								
RA102	P			P			P	P	P	P			P							
RS044	P	P	P	P		P	P		P	P										
RS110	P	P					P		P	P								P		
RS118	P				P		P	P	P	P										
RS124	P				P		P	P	P											
RS134	P	P		P	P		P		P	P			P							
RS139	P	P		P	P		P	P	P	P										
RS140	P				P		P	P	P											
RS221	P		P	P	P	P	P		P	P										
RS222	P	P		P	P		P	P		P										

Table 10. Mean number of cataloged belugas per survey, mean percent of group cataloged, mean group size, and number of surveys per area from 2005 to 2009 in Upper Cook Inlet, Alaska.

Area	Mean # Cataloged Belugas / Survey	Mean % of Group Cataloged	Mean Group Size	# of Surveys
Susitna River Delta	10.0	12	79.8	67
Knik Arm	11.4	29	39	74
Turnagain Arm	1.1	4	26.2	38
Chickaloon Bay/Southeast Fire Island	1.0	4	28.2	5

Table 11. Yearly sighting records of 131 individual beluga whales assumed to be mothers based on the close accompaniment of a calf at least once during 2005-2009. (C = photographed with a calf, P = photographed without a calf).

	# of Surveys						
	49	38	23	32	32	# Years See with a Calf	Age Information Inferred from Individuals seen with Calves in >1 year (CBD=Could not be determined)
Whale ID	**2005**	**2006**	**2007**	**2008**	**2009**		
Approximately		P		P	C	1	
Bubbleswhitelines				C	C	2	CBD
CC		C	C			2	CBD
Chocolate		P		C		1	
Crosscup				C	P	1	
Darkdimple				P	C	1	
Dubya			C	C		2	maturing calf
ET		C				1	
Fan				C	P	1	
Fish		C		P	P	1	
Fulllength				P	C	1	
GolfFlag			C	P	P	1	
GreaterThanEqualTo				C		1	
Groovy		C				1	
Grumpy		P		P	C	1	
Hockey		C		P		1	
Hut		C		P		1	
Inthecatalog		P	C			1	
Keloid				P	C	1	
Crustytop					C	1	
Dashslash					C	1	
Littlemark			P	C	P	1	
Marksalot			P	C	P	1	
MirrorC			P		C	1	
Music				P	C	1	
NewRipAnt				C	P	1	
ProppedOne-R				C	P	1	
Quack		C		P		1	
Question			C		P	1	
RA001	P	C	P	C	C	3	maturing calf (2006/2008); CBD 2008/2009
RA002	C	C	P	P	P	2	CBD
RA003	P	P		C		1	
RA004	P	P			C	1	
RA006	C	P				1	
RA007	P		P	P	C	1	
RA009	C	P	P	C	P	2	maturing calf
RA010	C					1	

Table 11. Continued.

RA013	P	P	P	C		1	
RA015	C	P	P			1	
RA017	P			C	P	1	
RA018	P				C	1	
RA020	P	P		C		1	
RA022	C					1	
RA024	C	C	C			3	CBD
RA025	P	P	C	C	P	2	CBD
RA026	C	P		C	P	2	2008 calf smaller than 2005 calf
RA032	C					1	
RA036	C	P	P	C	C	3	2008 calf smaller than 2005 & 2009 calf
RA039	P	C		P	C	2	maturing calf (neonate in 2006)
RA042	C				P	1	
RA043	P	C		P	C	2	2009 calf smaller
RA054	C	P	P	P	C	2	2009 calf smaller
RA060	P			P	C	1	
RA061	C	P				1	
RA062	P	P		C		1	
RA063	P	P	P	C		1	
RA064	C	C		P	P	2	maturing calf
RA066	P	C	C	P	C	3	CBD
RA067	P			C	C	2	maturing calf
RA079	P	P	C			1	
RA085	P		C	C	P	2	CBD
RA086	P			C		1	
RA087	C					1	
RA089		C		P		1	
RA090	P				C	1	
RA094	C	P	C	P	P	2	maturing calf
RA095	C		P	C		2	CBD
RA096	C			C	C	3	CBD
RA102	P	C	P	P	C	2	CBD
RA108	P	C		P	C	2	CBD
RA119	C	P				1	
RA121		C		C	C	3	2008 calf smaller
RA122	C	P		P	P	1	
RA123	P	C	P	C		2	maturing calf
RA126	P	P		C	P	1	
RA131	P	C		C	C	3	CBD 2006/2008; 2008 calf smaller than 2009
RA133		P	P	P	C	1	
RA141		P		C		1	
RA144		C		P		1	

Table 11. Continued.

RA145	C	C	C	C	C	5	maturing calf
RA146	P	C		C	P	2	CBD
RA147	C	P	P	P	C	2	CBD
RA148	P	P	C	C	P	2	maturing calf
RA151	C	P	P	P	P	1	
RA154	C	C	P	C	C	4	CBD
RA155	P	C	P	C	C	3	CBD; maturing calf 2008/2009
RA156	P		P	P	C	1	
RA157	P	C		C	C	3	maturing calf 2006/2008; in 2009 seen simultaneously with neonate and a maturing calf
RA158	P	C		P	C	2	CBD
RA160	P	P	P	C	P	1	
RA161		C				1	
RacinStripes				P	C	1	
Rearlongpock					C	1	
RS006	P	P		C	P	1	
RS007	C					1	
RS009	P	P			C	1	
RS012	P	P		C		1	
RS019	P				C	1	
RS024	P		C		P	1	
RS029	P			C	C	2	CBD
RS049	P	C		P		1	
RS054	P		C			1	
RS055	C		P	C	C	3	CBD (died Oct 2009 while pregnant)
RS056	P	P		C	P	1	
RS068	P	P	P	C		1	
RS069	P			C		1	
RS082	C	P		P	P	1	
RS089	P	P		P	C	1	
RS106	P			C		1	
RS110	P	P	P	C	C	2	maturing calf
RS112	P				C	1	
RS113	P	C		P		1	
RS124	C	P	P	P	P	1	
RS134	P	C	C	C	P	3	maturing calf
RS135	P		C	C	P	2	maturing calf
RS139	C	C	P	P	C	3	CBD 2005/2006, smaller calf in 2009
RS140	P	P	P	C	P	1	

Table 11. Continued.

RS150		P		C		1	
RS222	P	C	P	C	P	2	CBD
Scissis				C	P	1	
Seven					C	1	
Stickman				C		1	
Stork				P	C	1	
ThirdEyeBlind		C				1	
Turnpike				P	C	1	
Twelve		C	C	P	C	3	maturing calf
CanalDorsal					C	1	
Whitedotsupamarks				C	P	1	
Whitenick				C	C	2	maturing calf
Whitenotch				C	P	1	

Table 12. Yearly sighting records of seven individual beluga whales assumed to be calves based on the close proximity of a larger, whiter beluga at least once during 2005-2009. (P = photographed without a calf, C = photographed with a calf)

	# of Surveys					
	49	38	23	32	32	
Whale ID	**2005**	**2006**	**2007**	**2008**	**2009**	**Size Estimates/Comments**
Pocked					P	Large calf (=2/3 length of associated adult)
RS083	P	P		P	P	Large calf (=2/3 length of associated adult)
Target				P	P	Large calf (=2/3 length of associated adult)
Teeth				P	P	Large calf (=2/3 length of associated adult)
Whitespots Calf				P		Skin disease/injury
RS118	P	C	P	P	C	Large calf of RA133; seen with own calf in 2006& 2009
Acne		P		P	P	Large calf (=2/3 length of associated adult)

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

	Knik Arm					Susitna River Delta					Turnagain Arm					Chickaloon Bay/				
	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009	2005	2006	2007	2008	2009
	# of Surveys					# of Surveys					# of Surveys					# of Surveys				
Whale ID	32	15	10	12	12	17	21	4	8	15	1	6	8	12	12	0	1	1	2	1
RA139			P	P			P	P	P	P		P								
RA148	P	P	C	C		P	P	P	P	P				P						
RA159	P		P			P		P						P						
RA160	P		P	P	P	P		P	C	P		P								
RA161		C																		
RS220	P		P			P			P	P										

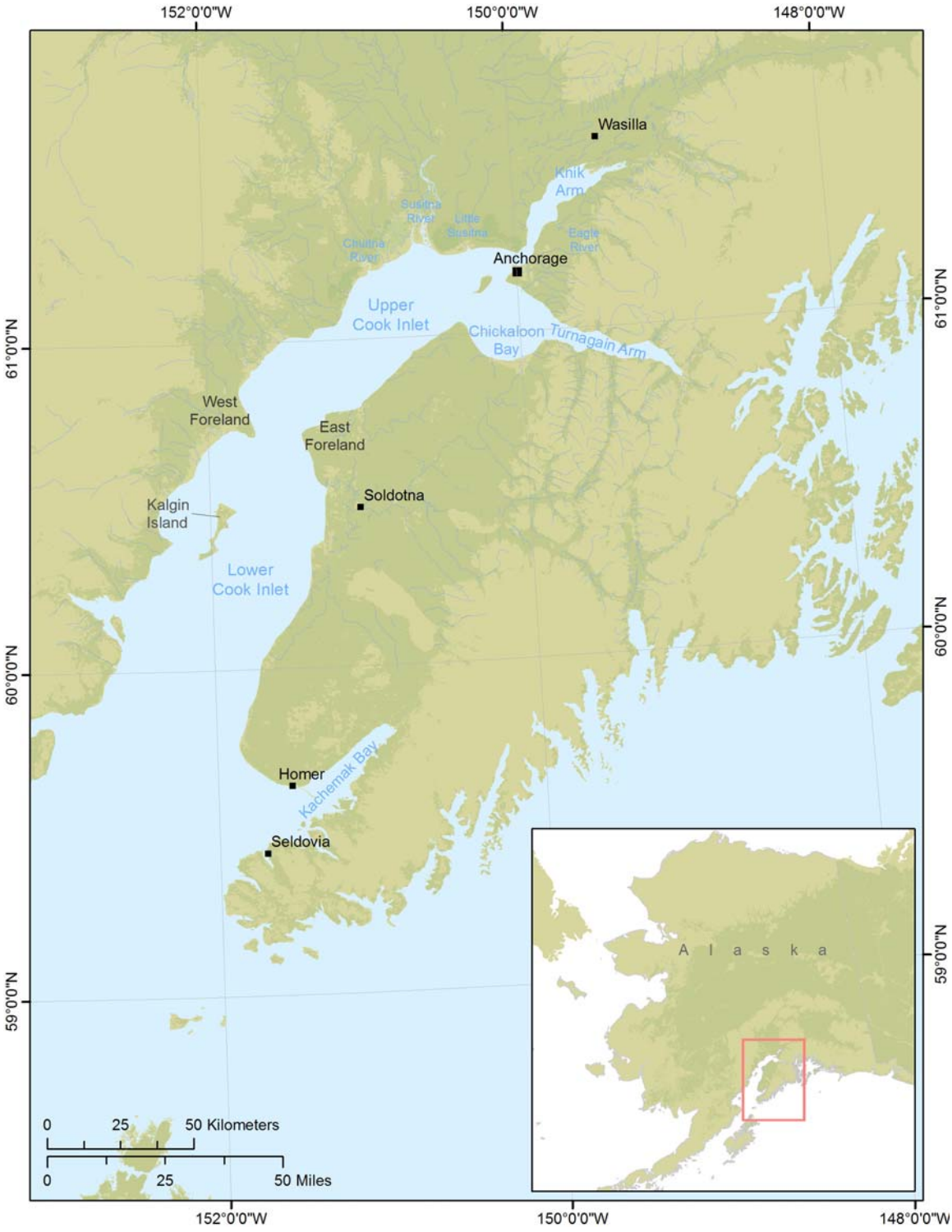

Figure 1. Map of Cook Inlet, Alaska, showing major features discussed in text.

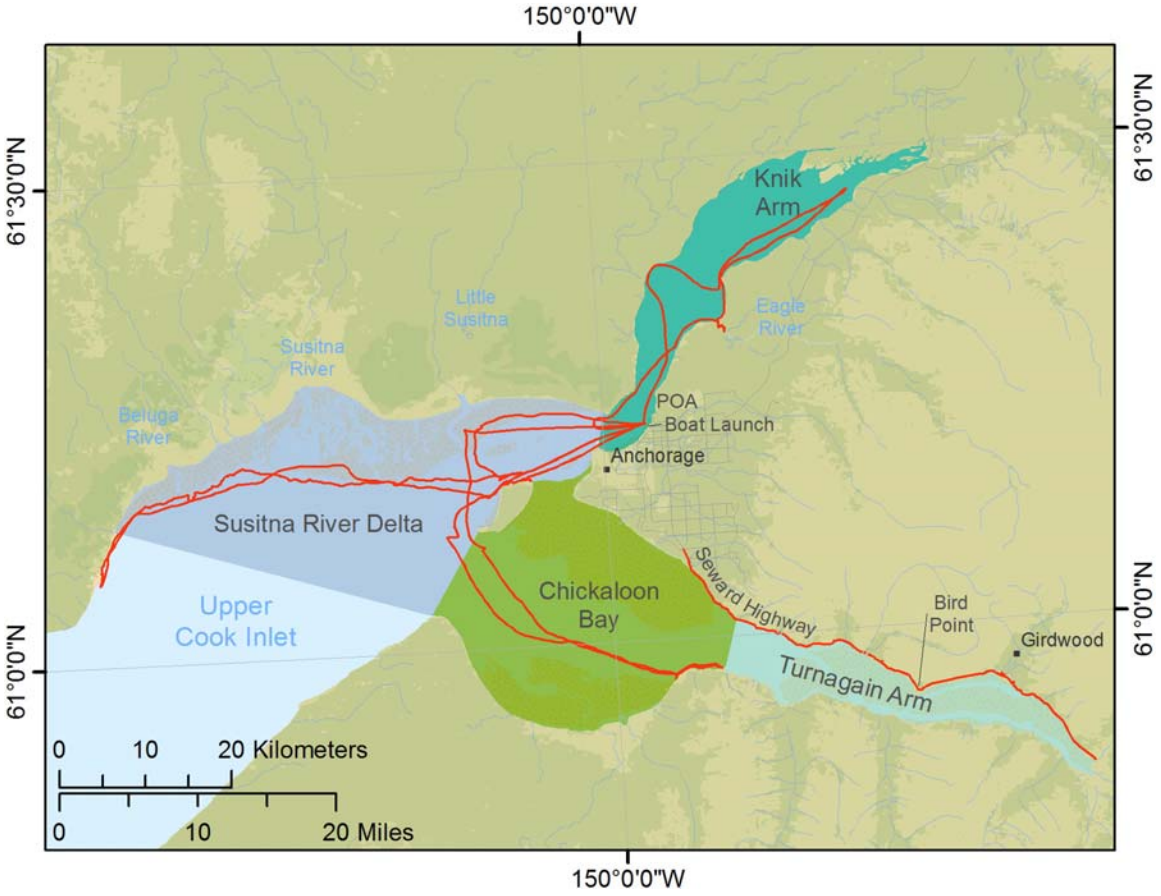

Figure 2. Map of Upper Cook Inlet, Alaska, showing boundaries of four sub-areas within the study area and the vessel- and land-based survey routes used during 2009.

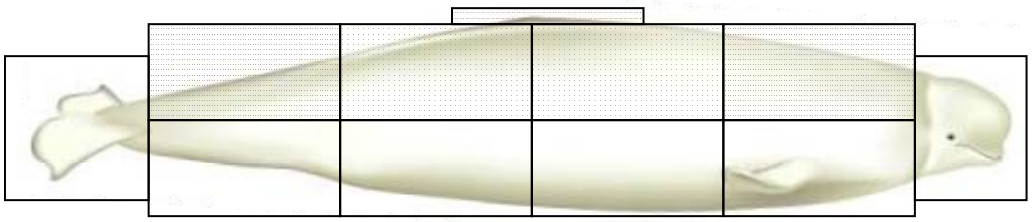

Figure 3. Diagram showing the various segments used when cataloging. The five shaded areas were the critical sections used in matching marks. Beluga illustration courtesy of Uko Gorter.

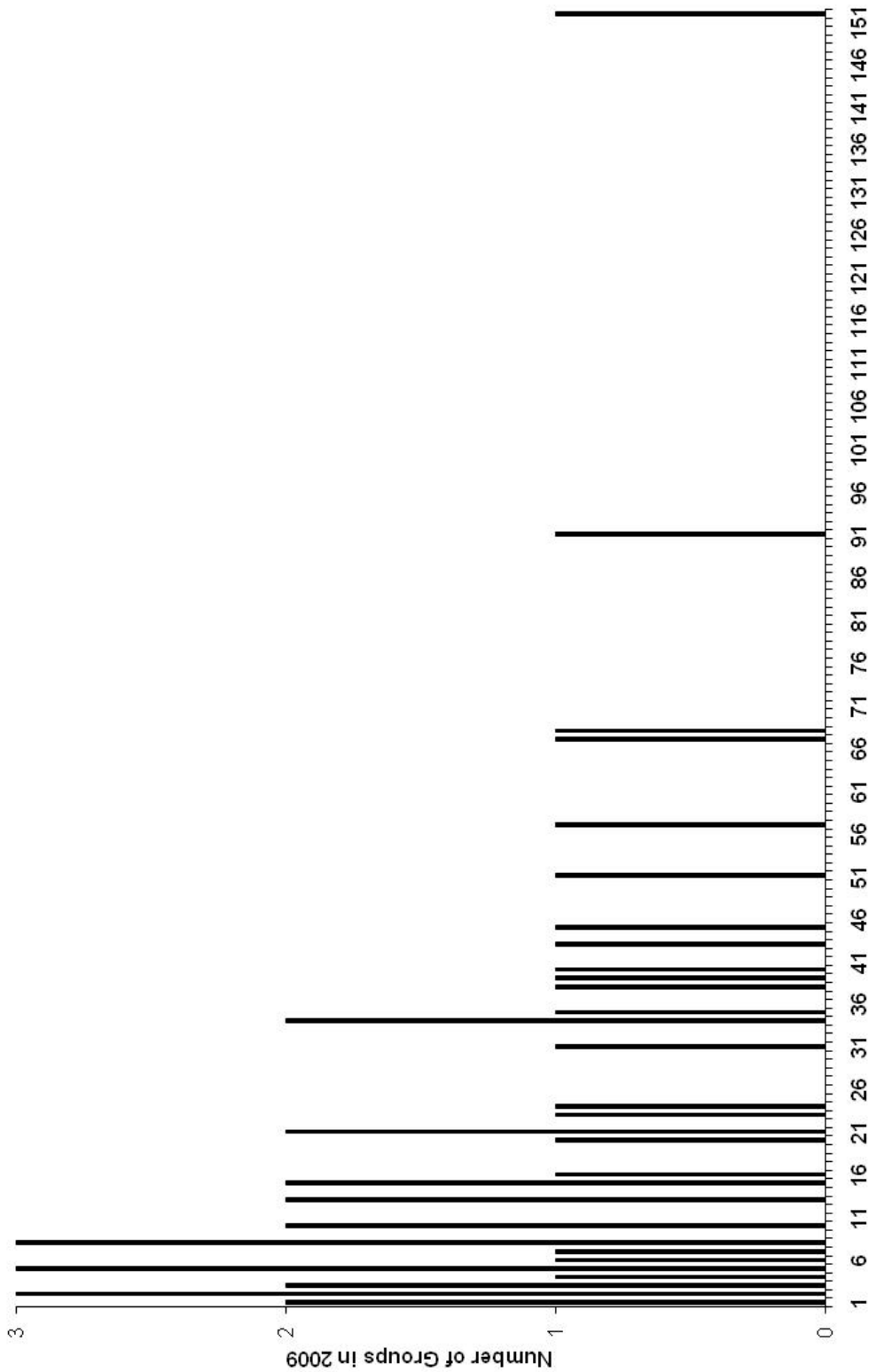

Figure 4. Group-size frequency distribution of beluga whales encountered during photo-identification surveys of Upper Cook Inlet conducted from land and vessels in 2009 (n=43 groups).

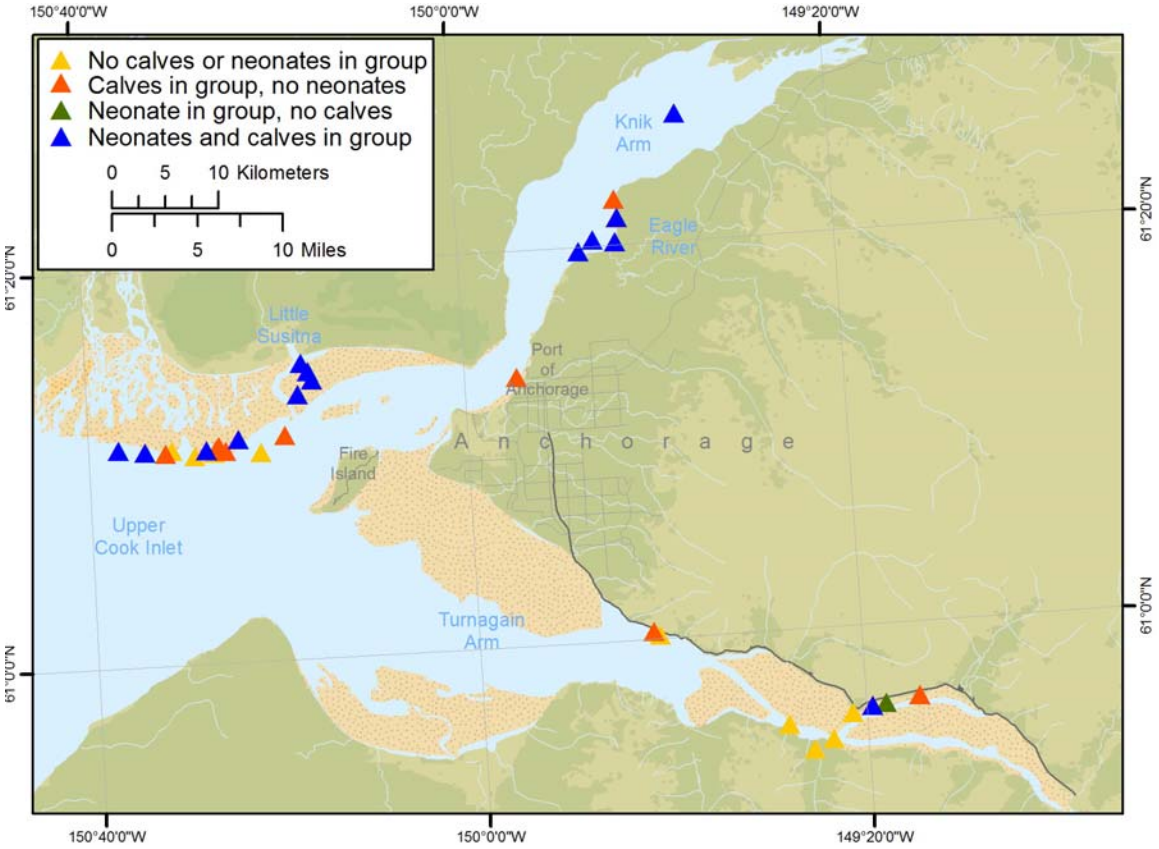

Figure 5. Location of groups with and without calves and neonates encountered during boat- and land-based photo-identification surveys of Upper Cook Inlet, Alaska in 2009.

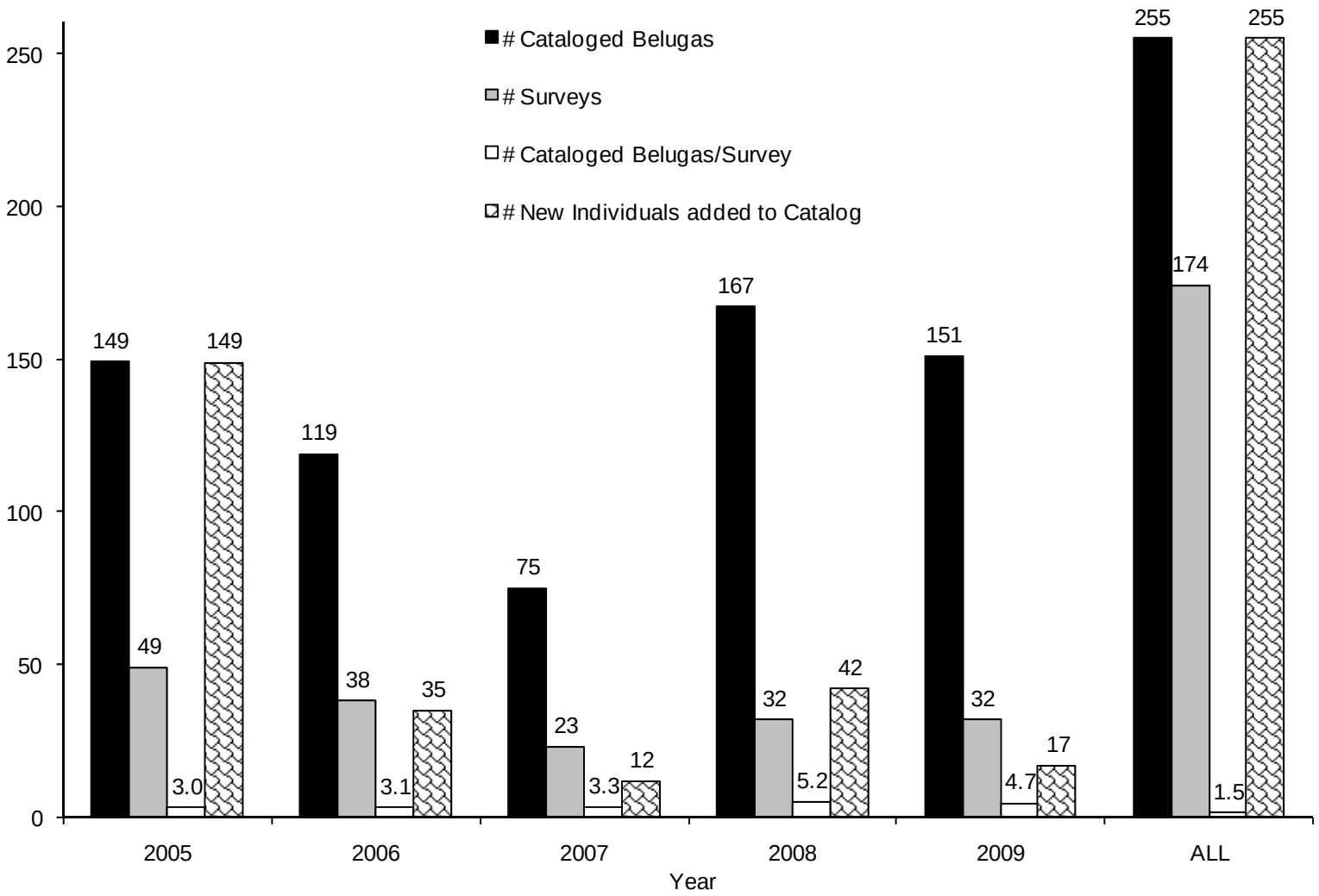

Figure 6. Number of belugas cataloged per year and yearly survey effort, 2005-2009.

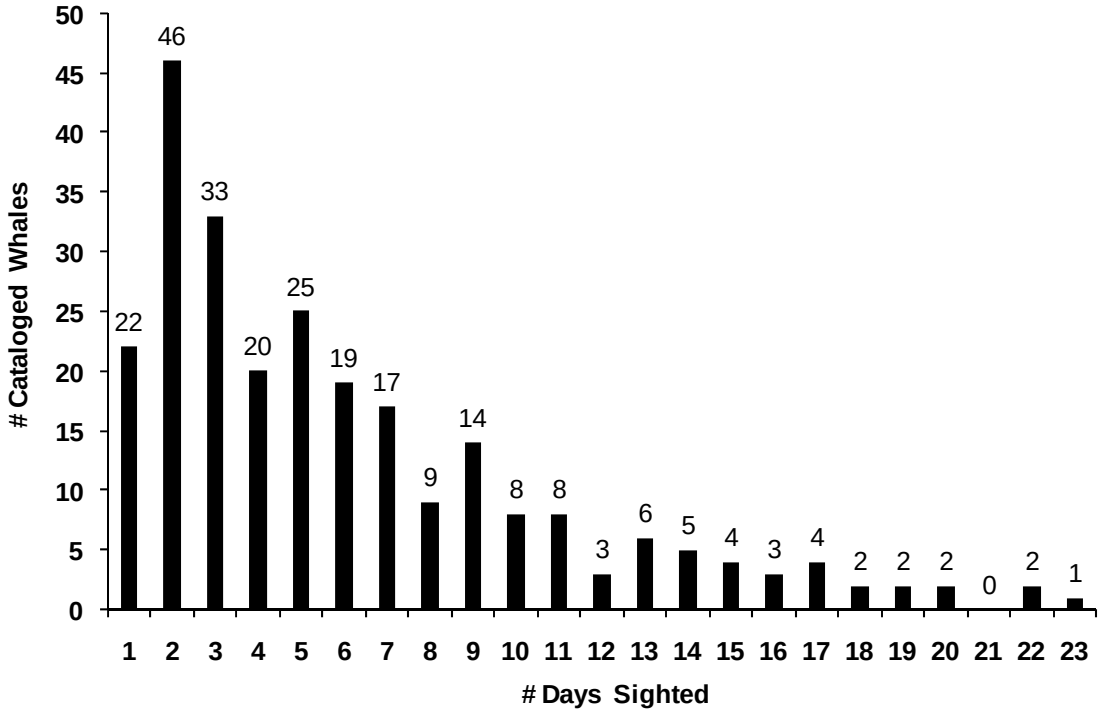

Figure 7. The number of days cataloged whales were re-sighted from 2005-2009.

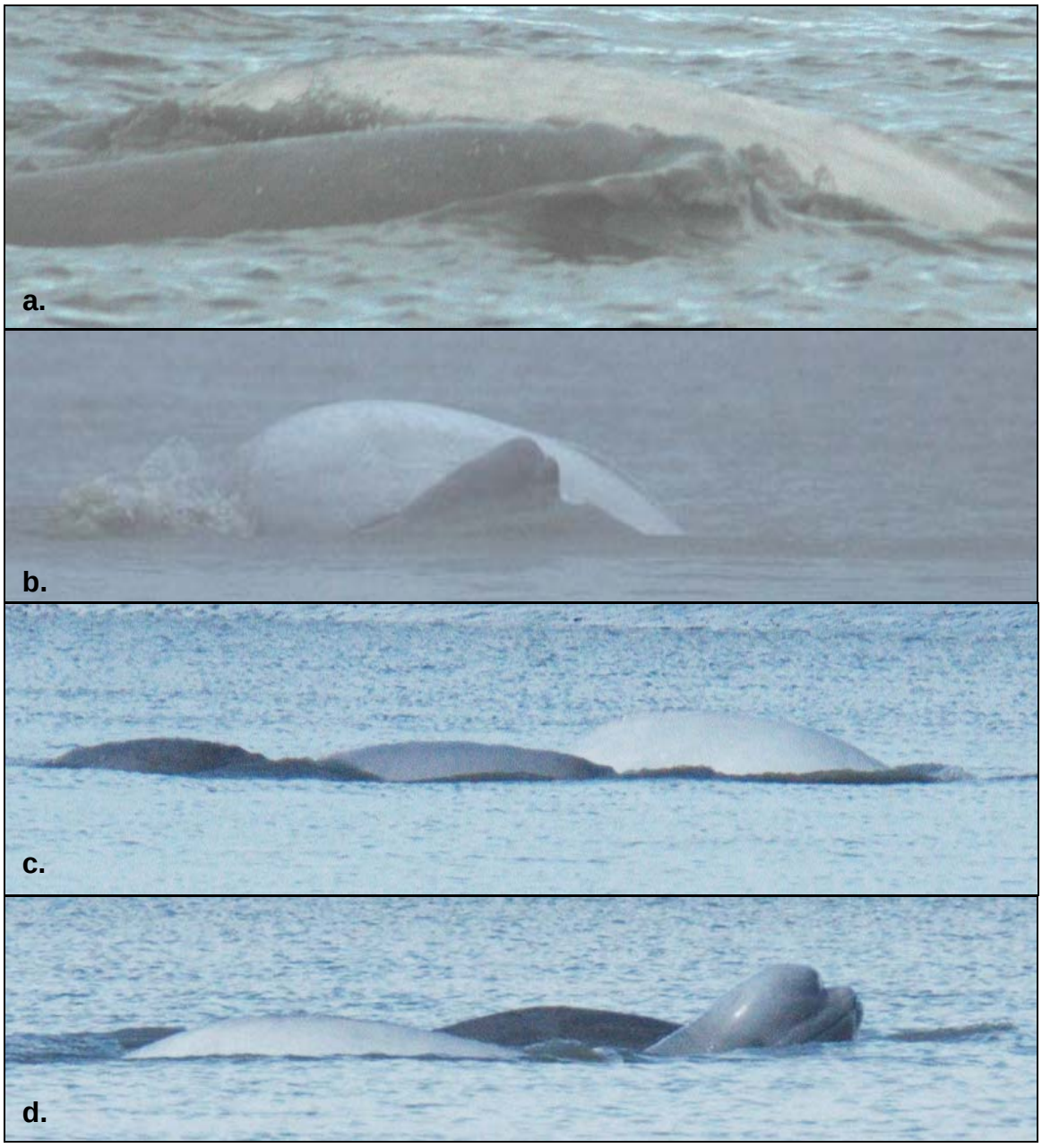

Figure 8. Adult beluga RA157 accompanied by a calf in 2006 (a), by a smaller calf in 2008 (b), and by a maturing calf and younger calf in 2009 (c and d). All photographs are of the right sides of the animals.

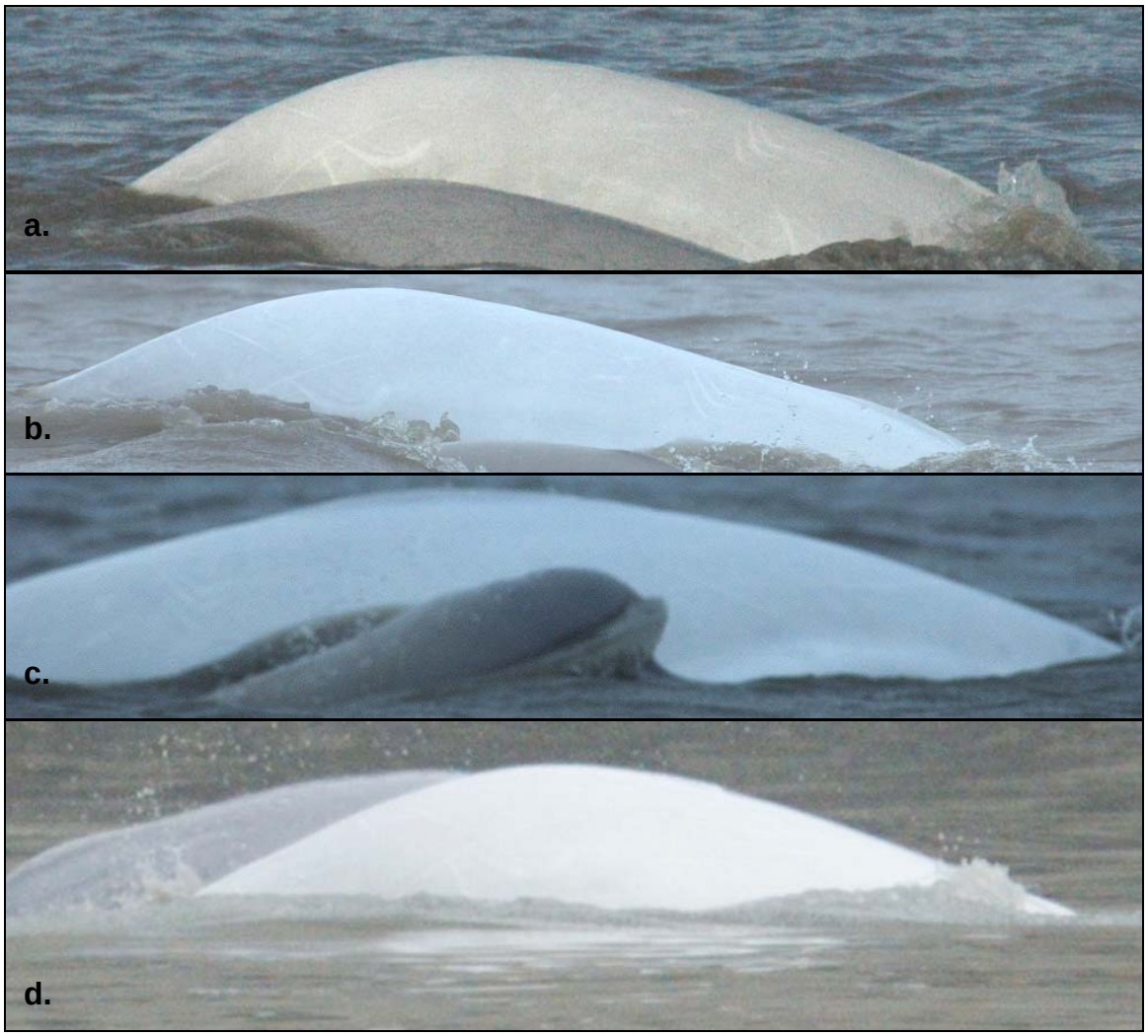

Figure 9. Adult beluga RA036 accompanied by a calf in 2005 (a), by a smaller calf in 2008 (b and c), and by a maturing calf in 2009 (d). All photographs are of the right sides of the animals.

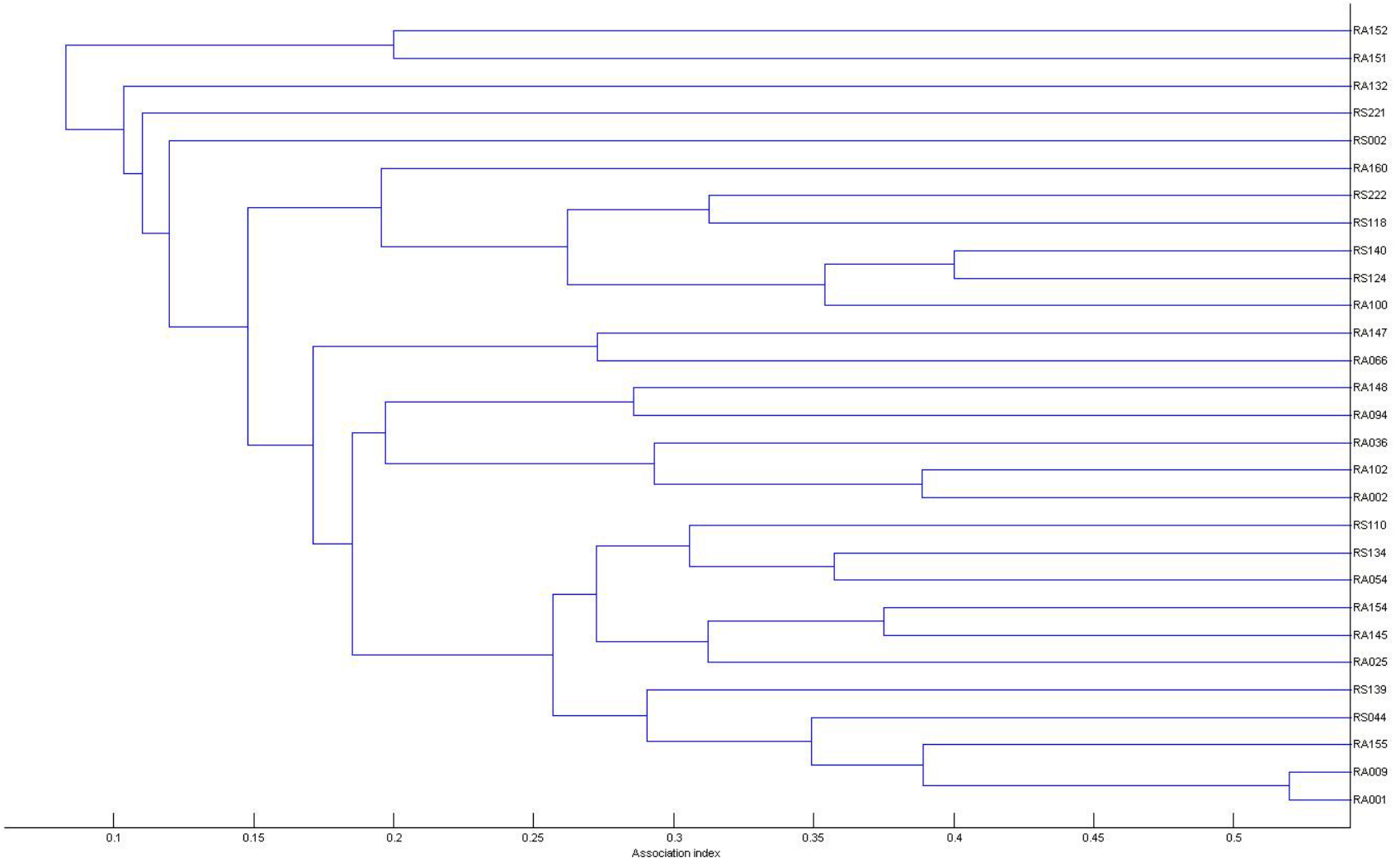

Figure 10. A dendrogram of the 29 cataloged belugas seen in all five years of the study (2005-2009), graphically displaying the association index for pair-wise comparisons among individuals.

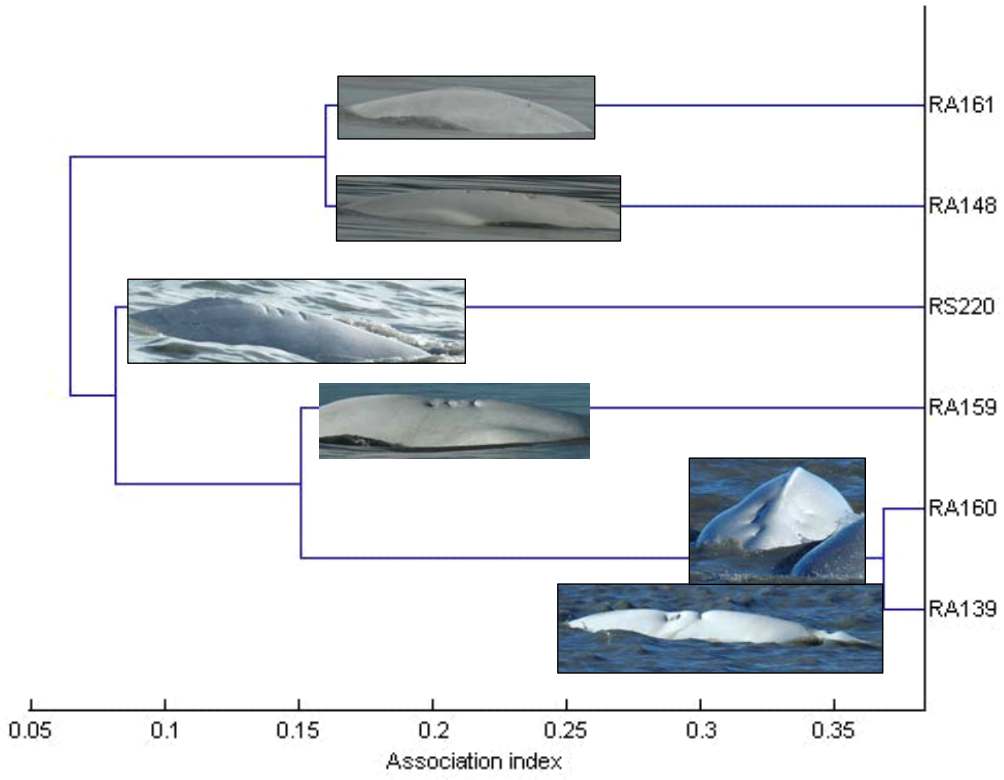

Figure 11. A dendrogram of the six whales identified by satellite tag scars on the right side of their bodies in the 2005-2009 catalog. The dendrogram displays the association index for pair-wise comparisons among individuals. A right-side photograph of each individual is presented next to its catalog name.

Figure 12. Dead male calf, 23 September 2009, Kincaid Park, Anchorage, Alaska. This whale could not be identified due to advanced skin decomposition. The carcass was secured to prevent it from washing away with the incoming tide and was marked with green paint to indicate that the whale had been reported to the Alaska Marine Mammal Stranding Network.

Figure 13. Dead adult beluga, 15 October 2009, Eagle Bay, Knik Arm, Alaska. This whale could not be identified due to advanced skin decomposition.

Figure 14. Photograph of the dead pregnant female beluga whale previously cataloged as RS055. The carcass was secured to prevent it from washing away with the incoming tide and was marked with green paint to indicate that the whale had been reported to the Alaska Marine Mammal Stranding Network.

Figure 15. Photograph of the live cataloged whale RS055, showing the right side of the body.

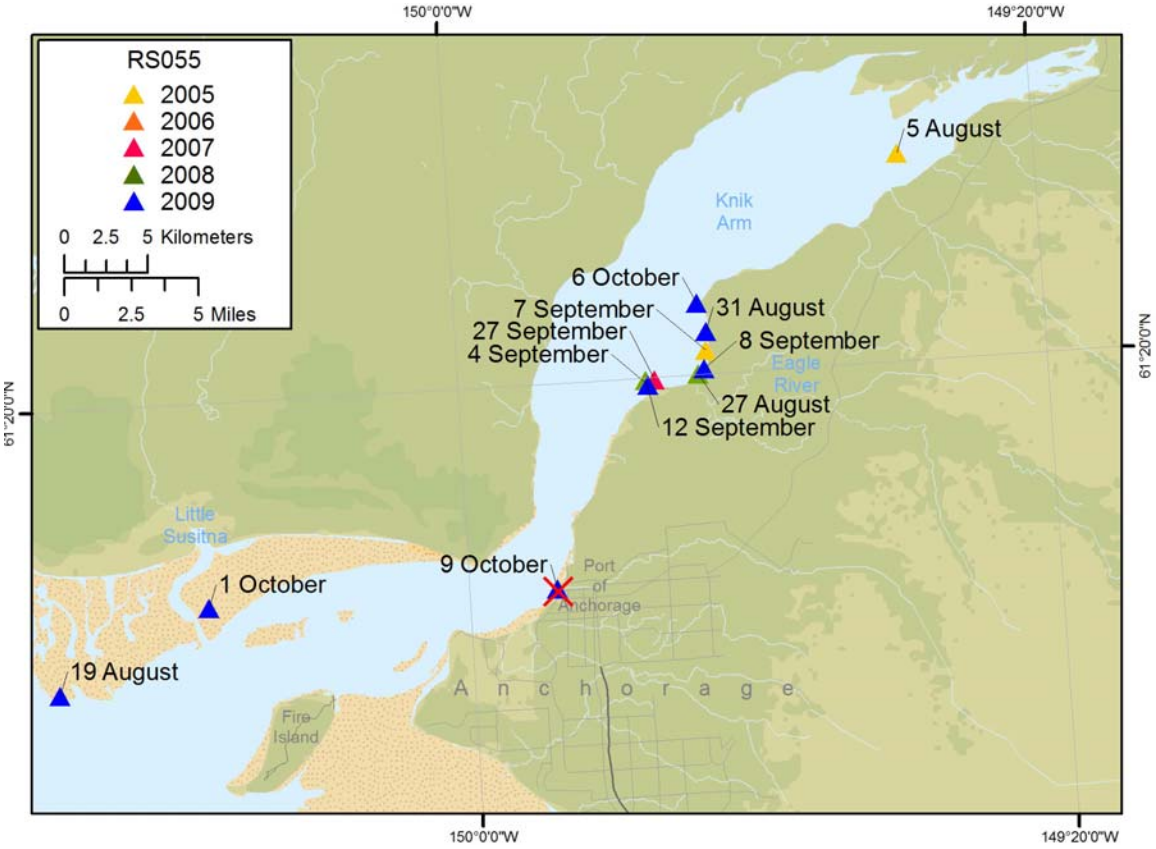

Figure 16. Re-sight history of beluga RS055, who was photographed in all years except 2006. The sighting indicated with a red 'X' is where RS055 stranded and died in 2009. This beluga was presumed to be a mother, based on photographs with an accompanying calf. Necropsy results determined that RS055 was pregnant at the time of death.

Figure 17. Photograph of the right side of beluga "Gmultilesion" in 2009 showing what appear to be lesions.

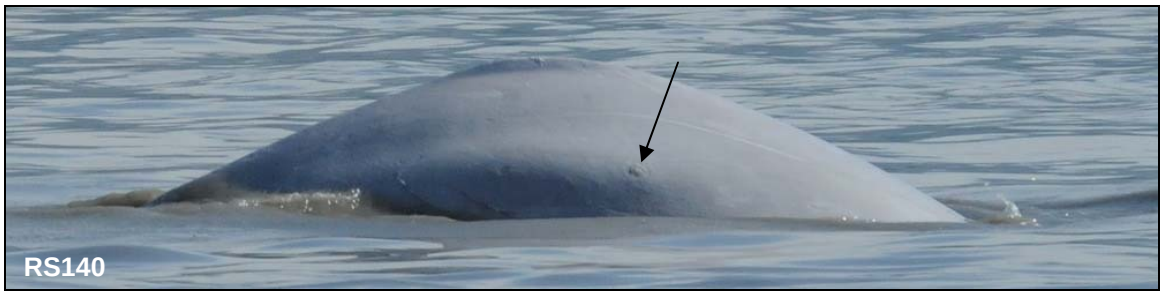

Figure 18. Photograph of the right side of beluga RS140 in 2009 showing what appears to be a lesion.

Figure 19. Photograph of the right side of beluga RA110 in 2009 with what appear to be healed predation marks, possibly from an orca whale (*Orcinus orca*).

Figure 20. Photograph of the right side of beluga "Newbites" in 2009 with what appear to be new tooth rake marks (possibly from an orca whale or conspecifics).

Figure 21. Photograph of the right side of beluga "Darkdimple" in 2009 with a suspected bullet wound in front of the dorsal ridge.

Figure 22. Photograph of the right side of beluga RA108 in 2009 with a suspected bullet wound behind the dorsal ridge that appears to have healed over time.

Figure 23. Photograph of the right side of beluga RS118 in 2009 with vertical, white marks that are suspected to be caused by a small propeller strike.

Figure 24. Photograph of the right side of beluga RA145 in 2009 with a wound possibly caused by a ship strike (either a large propeller or bow strike).

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, 2009 FIELD SEASON

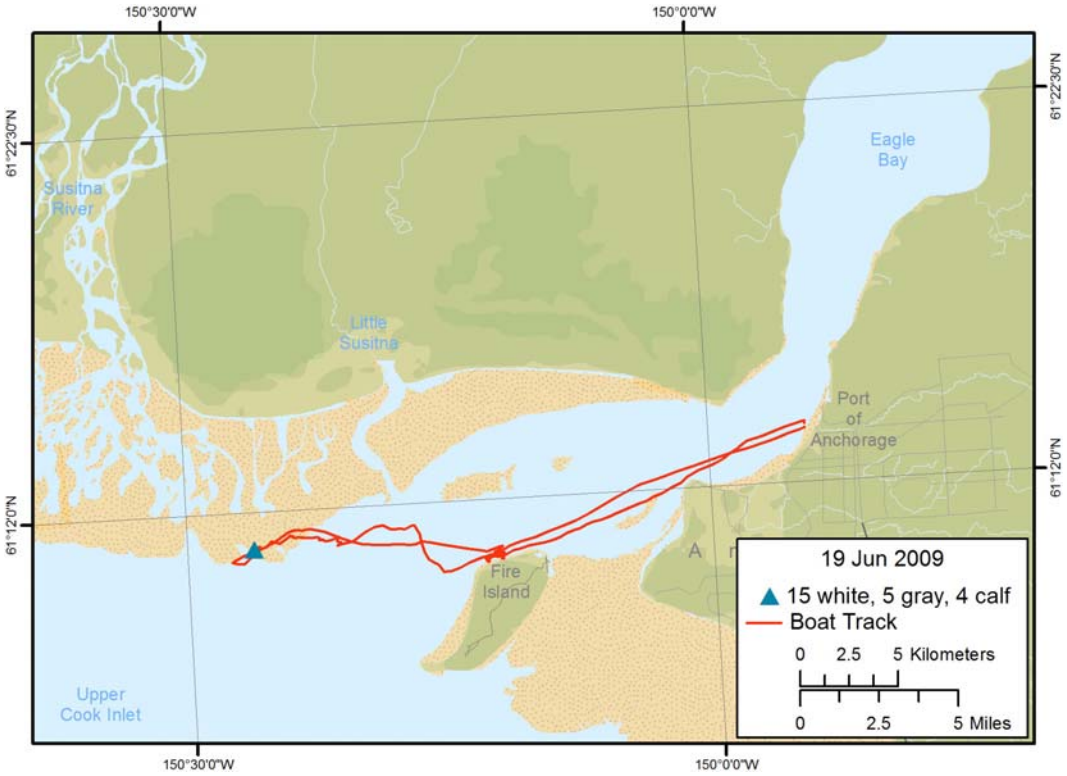

Figure A1. Route and beluga whale group(s) encountered during the vessel-based survey route of 19 June 2009 in Upper Cook Inlet, Alaska.

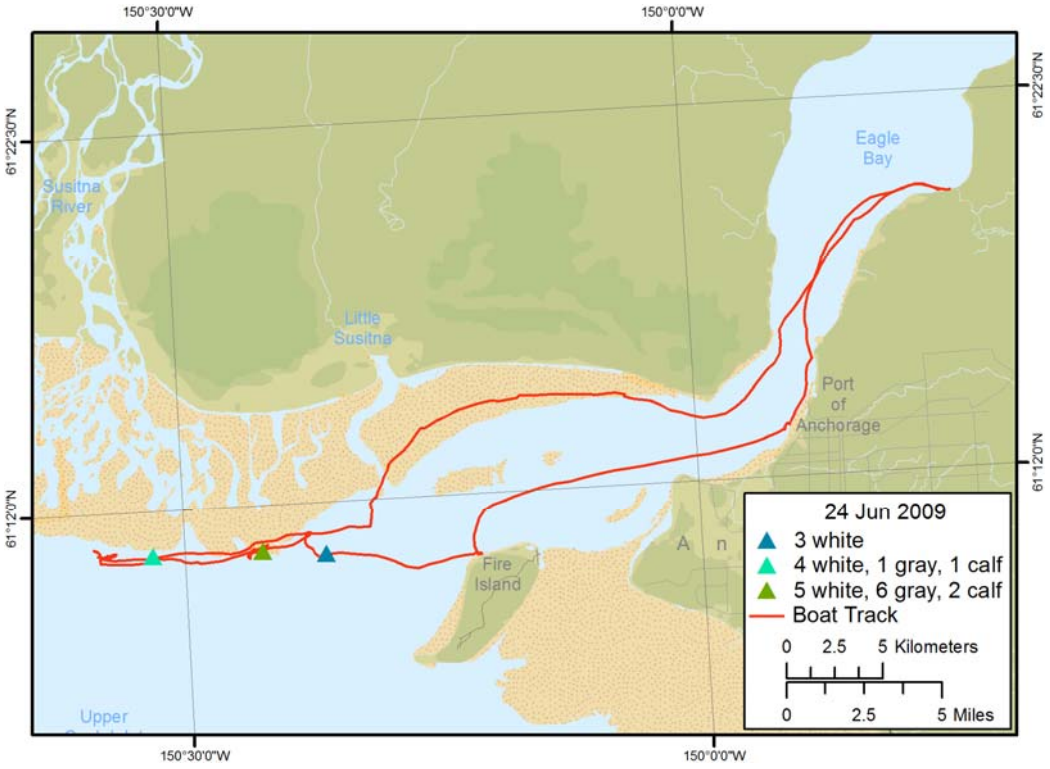

Figure A2. Route and beluga whale group(s) encountered during the vessel-based survey route of 24 June 2009 in Upper Cook Inlet, Alaska.

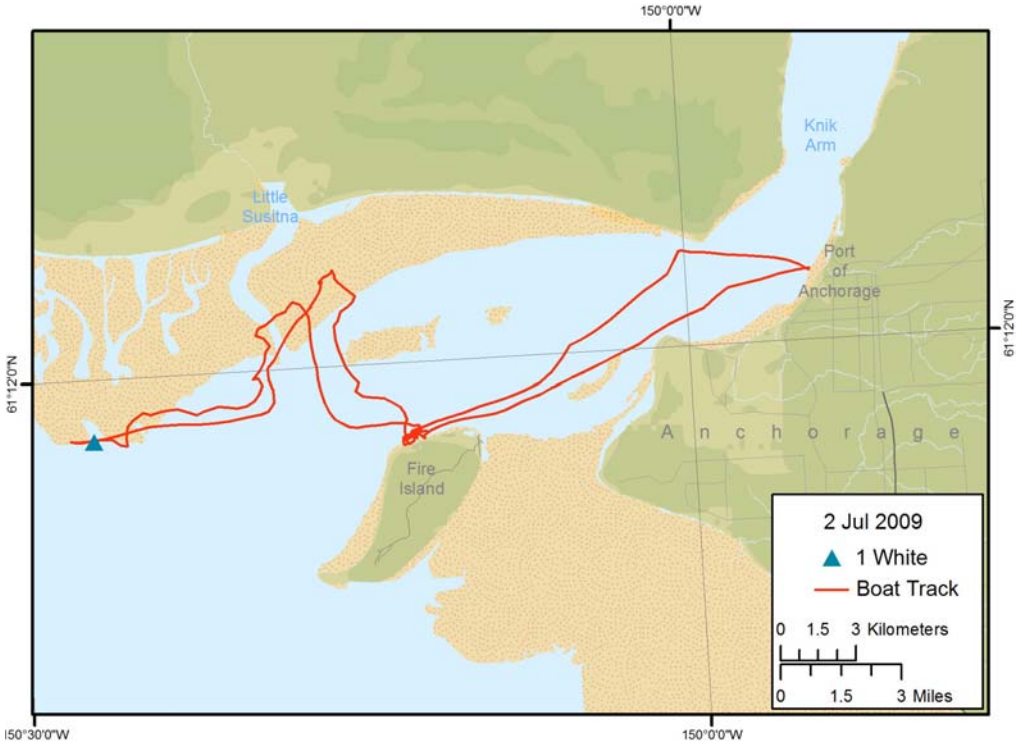

Figure A3. Route and beluga whale group(s) encountered during the vessel-based survey route of 2 July 2009 in Upper Cook Inlet, Alaska.

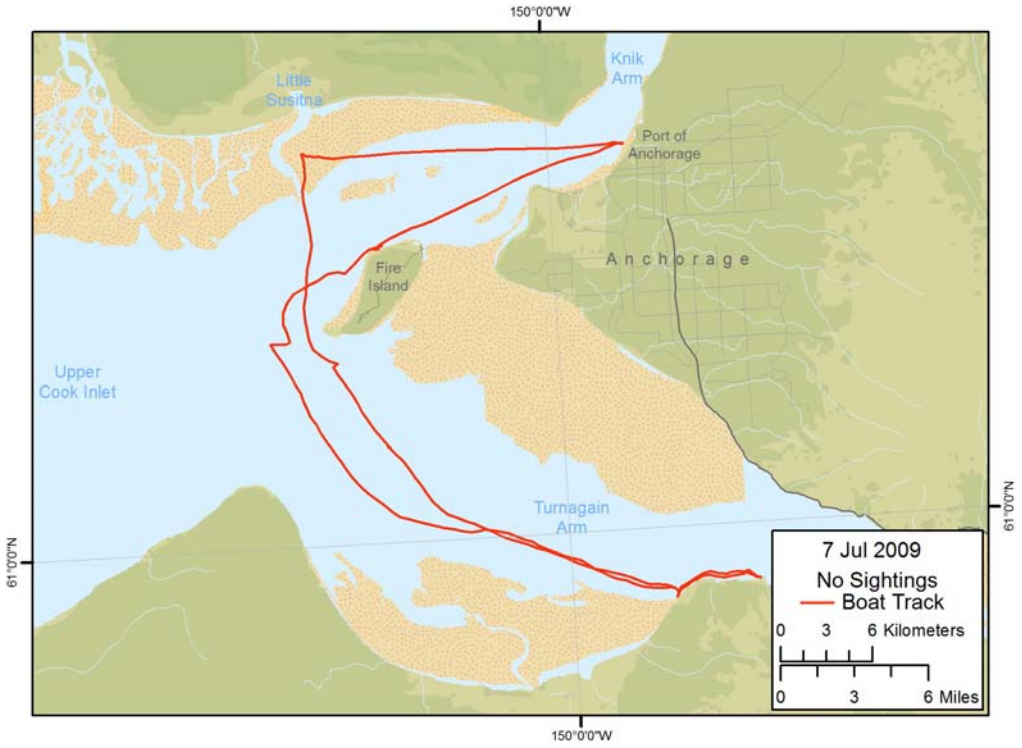

Figure A4. Route of the vessel-based survey route of 7 July 2009 in Upper Cook Inlet, Alaska. No belugas were encountered during this survey.

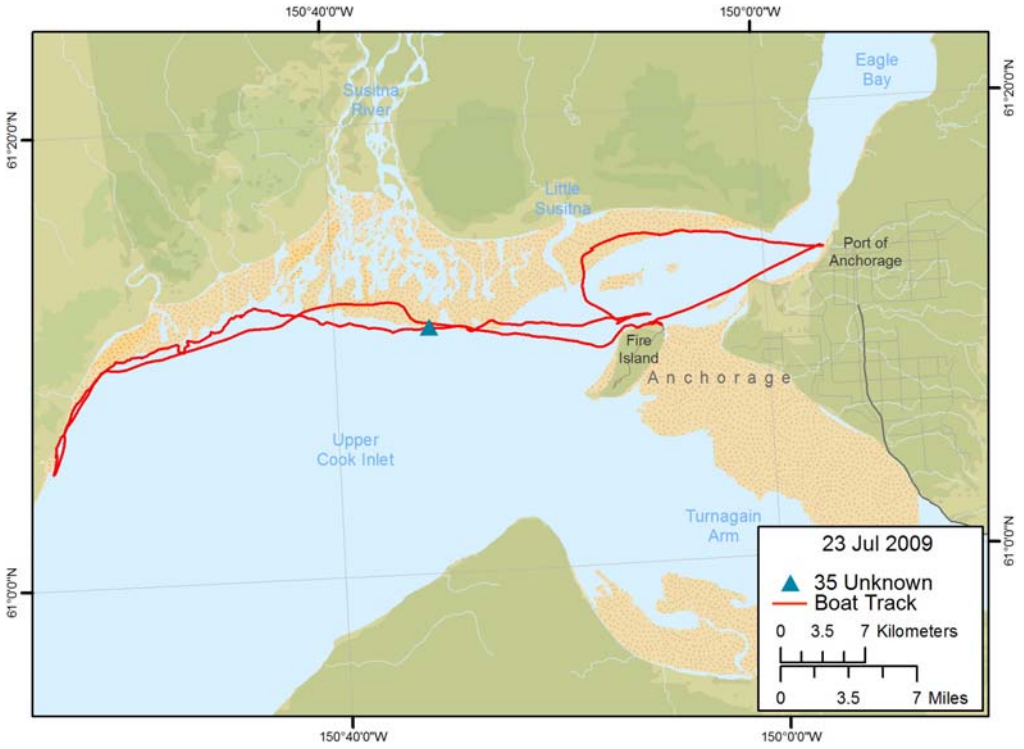

Figure A5. Route and beluga whale group(s) encountered during the vessel-based survey route of 23 July 2009 in Upper Cook Inlet, Alaska.

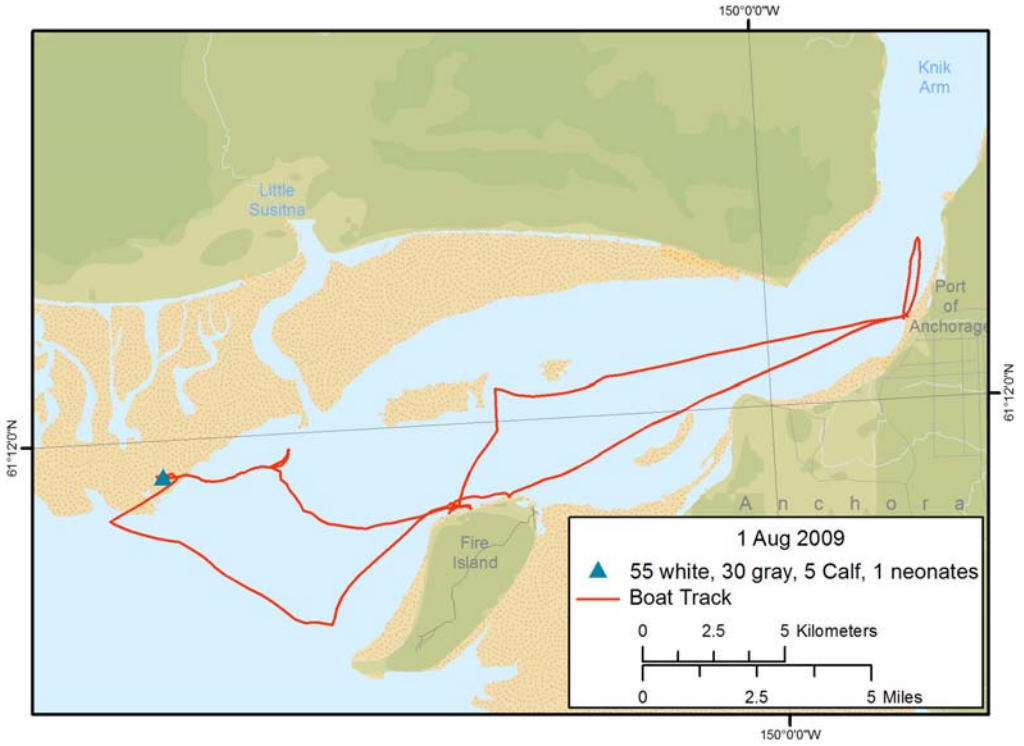

Figure A6. Route and beluga whale group(s) encountered during the vessel-based survey route of 1 August 2009 in Upper Cook Inlet, Alaska.

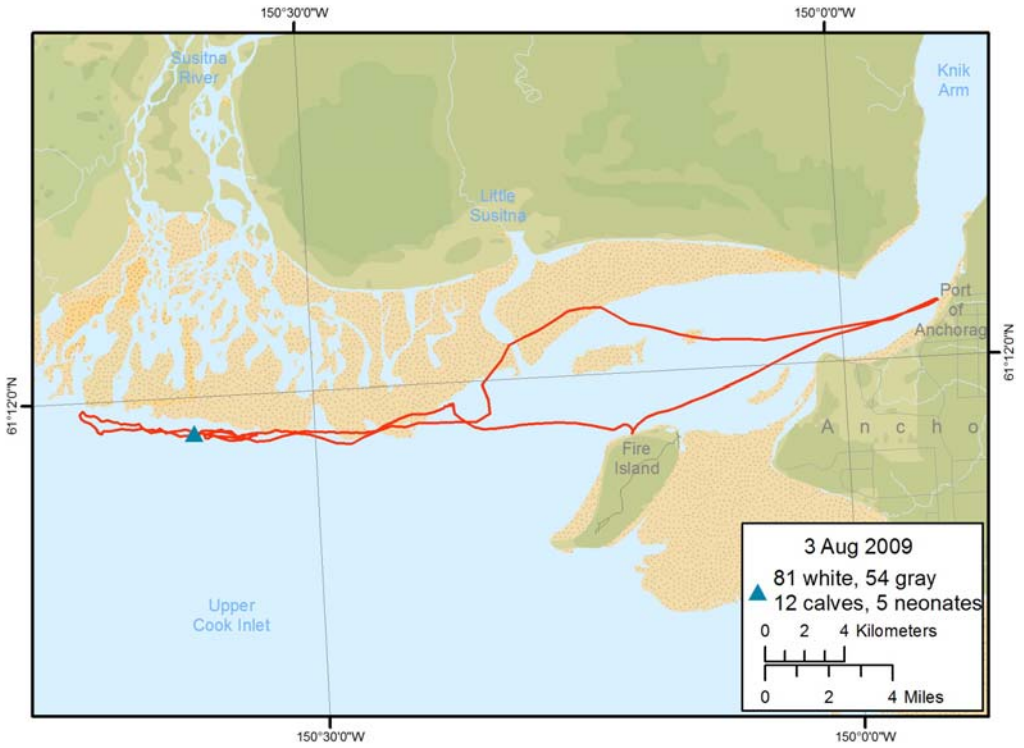

Figure A7. Route and beluga whale group(s) encountered during the vessel-based survey route of 3 August 2009 in Upper Cook Inlet, Alaska.

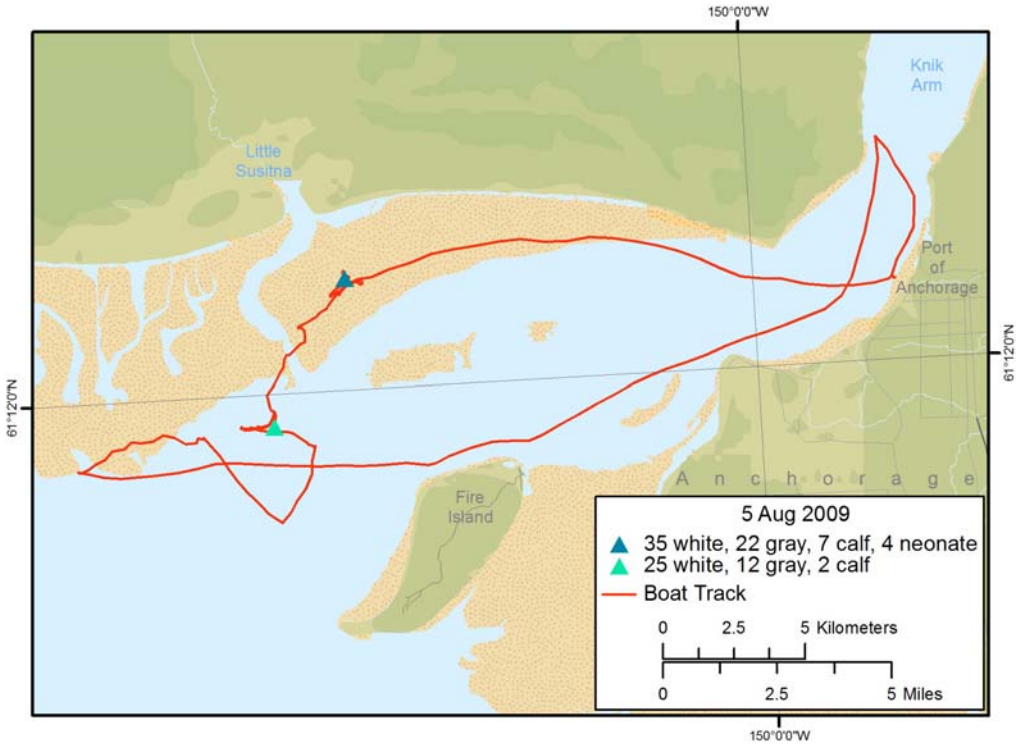

Figure A8. Route and beluga whale group(s) encountered during the vessel-based survey route of 5 August 2009 in Upper Cook Inlet, Alaska.

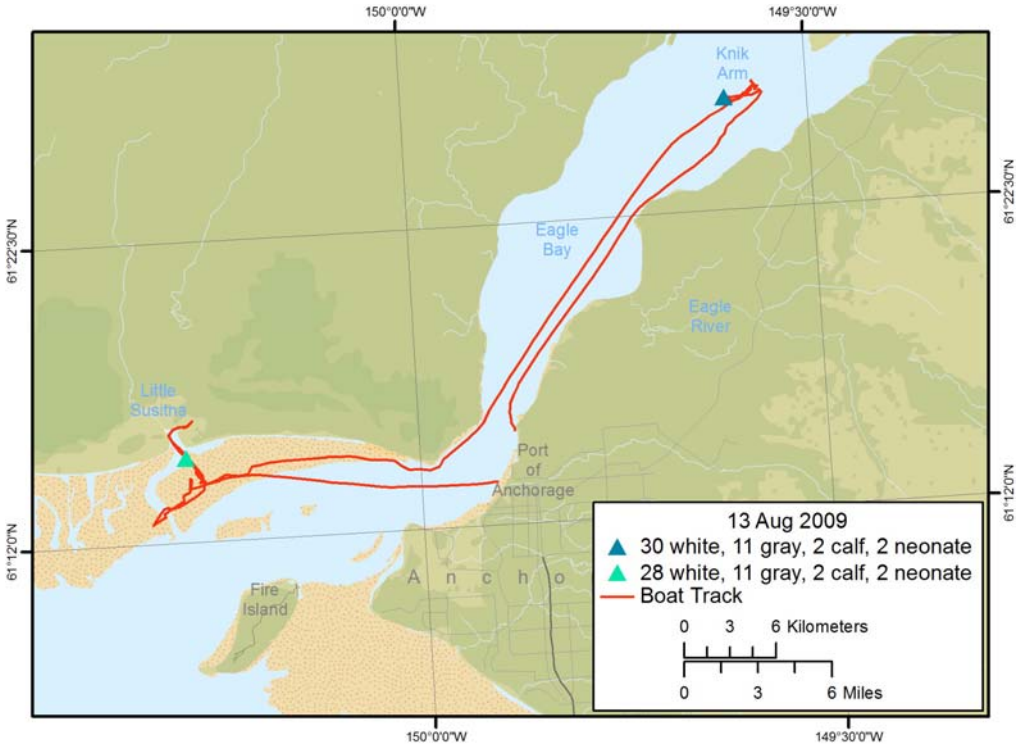

Figure A9. Route and beluga whale group(s) encountered during the vessel-based survey route of 13 August 2009 in Upper Cook Inlet, Alaska.

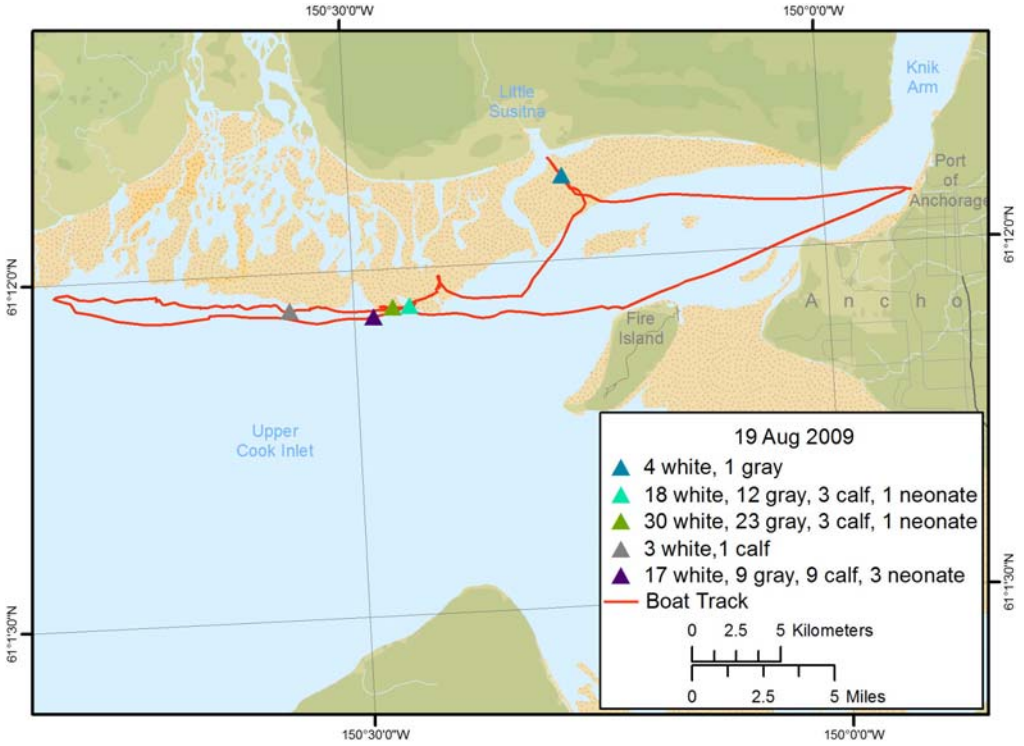

Figure A10. Route and beluga whale group(s) encountered during the vessel-based survey route of 13 August 2009 in Upper Cook Inlet, Alaska.

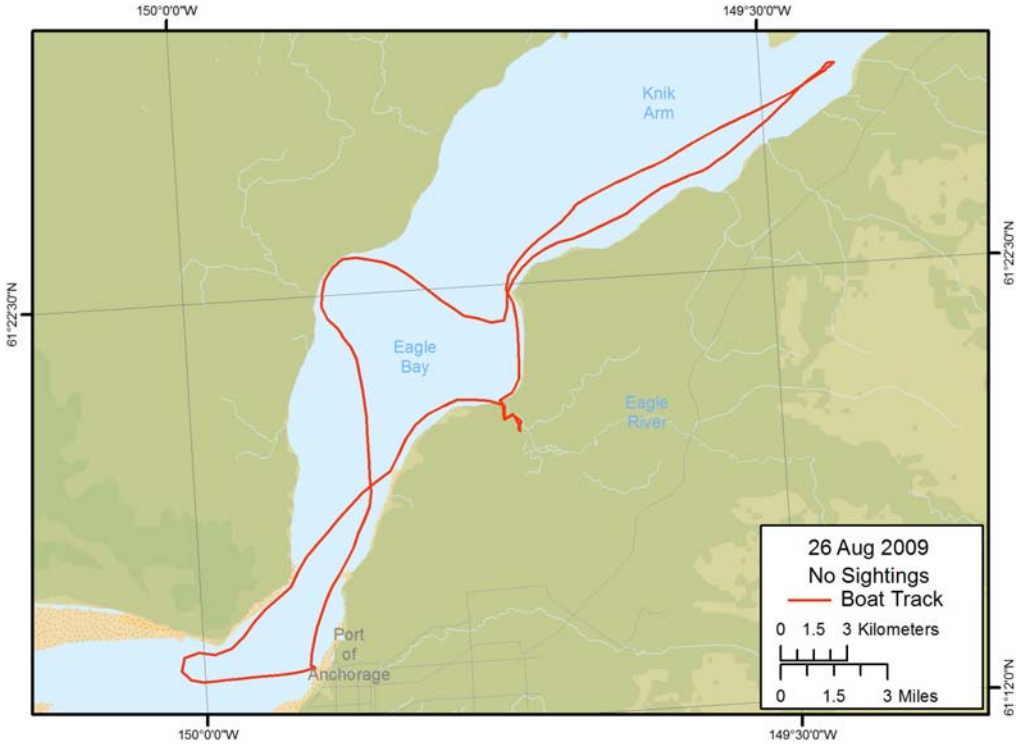

Figure A11. Route of the vessel-based survey route of 26 August 2009 in Upper Cook Inlet, Alaska. No belugas were encountered during this survey.

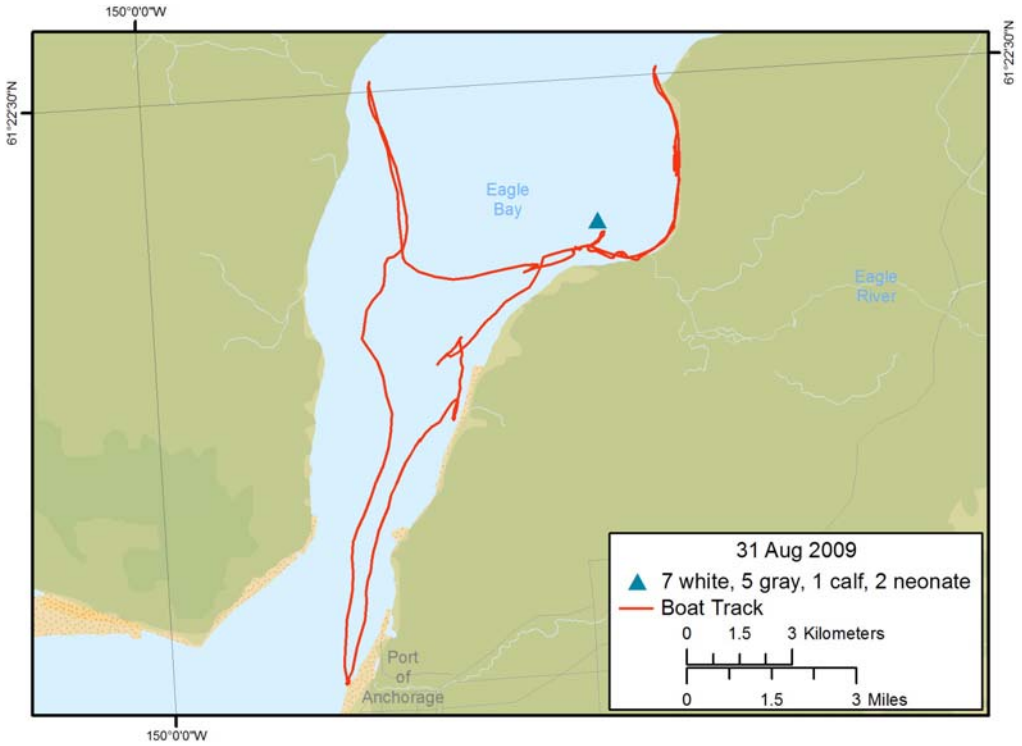

Figure A12. Route and beluga whale group(s) encountered during the vessel-based survey route of 31 August 2009 in Upper Cook Inlet, Alaska.

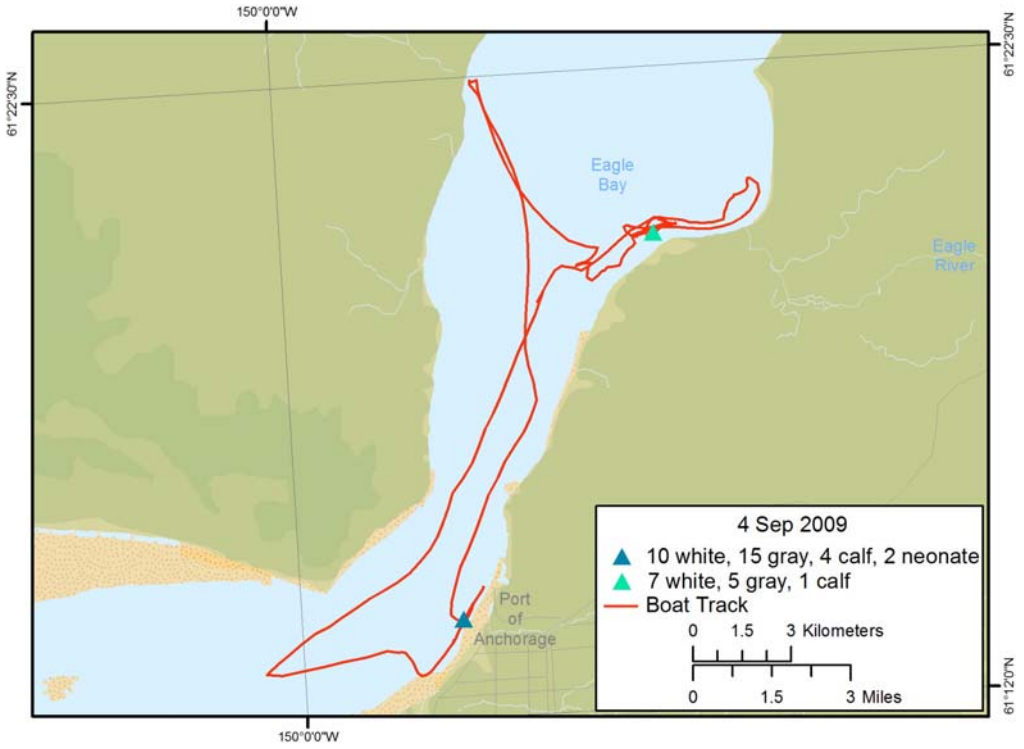

Figure A13. Route and beluga whale group(s) encountered during the vessel-based survey route of 4 September 2009 in Upper Cook Inlet, Alaska.

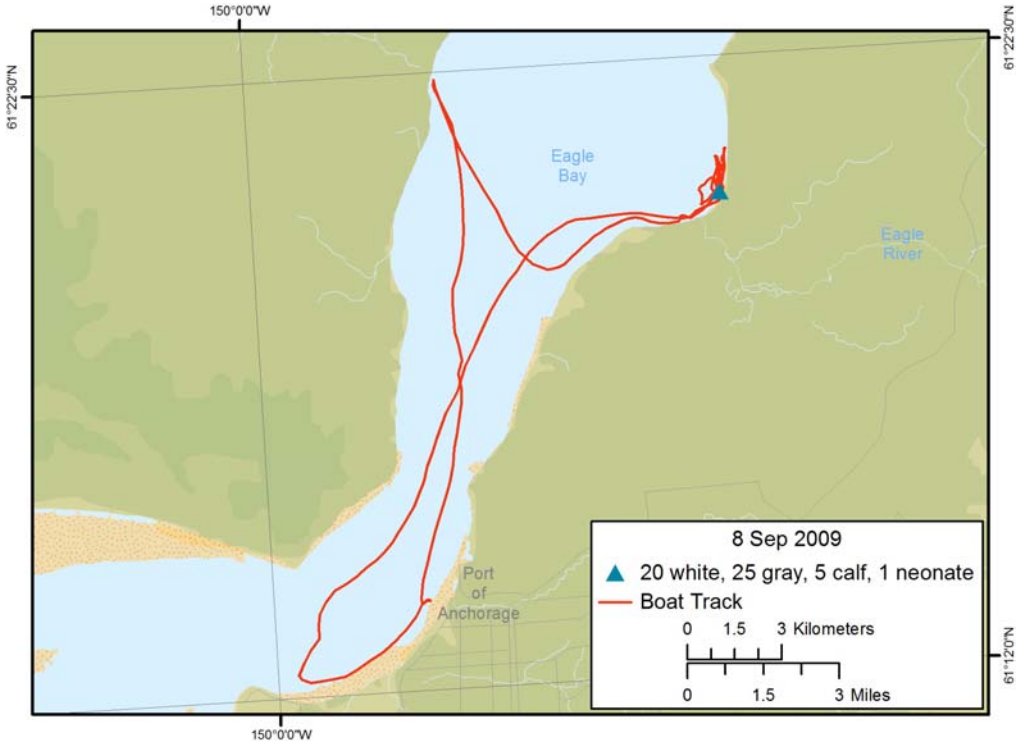

Figure A14. Route and beluga whale group(s) encountered during the vessel-based survey route of 8 September 2009 in Upper Cook Inlet, Alaska.

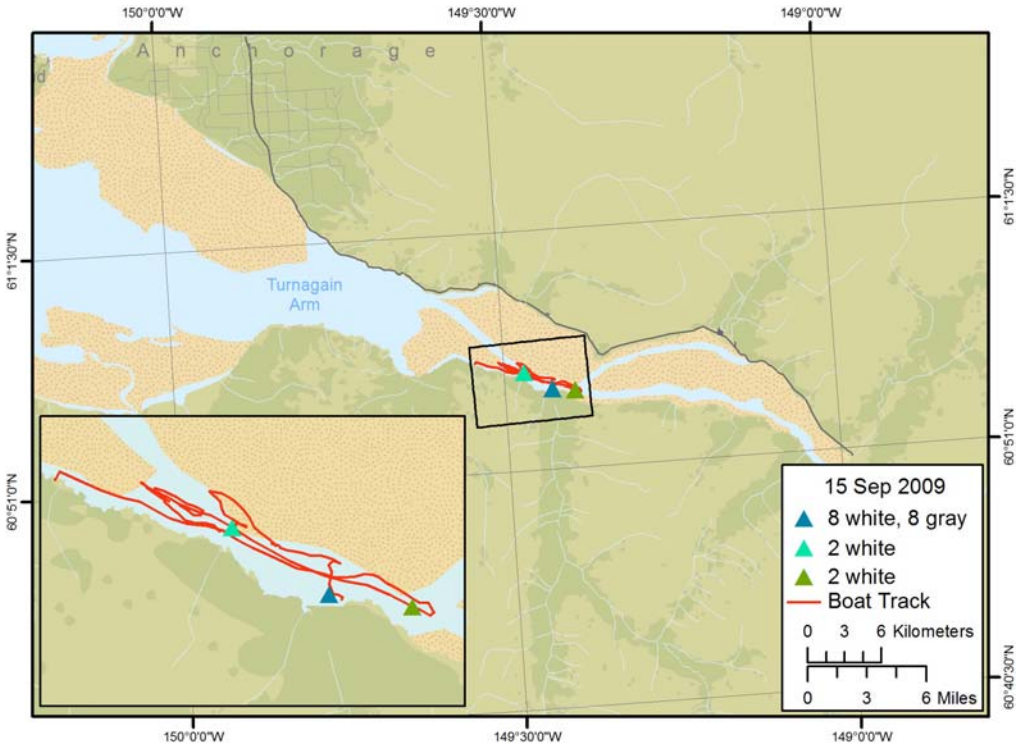

Figure A15. Route and beluga whale group(s) encountered during the vessel-based survey route of 15 September 2009 in Upper Cook Inlet, Alaska.

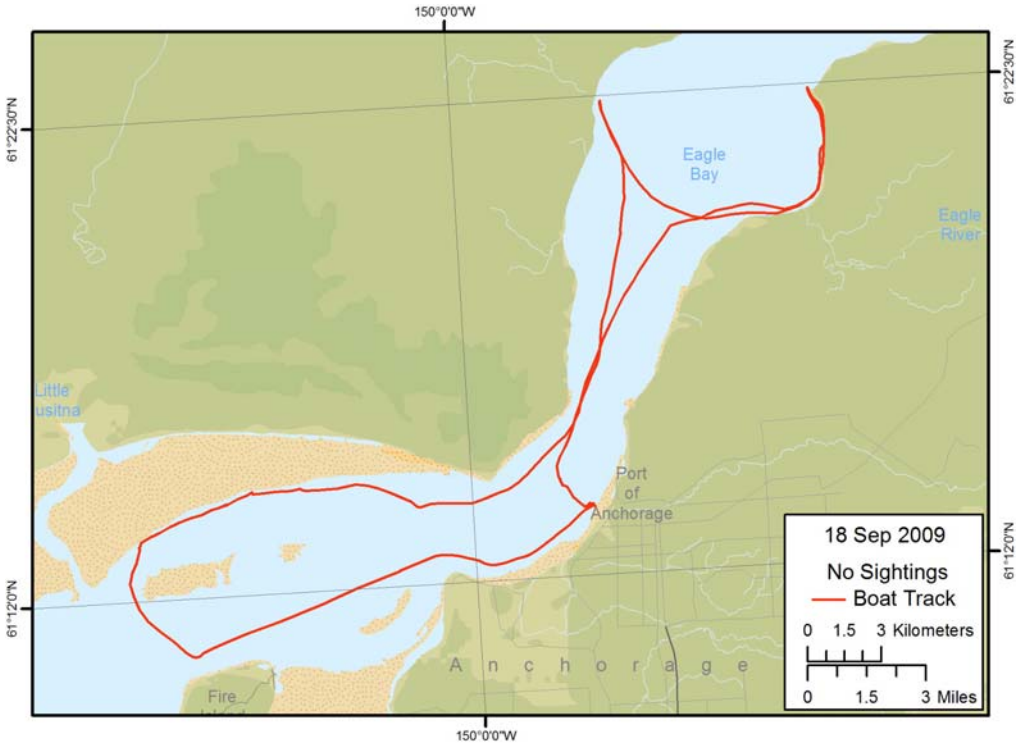

Figure A16. Route of the vessel-based survey route of 18 September 2009 in Upper Cook Inlet, Alaska. No belugas were encountered during this survey.

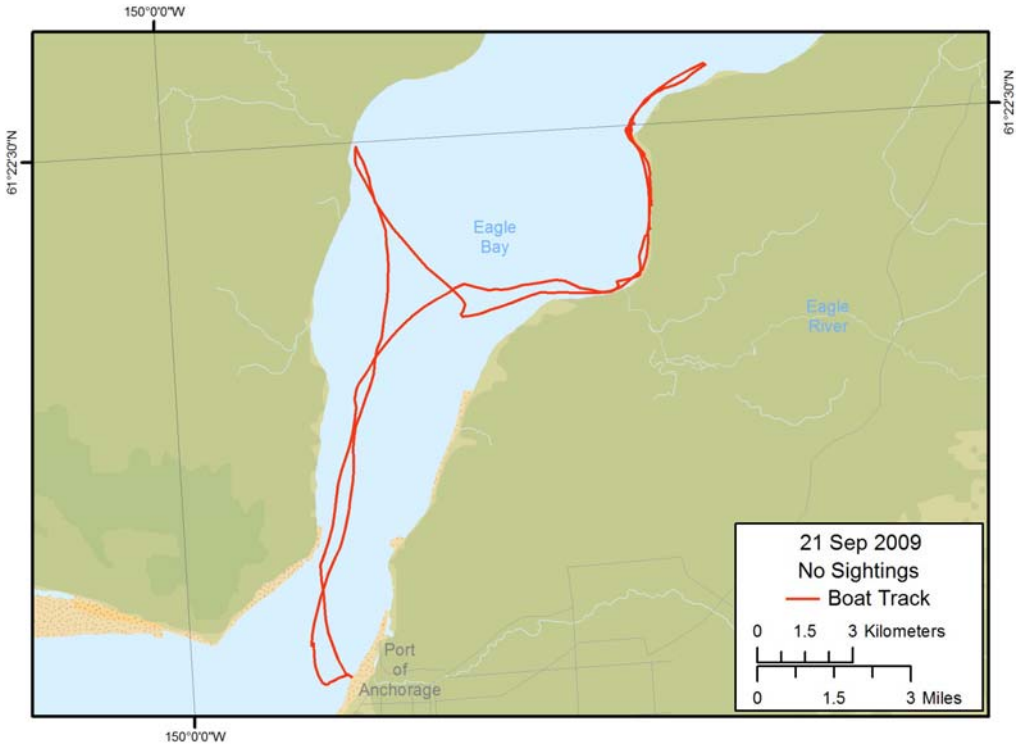

Figure A17. Route of the vessel-based survey route of 21 September 2009 in Upper Cook Inlet, Alaska. No belugas were encountered during this survey.

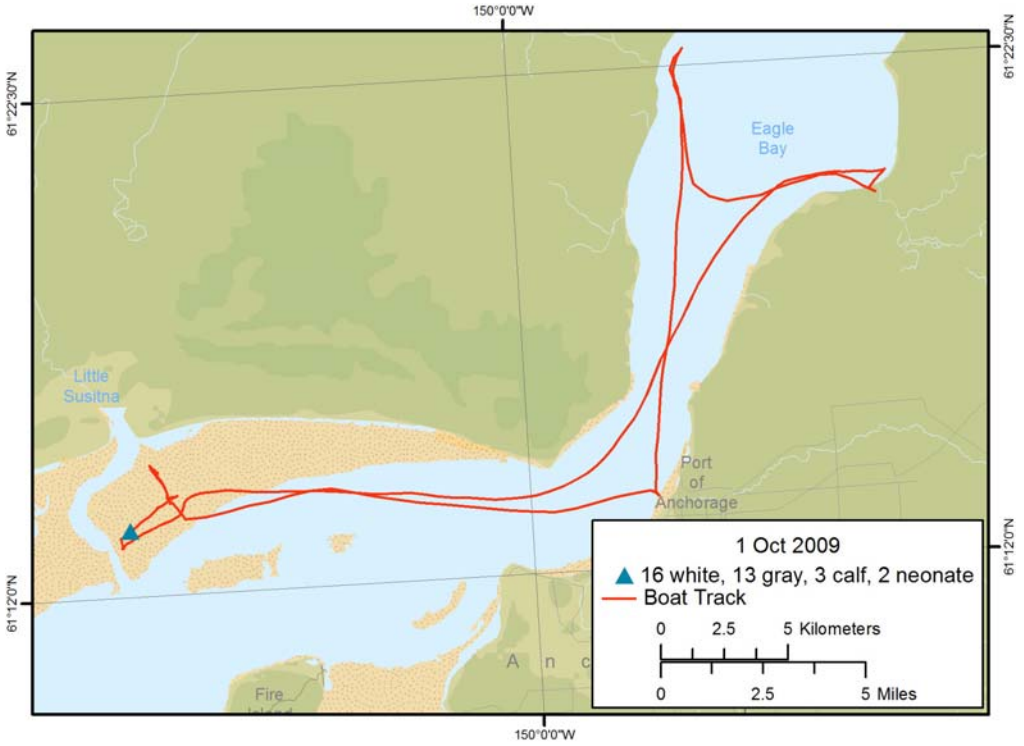

Figure A18. Route and beluga whale group(s) encountered during the vessel-based survey route of 1 October 2009 in Upper Cook Inlet, Alaska.

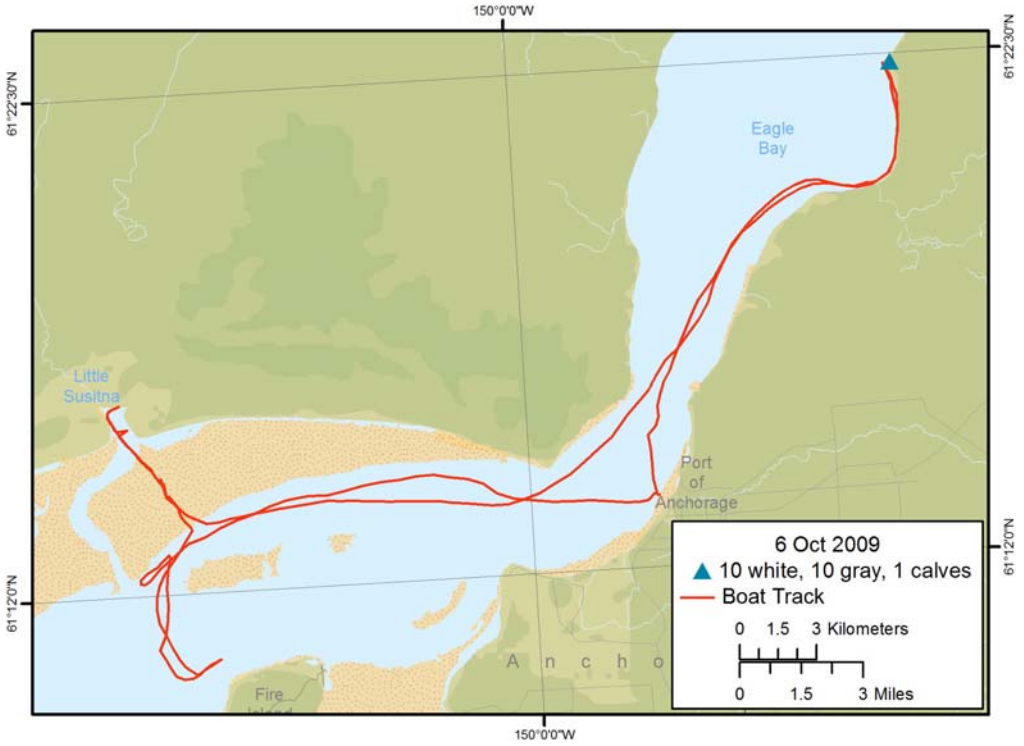

Figure A19. Route and beluga whale group(s) encountered during the vessel-based survey route of 6 October 2009 in Upper Cook Inlet, Alaska.

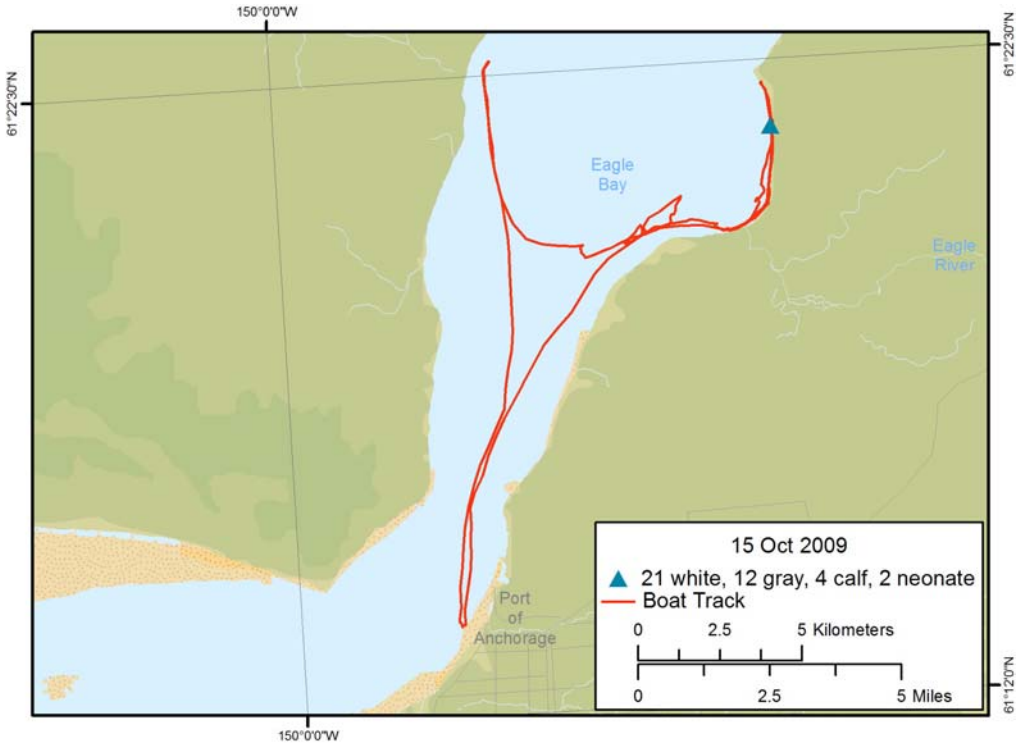

Figure A20. Route and beluga whale group(s) encountered during the vessel-based survey route of 15 October 2009 in Upper Cook Inlet, Alaska.

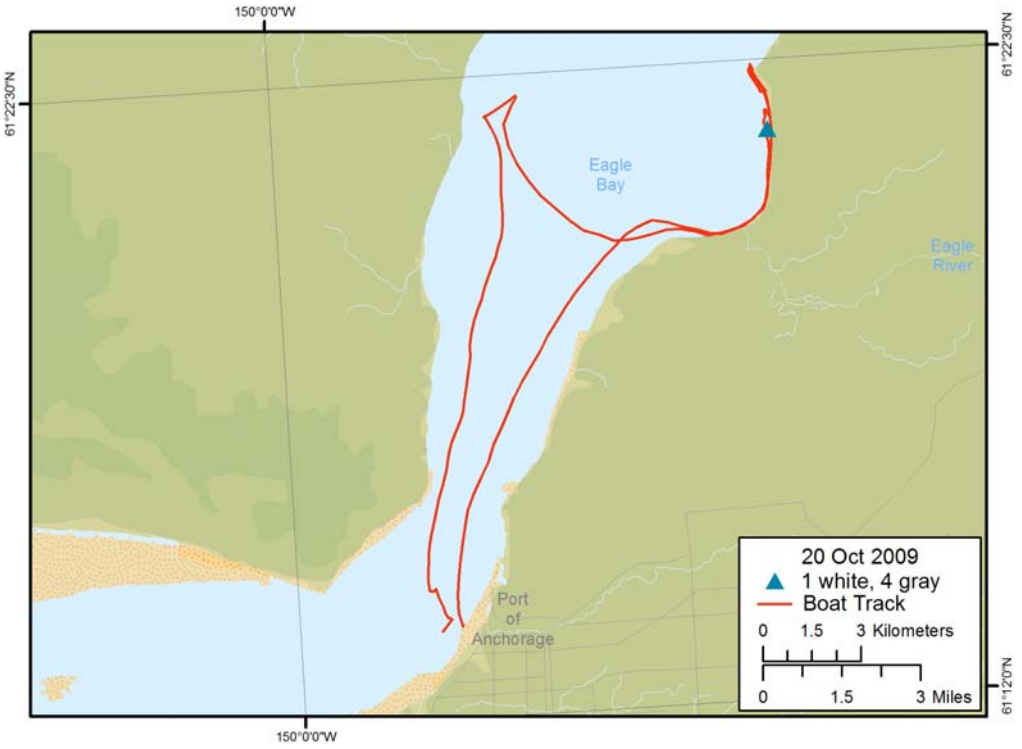

Figure A21. Route and beluga whale group(s) encountered during the vessel-based survey route of 20 October 2009 in Upper Cook Inlet, Alaska.

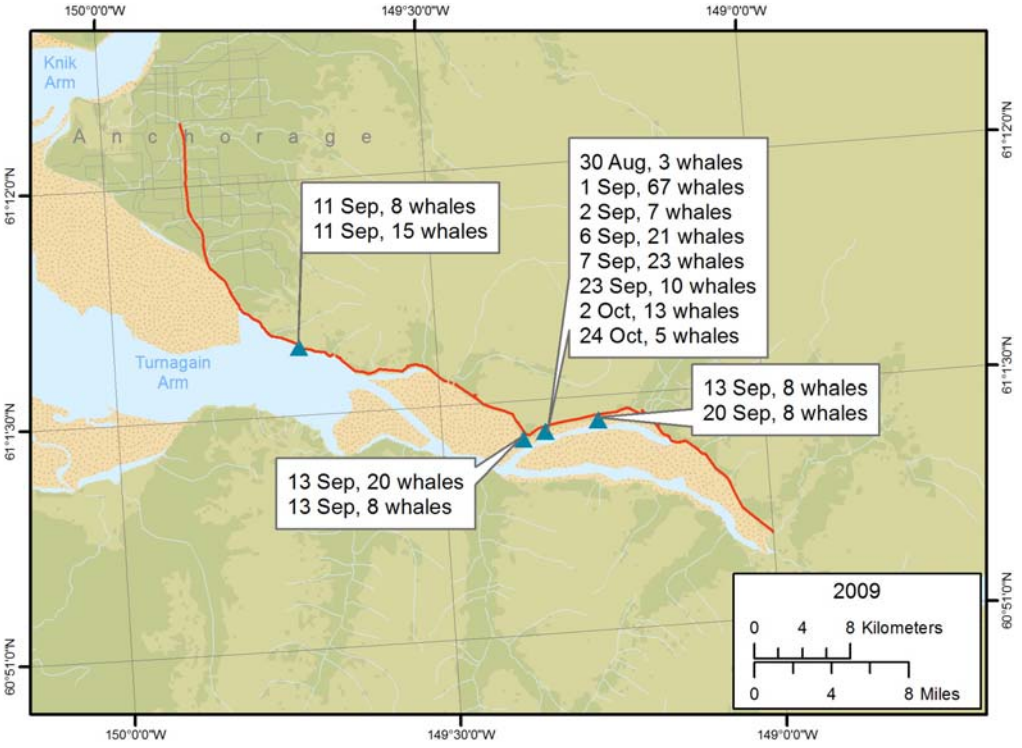

Figure A22. Beluga whale groups encountered and general survey route of all 2009 land-based surveys along Turnagain Arm, Upper Cook Inlet, Alaska.

APPENDIX B

INDIVIDUAL SIGHTING-HISTORY MAPS AND RIGHT SIDE PHOTOGRAPHS OF CATALOGED WHALES SEEN IN ALL FIVE YEARS OF THE STUDY (2005-2009).

WHEN APPLICABLE, SIGHTING HISTORIES ALSO INCLUDE RIGHT- AND LEFT-SIDE PHOTOGRAPHS FROM 2005-2008

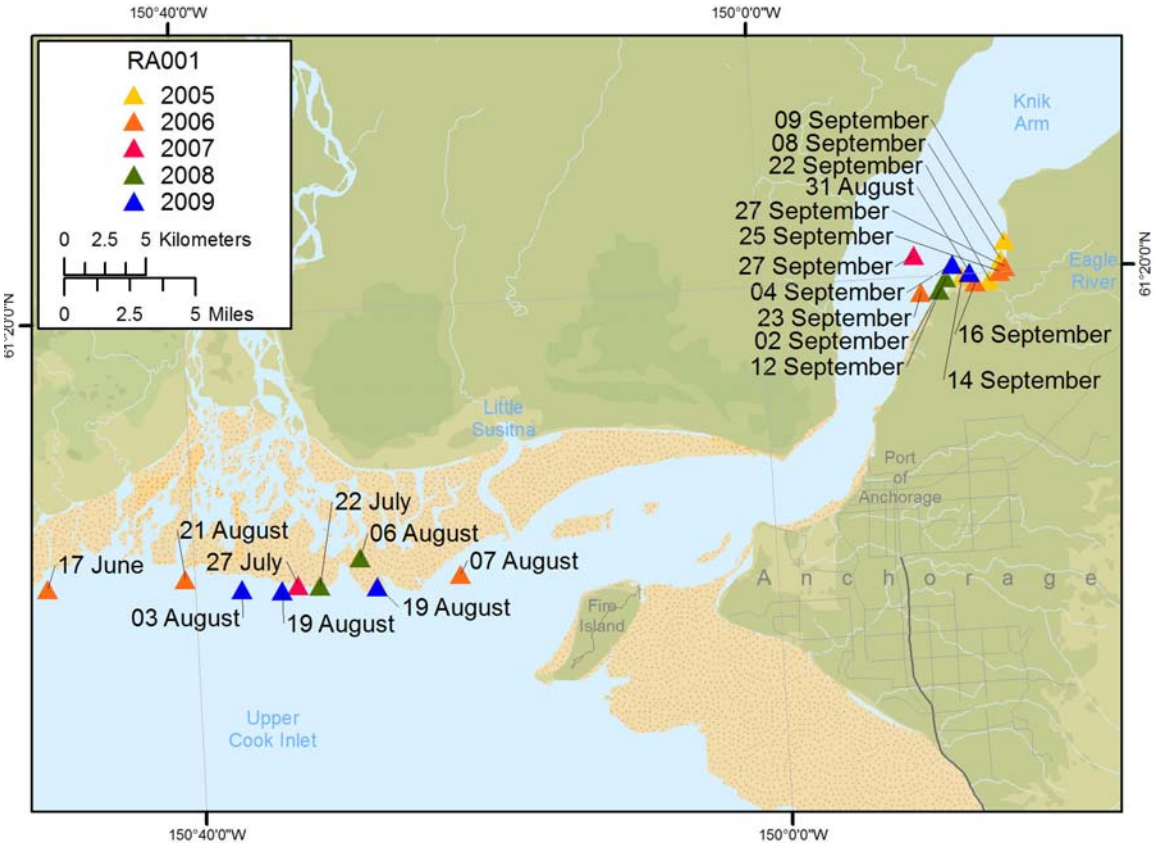

Figure B1. Sighting history and photograph of beluga RA001. This beluga is a presumed mother based on photographs with an accompanying calf.

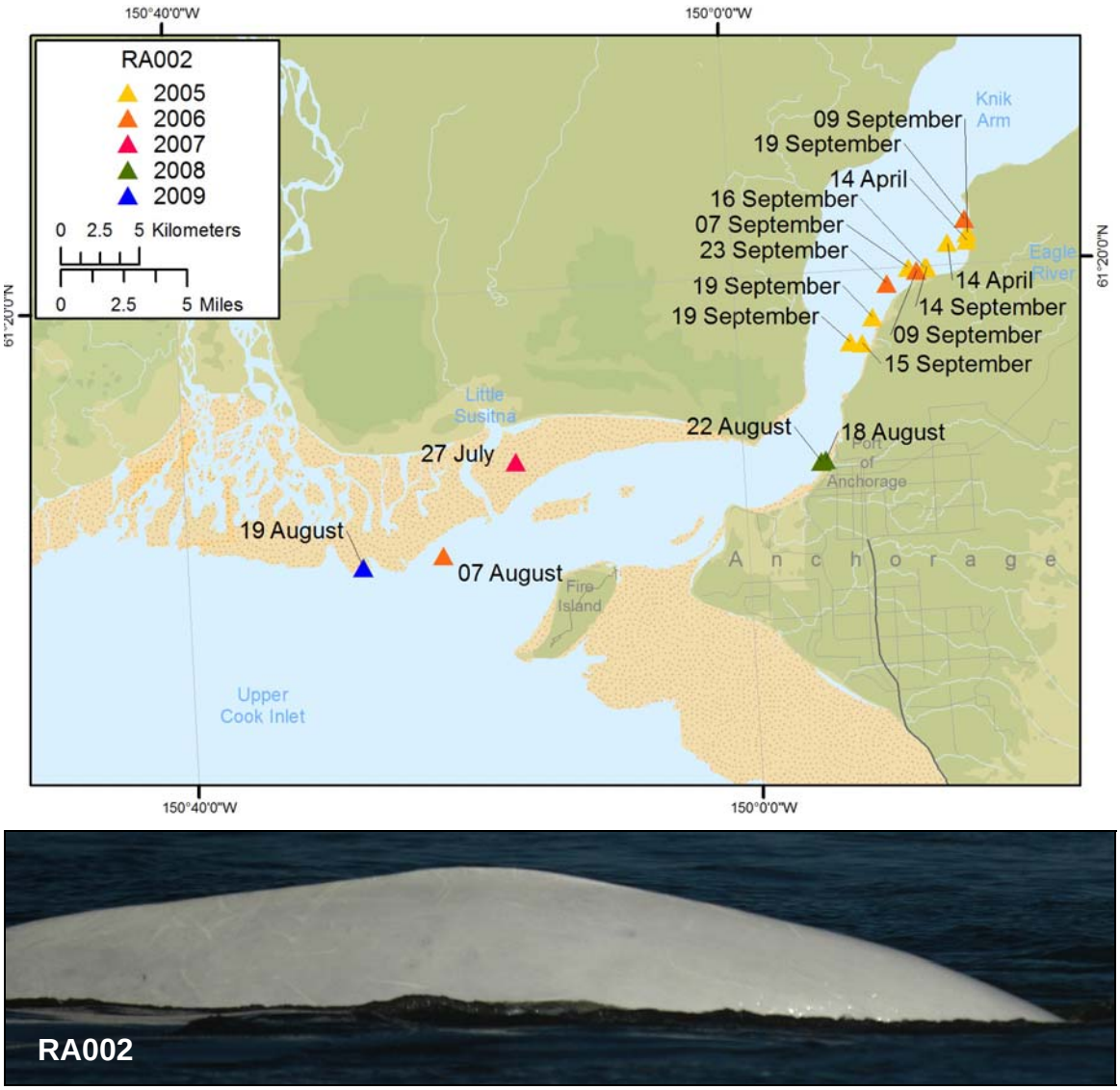

Figure B2. Sighting history and photograph of beluga RA002. This beluga is a presumed mother based on photographs with an accompanying calf.

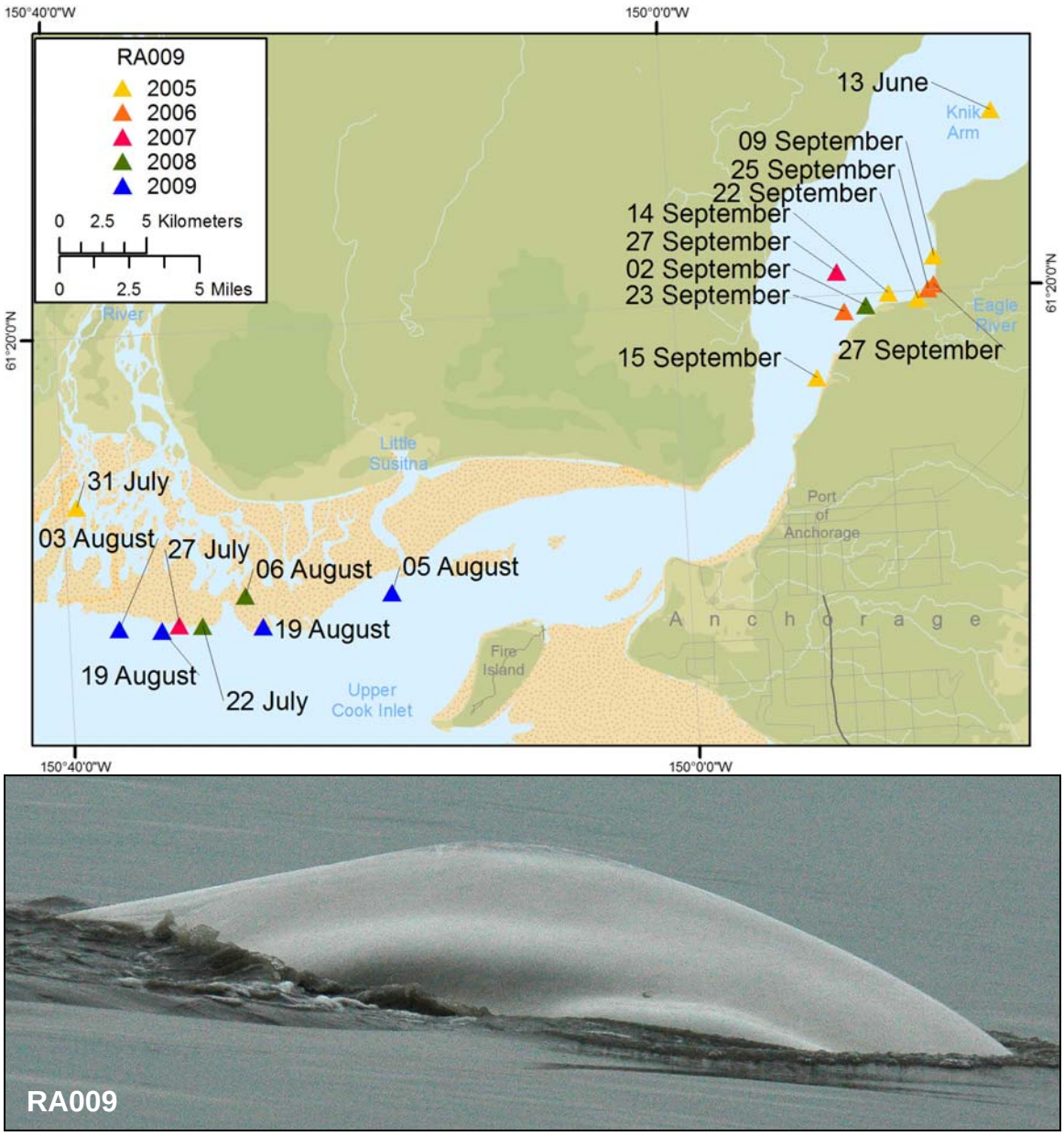

Figure B3. Sighting history and photograph of beluga RA009. This beluga is a presumed mother based on photographs with an accompanying calf.

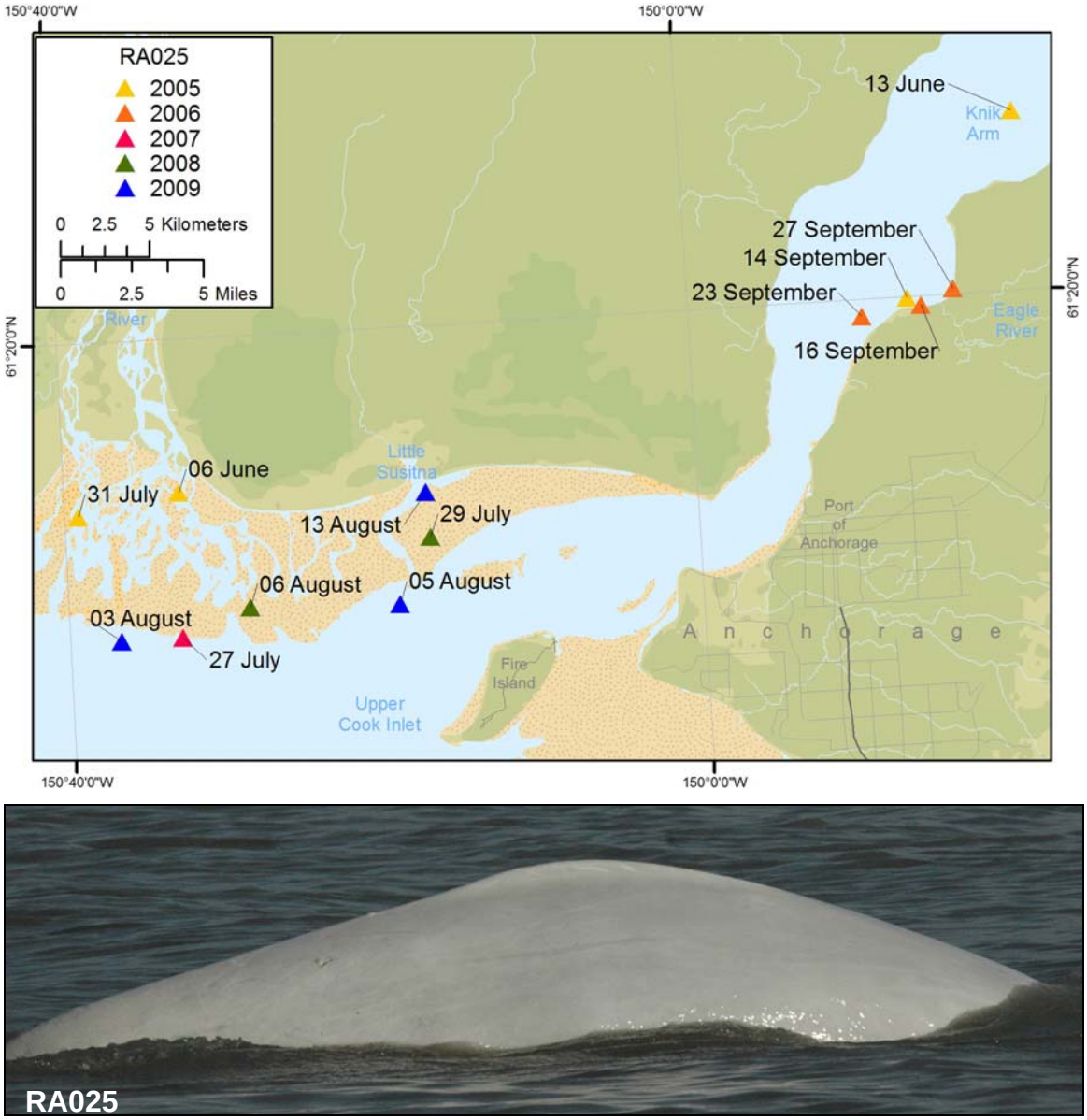

Figure B4. Sighting history and photograph of beluga RA025. This beluga is a presumed mother based on photographs with an accompanying calf.

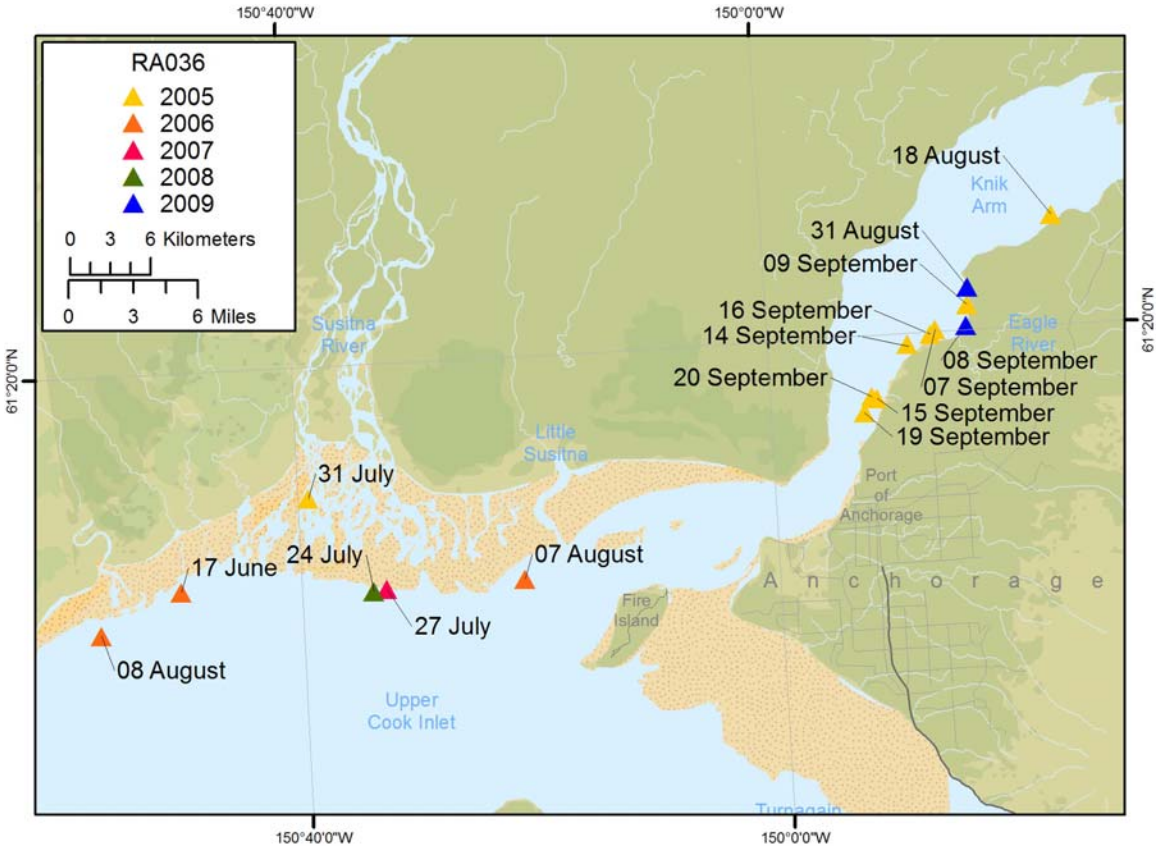

Figure B5. Sighting history and photograph of beluga RA036. This beluga is a presumed mother based on photographs with an accompanying calf.

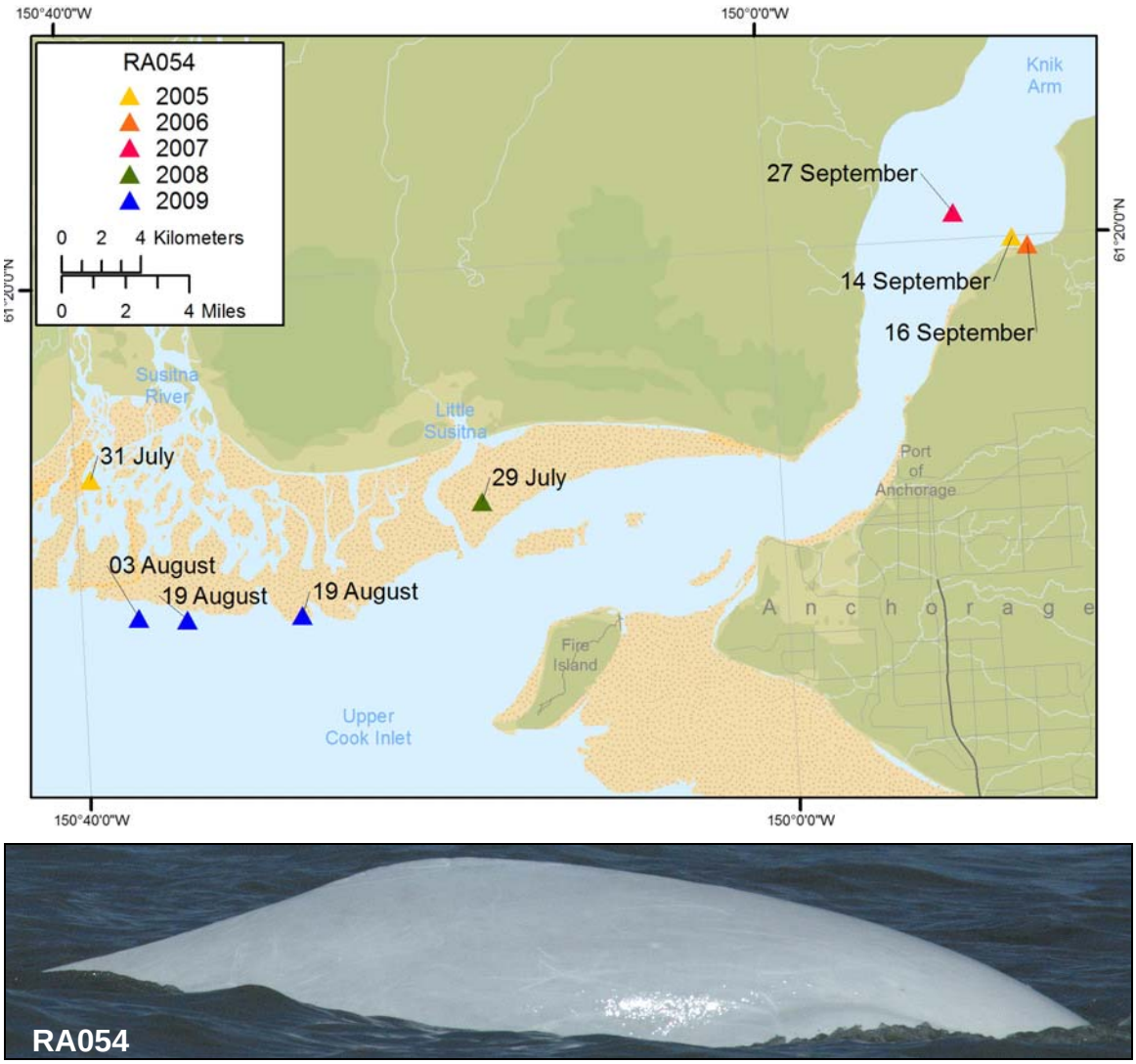

Figure B6. Sighting history and photograph of beluga RA054. This beluga is a presumed mother based on photographs with an accompanying calf.

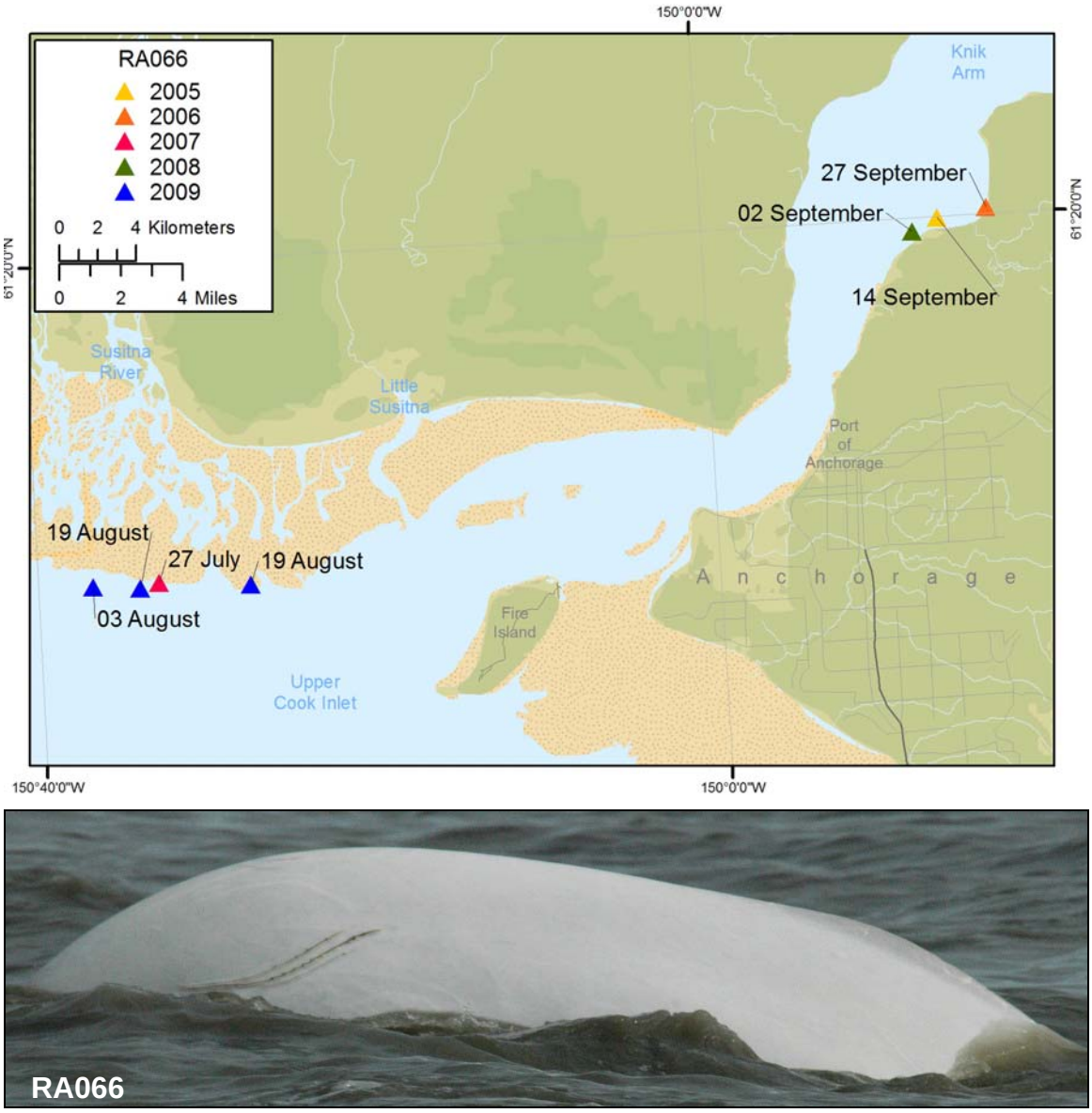

Figure B7. Sighting history and photograph of beluga RA066. This beluga is a presumed mother based on photographs with an accompanying calf.

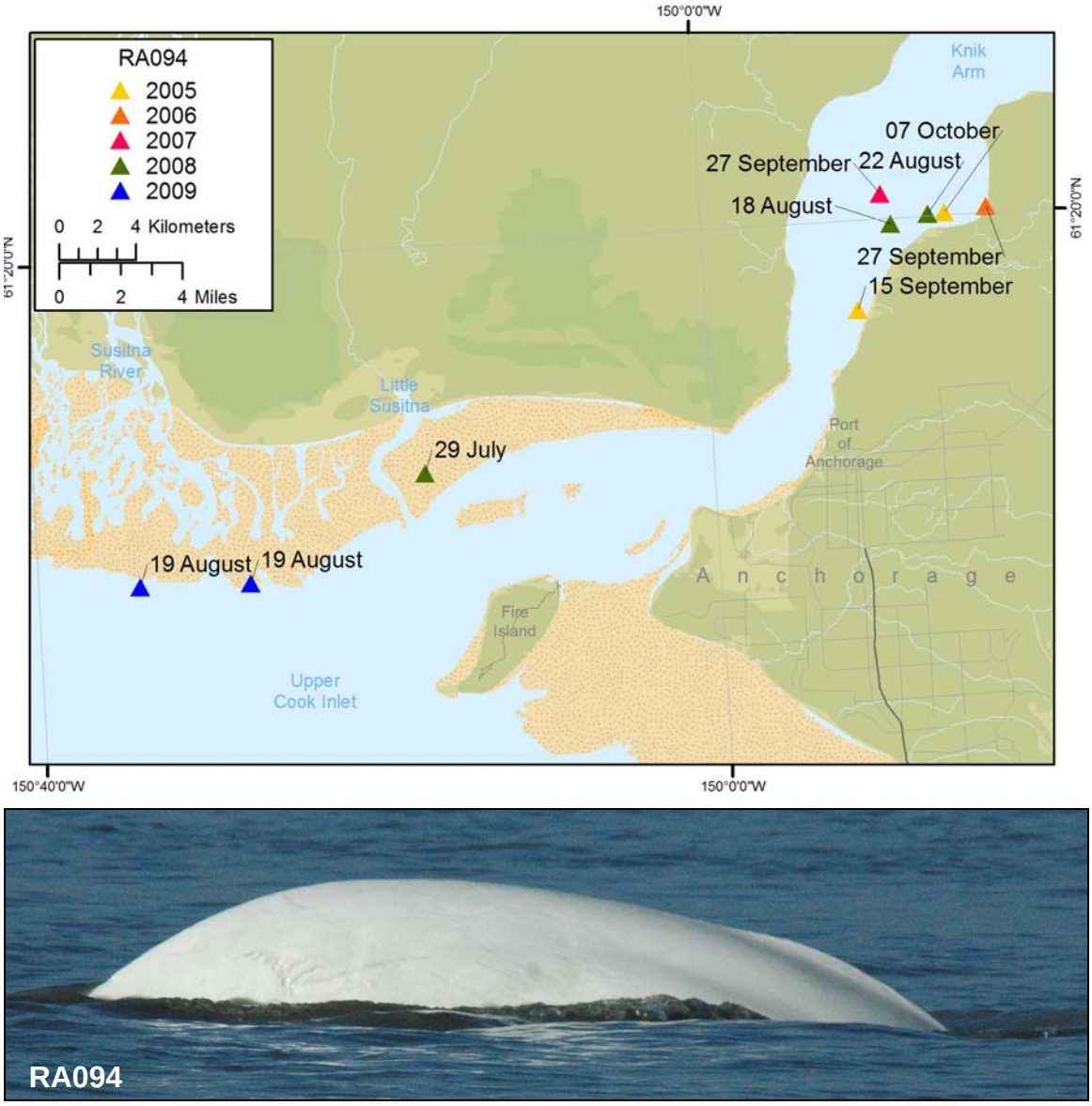

Figure B8. Sighting history and photograph of beluga RA094. This beluga is a presumed mother based on photographs with an accompanying calf.

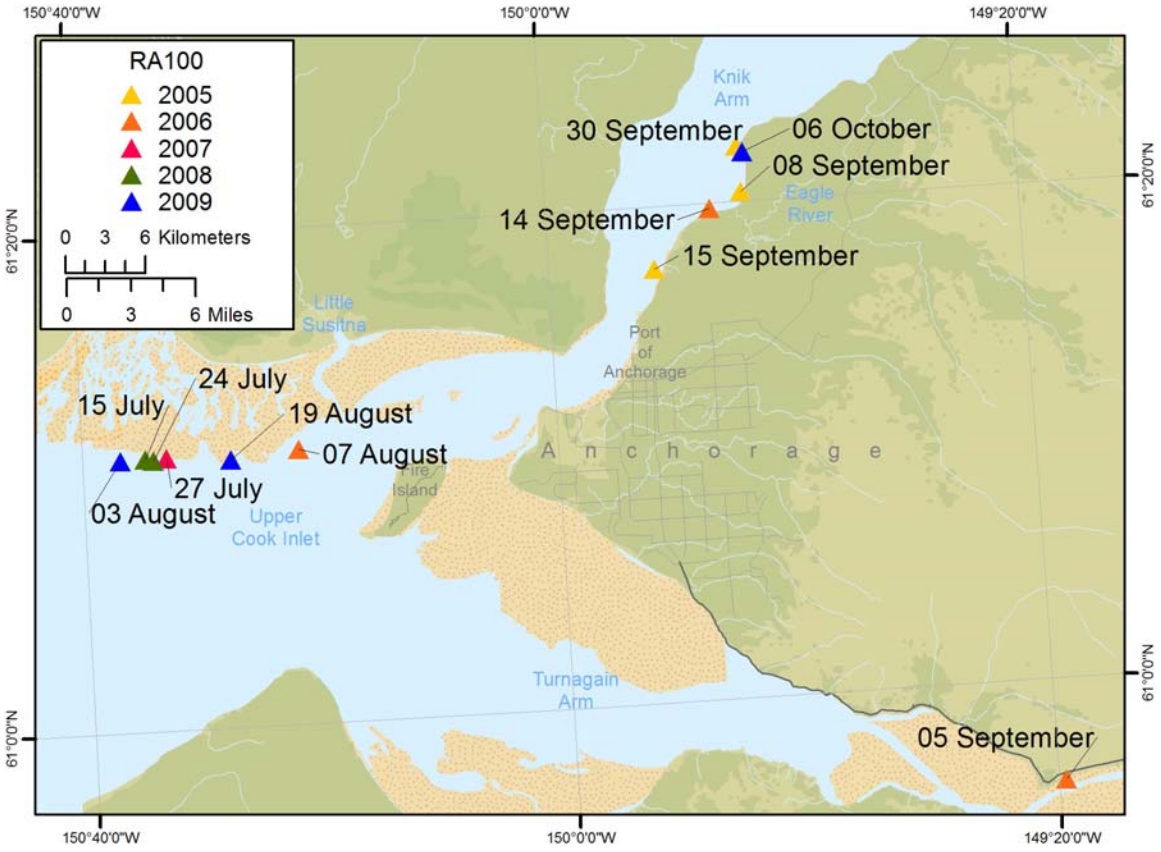

Figure B9. Sighting history and photograph of beluga RA100.

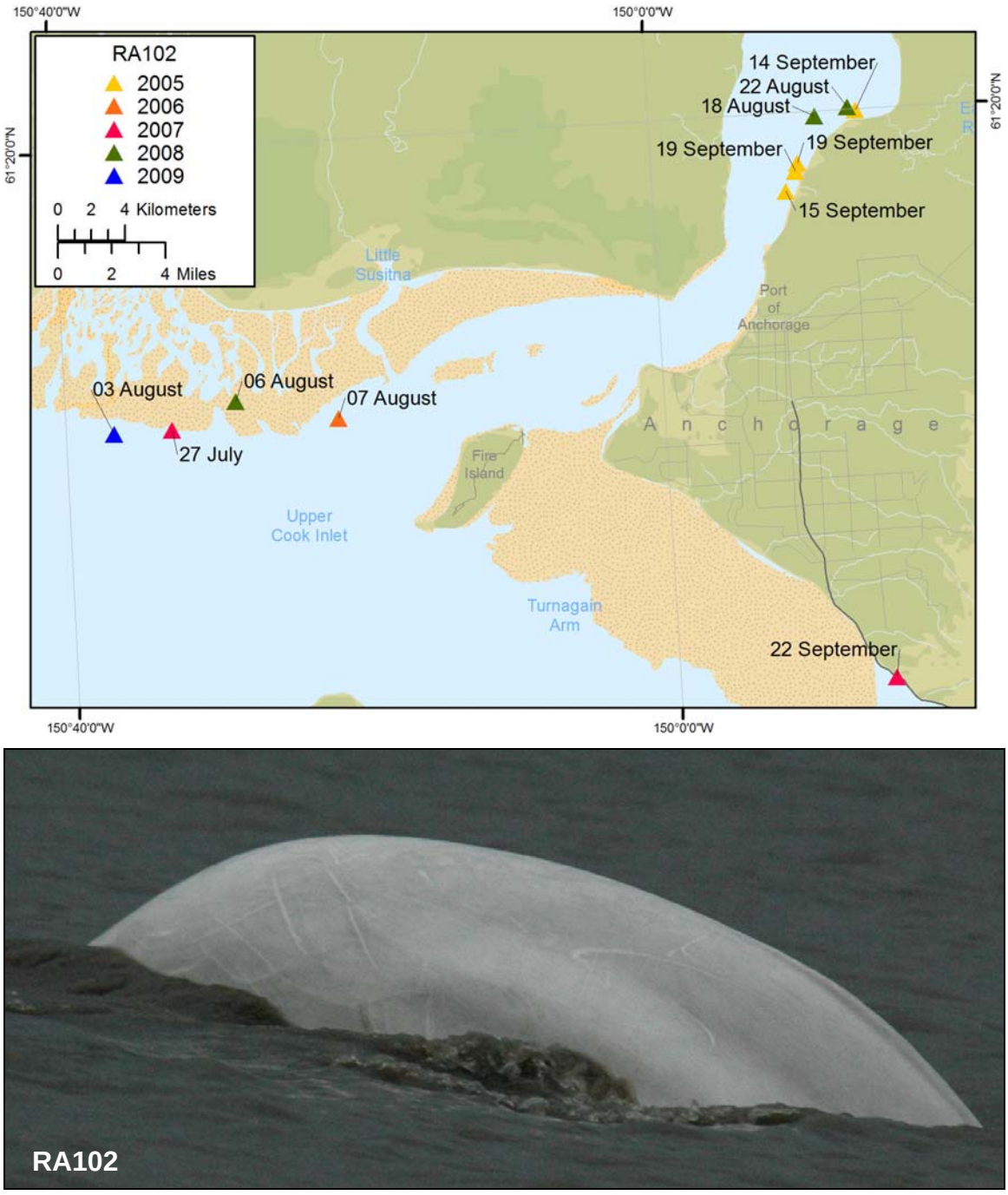

Figure B10. Sighting history and photograph of beluga RA102. This beluga is a presumed mother based on photographs with an accompanying calf.

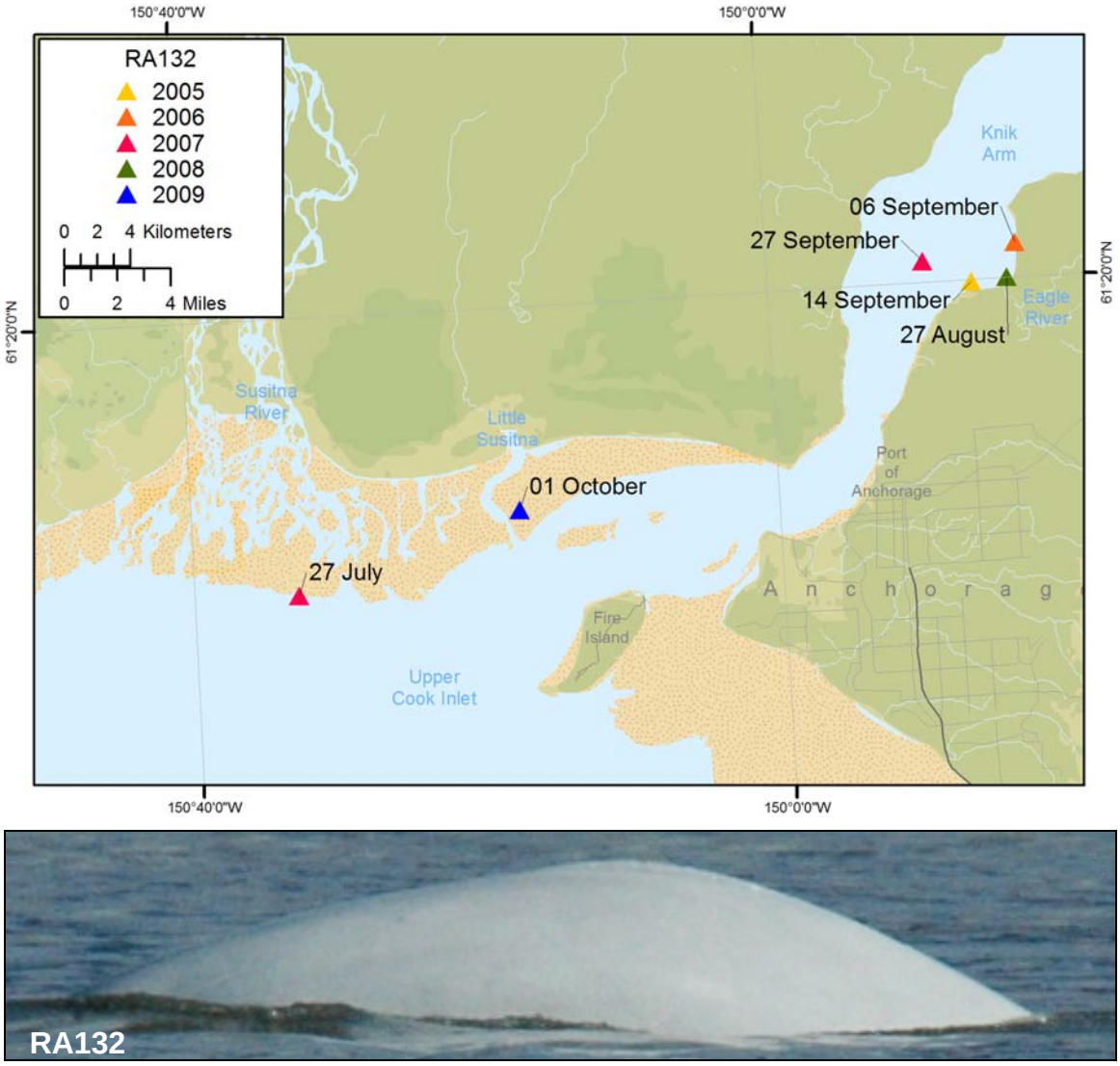

Figure B11. Sighting history and photograph of beluga RA132.

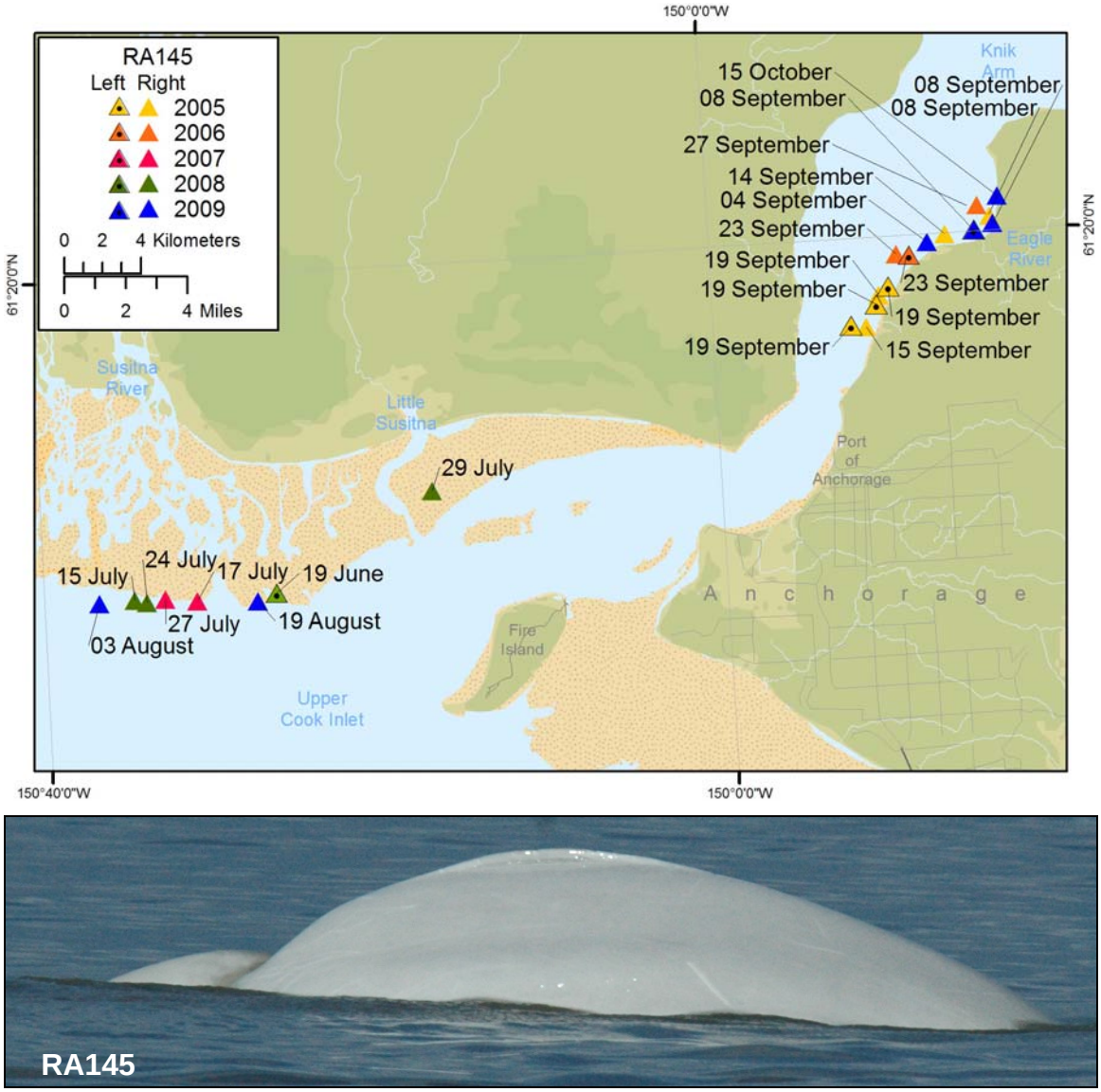

Figure B12. Sighting history and photograph of beluga RA145. This beluga is a presumed mother based on photographs with an accompanying calf.

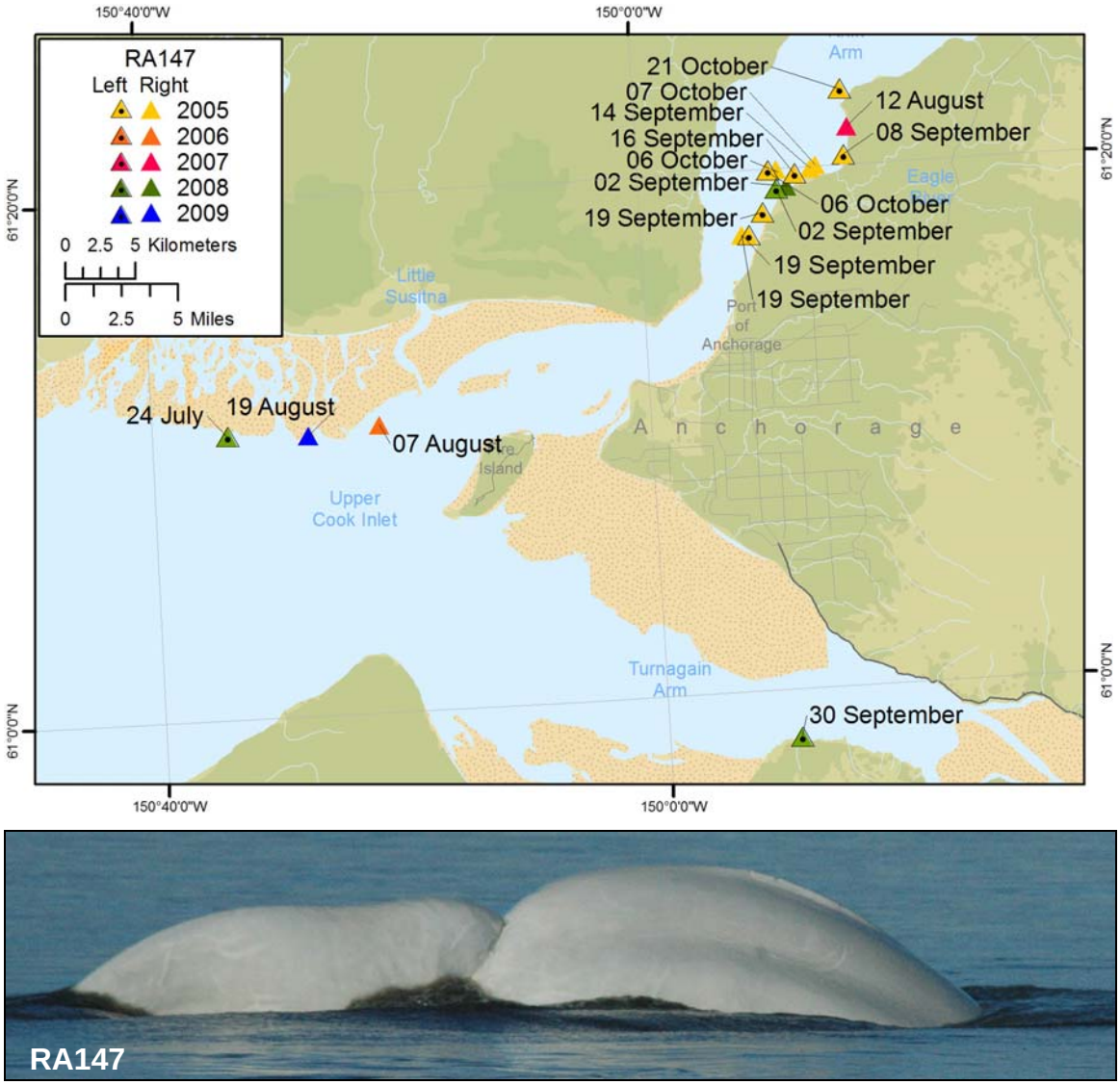

Figure B13. Sighting history and photograph of beluga RA147. This beluga is a presumed mother based on photographs with an accompanying calf.

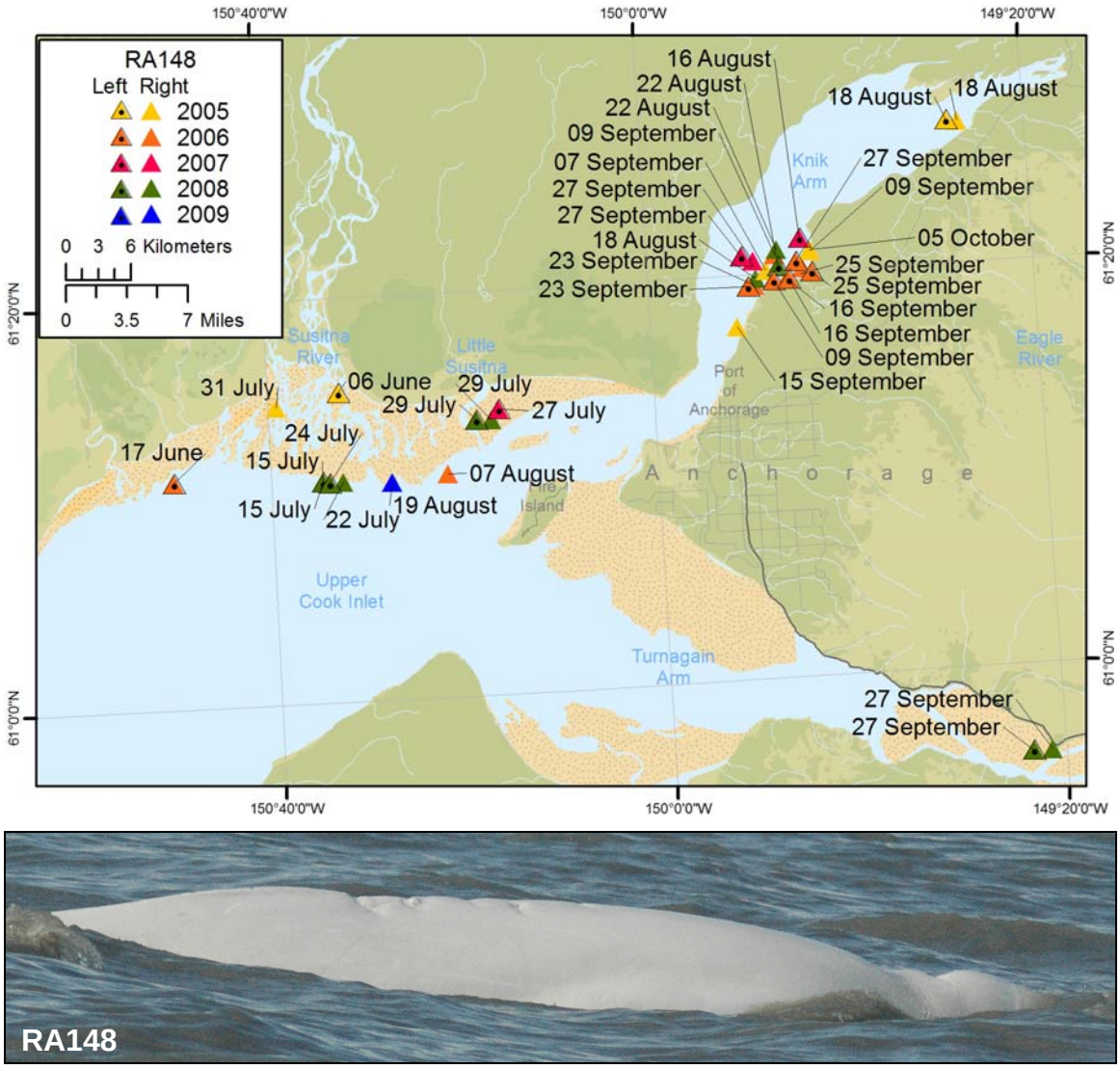

Figure B14. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA148. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

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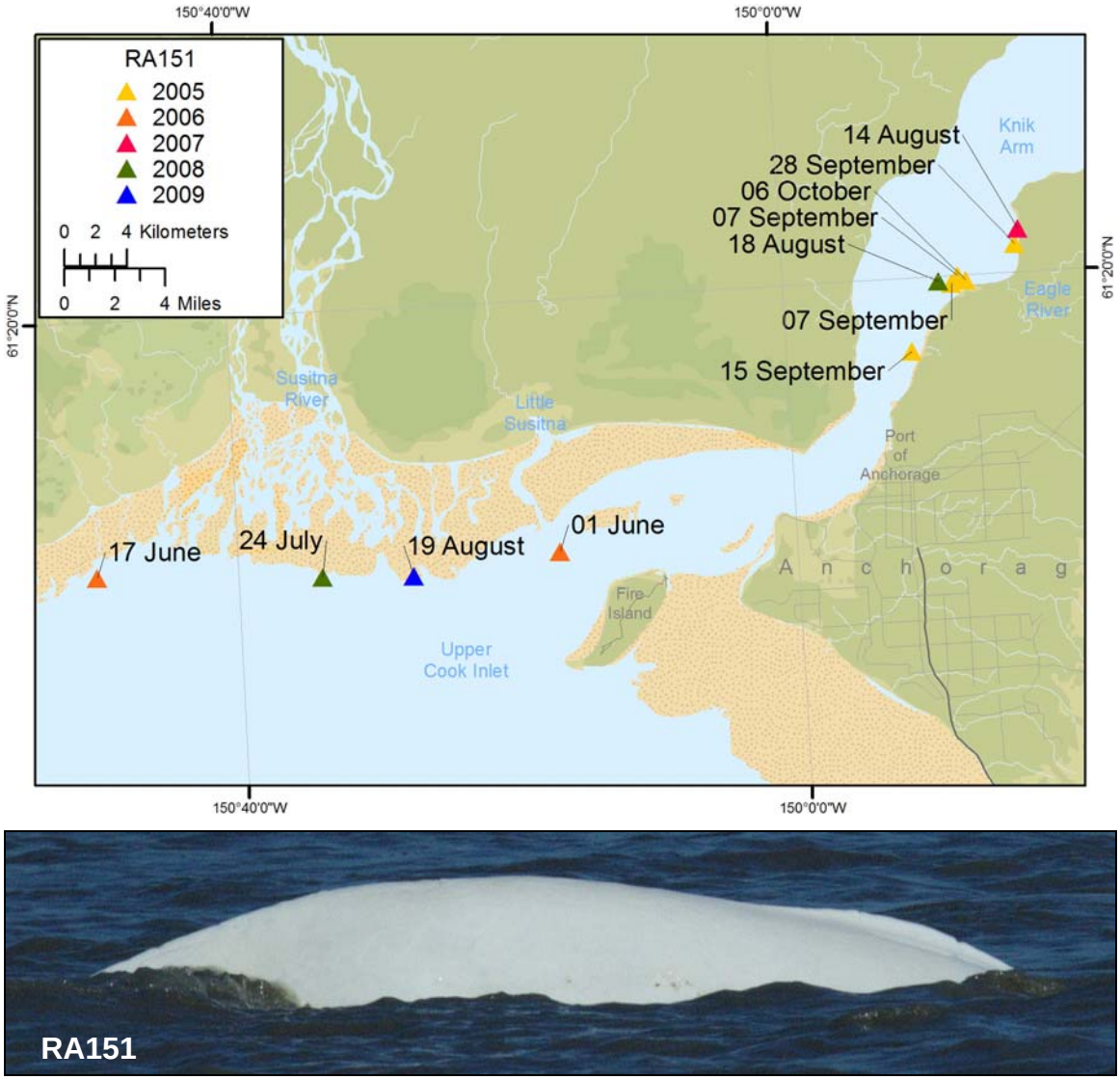

Figure B15. Sighting history and photograph of beluga RA151. This beluga is a presumed mother based on photographs with an accompanying calf.

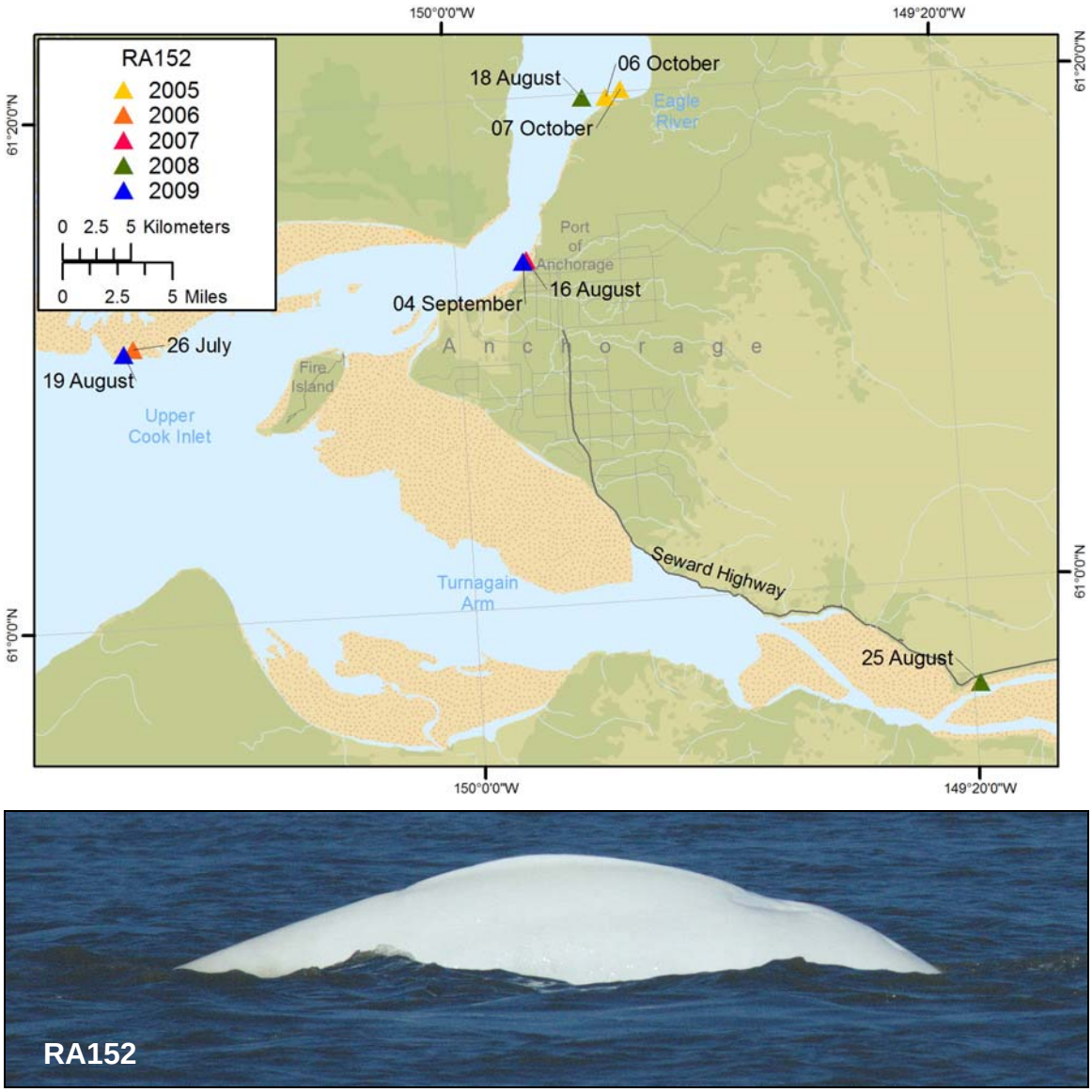

Figure B16. Sighting history and photograph of beluga RA152.

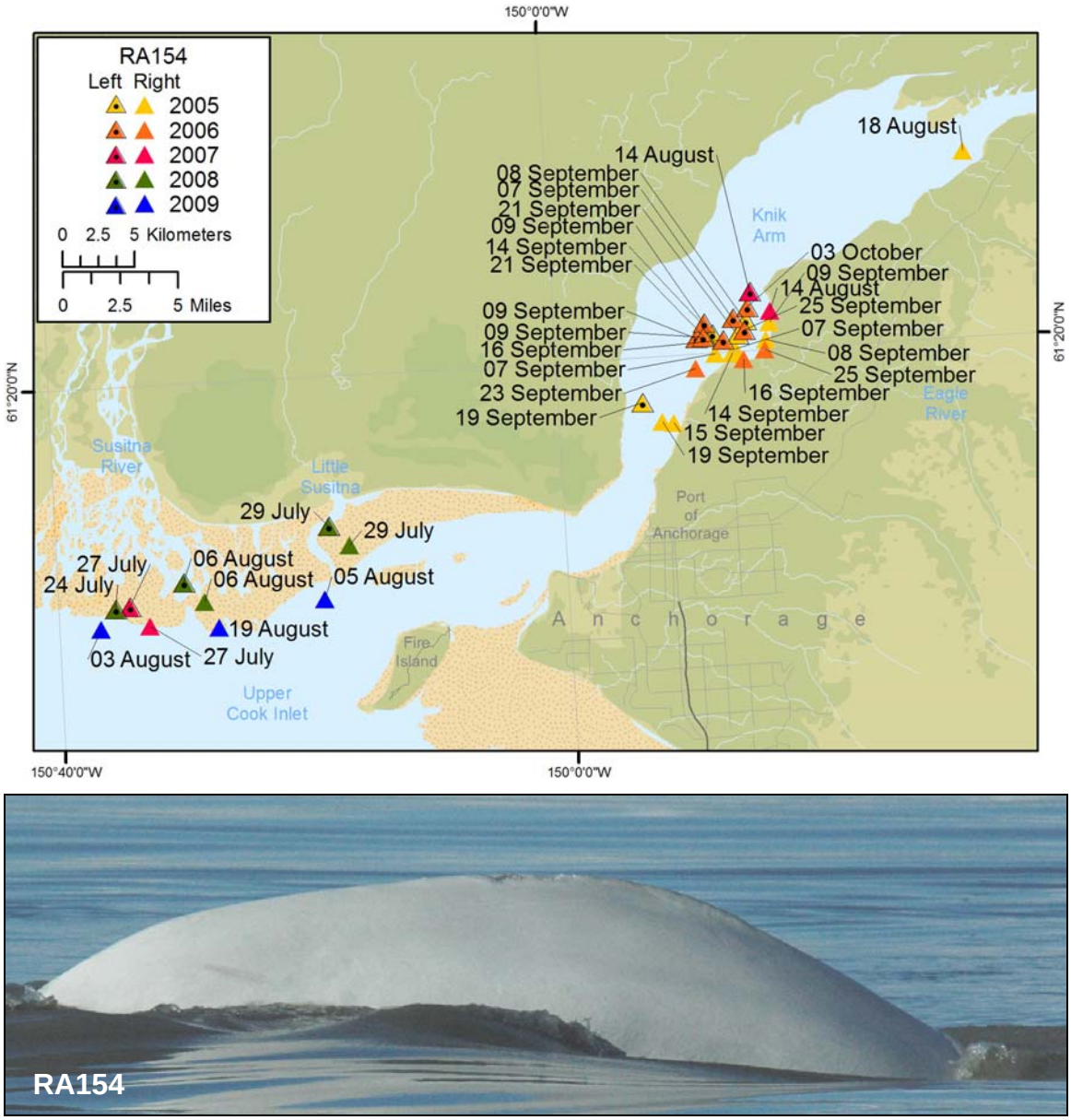

Figure B17. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA154. This beluga is a presumed mother based on photographs with an accompanying calf.

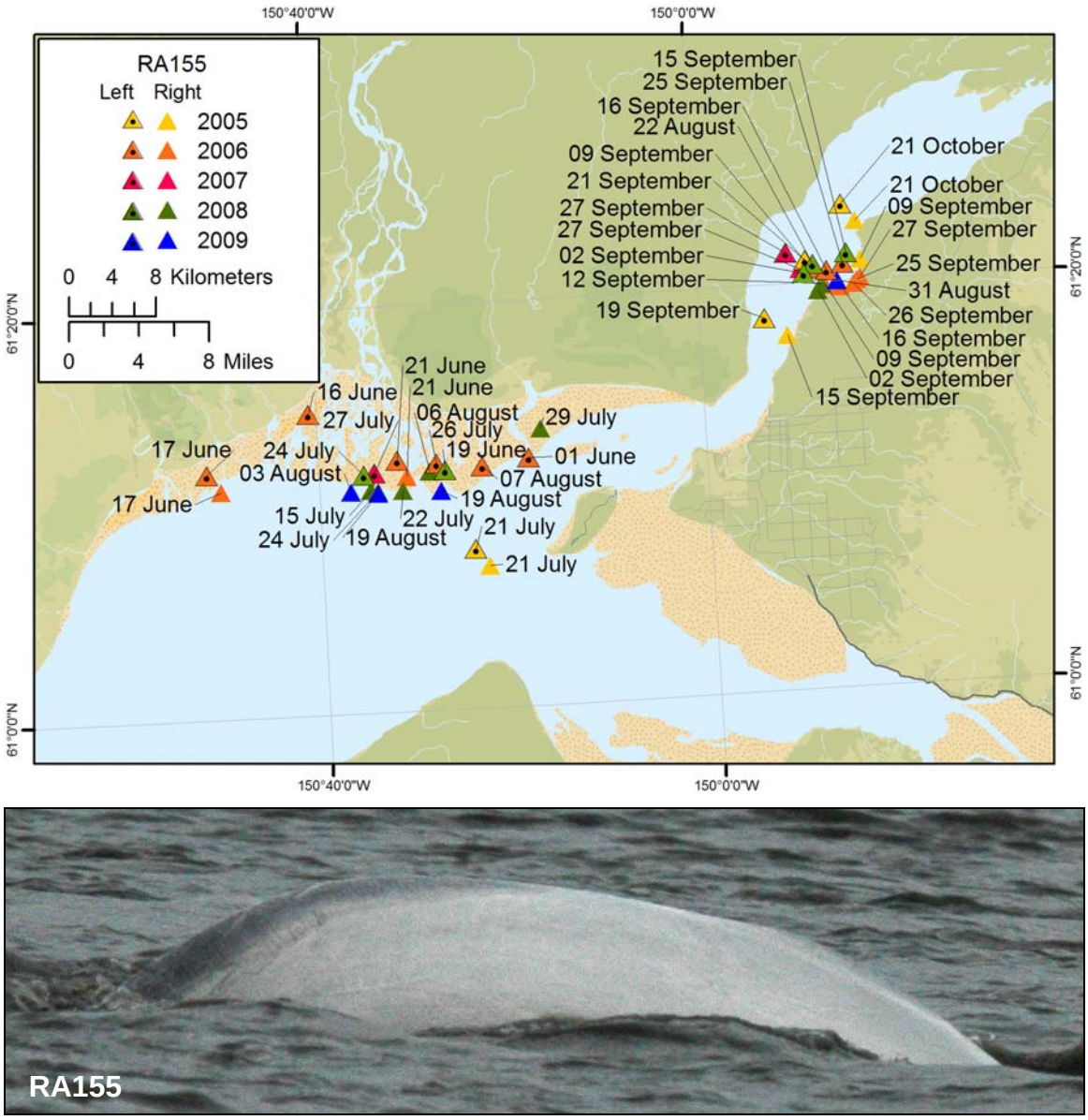

Figure B18. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA155. This beluga is a presumed mother based on photographs with an accompanying calf.

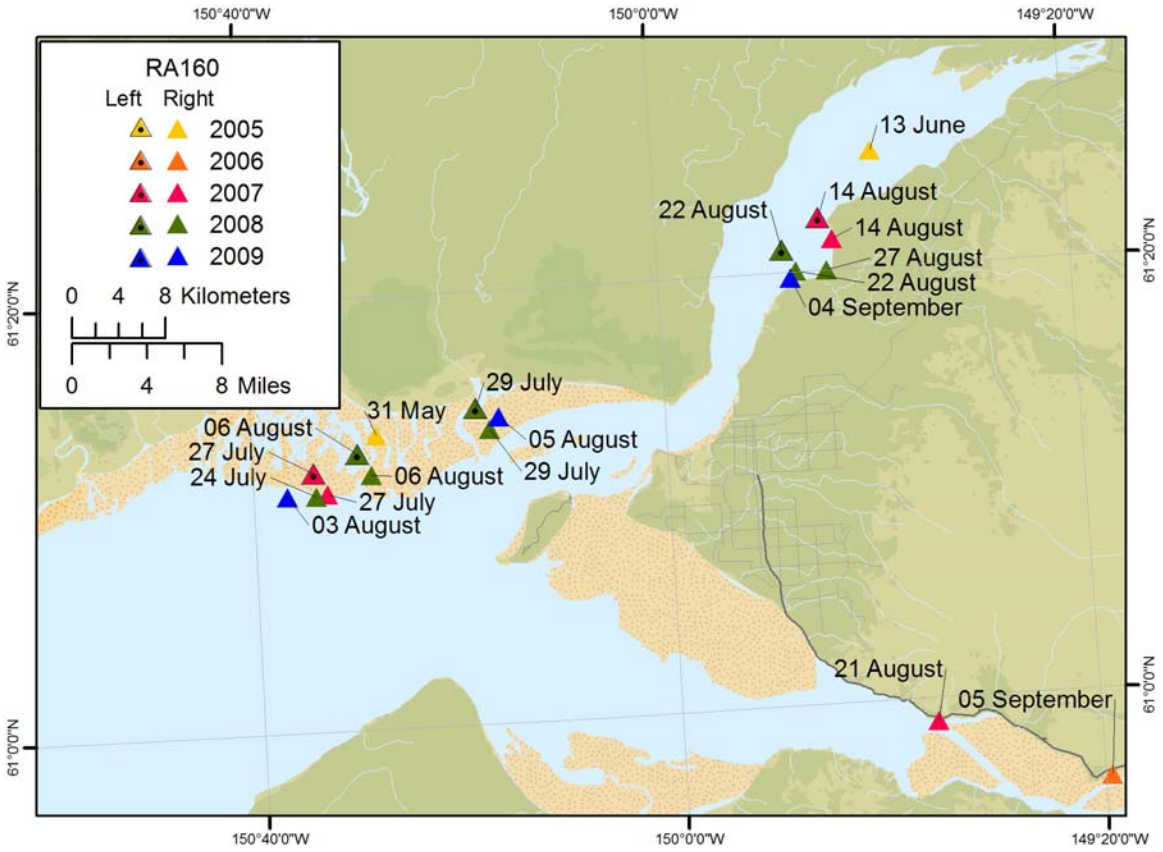

Figure B19. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA160. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

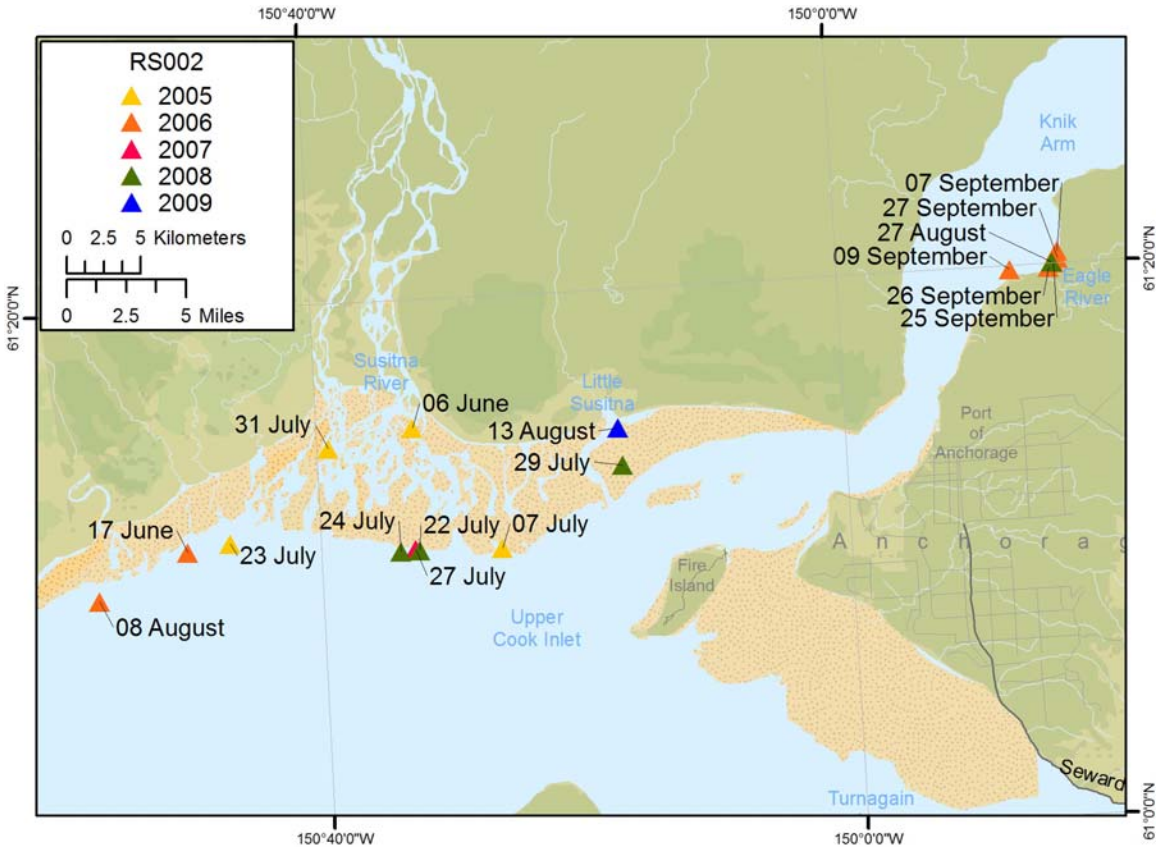

Figure B20. Sighting history and photograph of beluga RS002.

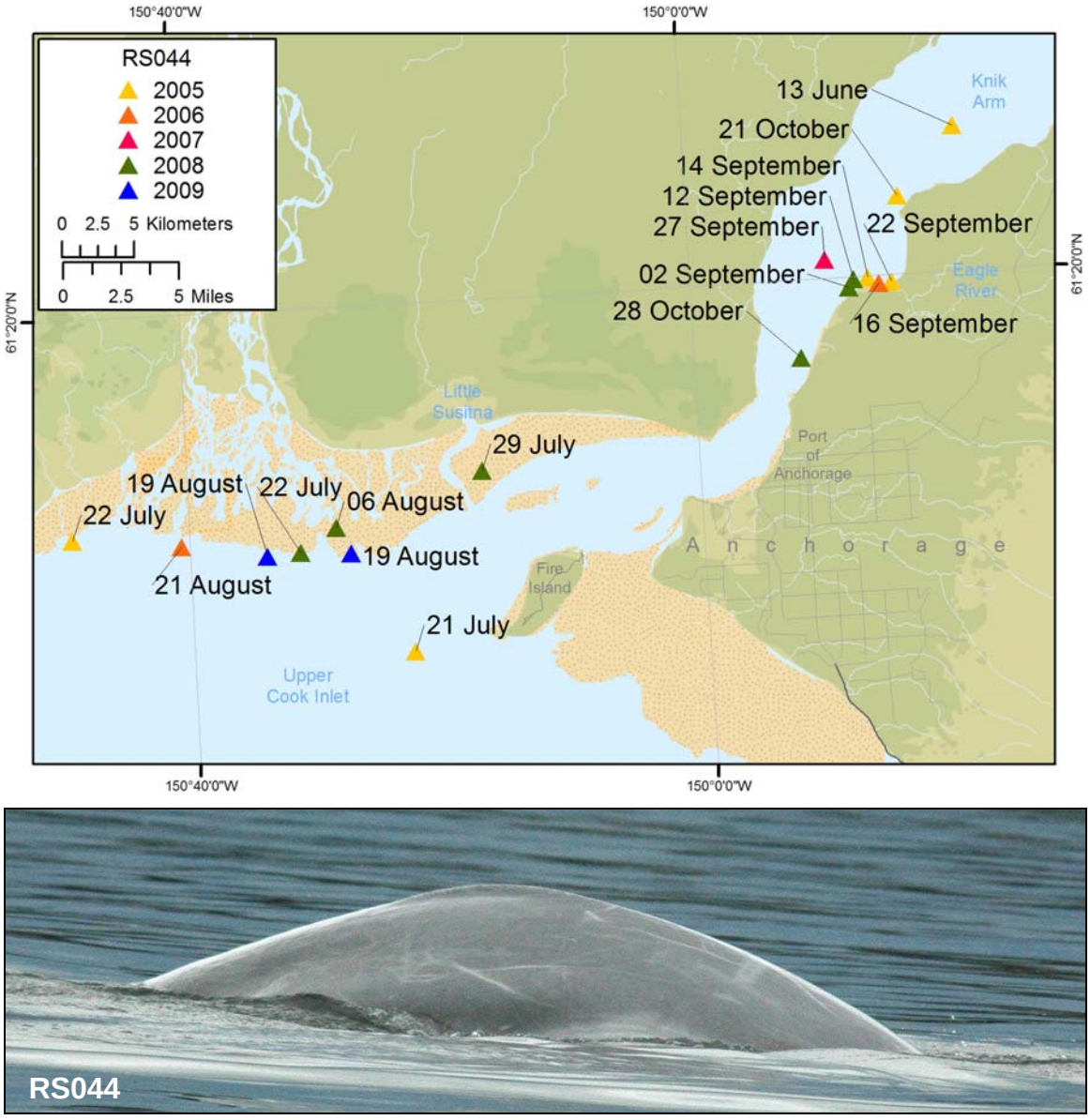

Figure B21. Sighting history and photograph of beluga RS044.

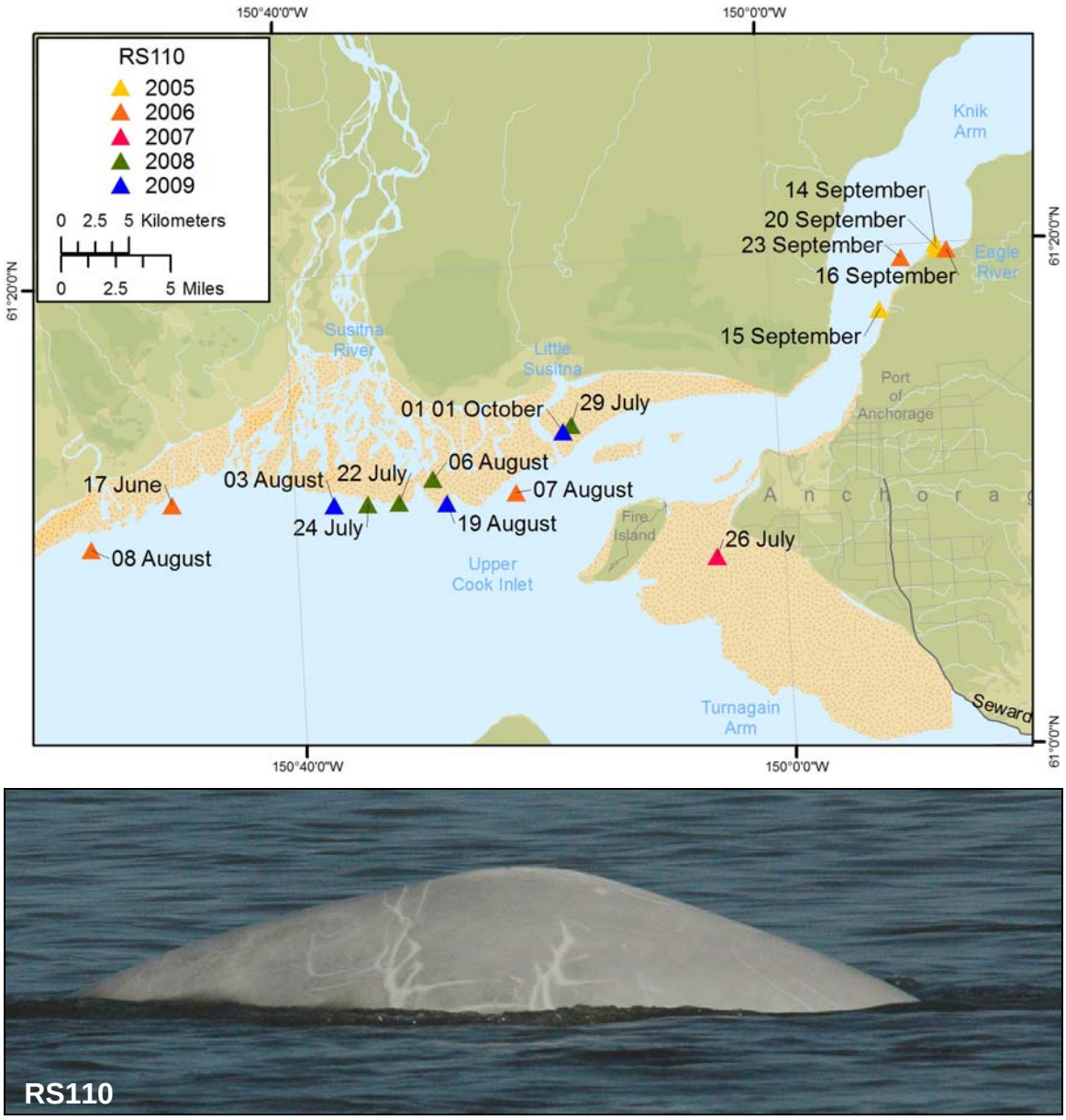

Figure B22. Sighting history and photograph of beluga RS110. This beluga is a presumed mother based on photographs with an accompanying calf.

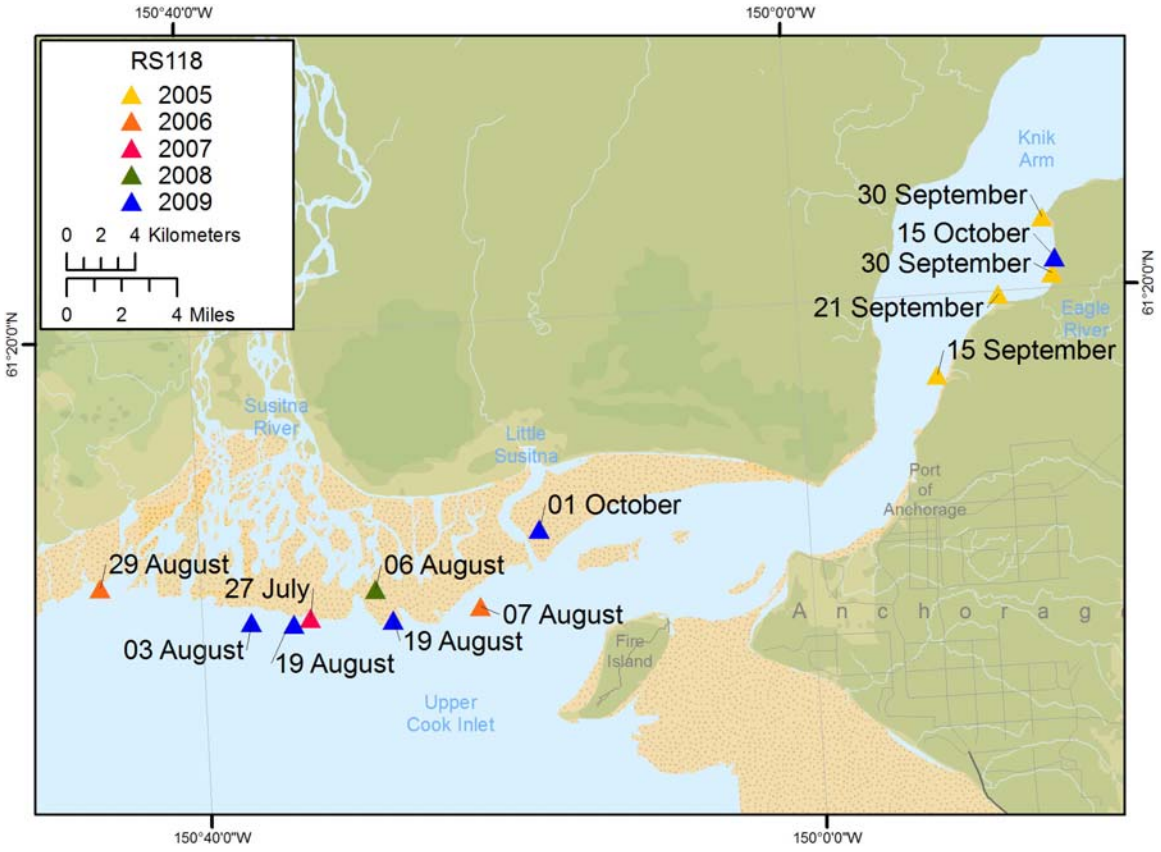

Figure B23. Sighting history and photograph of beluga RS118.

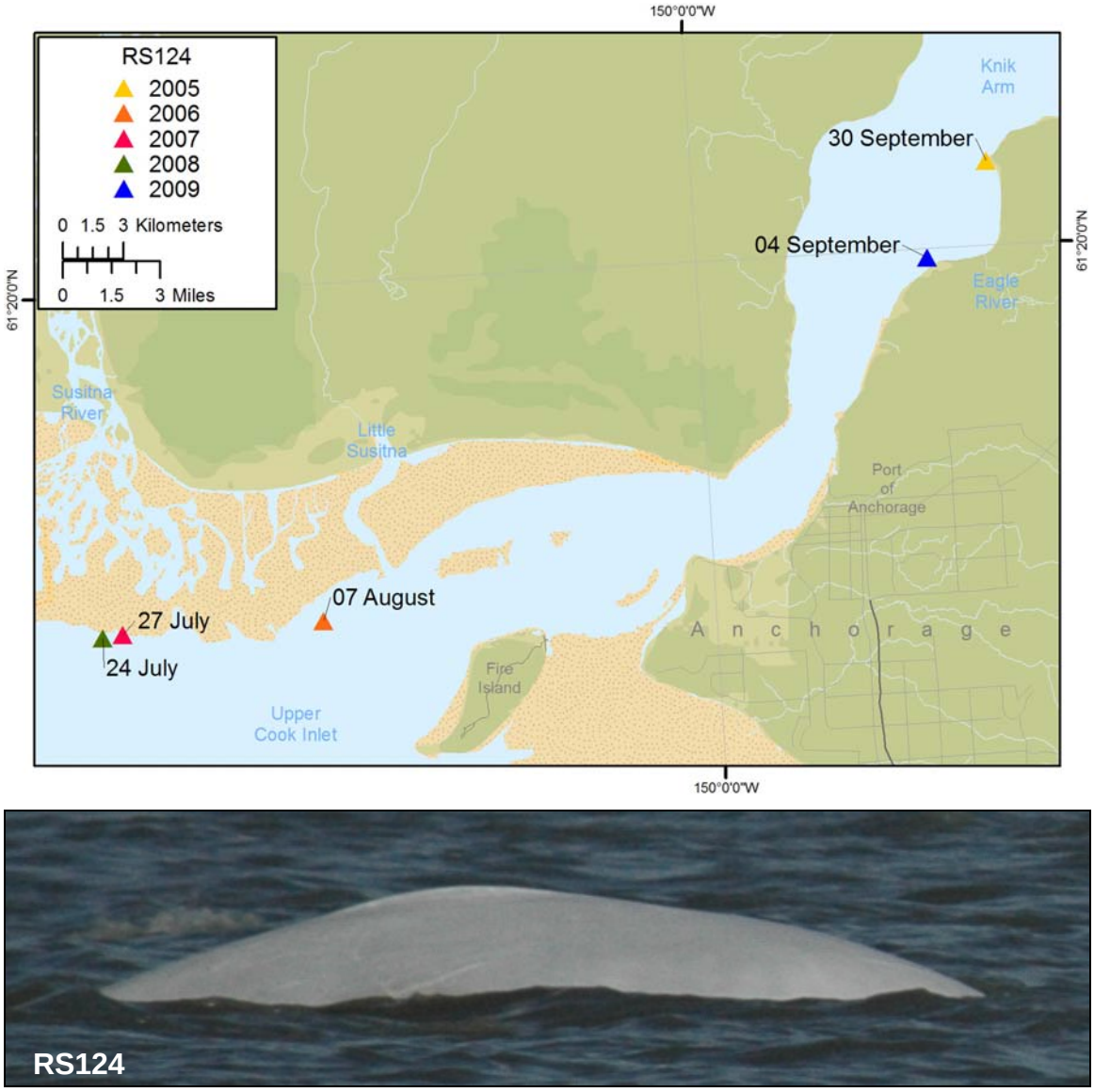

Figure B24. Sighting history and photograph of beluga RS124. This beluga is a presumed mother based on photographs with an accompanying calf.

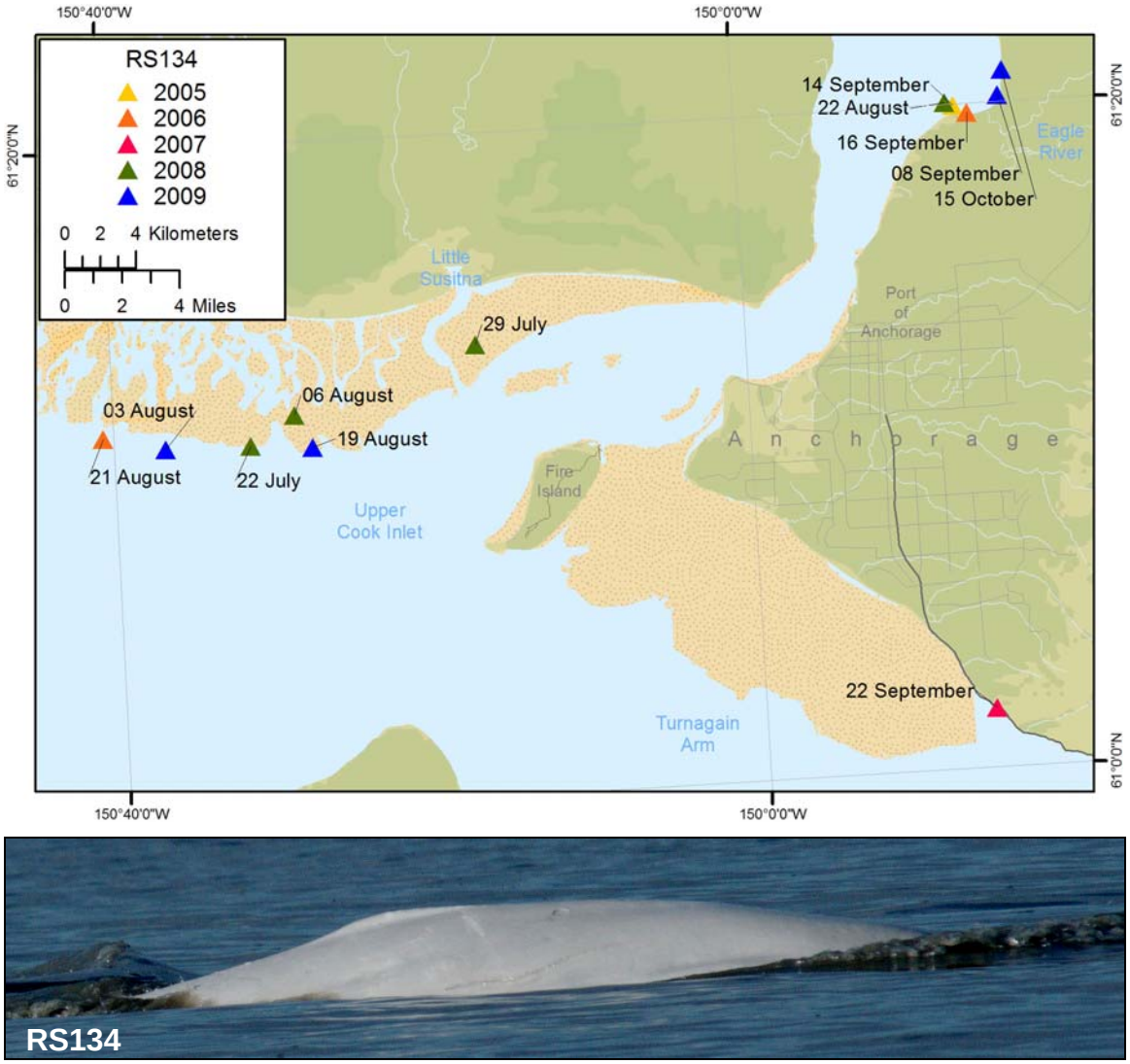

Figure B25. Sighting history and photograph of beluga RS134. This beluga is a presumed mother based on photographs with an accompanying calf.

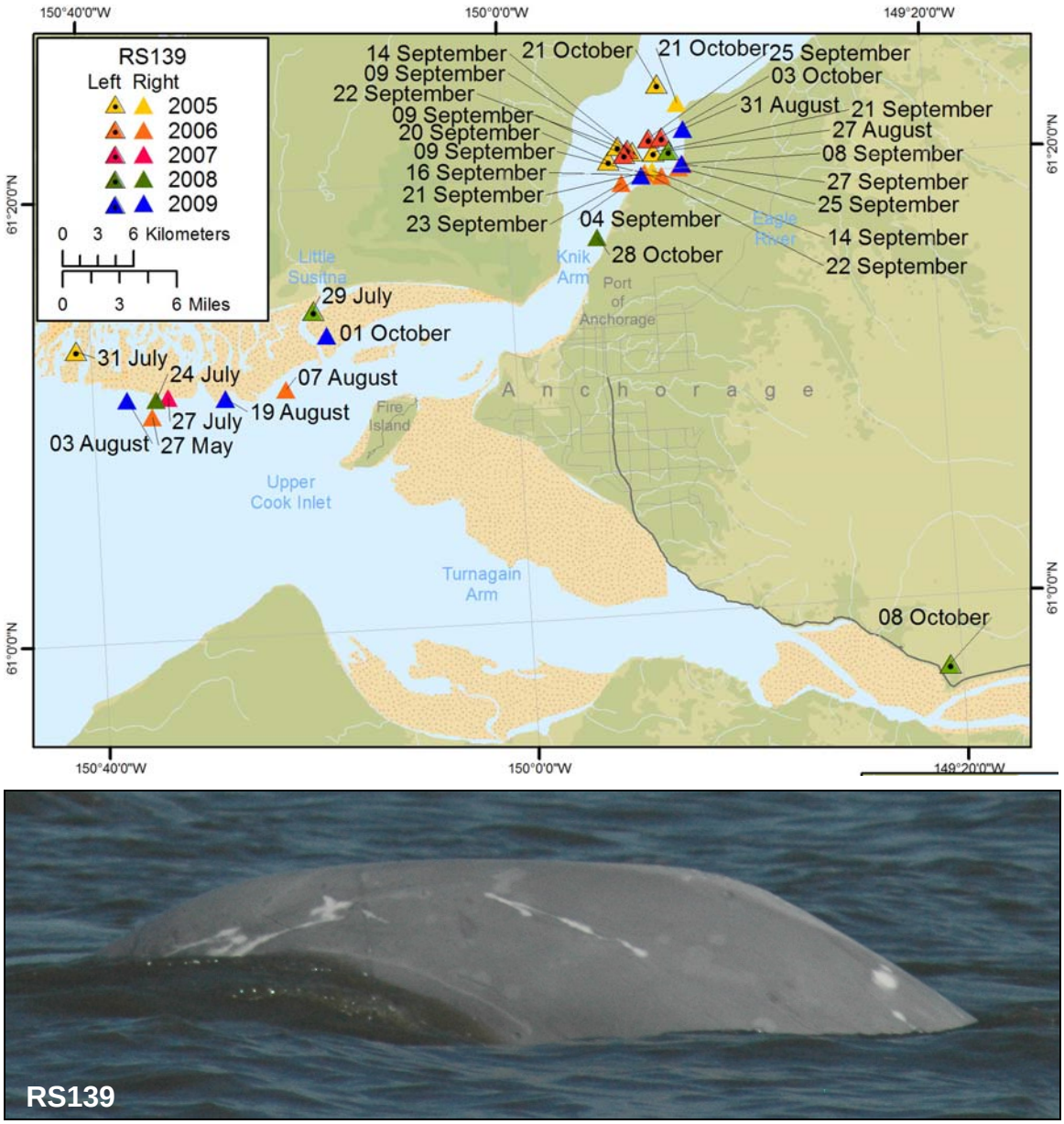

Figure B26. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RS139. This beluga is a presumed mother based on photographs with an accompanying calf.

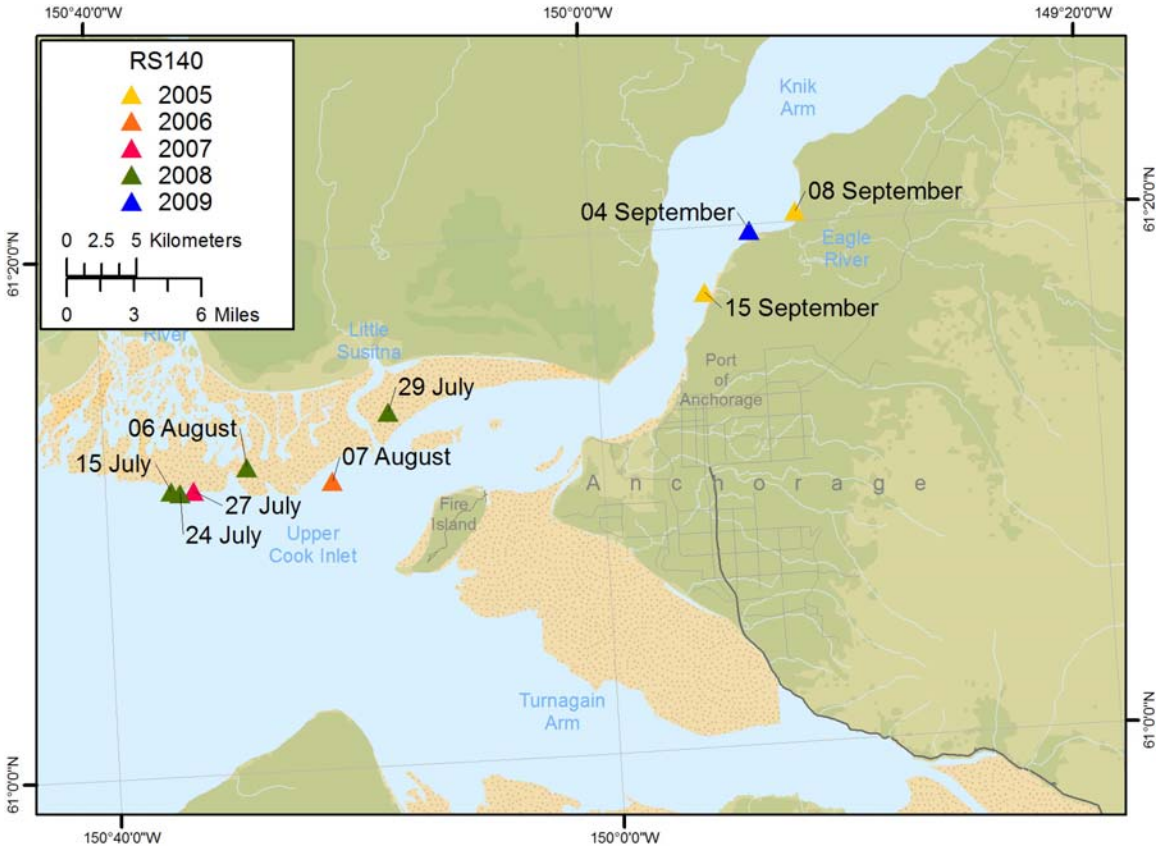

Figure B27. Sighting history and photograph of beluga RS140. This beluga is a presumed mother based on photographs with an accompanying calf.

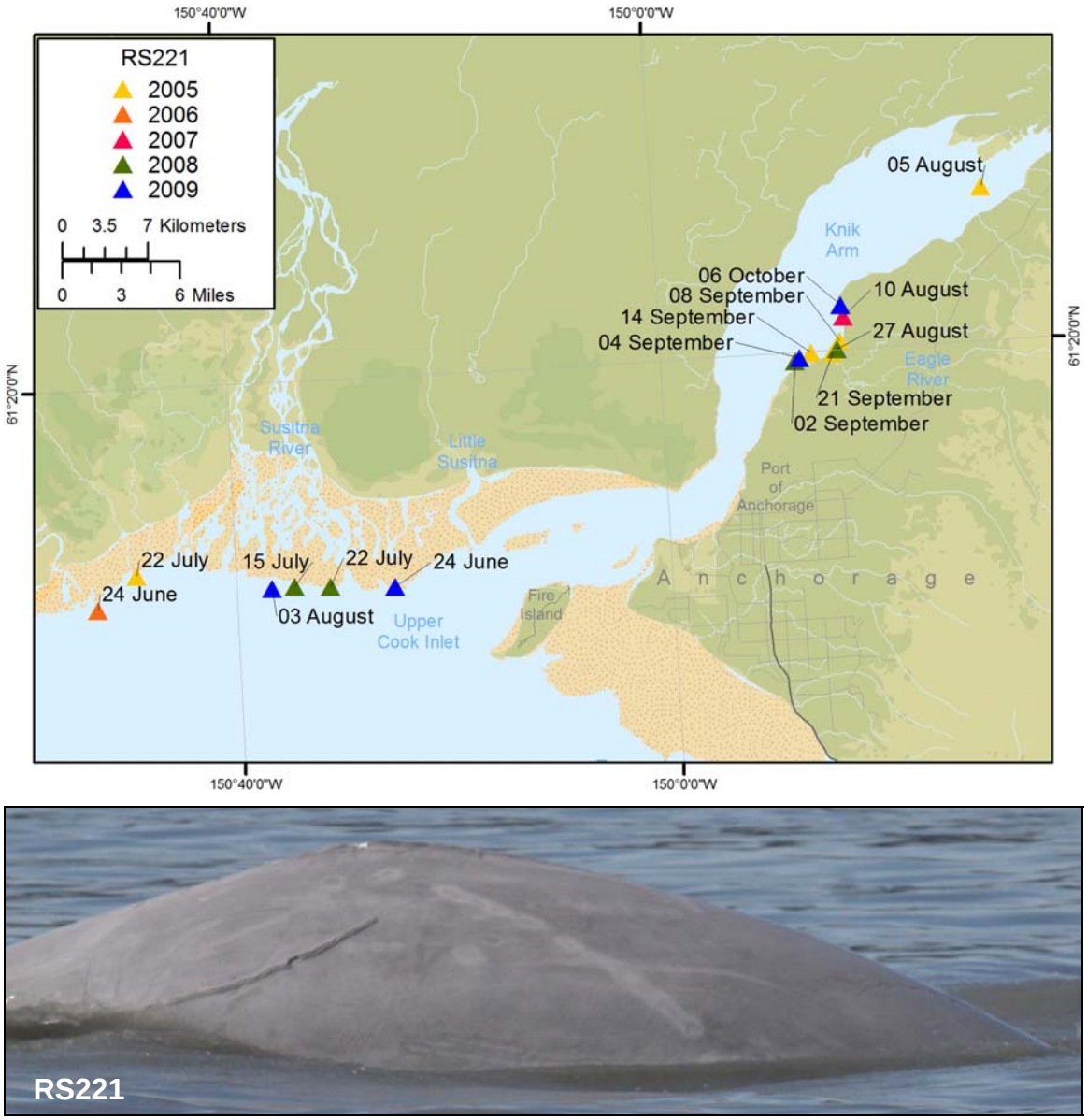

Figure B28. Sighting history and photograph of beluga RS221.

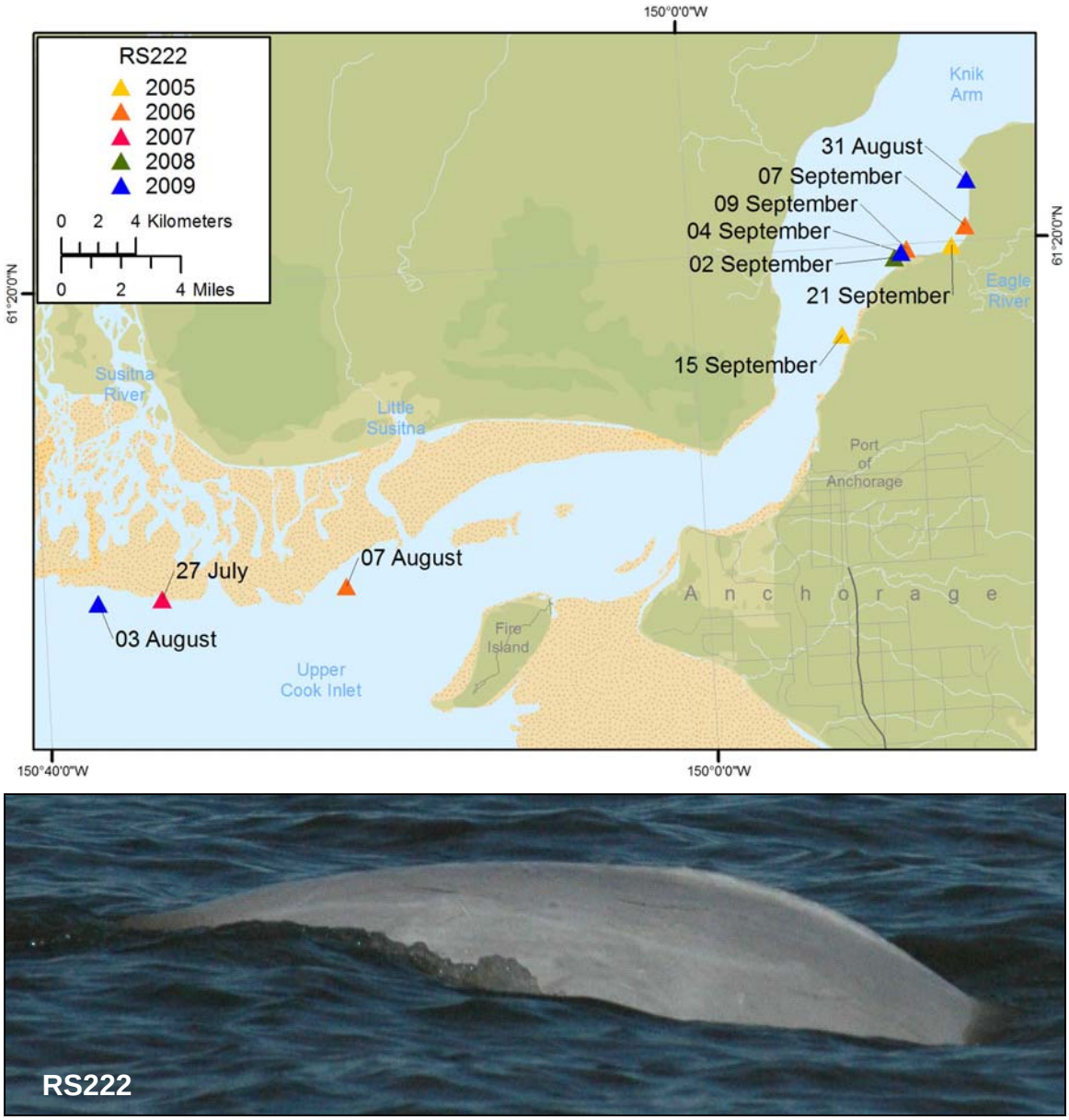

Figure B29. Sighting history and photograph of beluga RS222. This beluga is a presumed mother based on photographs with an accompanying calf.

APPENDIX C

INDIVIDUAL SIGHTING-HISTORY MAPS AND RIGHT SIDE PHOTOGRAPHS OF CATALOGED WHALES IDENTIFIED 2005-2009 BY SCARS FROM SATELLITE TAGS APPLIED BY NMFS BETWEEN 1999 AND 2002.

WHEN APPLICABLE, SIGHTING HISTORIES ALSO INCLUDE LEFT-SIDE PHOTOGRAPHS FROM 2005-2008

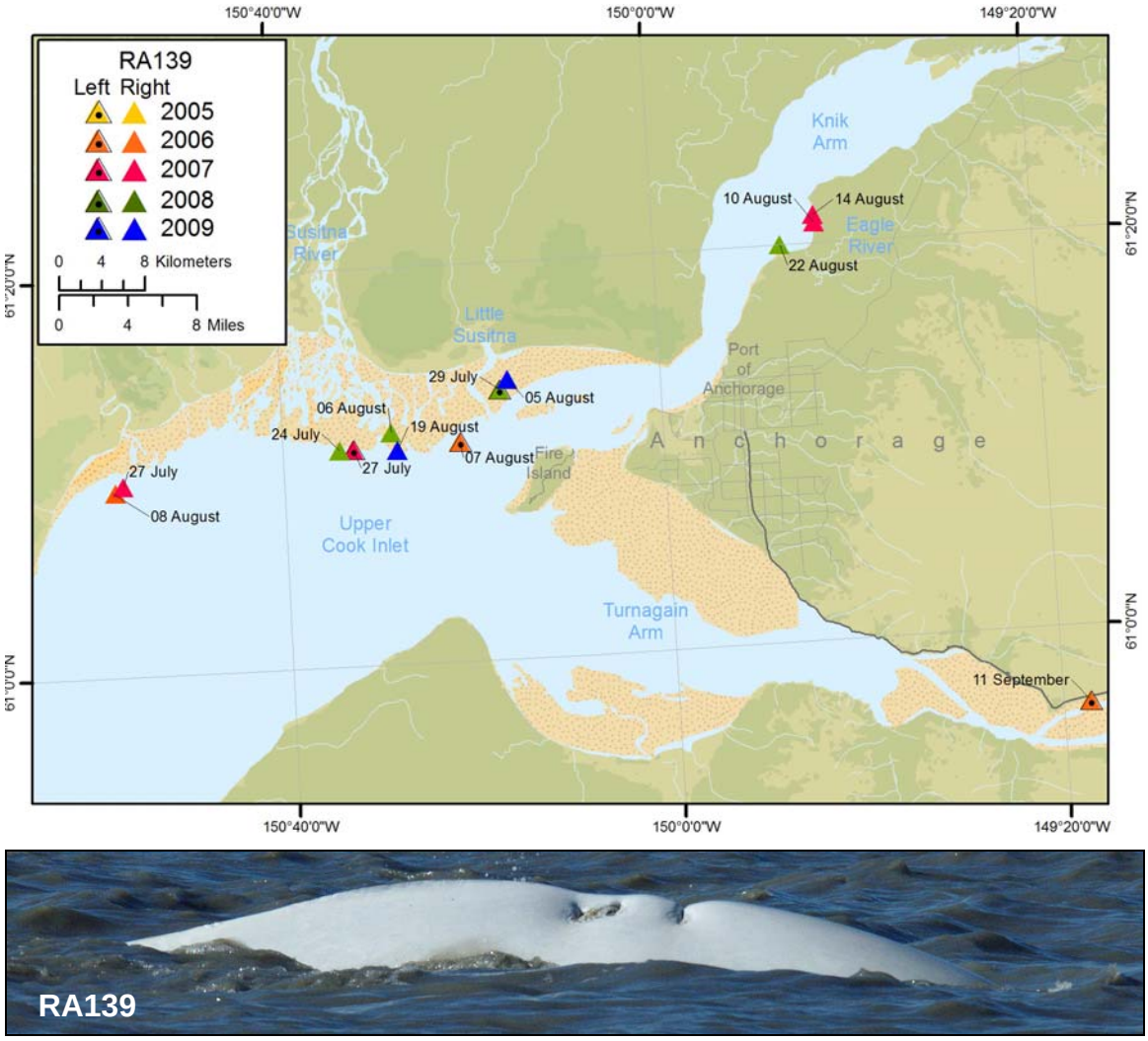

Figure C1. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA139. This beluga was tagged by NMFS sometime between 1999 and 2002.

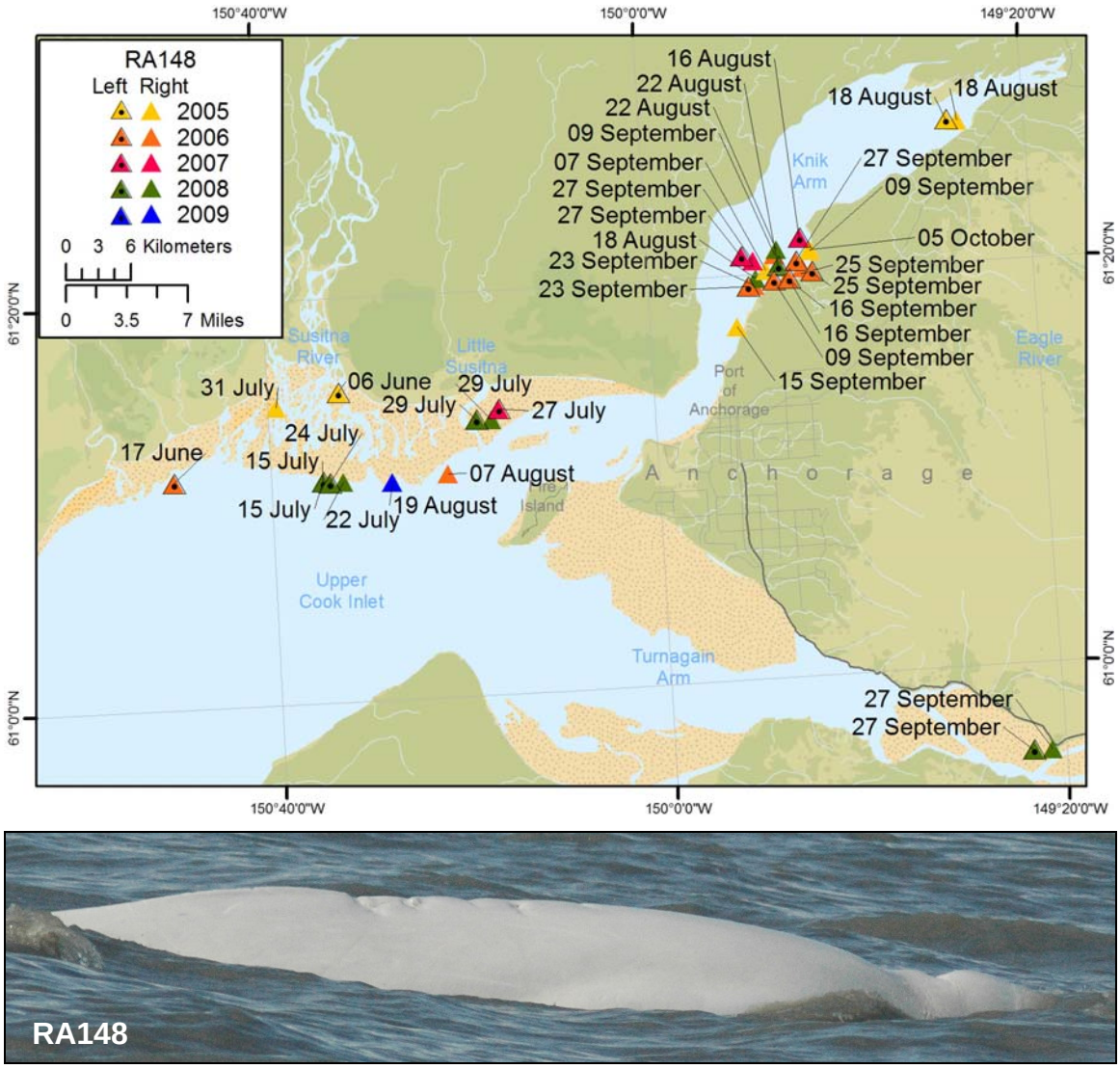

Figure C2. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA148. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

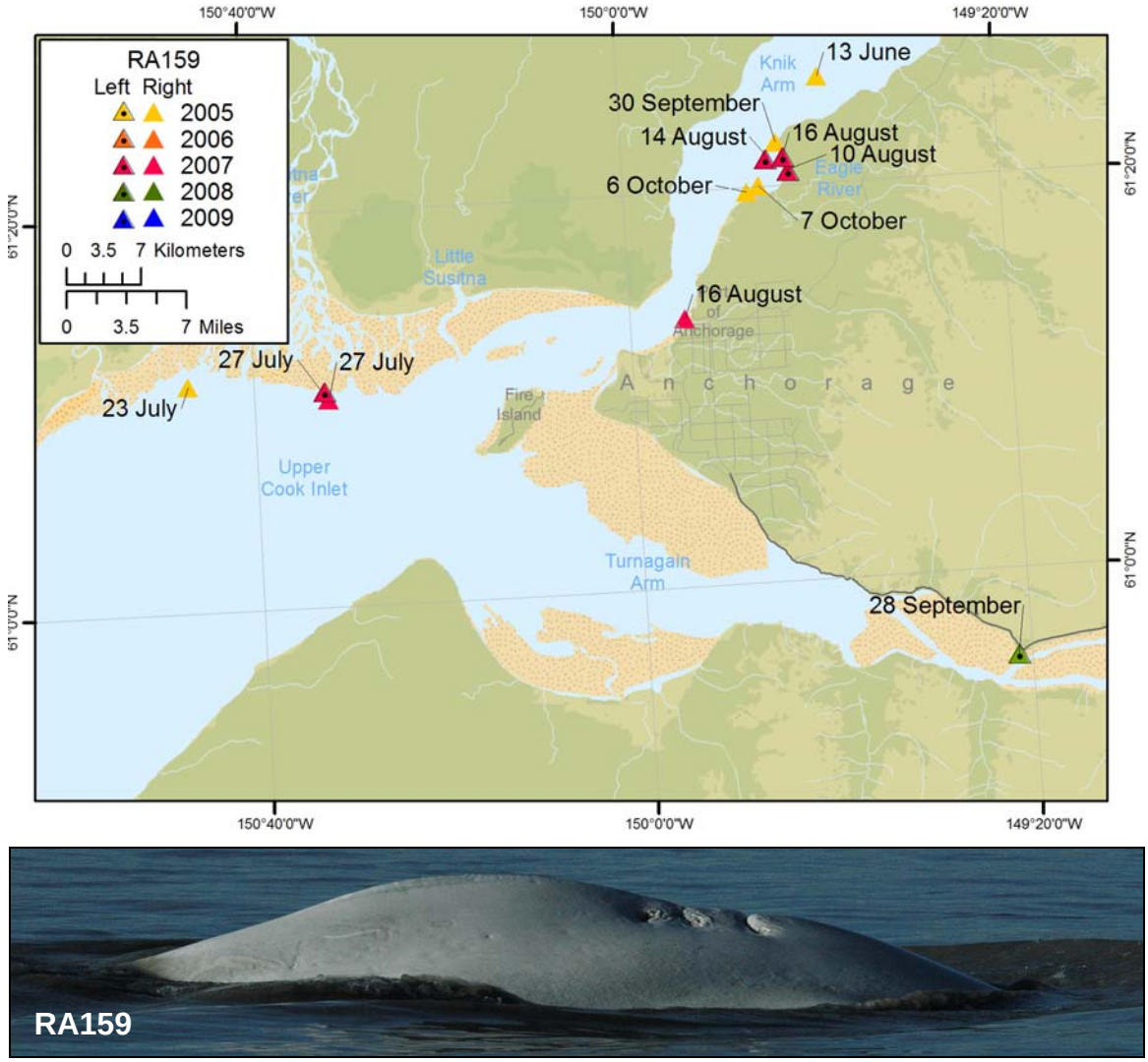

Figure C3. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA159, who was photographed in 2005 and 2007. This beluga was tagged by NMFS sometime between 1999 and 2002.

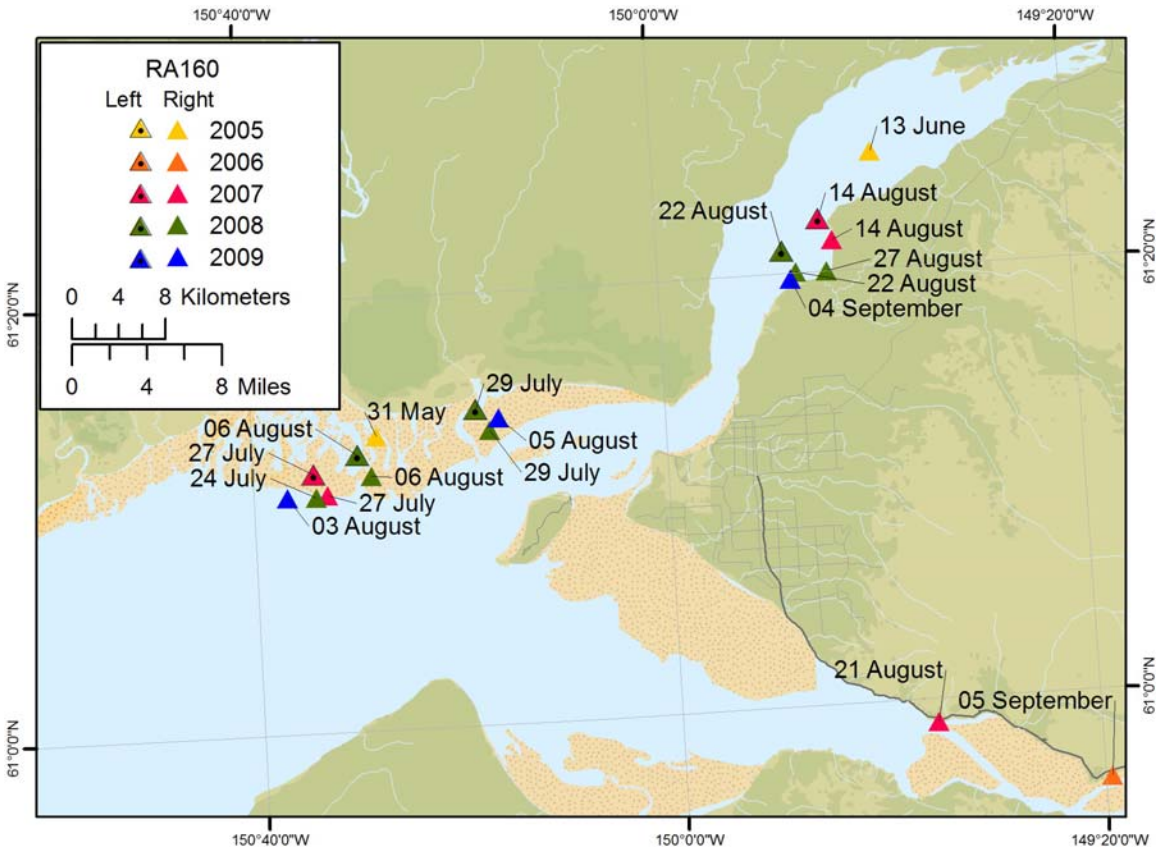

Figure C4. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA160. This beluga was tagged by NMFS sometime between 1999 and 2002. This beluga is a presumed mother based on photographs with an accompanying calf.

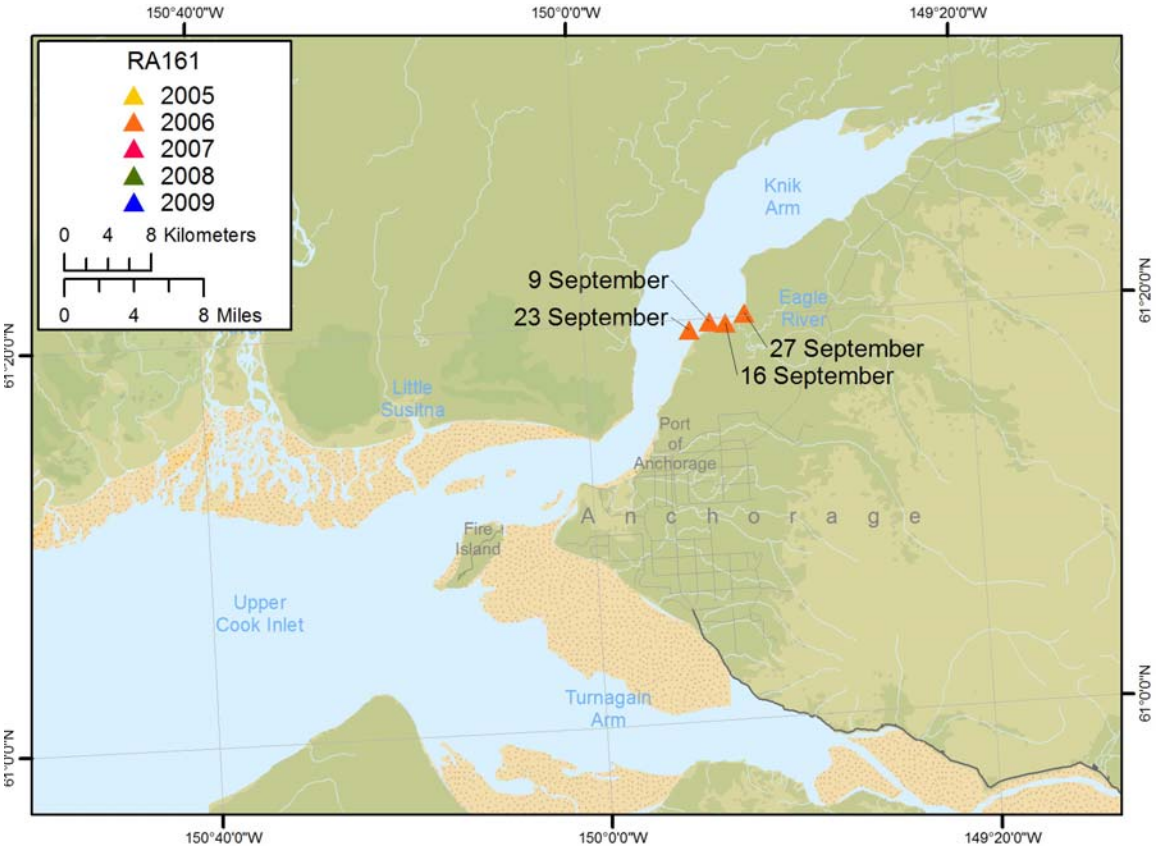

Figure C5. Sighting and photograph of beluga RA161, who was photographed from its right side during 2006. This beluga was tagged by NMFS sometime between 1999 and 2002. This beluga is a presumed mother based on photographs with an accompanying calf.

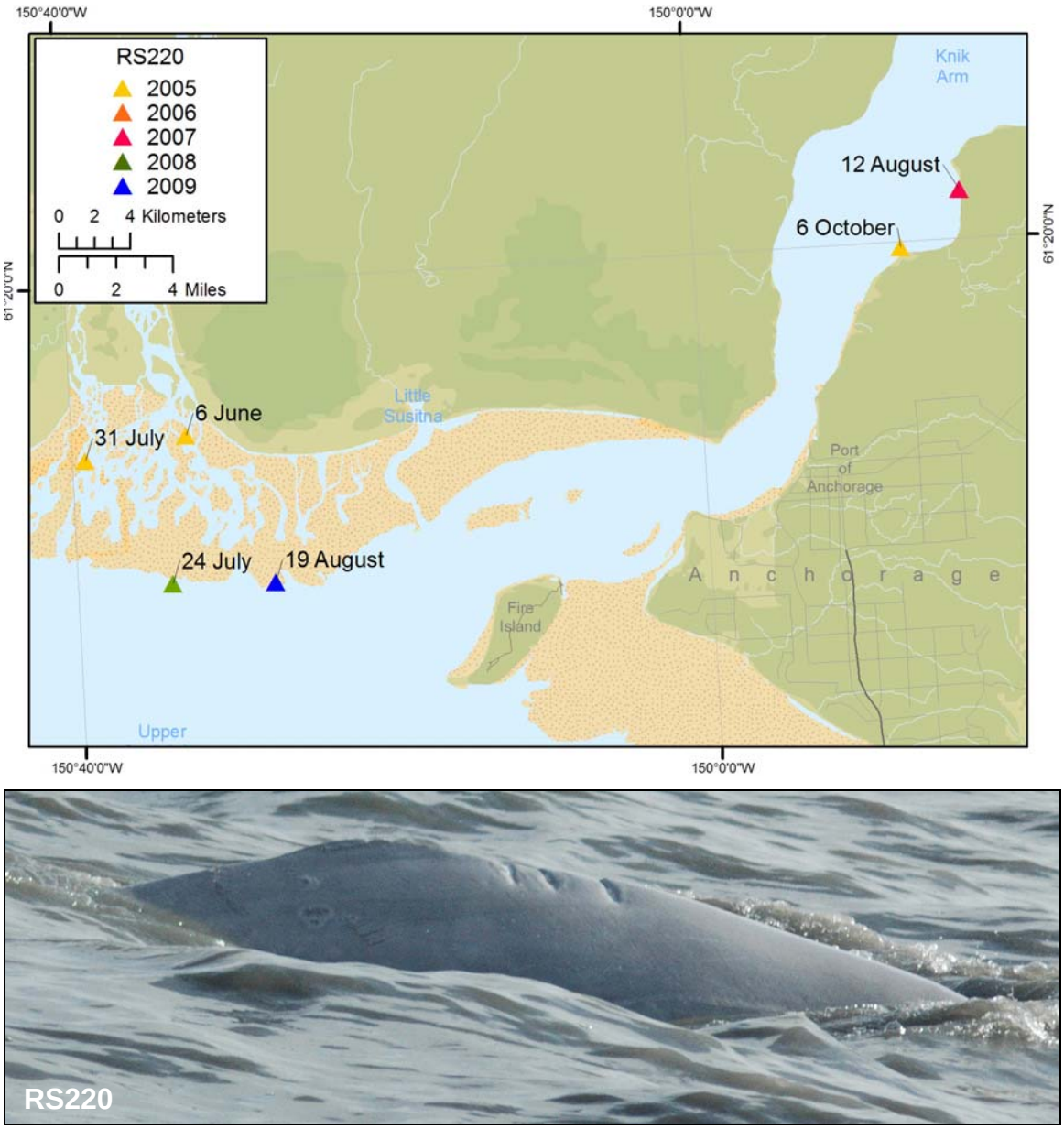

Figure C6. Sighting and photograph of beluga RS220, who's right side was photographed in all years but 2006. This beluga was tagged by NMFS sometime between 1999 and 2002.

APPENDIX D

INDIVIDUAL DUAL-SIDE SIGHTING-HISTORY MAPS AND RIGHT SIDE PHOTOGRAPHS OF WHALES CATALOGED IN 2009 BY THEIR RIGHT SIDE.

SIGHTING HISTORIES INCLUDE RIGHT- AND LEFT-SIDE PHOTOGRAPHS FROM 2005-2008 AND RIGHT-SIDE PHOTOGRAPHS FROM 2005-2009

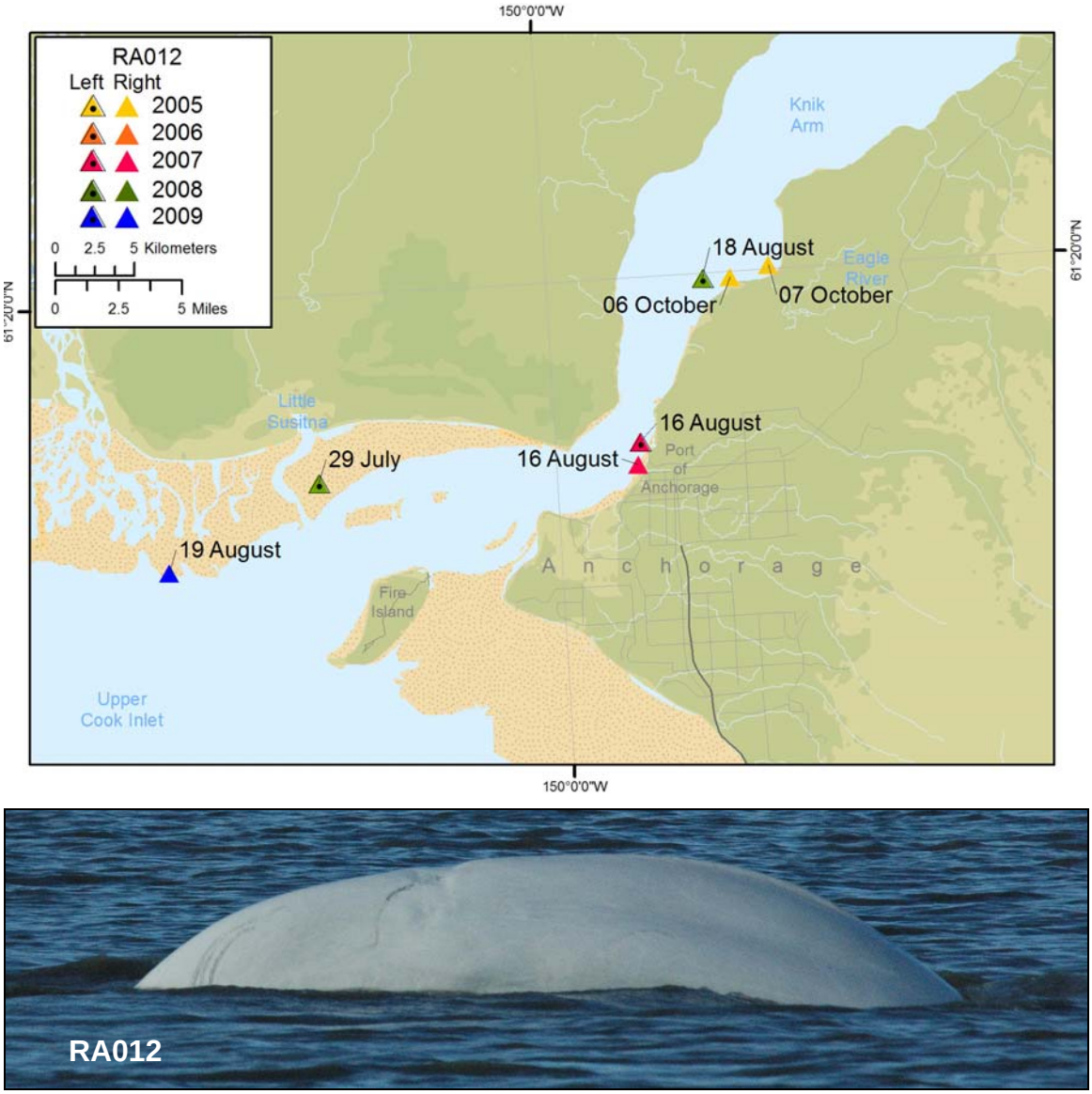

Figure D1. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA012.

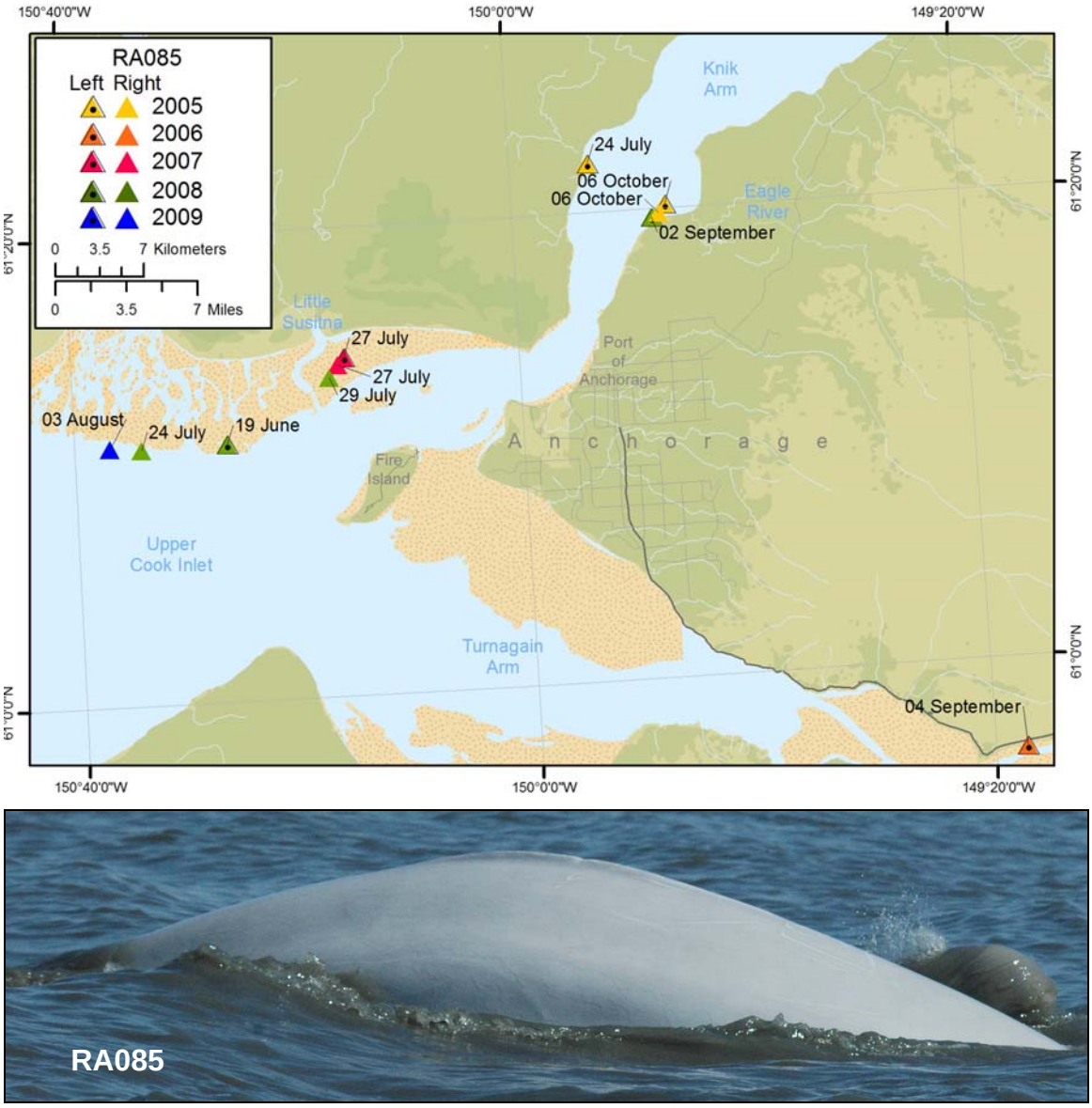

Figure D2. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA085. This beluga is a presumed mother based on photographs with an accompanying calf (as shown in this photograph).

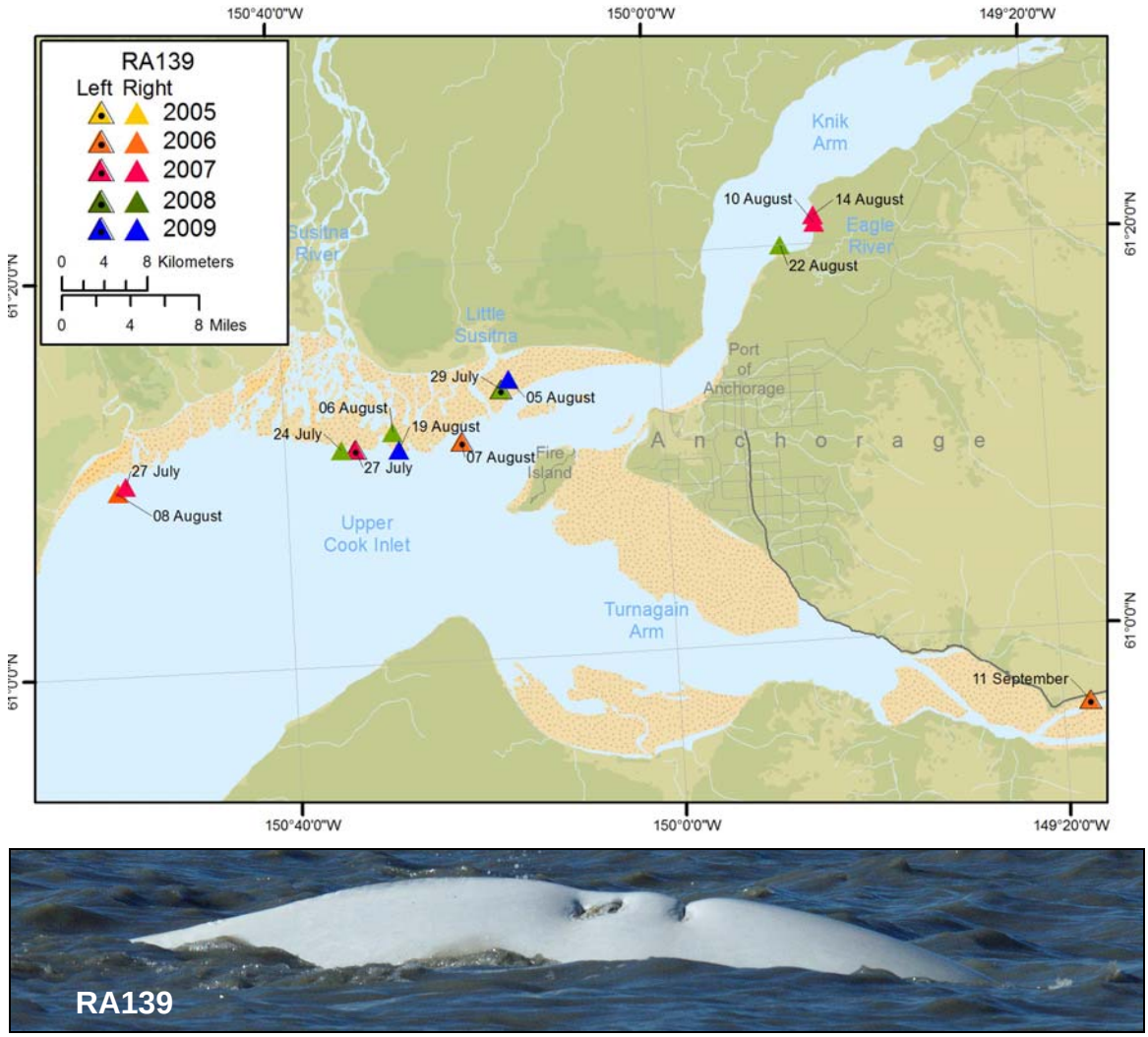

Figure D3. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA139. This beluga was tagged by NMFS sometime between 1999 and 2002.

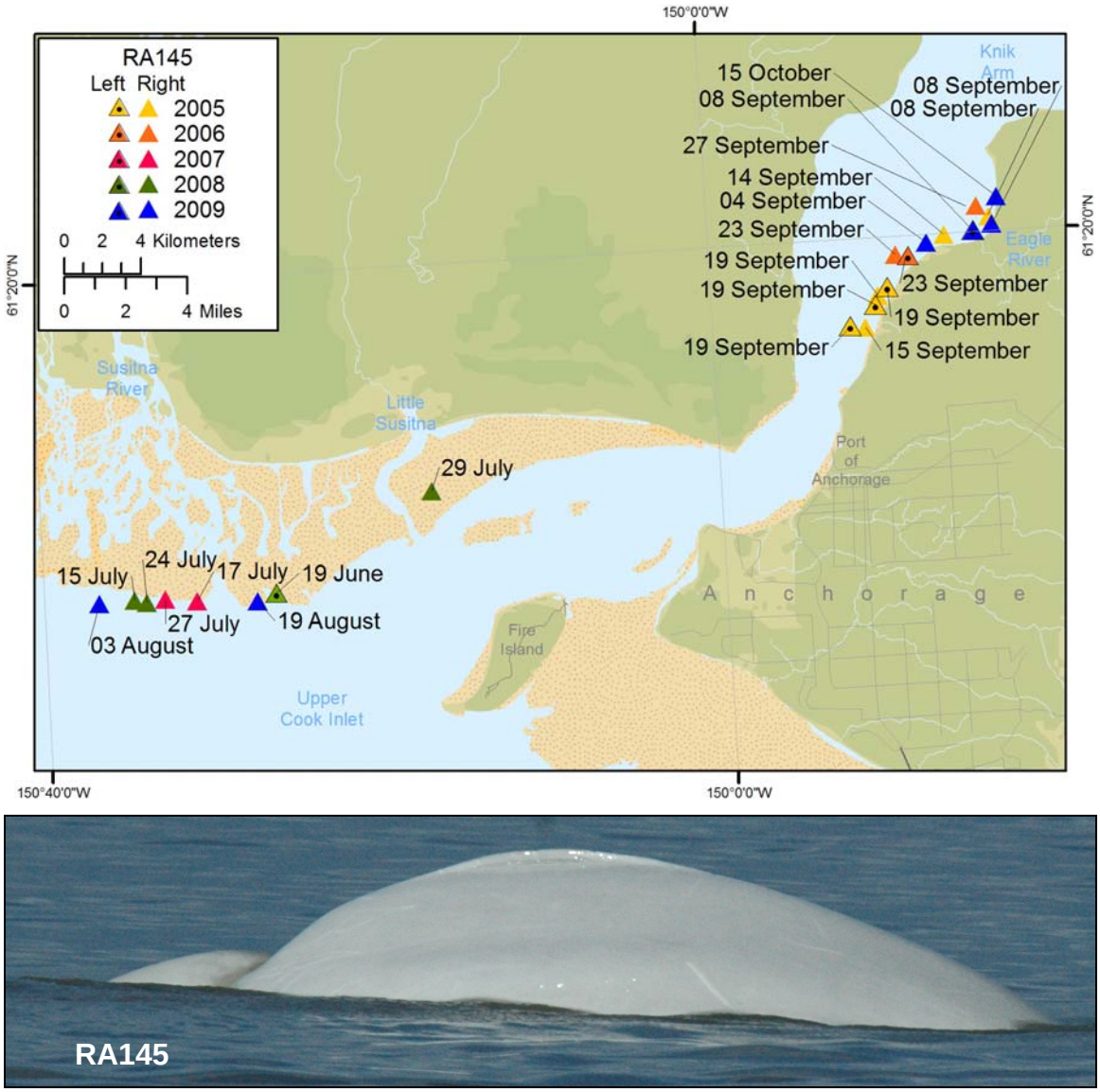

Figure D4. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA145. This beluga is a presumed mother based on photographs with an accompanying calf.

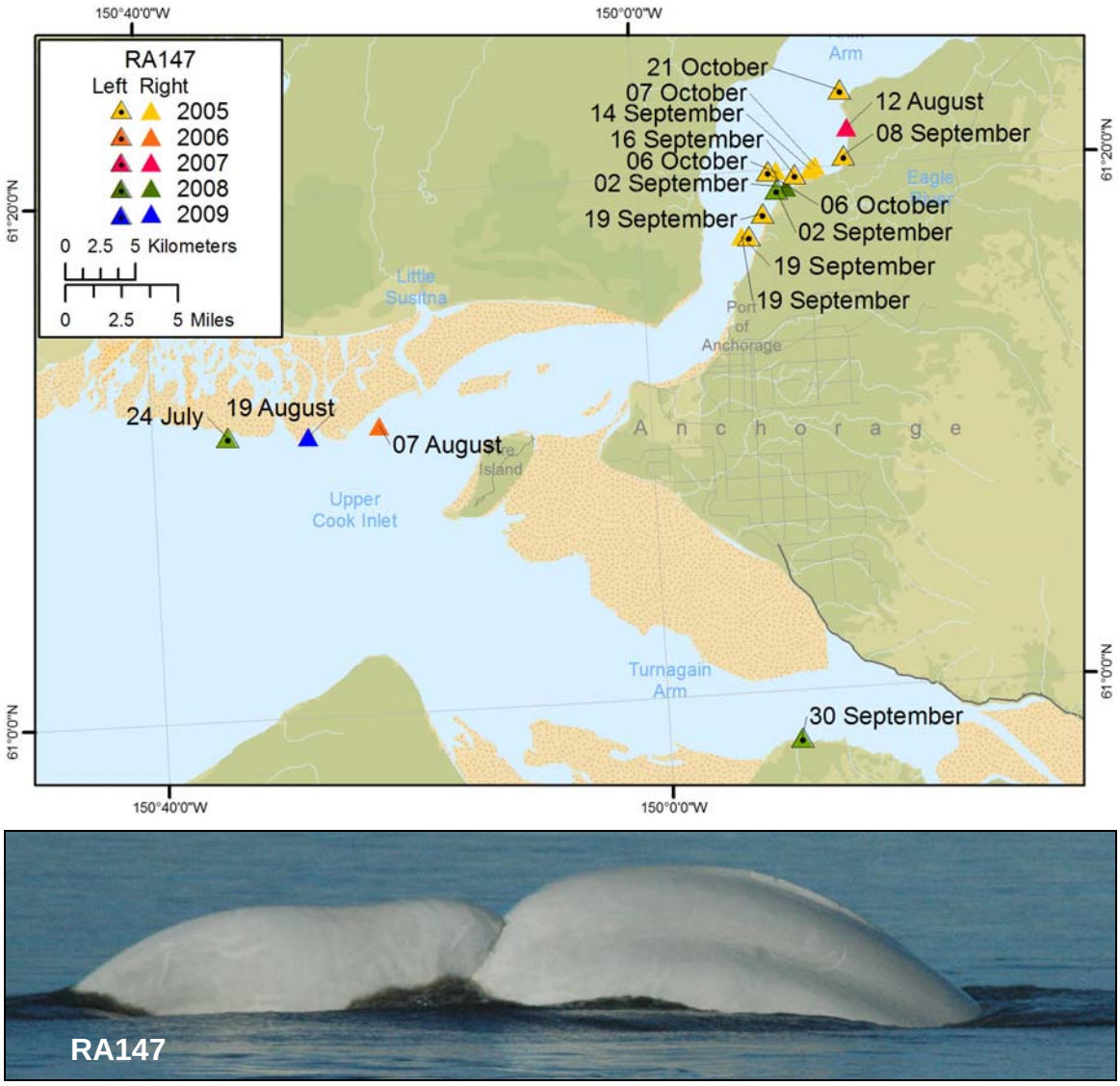

Figure D5. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA147. This beluga is a presumed mother based on photographs with an accompanying calf.

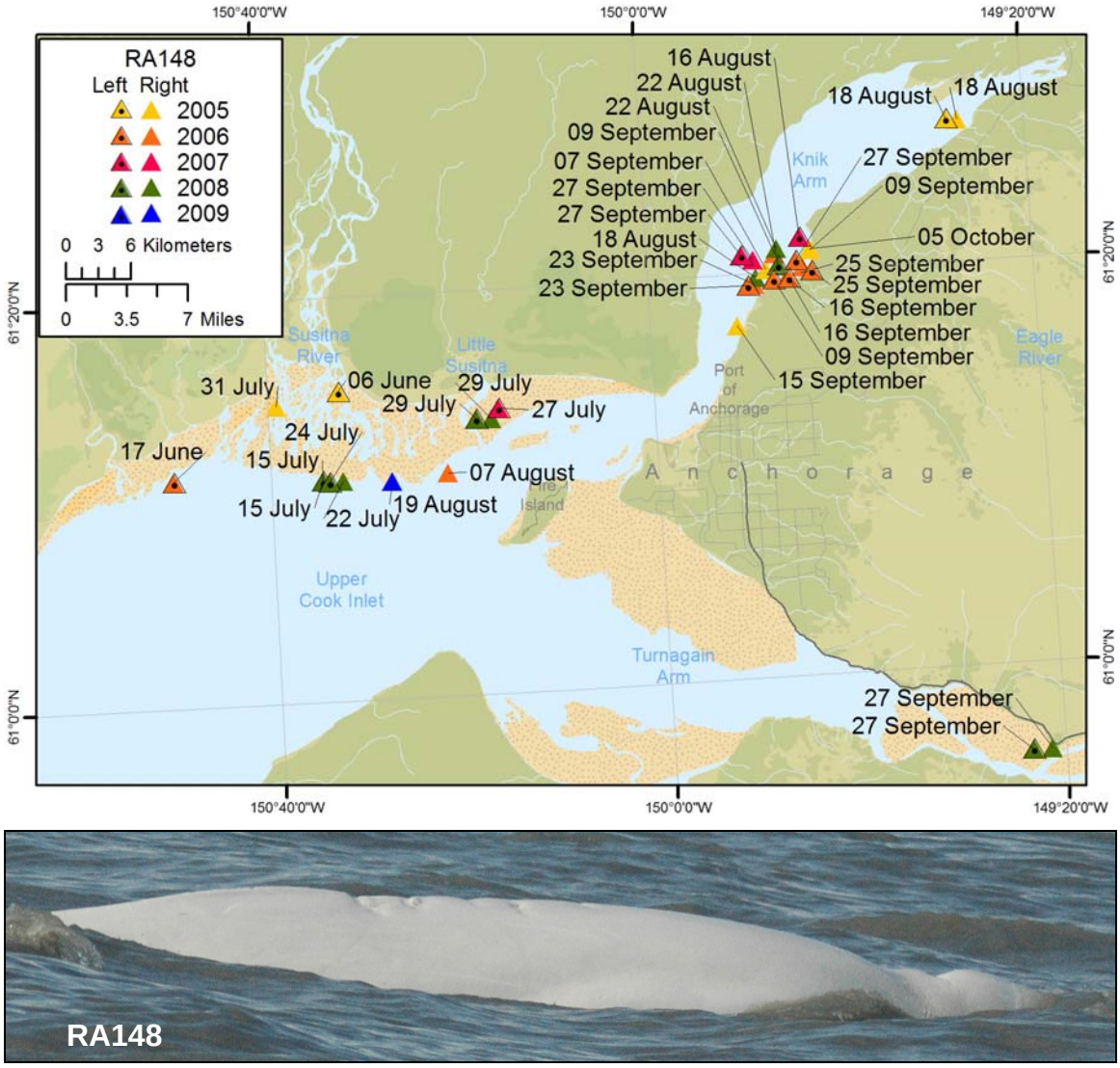

Figure D6. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA148. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

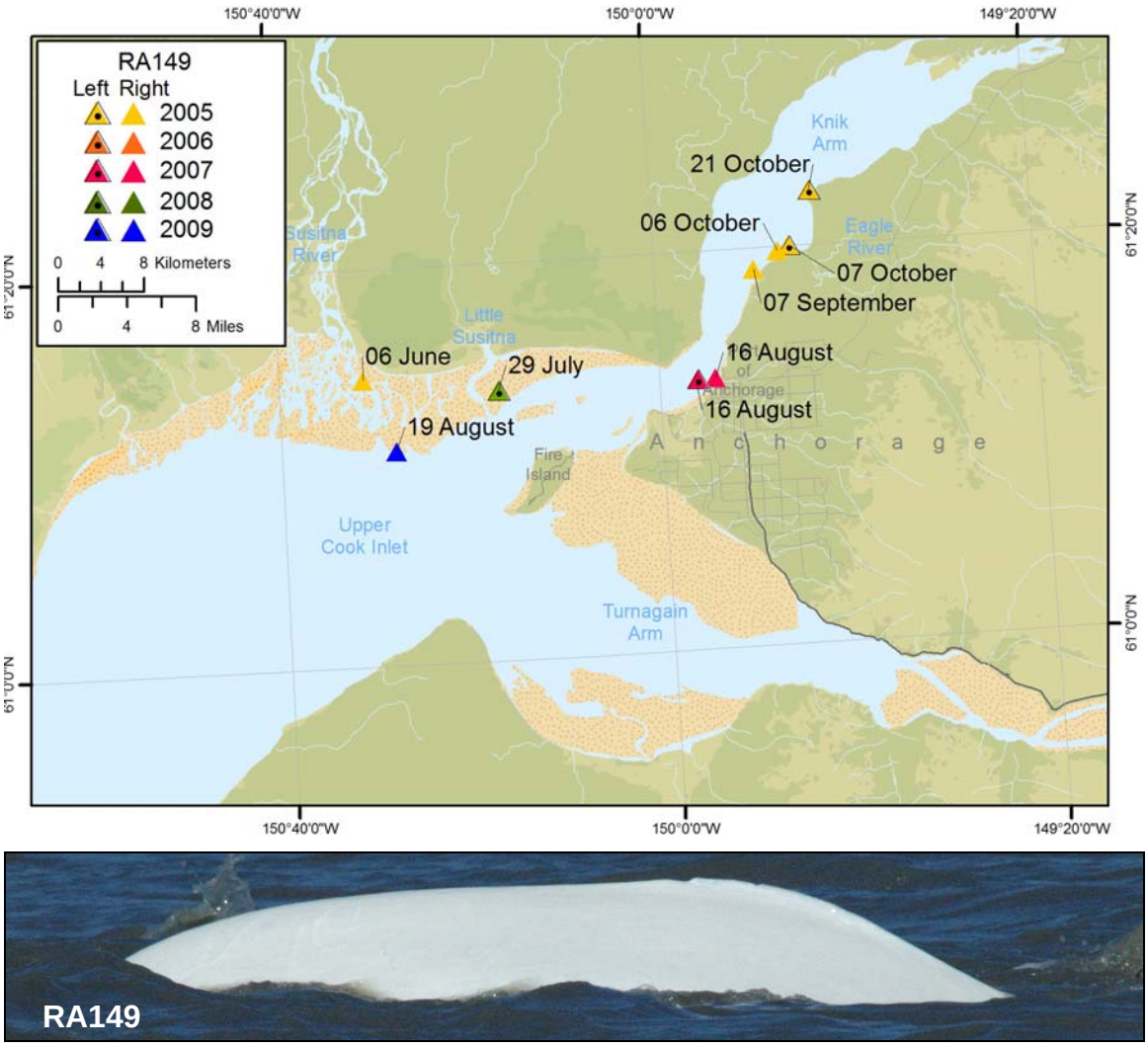

Figure D7. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA149.

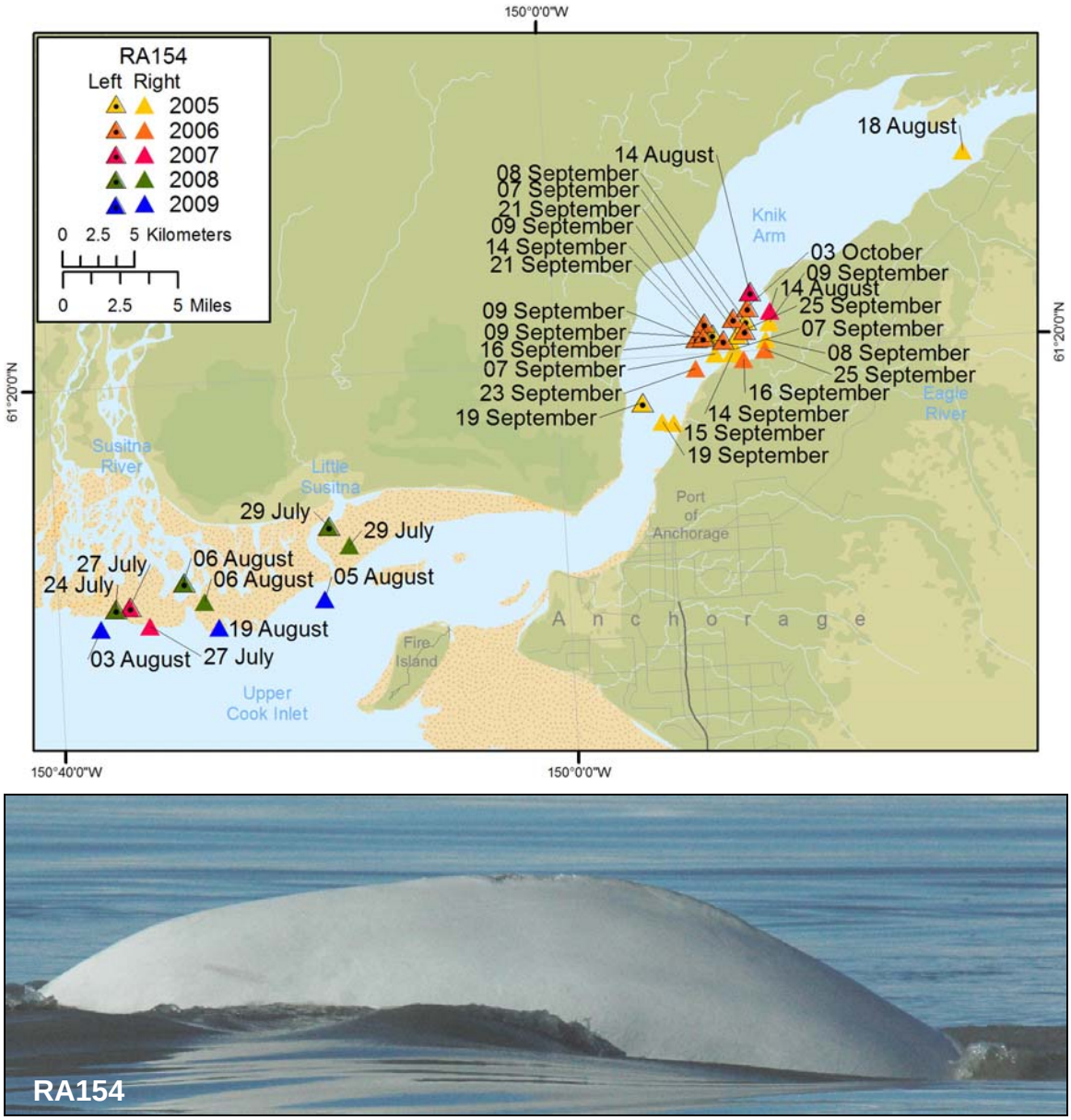

Figure D8. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA154. This beluga is a presumed mother based on photographs with an accompanying calf.

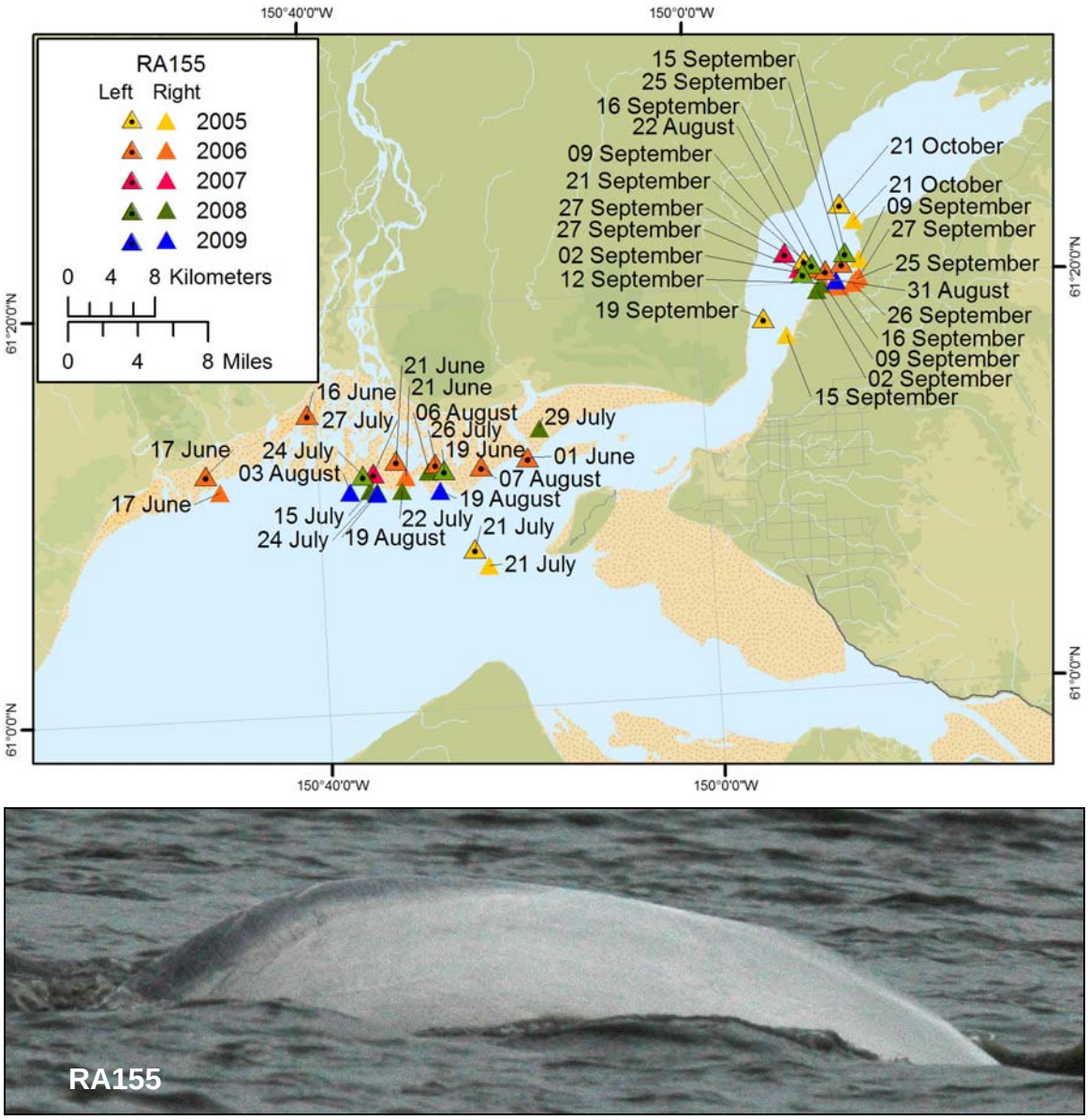

Figure D9. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA155. This beluga is a presumed mother based on photographs with an accompanying calf.

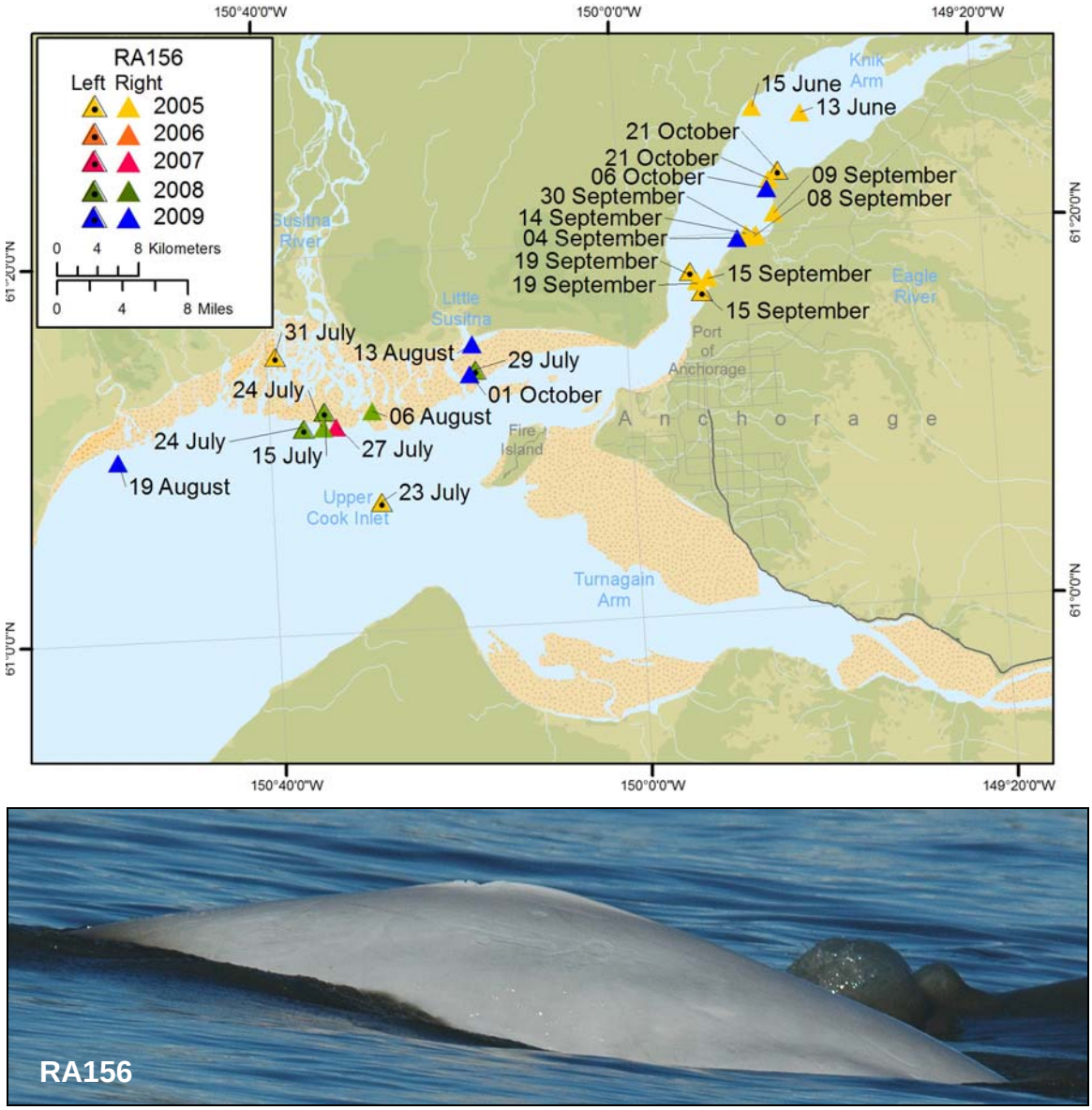

Figure D10. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA156. This beluga is a presumed mother based on photographs with an accompanying calf.

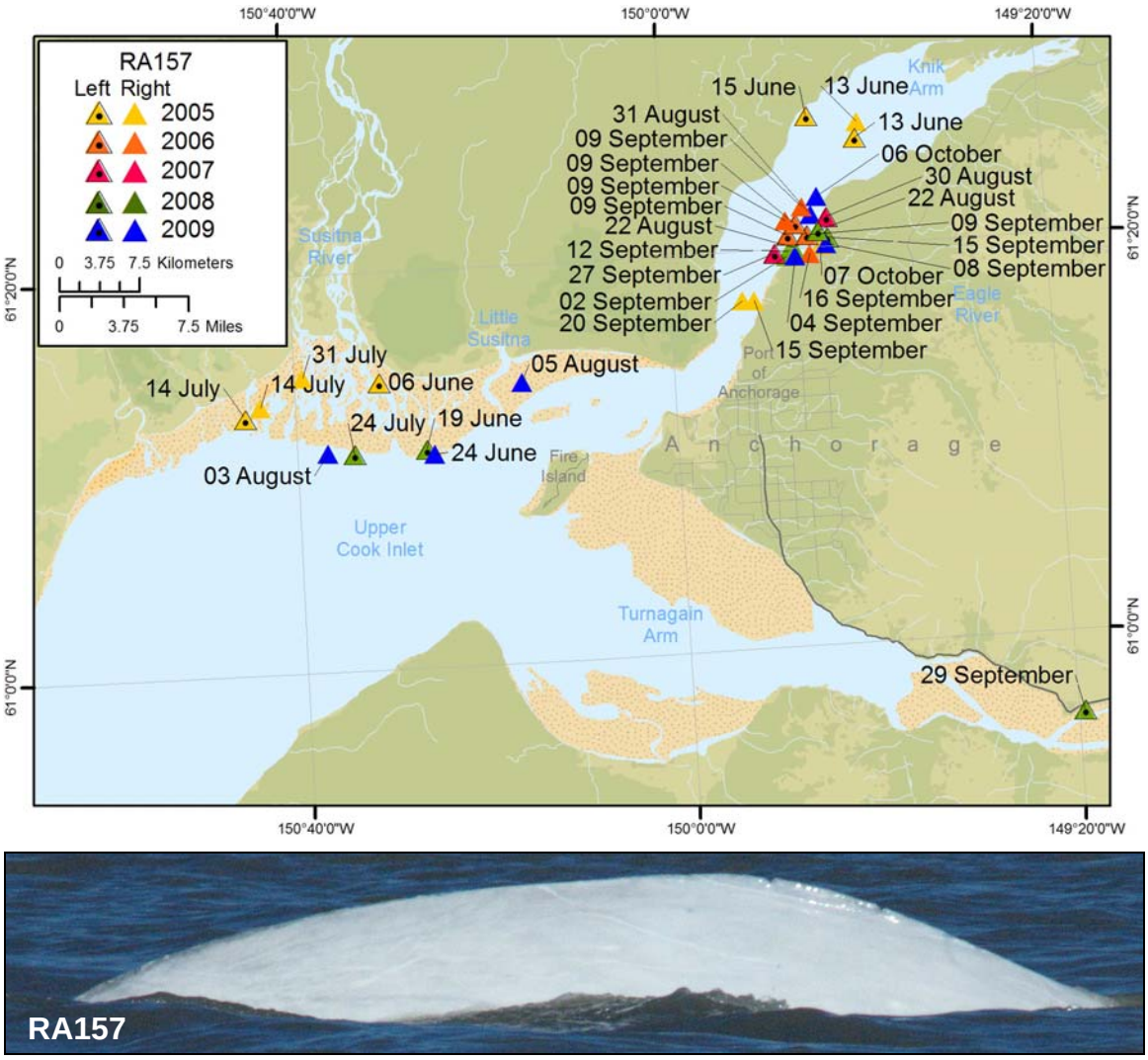

Figure D11. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA157. This beluga is a presumed mother based on photographs with an accompanying calf.

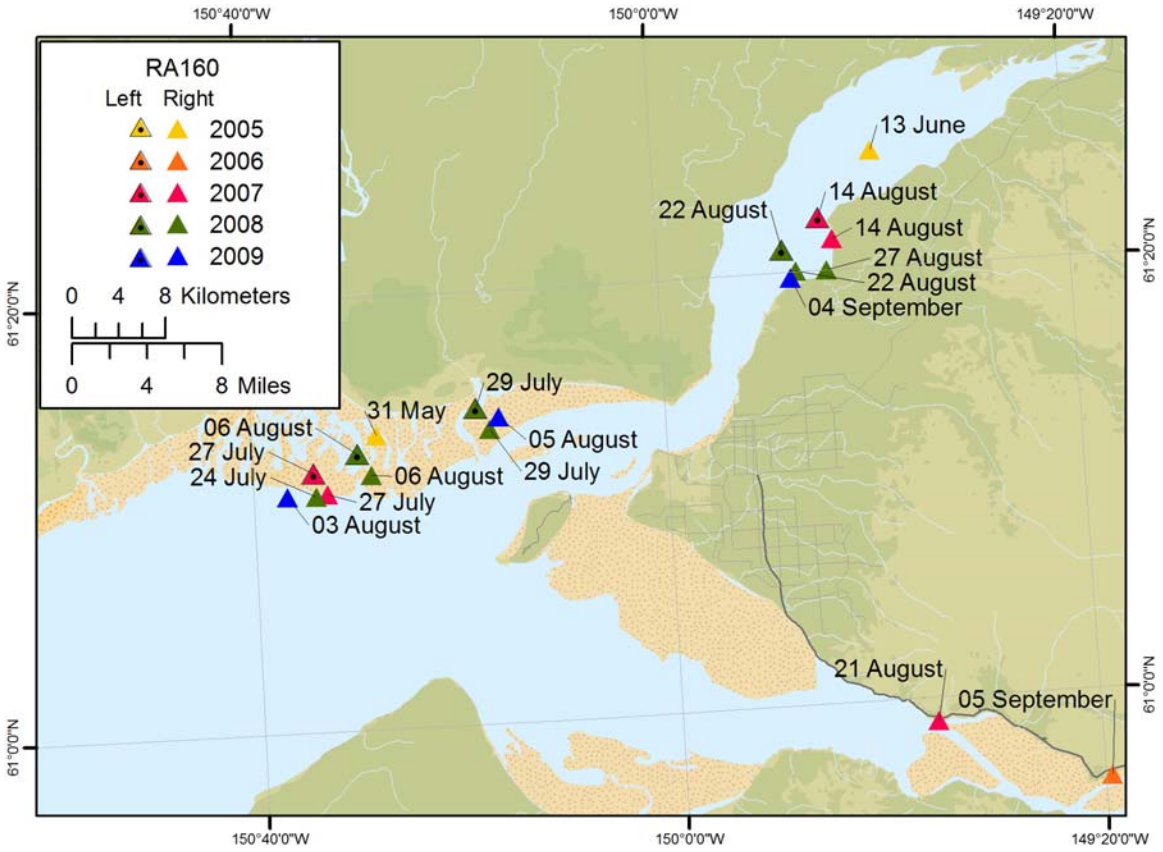

Figure D12. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RA160. This beluga was tagged by NMFS sometime between 1999 and 2002 and is a presumed mother based on photographs with an accompanying calf.

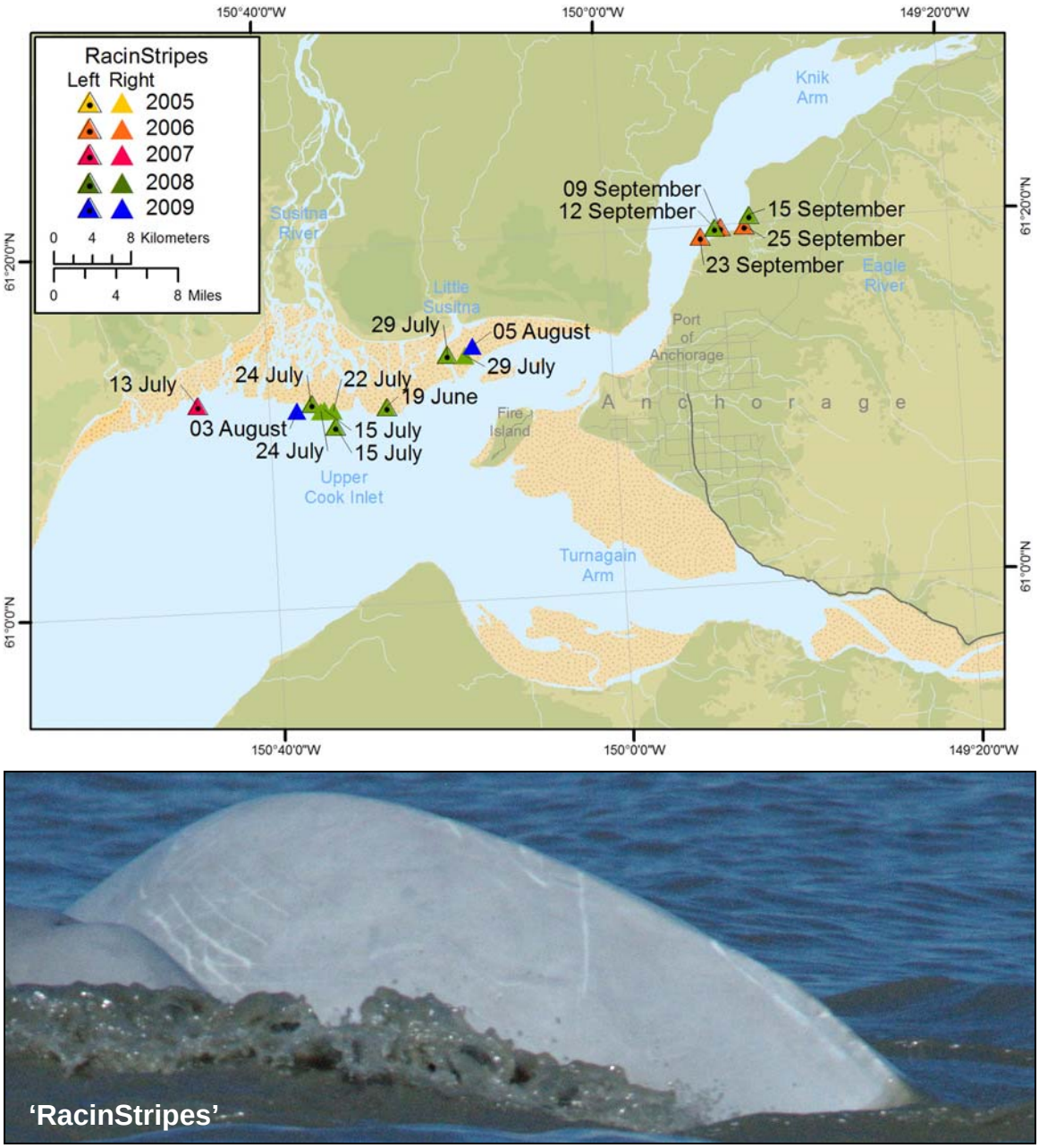

Figure D13. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga 'RacinStripes'. This beluga is a presumed mother based on photographs with an accompanying calf (as shown in this photograph).

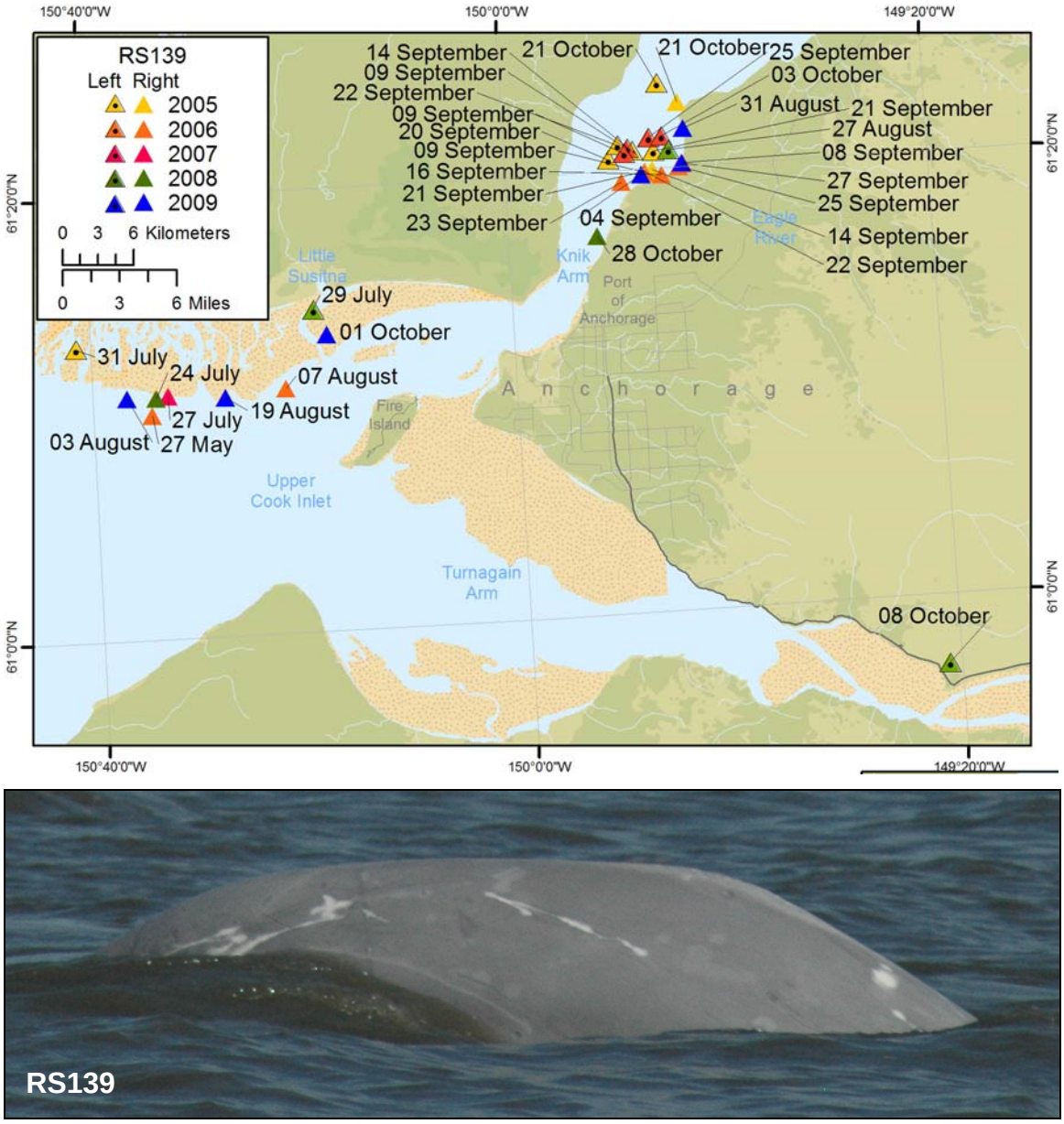

Figure D14. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RS139. This beluga is a presumed mother based on photographs with an accompanying calf.

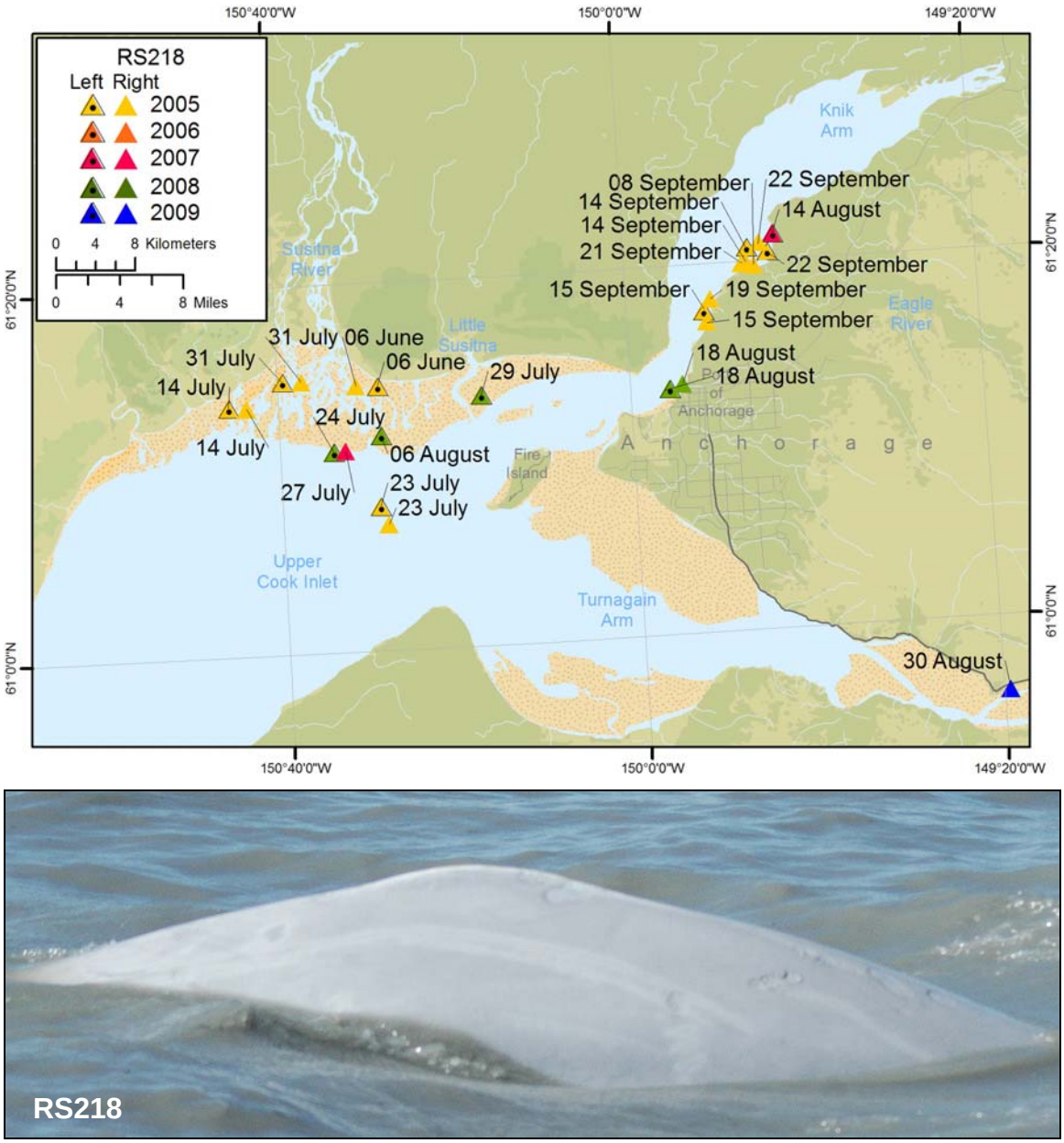

Figure D15. Sighting history (including sightings from both right- and left-side photographs) and photograph of beluga RS218.