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

Final Report of Belugas Re-sighted in 2008

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Prepared for:

National Fish and Wildlife Foundation
Chevron
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EXECUTIVE SUMMARY

Introduction

The Cook Inlet beluga whale (CIBW) photo-identification study has been ongoing since 2005. The objectives of this study are 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 Upper Cook Inlet, including age-class distribution, residency/movement patterns, behavior, and social group structure,
4. develop abundance estimates of CIBWs using mark-recapture models, and
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 addresses progress made in meeting objectives 2, 3, and 5, and is the second in a series of three reports from the 2008 field season. It contains results from analyses of photos of whales encountered and identified in 2008, including sighting rates, distribution, movement patterns, group associations, and reproductive information.

Methods

Dedicated surveys and opportunistic sampling of Upper Cook Inlet, Alaska were conducted from a small vessel and from shore, May through October, 2008. Detailed survey methods are presented in McGuire and Kaplan 2009.

Photographs were sorted according to quality with the use of ACDSee photo software. Photographs of belugas were cropped, sorted, and separated into images of left and right sides of the whales. Left-side images were archived and right-side images were examined to determine whether or not there was a match to photographs in the catalog. Side-profile photographs were divided into sections using the center of the dorsal ridge as the main reference point. The number of sections with high quality images was used to determine the profile completeness. Criteria for accepting new individuals into the catalog were further developed, and were based on completeness of profile sets and matches made within and between field seasons. Mark-type categories were created and locations of all visible marks were assigned to body sections. Specialized matching software was developed to allow for computer-aided filtering of the database according to mark type and location.

Sighting histories (i.e., dates and locations of sightings) of a subset of the catalog, consisting of all sightings of belugas that were photographed in all four years of the study (2005-2008) and of all sightings of whales bearing scars from previous satellite tags, were plotted and presented graphically. The study area was divided into five 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 and calves.

Coefficients of associations (COAs) were calculated for the whales cataloged in all four years of the study (2005-2008). A cluster analyses was performed to determine if distinct clusters or subgroups of belugas occurred within this data set. An estimate of social differentiation was calculated to provide a measure of the variation of association patterns within a population.

Results

As of April 1, 2009, the beluga photo-identification right-side catalog contained 4,866 photographs of belugas found in 128 groups encountered on 140 survey days between 2005 and 2008. The catalog contains 140 individual belugas photographed over two or more field seasons. Of these 140 whales, 30 were photographed and matched over all four field seasons. An additional 119 belugas were seen in only one field season. The current catalog has a total of 150 folders of individual belugas with complete profile sets of high quality photographs of their right sides. The catalog also contains 109 folders of belugas with incomplete profile sets.

Forty-six beluga whale groups were photographed during 29 survey days in 2008. From these 46 groups, 105 belugas were identified as belugas in the 2005-2007 catalog and an additional 28 folders were created of potentially new individual belugas. Survey effort was greater in 2008 than in 2007 and more belugas were identified in 2008 than in 2007. The highest encounter rate for an identified beluga in 2008 was for one whale seen on seven different survey days that year. For all surveys conducted throughout Upper Cook Inlet in 2008, on average 20% of each group was cataloged. Of the 30 individually identified belugas sighted in each of the four years of the study, none were observed exclusively in one survey area. Each of the 30 belugas was photographed in both Knik Arm and the Susitna River Delta.

Thirty-nine identified belugas were photographed with calves in 2008. Eighty-four identified belugas were presumed to be reproductive adult females based on photographs taken from 2005 to 2008 in which they were closely accompanied by calves. Ten 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). Three identified belugas were each first seen with a larger calf, then one, two, or three years later, were seen with a much smaller calf (which was assumed to be a new calf). Calves and neonates were seen in all areas of Upper Cook Inlet where beluga groups were encountered during photo-identification surveys in 2008, although groups with neonates were seen more often (after standardizing for unequal survey effort) in Knik Arm than in other areas.

Seven photo-identified belugas have unique scars from holes used by NMFS to affix satellite tags in the past. Five of these belugas were sighted in 2008. Four previously tagged belugas were photographed with calves, and one of these was photographed with a calf in more than one year.

The maximum COA per beluga ranged from 0.19 to 0.67. There was no evidence that this population was divided into clusters or subgroups. The estimate of social differentiation indicated a homogenous society. None of the belugas cataloged in all four years of the study were found in groups that were comprised of solely white or gray animals, and all of these belugas were found in groups that contained calves.

Categories of markings that were identified and assigned to photographs included those presumed to be caused by disease, predation, molting, and conspecifics, as well as those thought to be caused by anthropogenic sources such as satellite tags, ship strikes, entanglement, and bullets. Quantitative analyses of the different mark types will be presented in the third report.

Discussion

Whales identified in all four years of the study did not display fidelity to any single area of Upper Cook Inlet. Individual sighting histories indicated that all of these whales moved between different areas of Upper Cook Inlet. All of these whales were photographed in Knik Arm and the Susitna River Delta, and some were also photographed in Turnagain Arm and Chickaloon Bay/Southeast Fire Island. This same pattern of frequent occurrence in the Susitna River Delta and in Knik Arm, with less-frequent occurrence in Turnagain Arm, held true for the six of the seven whales identified by scars from satellite tags. 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 CIBWs based on sighting histories of individually identified whales, it is important to consider the results within the context of survey effort.

Of the 84 belugas assumed to be mothers, 10 were photographed with calves maturing over two or more field seasons, and one identified mother was photographed with a maturing calf during three field seasons. Additional years of photo-identification effort are needed to determine how long calves remain with their mothers and when these 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. Three 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. Three calves have been identified by their own marks rather than those of their mothers, which allows these calves to be tracked independently of their mothers. The mothers of these calves have not yet been identified. 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. It is unknown if groups of CIBWs are sexually segregated for all or even part of the year. 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.

Sighting histories for seven belugas known to have been tagged between 1999 and 2002 indicated that these individuals survived capture and tagging. In addition, four of these belugas have been identified as mothers with calves, indicating they reproduced post-tagging.

Several photographs of belugas contained marks indicative of disease and injury. 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.

Fieldwork from 2008 was completed October 28, and survey results were presented in McGuire and Kaplan (2009). Cataloging of photographs from 2008 was completed April 1, 2009, and results are presented in the current report. A third report will be issued in the fall of 2009, presenting results of a population estimate derived from information about individuals photographed in 2008, as well as results of analyses of mark types and mark location. This report will also present the results of whale color analyses, with data from gray cards photographed in the field and the development of a numerical scale to quantify gradations of gray based on pixel coloration. The three reports will be compiled into a single comprehensive report to be issued in December 2009. Additional plans for 2009 include an increase in the scope of photo-identification survey effort with a more-even distribution of survey effort throughout different locations.

Conclusion

Photo-identification surveys from the existing four years of uninterrupted effort 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 can help to identify appropriate conservation measures to preserve the population.

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INTRODUCTION

Alaska's Cook Inlet beluga whale (CIBW) population (*Delphinapterus leucas*) is considered a distinct population segment (DPS) by the National Marine Fisheries Service (NMFS) and was listed by NMFS as endangered in October 2008 (NMFS 2008a). As a result of the Endangered Species Act listing, NMFS is required to designate critical habitat for CIBWs. This designation identifies valuable habitat deemed necessary for the survival and recovery of the population. Currently available sources of information that will be used to identify and characterize critical habitat include the distribution of CIBWs 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, b, Shelden et al. 2008). This information will play a key role in characterizing habitat needs, as will 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. 2008a) can be used to characterize distribution and movement patterns of individual beluga whales, which can augment critical habitat information from aerial surveys and tagging-tracking studies.

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 (McGuire et al. 2008a, McGuire and Kaplan 2009). The photo-identification catalog and associated surveys from four field seasons (2005-2008) have provided information about the distribution and movement patterns 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 Upper 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 addresses progress made in meeting objectives 2, 3, and 5, and is the second in a series of three reports from the 2008 field season. It contains results from analyses of photos of whales encountered and identified in 2008, including sighting rates, distribution, movement patterns, group associations, and reproductive information. The first report (McGuire and Kaplan 2009) provided a summary of field effort and survey results from 2008, as well as descriptions of additions to photo-identification field methods implemented in 2008. A third report, to be issued in the fall of 2009, will address objective 4, and will present results of a population estimate derived from information about individuals photographed in 2008. The three reports will be compiled into a single comprehensive report to be issued December 2009.

METHODS

Field Surveys

Survey effort and field data

Dedicated surveys and opportunistic sampling of Upper Cook Inlet, Alaska (Figures 1 and 2) were conducted from a small vessel and from shore, May through October, 2008. Detailed survey methods are presented in McGuire and Kaplan 2009. All vessel surveys were conducted under NMFS General Authorization # LOC 481-1795-01.

Standardized data forms were used to record beluga whale sightings. For each beluga whale group sighting, observers recorded: time of day, group size, GPS position of the vessel, magnetic compass bearing to the group, and estimated distance of the vessel from the group (distance at first detection, and minimum distance to individual whales). For groups with multiple sighting 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.

Body color and relative size of individual whales in the group were classified as “white”, “gray”, and “calf”. Calves were usually dark gray, relatively small (i.e., <2/3 the total length of adult belugas), and generally seen 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.

Digital photographs of beluga whales were collected using a Nikon D70, 6.1 megapixel digital SLR camera, with Nikkor 80-400 mm image stabilized zoom telephoto auto focus lens. Typical settings included shutter speed priority, dynamic auto-focus, 800 ISO, and shutter speed of 1,000 or greater. Images were underexposed (setting at -1 or lower exposure bias value) to increase contrast and show otherwise faint marks in images of white animals (Robert Michaud, personal communication). A standard photographic white/gray balance card (18% gray) was photographed at least once per survey, and often several times throughout a 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. Photographs were taken in RAW (not compressed) format and stored on compact flash memory cards.

Processing and Cataloging of Photographs

All RAW format photographs taken on surveys 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. Images 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 to 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 placement in the catalog.

Photographs of belugas in a group were cropped to include a single whale, and were separated into images of left and right sides of the whales. When original field images contained two or more whales, each whale was cropped individually and given a separate file name. 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 photos 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 photograph records of individual belugas identified within that year or in previous years. If a match was made to a previous year, the new photos were entered into the catalog. If no match was made, the new photos were put into a newly created "potential whale" folder (potential whales are discussed in more detail below).

Cataloging of Photographs

As a beluga surfaced and submerged, different portions of its body were available to photograph. Side-profile photographs were most useful for matching marks used to identify individual whales. Profile images were divided into 11 sections along the right half of the whale from behind the blowhole to the base of the tail using the center of the dorsal ridge as the main reference point (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. The number of sections with high quality images was used to determine the profile completeness. 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.

Criteria for accepting new individuals into the catalog were further developed (Figure 4). If there were folders with complete profile sets from the most recent season that could not be matched to individuals in the existing catalog, they were considered "potential individuals" until after the following field season. Potential individuals were added to the catalog only after a second reviewer was unable match them to the existing catalog after the following season. This is done because some whales in the catalog lack full profile sets but were positively matched among years. Another criterion allows for the entrance of a whale into the catalog if two temporary whale folders that spanned two or more years were matched.

Ninety-six mark-type categories were created in order to further understand typical mark types and to facilitate cataloging. Mark location of all visible marks was assigned to a section of the whale (Figure 3). This was done for each individual within the catalog. Specialized matching software specific to this species was developed to allow for computer-aided filtering of the database according to mark type and location, resulting in candidate lists of whale folders that matched the search criteria (Appendix A).

Sighting Histories

Sighting histories (i.e., dates and locations of sightings) were compiled for all cataloged belugas in order to examine movement patterns. Sighting histories of a subset of the catalog, consisting of all sightings of belugas that were photographed in all four years of the study (2005-2008) and of all sightings of whales bearing scars from previous satellite tags, were plotted and presented graphically. Positions of cataloged beluga whale sightings were mapped in ArcGIS ™ Version 9.1 (http://www.esri.com). The study area was divided into five 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 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. 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. Neonates were distinguished in photographs by visible fetal folds.

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 are calculated for pairs of individuals, where a COA=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 four years of the study (2005-2008). This subset of the catalog was selected because each whale had been resighted yearly for the duration of the study, thus eliminating the possibility that sightings had been missed due to mark loss. 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 SOCPROG2.3 for MATLAB7.4 (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 was displayed in a sociogram, in which points represent the four-year subset of cataloged belugas and the thickness of the lines connecting the points represents the COA between the two individuals (Whitehead 2008). A cluster analyses was performed to determine if distinct clusters or subgroups of belugas occurred within the population (in this case the "population" is defined as the subset of belugas sighted in all four years of the study). 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 calves of indentified mothers could not be identified independently, COAs for mother-calf pairs were not calculated.

Additional Information Provided by the Study

Causes of markings

Many photographs of belugas contained marks indicative of disease and injury (McGuire et al. 2009). Using the catalog interface tools (Appendix A) the different markings for each cataloged whale were labeled according to the body segment in which they occurred (Figure 3). Specific photographs were also labeled to indicate the best examples of different mark types.

Lasers

Similar to Durban and Parsons (2006), we attempted to measure mark sizes and other morphometrics on beluga whales using lasers mounted a known distance apart on top of the camera lens. The lasers (model # BTG10; www.z-bolt.com) were 10 cm in length and 2 cm in diameter and were mounted horizontally on a custom aluminum plate attached to the tripod mount of an 80-400 mm Nikon zoom lens (Figure 5). Lasers were calibrated before each survey to project two concentrated beams of green light a fixed distance of 16 cm apart. The two resulting points of light projected onto the bodies of photographed beluga whales (Figure 6) allowed for measurement of marks on photographed whales and for estimation of body length.

Database Development

We continued to work with a database specialist to consolidate all photo-identification data (2005-2008) into a single, comprehensive, and integrated database, and to aid in management of photos during the cataloging process. Data from surveys included the survey route, environmental conditions, and group size, color, and behavior. Data associated with each photograph included the “metadata”, such as the original camera settings, the time the original photograph was taken, and the lighting conditions. Finally, data included the number of photos in the catalog, the dates and locations when photos were taken, the number of individual whales represented in the catalog, the number of temporary files yet to be matched and the number of photos of whales with few or no visible markings.

RESULTS

Catalog Development and Current Status

Catalog development

As is typical for a maturing photo-identification catalog, revisions to the right-side catalog continued through the addition of 2008 field season photographs. Of the belugas photographed in 2008, 105 were identified as whales already in the 2005-2007 catalog, and an additional 28 folders were created of potentially new individual belugas. These 28 potentially new individuals had complete, high quality profile sets of photographs, although these photos must still undergo the complete review process before they can be fully incorporated into the catalog. In addition, some linkages were discovered within the catalog, and linked folders of the same beluga were merged into a single folder.

The cataloging process was greatly facilitated by the continued development of the photo-identification database. Consolidation of all the project files into a single database is complete. A summary of database development in 2008 is provided in Appendix A.

Current status of the 2005-2008 catalog

As of April 1, 2009, the beluga photo-identification right-side catalog contained 4,866 photographs of belugas found in 128 groups encountered on 140 survey days between 2005 and 2008. The catalog contains photographs of only the right sides of individuals. Photographs of left-side images have been archived, and a left-side catalog will be created at a future opportunity.

The catalog currently contains 140 individual belugas photographed over two or more field seasons. Of these 140 whales, 30 were photographed and matched over all four field seasons. An additional 119 belugas were seen in only one field season.

The current catalog has a total of 150 folders of individual belugas with complete profile sets of high quality photographs of their right sides. The catalog also contains 109 folders of belugas with incomplete profile sets.

Sighting Histories

Sighting histories of belugas 2005-2008

Forty-six beluga whale groups were photographed during 29 survey days in 2008. From these 46 groups, 105 belugas were identified as belugas in the 2005-2007 catalog. Survey effort was greater in 2008 than in 2007 and more belugas were identified in 2008 than in 2007 (Figure 7). Details on survey locations, survey effort, and group encounter rates, size, color/age composition, and behavior are presented in McGuire and Kaplan (2009).

Thirty individual belugas were identified in all four years of the study (2005-2008), and their individual sighting histories and photographs are presented in Appendix B. In addition, 45 belugas were sighted in three years of the study, 65 belugas were sighted in two years of the study, and 119 individual belugas were identified in only a single year.

Of the 30 individually identified belugas sighted in each of the four years of the study (Table 1), none were observed exclusively in one survey area. Each of the 30 belugas was photographed in both Knik Arm and the Susitna River Delta. Twenty- three percent of these belugas were also seen in Turnagain Arm, 7% were seen at the Port of Anchorage, and 7% were seen in the Chickaloon Bay/Southeast Fire Island area. Sixty-seven percent of the belugas seen in Knik Arm and the Susitna River Delta were only seen in these two areas.

The highest seasonal encounter rate (number of sightings per season) for an identified beluga in 2008 was for one whale seen on seven different survey days that year. The highest total encounter rate (number of sightings for all seasons combined) during the course of the study was for one identified beluga sighted on 20 different days over a period of three years (this beluga was not sighted in 2008). On average, belugas in the 2005-2008 catalog were photographed on 4.4 separate surveys days. Twenty-seven percent of belugas identified 2005-2008 were sighted on one day only (Figure 8). Of 1,170 sightings of belugas identified between 2005 and 2008, all but 16 sightings were of belugas seen in one group per survey day. Identified belugas were never photographed in more than two groups per survey day. The identification rate (number of beluga identifications/survey) was highest in Kink Arm, followed by Susitna Delta, and was much lower in Chickaloon Bay and the Port of Anchorage (Table 2). On average, 24% of each group was identified in Knik Arm, while only 2% of each group was identified in Turnagain Arm. For all surveys conducted throughout Upper Cook Inlet in 2008, on average 20% of each group was identified (Figure 9).

Sighting histories of belugas identified by satellite tag scars

Seven photo-identified belugas have unique scars from holes used by NMFS to affix satellite tags in the past. These individuals were identified based on a combination of natural marks and the tag scars to avoid mistakenly matching similar scar patterns caused by the same tag type. Five of these belugas were sighted in 2008. Four previously tagged belugas were photographed with calves, and one of these was photographed with a calf in more than one year (Table 3). Six previously tagged belugas were photographed in both Knik Arm and the Susitna River Delta. Two 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 three surveys conducted in the area. Individual sighting histories and photographs of previously tagged belugas are presented in Appendix C.

Sighting histories of mothers and their calves

Thirty-nine identified belugas were photographed with calves in 2008. Eighty-four identified belugas were presumed to be reproductive adult females based on photographs taken from 2005 to 2008 in which they were closely accompanied by calves (Table 4). The position of the calf relative to the (assumed) mother was either the "neonate position", in which the calf surfaced just above the mother's midline (Figure 10), or the "calf position" alongside the posterior half of the mother (Figure 11). Position descriptions are based on those described for bottlenose dolphins (*Tursiops* sp.) by Mann and Smuts (1999), and for belugas by Krasnova et al. (2009).

Twenty-two identified belugas were photographed with calves in more than one year (Table 4). Twelve identified belugas were seen with calves in consecutive years. Seven identified belugas were seen with calves in two years, but with one intervening year without a calf. Three identified belugas were seen with calves in two years, but with two intervening years without calves. Ten 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; Figure 12). Three identified belugas were each first seen with a larger calf, then one, two, or three years later, were seen with a much smaller calf (which was assumed to be a new calf; Figure 13).

The majority of calves could not be identified because they were either not marked or they were never photographed with enough of the body above water to allow marks to be seen. Three calves were identified between 2005 and 2008 (Table 5). All 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.

An additional 15 identified belugas may have been accompanied by calves as suggested by the size, shape, and location of submerged objects in the water next to them. Because these submerged objects were never photographed above the water, they could not be unequivocally classified as calves (Figure 14).

Calves and neonates were seen in all areas of Upper Cook Inlet where beluga groups were encountered during photo-identification surveys in 2008 (Figure 15), although groups with neonates were seen more often (after standardizing for unequal survey effort among areas) in Knik Arm than in other areas. Details of calf and neonate composition of groups according to area and date are described in McGuire and Kaplan 2009.

Associations among identified belugas

COAs for the 30 whales seen in all four years of the study (2005-2008) are presented in Table 6. The mean COA for each beluga was calculated by taking the mean of that beluga's 29 COAs from 29 pair-wise comparisons. Mean COAs ranged from 0.09 to 0.22. The maximum COA per beluga ranged from 0.19 to 0.67. A sociogram was created (Figure 16) in which points represent the 30 cataloged belugas and the thickness of the lines between the points indicated the strength of the association between individuals. The maximum COA occurred between RA100 and RS140 and was 0.67, indicating that that these two belugas were sighted together in 67% of groups in which they were each 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 30 belugas identified in all four 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 0.128. 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 0.232. This value provides a measure of the variation of association patterns within a social system (Whitehead 2008). In this case, the value indicated a homogenous society. Values <0.3 are indicative of a homogenous society, and those >0.5 indicate evidence of a well-differentiated society (Whitehead 2008).

The mean group size in which these 30 belugas were seen was 52.3, with a mean of 28.7 white belugas, 19.0 gray belugas, and 4.6 calves (the calf category includes calves and neonates). Mean group attributes (size, color composition, presence of calves) were calculated for the groups in which each of the 30 belugas seen in all four years of the study was photographed. None of these belugas were found in groups that were comprised of solely white or gray animals, and all of these belugas were found in groups that contained calves (Table 7).

Additional Information Provided by the Study

Causes of markings

Categories of markings that were identified and assigned to photographs included those presumed to be caused by natural sources such as disease (Figure 17), predation

(Figure 18), molting, and conspecifics, as well as anthropogenic sources such as satellite tags (Appendix C), ship strikes (Figures 19 and 20), debris constriction (Figure 21), and bullets (Figure 22). Quantitative analyses of the different mark types will be presented in the third report.

Lasers

Lasers were used successfully to scale the markings on at least two known cataloged individuals (Figure 6). 2008 was the first field season in which the lasers were used, and problems associated with the laser housing and battery life were identified and modifications are underway for future work.

DISCUSSION

The photo-identification catalog and associated surveys from four continuous years of effort provide information about the distribution and movement patterns of individually identified CIBWs, including mothers with calves. 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 about the life history of the CIBW population.

Sighting Histories and Movement Patterns

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 four years of the study and for whales identified by satellite tag scars. This subset of whales (i.e., whales seen in four years and whales with satellite-tag marks) was the most likely to have a consistently high probably of being recognized if present because significant mark loss had not occurred. Individual sighting histories of the 30 beluga whales photographed in all four 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 six of the seven 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).

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. Overall sampling effort has been lower in Turnagain Arm and Chickaloon Bay/Southeast Fire Island. In addition, group encounters in Turnagain Arm typically yield a much lower percentage of identified whales than do groups encountered in other areas. Some, and perhaps all, of the low rate of identification in Turnagain Arm is likely because surveys in this area are land-based and the distance between the photographer and the whales is typically much greater than during boat-based surveys in other areas, resulting in fewer useable photographs.

When making inferences about the greater population of CIBWs 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 (2005-2008) was never more than 152 which indicated that most of the population was elsewhere (population estimated at 375 in 2008; 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 84 belugas assumed to be mothers, 10 were photographed with calves maturing over two or more field seasons, and one identified mother was photographed with a maturing calf during three field seasons. Additional years of photo-identification effort are needed to determine how long calves remain with their mothers and when these 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. Three 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.

Three calves have been identified by their own marks rather than those of their mothers, which allows these calves to be tracked independently of their mothers. The mothers 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).

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 four years of the study 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. Groups encountered during surveys were never exclusively comprised of white or gray animals, but always had both colors present. The 30 identified whales seen in four 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. 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 may also be more wary of vessels and may have left the area when the survey vessel approached.

Catalog Development and Current Status

It is important to characterize the quality of photographic records (i.e., quality of the photograph and quality of the marks) of identified individuals, because some of the belugas in the catalog are more distinctively marked and thus more likely to be identified in photographs of variable quality (Rugh et al. 1998, Friday et al. 2000, Gowans and Whitehead 2001, McGuire et al. 2008a). Classifying and sorting photographs according to a minimum quality standard is also necessary to distinguish between similarly marked belugas and to avoid grouping two or more individuals with similar markings under the same identification number (Auger-Méthé and Whitehead 2007).

Additional Information Provided by the Study

Sighting histories for seven belugas known to have been tagged between 1999 and 2002 indicated that these individuals survived capture and tagging. In addition, four of these belugas have been identified as mothers with calves, indicating they reproduced post-tagging. Sighting information on these whales provided between four (if tagged in 2002 and re-sighted in 2005) and nine (if tagged in 1999 and re-sighted in 2008) years of survivorship data on these individuals. Eighteen Cook Inlet belugas were tagged with satellite tags by NMFS between 1999 and 2002 (Hobbs et al. 2005). Tag type and attachment 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.

Several photographs of belugas contained marks indicative of disease and injury. 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.

We noted fresh wounds in photographs and followed them through the healing stages within and across seasons in order to better understand mark types. Characterization of the wound healing process came from our own observations and also from those in the literature (Bruce-Allen and Geraci 1985, Geraci and Bruce-Allen 1987, Orams and Deakin 1997, Auger-Méthé and Whitehead 2007). One study of belugas in a laboratory setting inflicted clean scalpel cuts 10 cm through the skin to the dermis layer. The cuts healed, leaving a “pale, slightly depressed line” after 50 days (Geraci and Bruce-Allen 1987). These types of lines were likely the same as the lasting pale or white scars from wounds that we have used to follow individual whales over several seasons.

Marks can serve to identify potential sources of predation. Studies of shark bites found on narwhals (*Monodon monoceros*) off Greenland were attributed to the Greenland shark (*Somniosus microcephalus;* Reeves 1980). Pacific sleeper sharks (*Somniosus pacificus*) are found in the North Pacific, are known to feed on live prey, and can reach lengths of over seven meters (Campangno 1984). Sleeper sharks feed heavily on cetacean carrion in Alaskan waters, but it is uncertain if they also prey on live whales (Sigler et al. 2006). Because sleeper sharks feed within in the water column as well as on the bottom, and eat live Pacific salmon (*Oncorhynchus* sp), it is possible that they feed alongside belugas and take bites from them and/or prey on them.

We also studied marks caused by skin conditions such as molting and lesions from disease (Figure 17). Molting in Cook Inlet belugas has not been previously studied. A small fraction of our photographs show conditions that may be considered molting, although it appears to be a more-diffuse molt than described for this species elsewhere (St. Aubin et al. 1990). It would be informative to compare our observations with those of other researchers and the traditional knowledge of subsistence users in Cook Inlet and other parts of Alaska. 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, Bearazi et. al 2009). In several of our photographs we saw lesions that could be attributed to disease, and again, by collaborating with other investigators, particularly those authorized to investigate mortalities (NMFS, stranding groups, and subsistence users), we could increase the power of our observations. Appendix D contains a protocol for photographing beluga mortalities that we have 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. A more detailed examination of marks, their sizes, locations, and possible causes will be presented in future reports.

Status of the Study with Respect to its Original Objectives

The catalog currently contains information on sighting histories of 30 individual beluga whales seen in all four years of the study. Additionally, we have identified 84 individuals thought to be mothers. These results indicate *the feasibility and utility of photo-identification for studies of CIBWs* as outlined in the first objective of this study. The second objective of *building a photo-identification catalog to examine re-sight rates and discovery of new individuals over time* has also been met, though this is an ongoing process.

The third project objective, *to describe population characteristics of beluga whales in Upper Cook Inlet, including age class distribution, residency/movement patterns, behavior, and social group structure,* is being met, and results will continue to develop with increased field work and refinements of methods.

The fourth objective, *to develop abundance estimates of Cook Inlet beluga whales using mark-recapture models*, has not yet been met. Before an abundance estimate can be produced from the catalog, some work remains. Several factors have been identified (McGuire et al. 2008a) which must first be quantified before estimating abundance: mark persistence, heterogeneity (non-uniformity) of photographic samples, and limitations of sampling locations. We are in the process of quantifying these factors.

Age-class distribution - As mentioned in previous project reports (McGuire et al. 2008a, McGuire and Kaplan 2009), the use of body color as an index for age class needs to be examined more closely and revisions to current techniques to observe and quantify body color are being explored.

Residency/movement patterns - Chronological maps of individual sighting histories illustrating residency and movement patterns have been provided in this report and may be used to examine the potential occurrence of spatial/temporal stratification of the population around Upper Cook Inlet. Knowledge of the existence of population stratification is important for impact assessment of human activities in and around Upper Cook Inlet.

Behavior - Current methods of recording behavior provide a general sense of the behavior of the group during an encounter. Behavior of groups encountered during surveys conducted in 2008 is reported in McGuire and Kaplan 2009. In the future behavior should be sampled with more rigorous methods (sampling and recording rules; Martin and Bateson 1993), using a digital video recorder and/or dedicated observer and shore stations when feasible.

Social group structure - To better understand social group structure, relationships among individuals seen in all four years of the study were quantified with indices of association.

A fifth objective has been added to the original objectives: *to determine life history characteristics of Cook Inlet beluga whales*. As already discussed, photo-identification techniques can be used to study calving frequency, calving interval, period of maternal care/association, survival rates of calves, and survival rates of identified individuals, which will increase our knowledge of the life history of Cook Inlet beluga whales. This objective is being met, but requires a long-term, continuous dataset.

Progress Made in 2008 and Dissemination of Project Results

Progress made in 2008 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 2008 and early 2009, project results were presented as talks and posters at scientific and stakeholder meetings, including posters at the Alaska Marine Science Symposium (Kaplan et al. 2008b, McGuire et al. 2009), a talk and two posters at the Alaska Chapter Meeting of the Wildlife Society (Blees et al. 2008, Kaplan et al. 2008a, McGuire et al. 2008b), an invited talk at the Alaska Beluga Whale Committee meeting (Kaplan et al. 2008c), a meeting about CIBW research hosted by the Alaska SeaLife Center, a poster at the Alaska Marine Mammal Stranding Network Meeting (McGuire et al. 2009), an invited talk at the Defenders of Wildlife Cook Inlet Beluga Whale Symposium, and an invited talk at the Alaska Oil and Gas Association Environmental Studies 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; 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 2008 was completed October 28, and survey results were presented in McGuire and Kaplan (2009). Cataloging of photographs from 2008 was completed April 1, 2009, and results are presented in the current report. A third report will be issued in the fall of 2009, presenting results of a population estimate derived from information about individuals photographed in 2008, as well as results of analyses of mark types and mark location. This report will also present the results of whale color analyses, with data from gray cards photographed in the field and the development of a numerical scale to quantify gradations of gray based on pixel coloration. The three reports will be compiled into a single comprehensive report to be issued in December 2009.

Additional plans for 2009 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 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 increases with the proportion of the CIBW population that is photographed and identified. Photo-identification surveys from the existing four years of uninterrupted effort provide information about the distribution, habitat associations, behavior, color, and age-class compositions of CIBW groups. Identifications of whales photographed during the surveys 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 can help to identify appropriate conservation measures to preserve the population.

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Table 1. Sighting records of individual beluga whales cataloged in all four years of the study (2005-2008) according to year and location. (P=photographed)

	Knik Arm				**Susitna River Delta**				**Turnagain Arm**				**Chickaloon Bay/ SE Fire Island**				**POA**			
	2005	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**	**2005**	**2006**	**2007**	**2008**
	# of Surveys				**# of Surveys**				**# of Surveys**				**# of Surveys**				**# of Surveys**			
Whale ID	31	12	4	10	17	16	4	8	1	5	7	12	0	0	1	2	31	16	7	17
RA001	P	P	P	P		P	P	P												
RA002	P	P				P	P													P
RA009	P	P	P	P	P		P	P												
RA013	P	P		P		P		P				P			P		P			
RA025	P	P			P		P	P												
RA029	P	P		P			P	P												
RA036	P				P	P	P	P												
RA066	P	P		P			P													
RA100	P	P				P	P	P		P										
RA102	P			P		P	P	P			P									
RA123	P			P		P	P	P		P										
RA132	P	P	P	P			P													
RA145	P	P					P	P												
RA148	P	P	P	P	P	P		P				P								
RA154	P	P	P				P	P												
RA155	P	P	P	P	P	P		P												
RA160	P		P	P	P		P	P		P	P									
RA54	P	P	P		P			P												
RA63	P			P		P	P	P												
RS002		P		P	P	P	P	P												
RS044	P	P	P	P	P	P		P												
RS110	P	P				P		P							P					
RS118	P					P	P	P												
RS124	P					P	P	P												
RS134	P	P		P		P		P			P									
RS139	P	P		P		P	P	P												
RS140	P					P	P	P												
RS221	P		P	P	P	P		P												
RS222	P	P		P		P	P													
RA147	P		P	P		P														

Table 2. Number of cataloged belugas per survey, mean percent of group cataloged, and mean group size per area surveyed from 2005 to 2008 in Upper Cook Inlet, Alaska.

Area	# Cataloged Belugas / Survey	Mean % of Group Cataloged	Mean Group Size	# of Surveys
Susitna River Delta	8.1	17.3%	23.6	45
Knik Arm	11.6	23.6%	20.0	57
Port of Anchorage	0.1	18.5%	4.5	71
Chickaloon Bay/South Fire Island	2.0	7.3%	11.7	3
Turnagain Arm	0.6	2.3%	14.0	25

Table 3. Sighting records of seven individual belugas identified by scars from satellite tags applied by NMFS between 1999 and 2002, according to year and location. (P=photographed)

	Knik Arm				Susitna River Delta				Turnagain Arm				Chickaloon Bay/SE Fire Island				POA			
	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008	2005	2006	2007	2008
	# of Surveys				# of Surveys				# of Surveys				# of Surveys				# of Surveys			
Whale ID	31	12	4	10	17	16	4	8	1	5	7	12	0	0	1	2	31	16	7	17
RA 139			P	P		C	P	P												
RA 148	P	P	C	C	P	P		P				P								
RA 156	P						P	C												
RA 159	P				P		P													P
RA 160	P		P	P	P		P	C		P										
RA 161		P																		
RS 220	P		P		P			P												

Table 4. Yearly sighting records of 84 individual beluga whales assumed to be mothers based on the close accompaniment of a calf at least once during 2005-2008. (C=photographed with a calf, P=photographed without calf)

	# of Surveys					
	49	33	17	29		
Whale ID	**2005**	**2006**	**2007**	**2008**	**# Years Seen with a Calf**	**Age Information Inferred from Individuals seen with Calves in >1year (CBD=Could not be determined)**
RA061	C	P			1	
RA063	P	P	P	C	1	
RS056	P	P		C	1	
RA054	C	P	P	P	1	
RA067	P			C	1	maturing calf
RA145	P	C	C	C	3	
RA039	P	C		P	1	
RS106	P			C	1	maturing calf
RA085	P		C	C	2	
RA17	P			C	1	
RA108	P	C		P	1	
RS055	C				1	CBD
RA096	C			C	2	
RS054	P		C		1	
RA015	C	P	P		1	
RS124	C	P	P	P	1	2008 calf smaller than 2005 calf
RA036	C	P	P	C	2	
RA079	P	P	C		1	
RS006	P	P		C	1	
RA033	C				1	
RA062	P	P		C	1	
RA119	C	P			1	
DUB			C	P	1	
ET		C			1	
RS071	P	P		C	1	
RS118	P	C	P	P	1	
RA020	P	P		C	1	
FIS		C		P	1	
RS069	P			C	1	
RS024	P		C		1	maturing calf
RA009	C	P	P	C	2	
HOC		C		P	1	
RA156	P		P	C	1	
HUT		C		P	1	
INT		P	C		1	
RA139		C	P	P	1	CBD
RA155	P	C	P	C	2	
RA146	P	P		C	1	
LUN		C			1	
RS007	C				1	CBD
RA025	P	P	C	C	2	

Table 4. Continued.

	# of Surveys					
	49	33	17	29		
Whale ID	2005	2006	2007	2008	# Years Seen with a Calf	Individuals seen with Calves in >1year (CBD=Could not be determined)
RA126	P	P		C	1	
RA123	P	C	P	C	2	maturing calf
RS029	P			C	1	
RS135	P			C	1	
RA121		C		C	2	CBD
NOT		C			1	
RS150		P		C	1	
QUA		C		P	1	
RA066	P	C	C	P	2	maturing calf
RA071	C				1	
RA087	C				1	
RA141		P		C	1	
RA154	C	C	P	C	3	CBD
RS110	P	P	P	C	1	
RS134	P	C	C	C	3	CBD
RA157	P	C		C	2	2008 calf smaller than 2006 calf
RA026	P	P		C	1	
RA160	P	P	P	C	1	
RA032	C				1	
RA094	C		C	P	2	maturing calf
RA111	P	C			1	
RS113	C	C		P	2	2006 calf smaller than 2005 calf
RS068		P	P	C	1	
RA122	C	P		P	1	
RA148	P	P	C	C	2	maturing calf
RA102	P	C	P	P	1	
RA147	C	P	P	P	1	
RS082	C	P			1	
RA013	P	P	P	C	1	
THI		C			1	
RA151	C	P			1	
RS139	C	C	P	P	2	CBD
RA010	C				1	
RA042	C				1	
TWE		C	C	P	2	maturing calf
RS049	P	C		P	1	
RA024	C	C	C		3	CBD
RA089		C		P	1	
RA131	P	C		C	2	CBD
RA064	C	C		P	2	maturing calf
RA095	P		P	C	1	
RS222	P	C	P	C	2	maturing calf
RS140	P	P	P	C	1	

Table 5. Yearly sighting records of three individual beluga whales presumed to be calves. P= photographed at least once during 2005-2008. Each of the three calves was photographed accompanied by a larger, whiter beluga.

	# of Surveys				Size Estimates
	49	33	17	29	
Whale ID	**2005**	**2006**	**2007**	**2008**	
RS047	P				large calf (=2/3 length associated adult)
RS105	P				large calf (=2/3 length associated adult)
ACNN		P		P	large calf (=2/3 length associated adult)

Table 6. Mean and maximum association indices for the 30 beluga whales cataloged in all four years of the study (2005-2008). Standard deviations are shown in parenthesis.

Whale ID	Mean Association	Max. Association
RA001	0.22	0.53
RA002	0.12	0.33
RA009	0.21	0.53
RA013	0.16	0.35
RA025	0.20	0.40
RA029	0.15	0.35
RA036	0.15	0.29
RA054	0.14	0.40
RA063	0.12	0.33
RA066	0.16	0.30
RA100	0.18	0.67
RA102	0.19	0.31
RA123	0.13	0.33
RA132	0.12	0.29
RA145	0.22	0.50
RA147	0.12	0.33
RA148	0.16	0.35
RA154	0.22	0.40
RA155	0.17	0.39
RA160	0.14	0.33
RS002	0.12	0.28
RS044	0.14	0.39
RS110	0.21	0.30
RS118	0.12	0.30
RS124	0.13	0.57
RS134	0.15	0.36
RS139	0.18	0.33
RS140	0.22	0.67
RS221	0.09	0.19
RS222	0.16	0.33
Mean	0.16 (0.04)	0.38 (0.11)

Table 7. Mean group color composition, number of calves, group size, and number of cataloged belugas for groups in which each of the 30 belugas sighted in all four years of the study were photographed.

Whale ID	Mean # Whites	Mean # Grays	Mean # Calves	Mean Group Size	# Cataloged Whales In Group
RA001	25.9	17.2	4.1	47.5	26.6
RA002	23.4	12.7	2.9	40.4	17.9
RA013	28.1	14.5	3.8	47.6	20.4
RA025	38.4	27.0	5.6	71.0	33.7
RA029	27.9	15.3	4.7	47.9	26.4
RA036	29.5	20.5	3.2	55.3	22.9
RA066	26.5	18.5	6.8	51.8	36.0
RA100	32.6	26.6	4.4	63.6	30.2
RA102	23.8	15.1	4.2	43.1	27.6
RA123	23.7	14.3	5.3	43.3	15.9
RA132	23.6	18.4	5.4	47.4	26.2
RA145	34.2	24.6	4.7	63.5	35.7
RA148	30.8	17.6	4.3	53.6	21.3
RA154	31.8	22.6	3.3	58.1	29.2
RA155	26.8	17.8	4.1	51.4	20.9
RA160	34.4	25.0	5.0	64.8	19.5
RA054	39.4	25.0	5.8	70.2	36.6
RA063	27.8	16.7	4.2	48.7	28.3
RS002	39.6	21.6	5.0	70.4	18.8
RS044	22.8	14.6	4.3	42.3	20.0
RS110	30.4	20.0	4.5	54.9	29.8
RS118	19.4	13.8	3.0	36.1	25.4
RS124	35.0	27.3	5.0	67.3	35.8
RS134	25.3	15.5	4.0	44.8	27.4
RS139	24.5	15.7	4.5	44.7	23.6
RS140	39.8	29.6	4.9	74.3	38.9
RS221	18.6	14.6	4.1	37.4	19.9
RS222	28.6	16.8	6.4	51.8	34.2
RA147	19.5	10.8	5.0	35.3	28.7
Mean	28.7	19.0	4.6	52.7	26.8

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

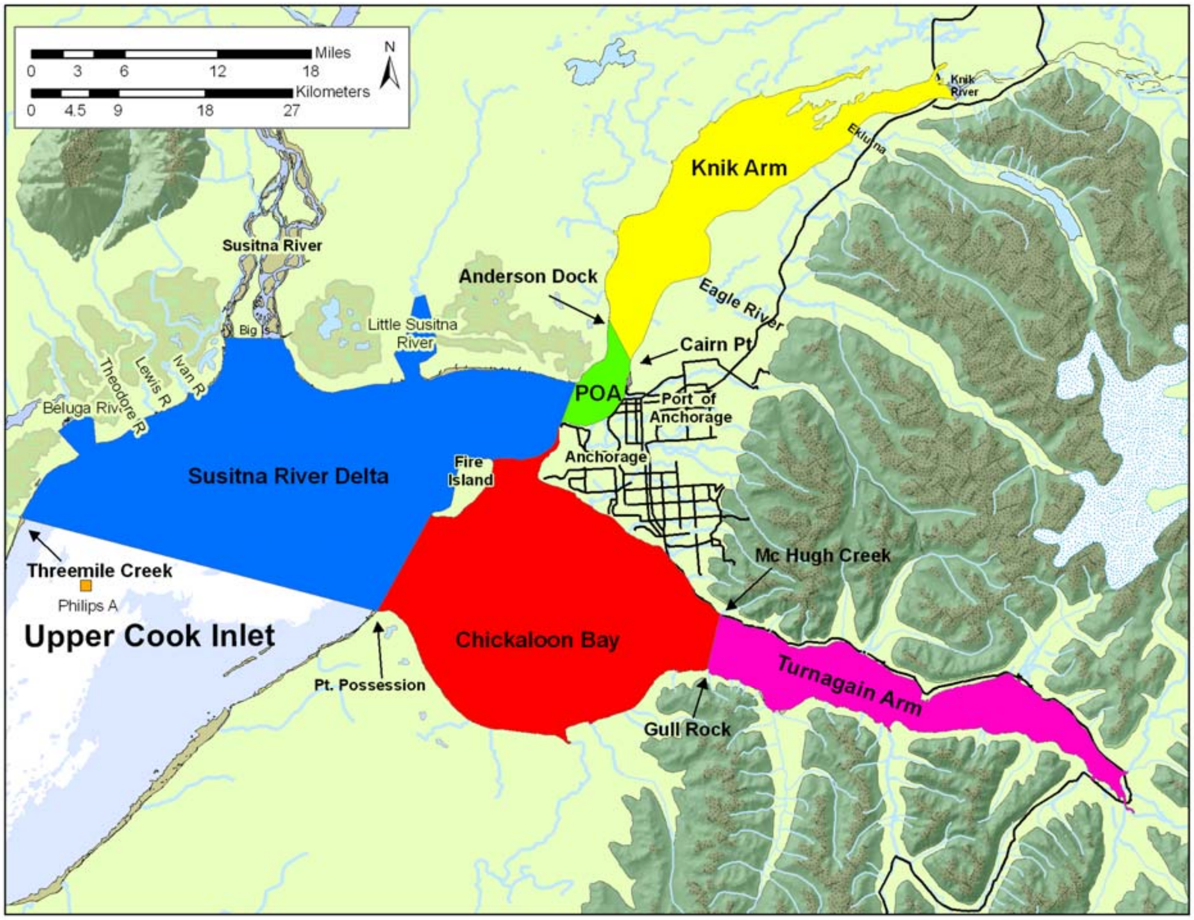


Figure 2. Map of Upper Cook Inlet, Alaska, showing boundaries of five sub-areas within the study area.

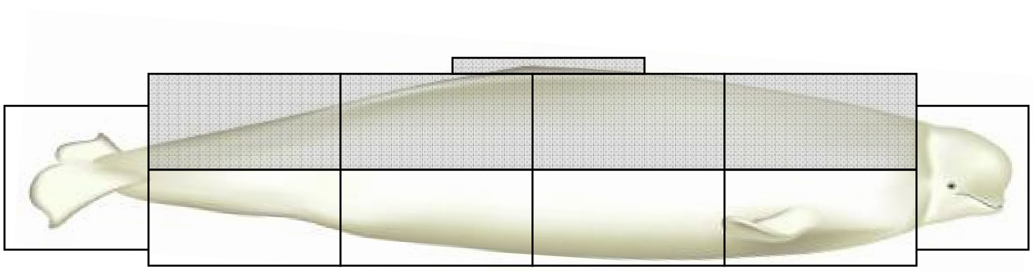
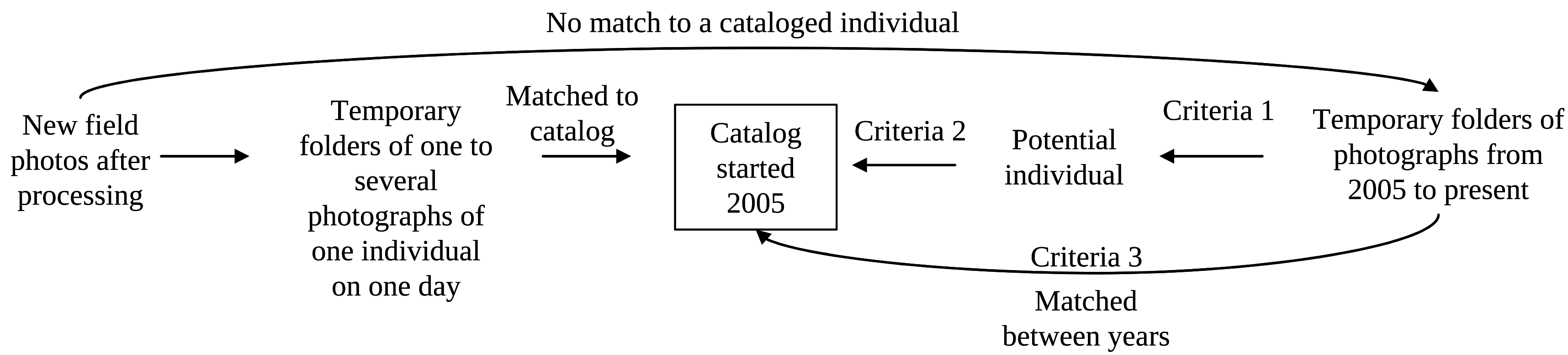


Figure 3. Diagram showing the various segments used when cataloging. The five shaded areas were the critical sections used in matching marks. Beluga illustration courtesy of Uko Gorter.



Criteria 1: New temporary folders that do not match any cataloged whales but have complete sequences of high quality photographs.

Criteria 2: Potential individuals (from the previous season) checked against a new season's photographs by two reviewers that decide a) that they do not match any previous photos OR, b) they do not match photos from the new season – Both allow for a new individual to be added to the catalog.

Criteria 3: Temporary folders that can be matched between years are moved to the catalog as a new individual.

Figure 4. This figure shows how photographs are moved from the field photographs into the catalog.

Figure 5. Two laser-pointers were mounted horizontally in parallel by an aluminum bracket attached to the tripod-mount of a Nikon 80-400 mm zoom lens.

Figure 6. Photograph of the right side of beluga RS056 showing green laser dots 16 cm apart (below the dorsal ridge at middle right). The distance between the dots was used as a reference scale.

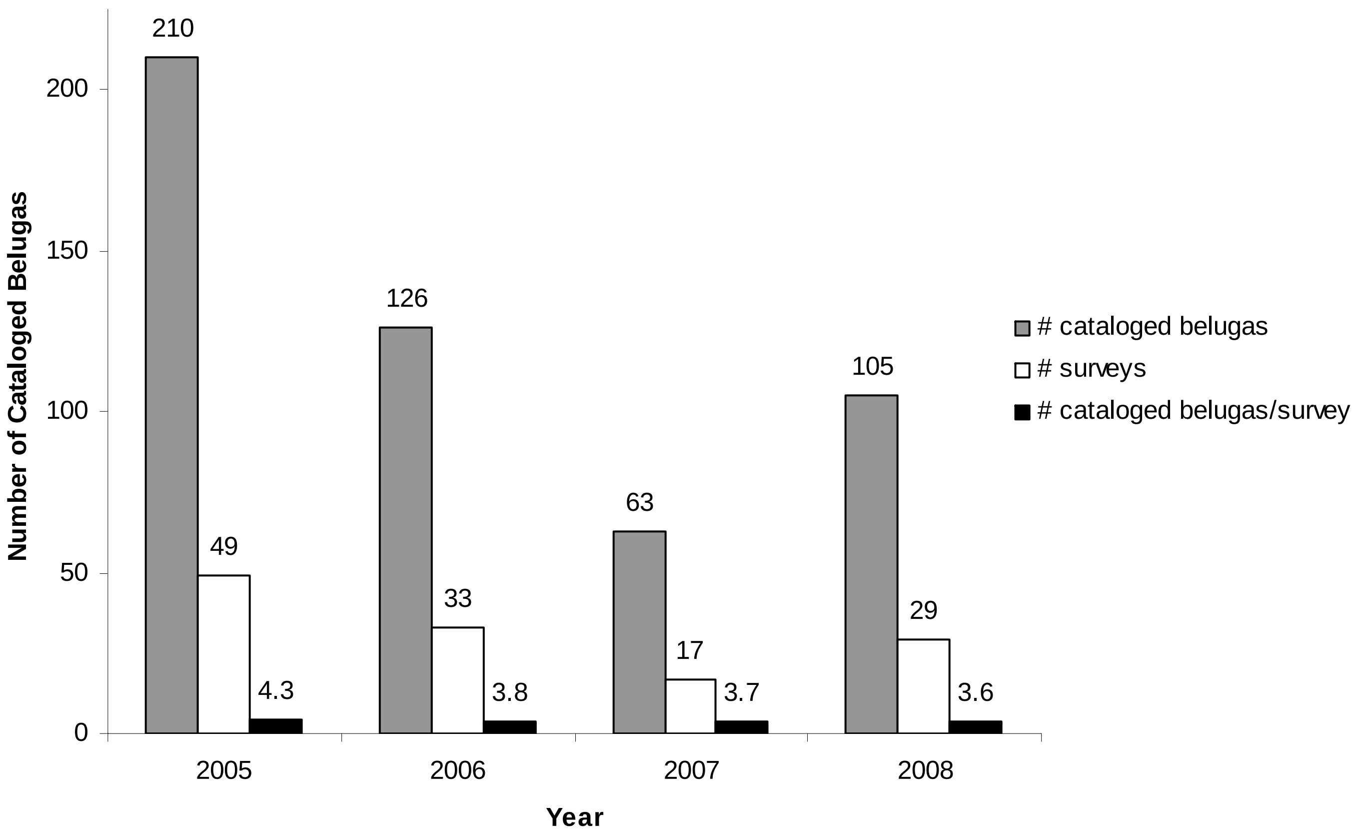


Figure 7. Number of belugas cataloged per year and yearly survey effort, 2005-2008.

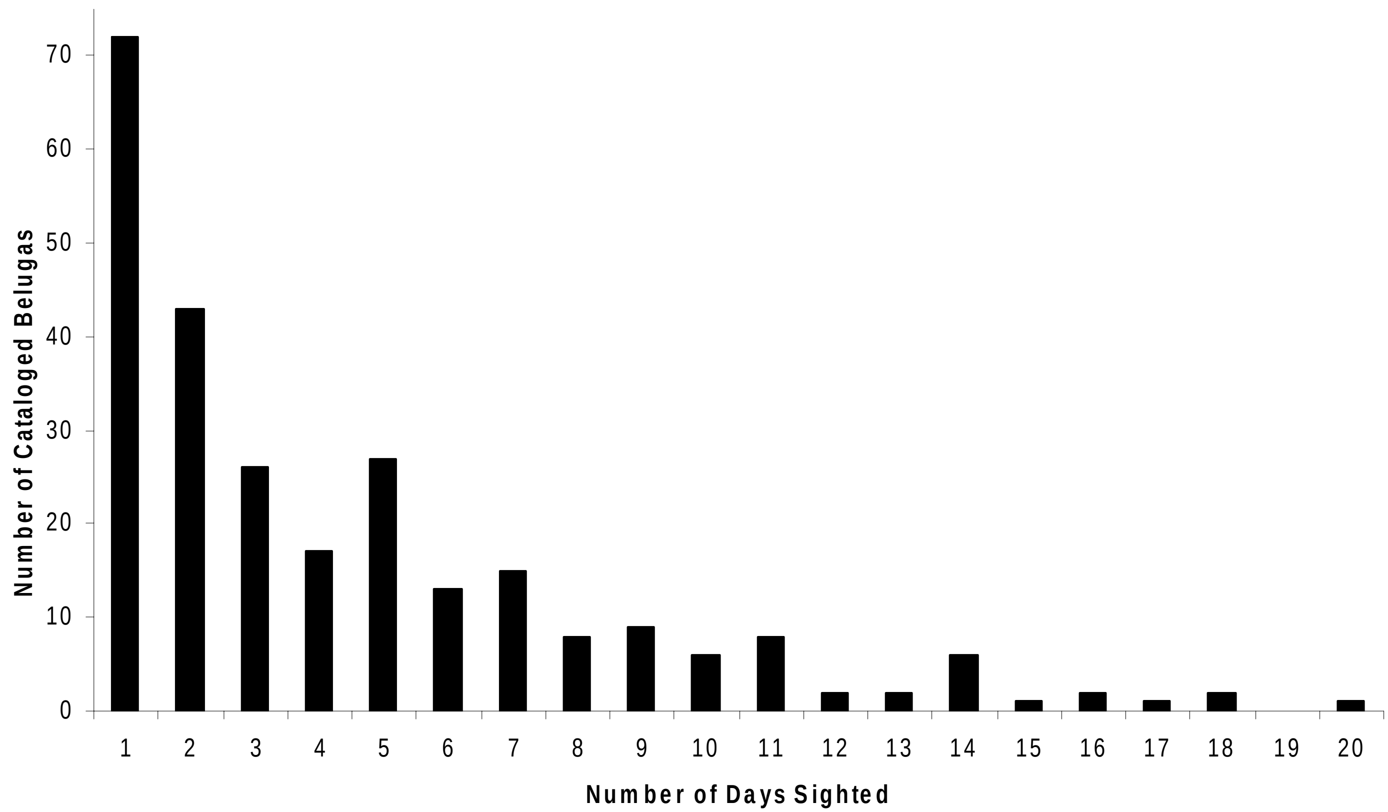


Figure 8. Frequency distribution of sightings of cataloged beluga whales photographed from 2005 to 2008 in Upper Cook Inlet, Alaska.

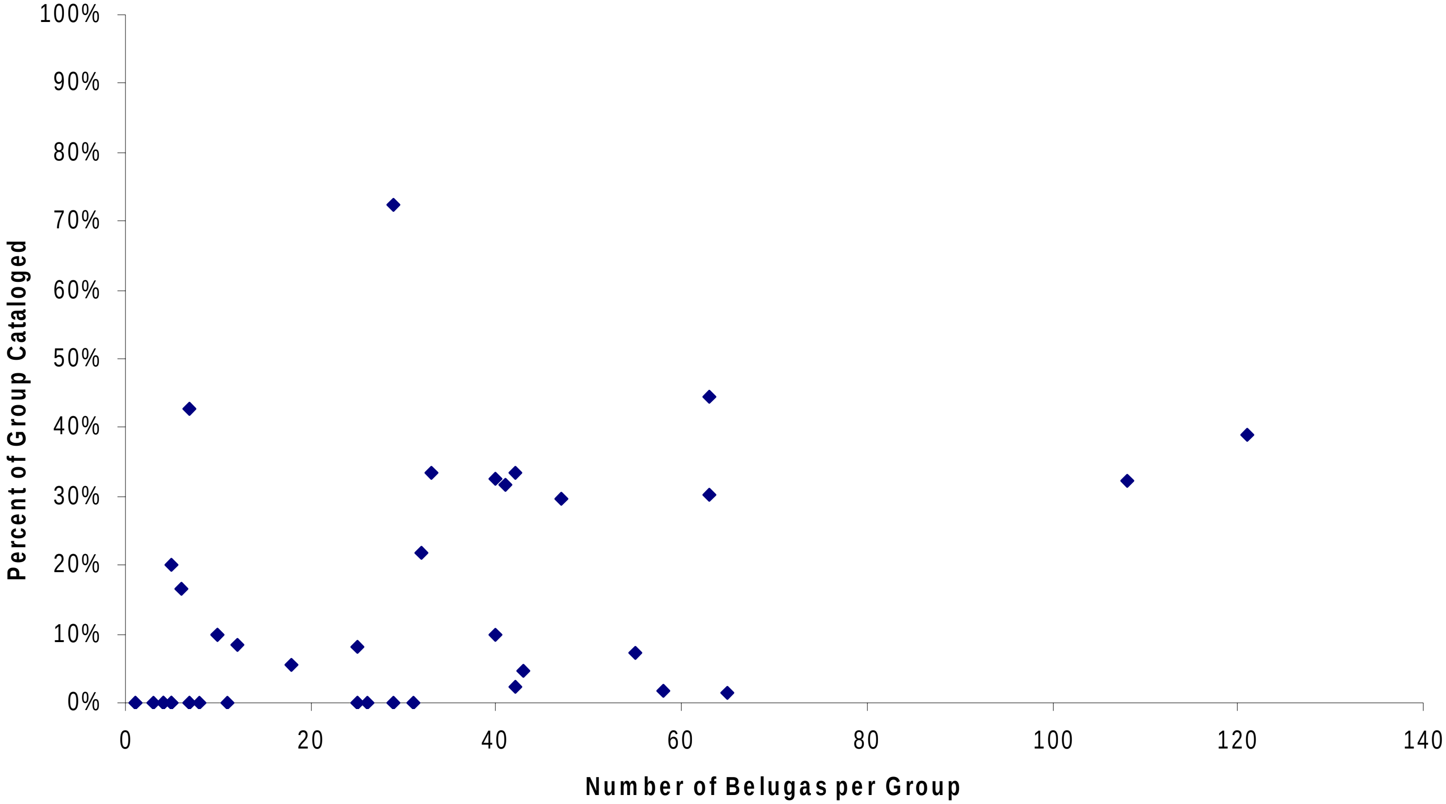


Figure 9. The percent of each group that was cataloged, according to group size, for all groups photographed in 2008 in Upper Cook Inlet, Alaska.

Figure 10. Example of a calf swimming alongside the front half of the presumed mother, in the “neonate position”. Noted the vertical fetal folds of the calf. Image is of the right side of the whales.

Figure 11. Example of a large calf swimming alongside the rear half of the presumed mother, in the “calf position”.

a.

b.

Figure 12. Photograph of the right side of adult beluga RA123, accompanied by a maturing calf in 2006 (a) and 2008 (b). In photo a, the calf is surfacing at the right edge of the photograph. In photo b, the calf is the darker whale in the foreground.

a.

b.

Figure 13. Adult beluga RA036, accompanied by a calf in 2005 (a), and a smaller calf in 2008 (b).

Figure 14. Example of a water pattern suggestive of a submerged calf alongside the right side of the identified adult RA029, located in the foreground, towards the left edge of the photograph. Because the body of the calf was not visible, it could not be confirmed as a calf.

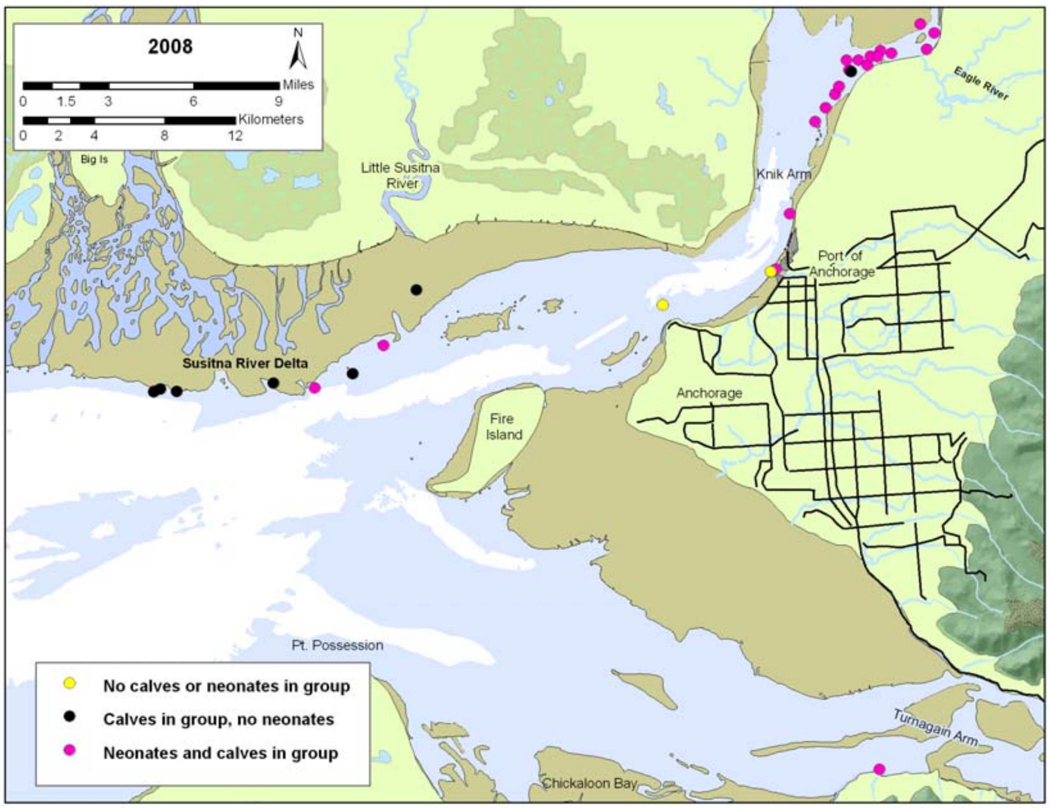


Figure 15. Location of groups with and without calves and neonates encountered during boat-based surveys of Upper Cook Inlet Alaska in 2008. Groups with calves and neonates were also seen from land up Turnagain Arm (not shown on map).

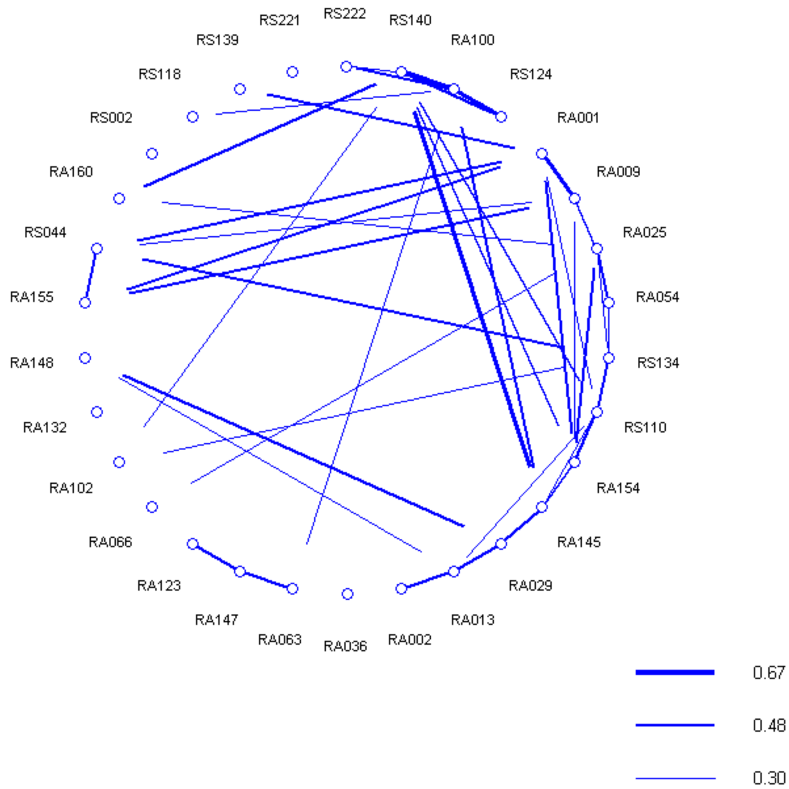


Figure 16. A sociogram in which points represent cataloged beluga whales sighted in all four years of the study (2005-2008). The thickness of the lines between the points indicates the strength of the association between individuals. A coefficient of association (COA) of 0.67 indicates that the two individuals were sighted together on 67% of the occasions in which they were each sighted. COAs <0.3 are not displayed.

Figure 17. Photograph of the right side of a beluga whale showing what appear to be lesions below and in front of the dorsal ridge (at left).

Figure 18. Photograph of the rear right flank portion of a beluga whale and what appears to be large tooth rakes from predation, possibly from an orca whale (*Orcinus orca*) or shark.

Figure 19. Photograph of the right side of beluga RS083. The white markings in the left of the image appear to be from a small propeller strike, with the white line to the right possibly resulting from the bottom edge of the outboard motor's lower unit.

Figure 20. Photograph of the right side of beluga RA145 with a wound possibly caused by a ship strike (either a large propeller or a bow strike).

Figure 21. Photograph of the right side of beluga RA147. This wound may have been caused by constriction from marine debris.

Figure 22. Photograph of the right side of a beluga whale with what appears to be a healed bullet wound a short distance down and anterior to the dorsal ridge.

APPENDIX A.

SUMMARY OF DATABASE DEVELOPMENT (AXIOM)

DATABASE DEVELOPMENT AND CONSOLIDATION EFFORTS

Shane StClair
Axiom Consulting & Design
Anchorage, Alaska

BACKGROUND

The LGL beluga photo-identification project collects large amounts of data that must be analyzed and summarized at the end of each season. In addition to this field data, the project maintains an ever evolving set of whale identities consisting of linked photos from multiple survey efforts. In past years the human effort involved in manually managing and analyzing this data has been formidable, and as the project's dataset grew it became apparent that a more automated solution was needed. In addition to the massive effort that organizing the growing data required, human management of the data was introducing inconsistencies that made subsequent analysis time consuming and laborious. A standardized, computer managed data repository was needed to allow project biologists to focus on high level analysis and interpretation of their data.

Axiom Consulting was hired in 2007 to perform data summaries over several distinct datasets spanning four years and being stored in disparate formats. A simple unified database structure was developed to allow for this summary, but only data applicable to the summaries being performed were imported into the new structure. In 2008 the beluga photo-id team decided to pursue a comprehensive data management system for their project.

DATABASE DEVELOPMENT

The first stage in developing a comprehensive data management solution for the beluga photo-id project was to construct a logical data model. As with any data model, the objective was to store real world entities such as survey efforts and observations as discreet objects in a database system. Data integrity was ensured by enforcing standardized data values, eliminating ambiguities, and ensuring that data were stored in singular locations rather than duplicated in several places. The simplified database structure developed by Axiom in 2007 was used as a starting point for developing the current, more comprehensive structure. Microsoft® SQL Server was chosen as the database platform due to its stability and scalability.

Logical entity tables were created to store the following collected data objects: survey efforts, observed animal groups, animal observations, environmental observations, photos, and individual whales. Explicitly enumerated data values, which allowed for standardization and error reduction, were created for the following fields: survey types, habitat types, environmental conditions, human activities, tide information source, species, beluga group formation, beluga group spread, beluga activity, beluga direction of travel, and photo categories.

Another important aspect of database design was the definition of relationships between the logical entities that mirror their real world relationships. Hierarchical relationships were defined for the following: survey efforts and environmental observations, survey efforts and observed animal groups, observed animal groups and animal observations, and surveys and photos. More complex many to many relationships, in which each entity can be linked to multiple instances of its related entity, were defined for the following pairs of objects: animal observation groups and photos, photos and photo categories, and photos and individuals.

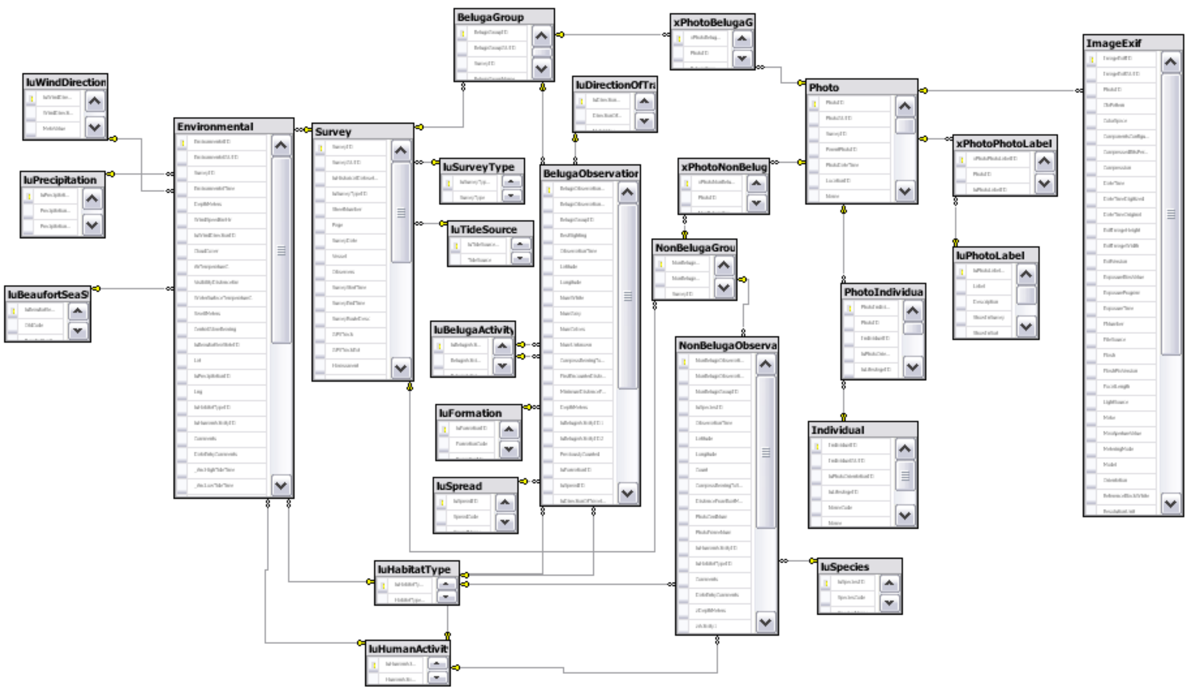


Figure A1. Beluga photo-id database structure.

HISTORICAL DATA AGGREGATION, TRANSFORMATION, AND CORRECTION

Due to the redesign of the unified database, historical beluga photo-id datasets from 2004 - 2007 had to be re-imported into the new structure. This processing allowed for the inclusion of all data fields from each dataset that were determined to be relevant to the project. Because the datasets were collected over a span of four years by different projects, many used dissimilar sets of standardized codes in their collection. These had to be detected, in some cases through statistical analysis and cross-dataset comparison, and translated to the current code set before the datasets could be combined. Obvious data problems or omissions were reported to LGL beluga biologists, who provided historical insight or checked values against paper collection forms. Because not all fields in the unified data model were collected by all historical projects, it was especially important to specify what a null value means. For example, null values could indicate a 0 quantity, false, a missing value, a not applicable value, a value other than the standardized options allow, or a value that was not collected. Null values were replaced with values indicating said possibilities wherever possible to eliminate ambiguities and allow for more meaningful interpretations and analyses of the data.

SERVER SETUP

The beluga photo-id project involved the processing, comparison, and manipulation of thousands of high quality digital photos. The activities were highly resource intensive, and required high connectivity speeds between users and the data management system. Because of this requirement it was determined that the data management system should be hosted at the Anchorage LGL office and connected to the local network. The prices of modern servers have fallen drastically over the past few years, and it was decided that the relatively inexpensive purchase price of a new server would be well worth the benefits of extra speed, stability, and customization that a dedicated system would allow. A Dell server was purchased and installed in the LGL office. The server also provided a convenient unified location to store the project's working file directories, which will help to avoid duplication and versioning problems that can occur when project members store redundant copies of files in various stages of revision on their personal office computers. A protocol to backup server data to an external hard drive that can be stored offsite was also developed. The installation of virtual networking software allowed Axiom developers to remotely access, update, and monitor the LGL server.

DATA ENTRY INTERFACE

A data entry interface was developed to allow project biologists to add to and interact with the data in the new data repository. The developers chose to create a web based data entry application based on many factors. In recent years web based technologies like AJAX have blurred the boundaries between traditional desktop applications and web based application by allowing for highly interactive and fluid user interfaces. Web based applications are ideally built according to universal web standards and can be accessed from any computer using a browser that adheres to these standards. These standards based applications can be accessed from Windows, Apple, and Linux based machines, unlike most desktop applications which are tied to a particular architecture. With AJAX technologies, user interfaces are accessed through web browsers, which in turn communicate with the centralized server where data are stored. Any intensive data processing is left to the dedicated server, while client machines are focused on managing the user interface. Because the area of web browser development has become increasingly competitive, users will be able to take advantage of browser speed optimizations in the future provided they choose a standards compliant browser. Because the code for the user interface is centrally stored on the server, new versions of the application can easily be deployed to a single location rather than having to install updates on each client computer.

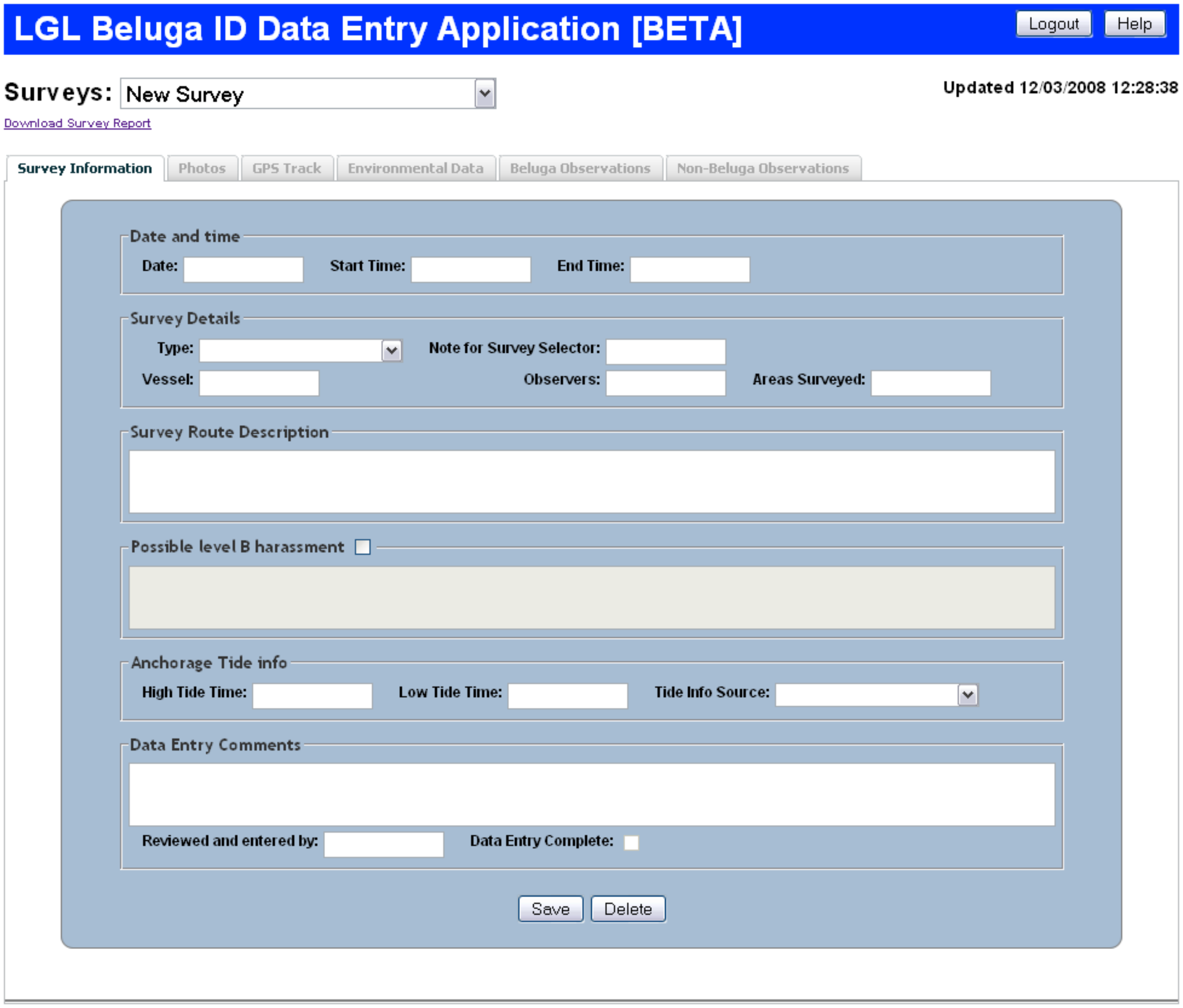


Figure A2. The data entry page in the beluga photo-id application.

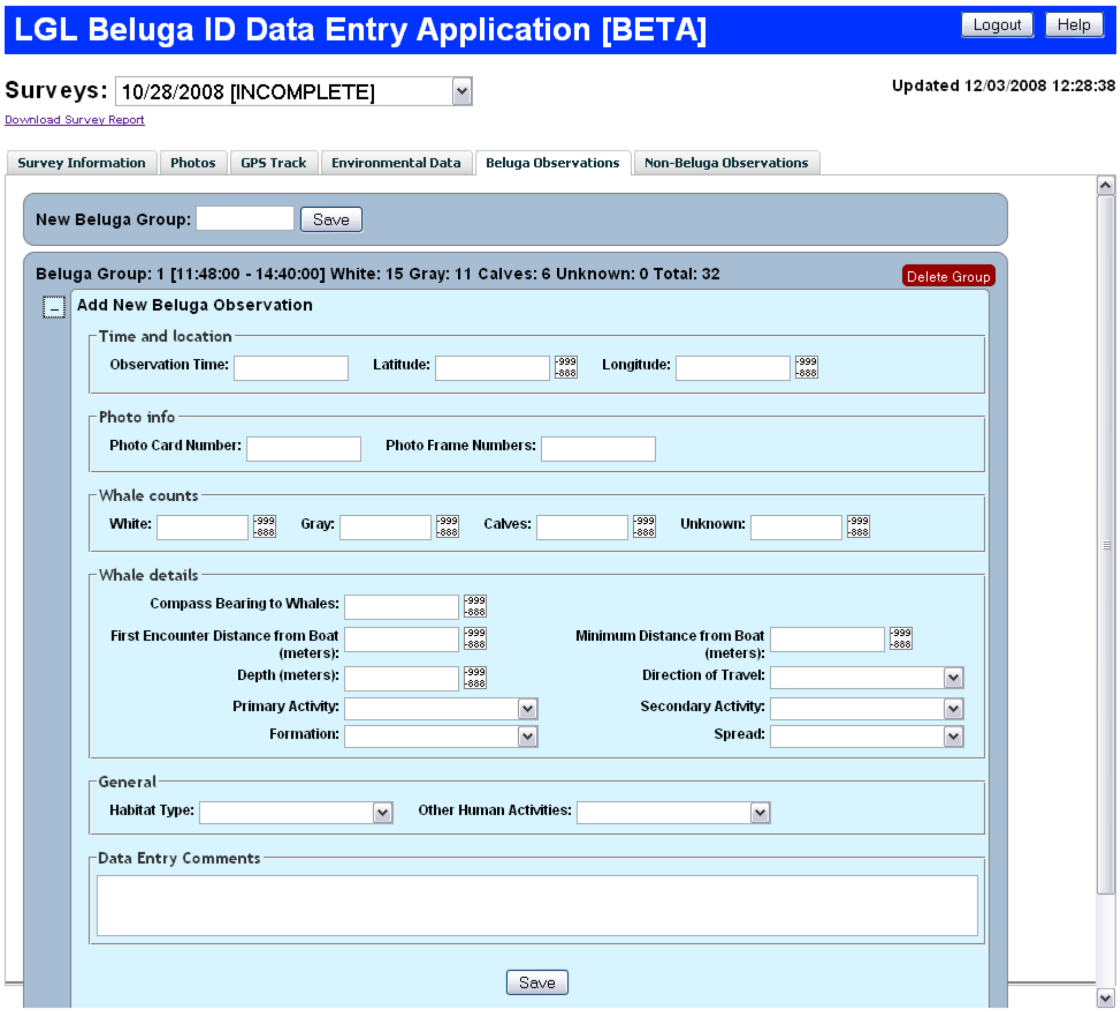


Figure A3. The survey information page in the beluga photo-id application.

The user interface was created using standards compliant html and css code. A combination of the AJAX enabled javascript framework jQuery and Coldfusion® 8 user interface elements was used to add interactivity to the interface. Coldfusion® 8 was also used to create the background data processing code that runs on the server.

The user interface layout and data entry forms themselves were created with logical flow and ease of use in mind. Objects with hierarchical relationships were presented as nested, expandable data forms whenever possible. Repetitive data entry tasks, such as typing colons when entering times, were also automated whenever possible. Custom data validation rules were defined for each column, and live feedback was provided to the user when entered values violate these rules. Data records were automatically checked for completeness when data entry was marked as finished, and the user was provided with an overridable warning about any missing fields. Field with standardized, enumerated value options were presented as selectable lists with options to indicate descriptive metavalues such as "not applicable" or "other". Data fields restricted to numbers had a small menu attached to allow users to indicate metavalue codes for these fields as well. Project staff could also upload GPS track files for each survey.

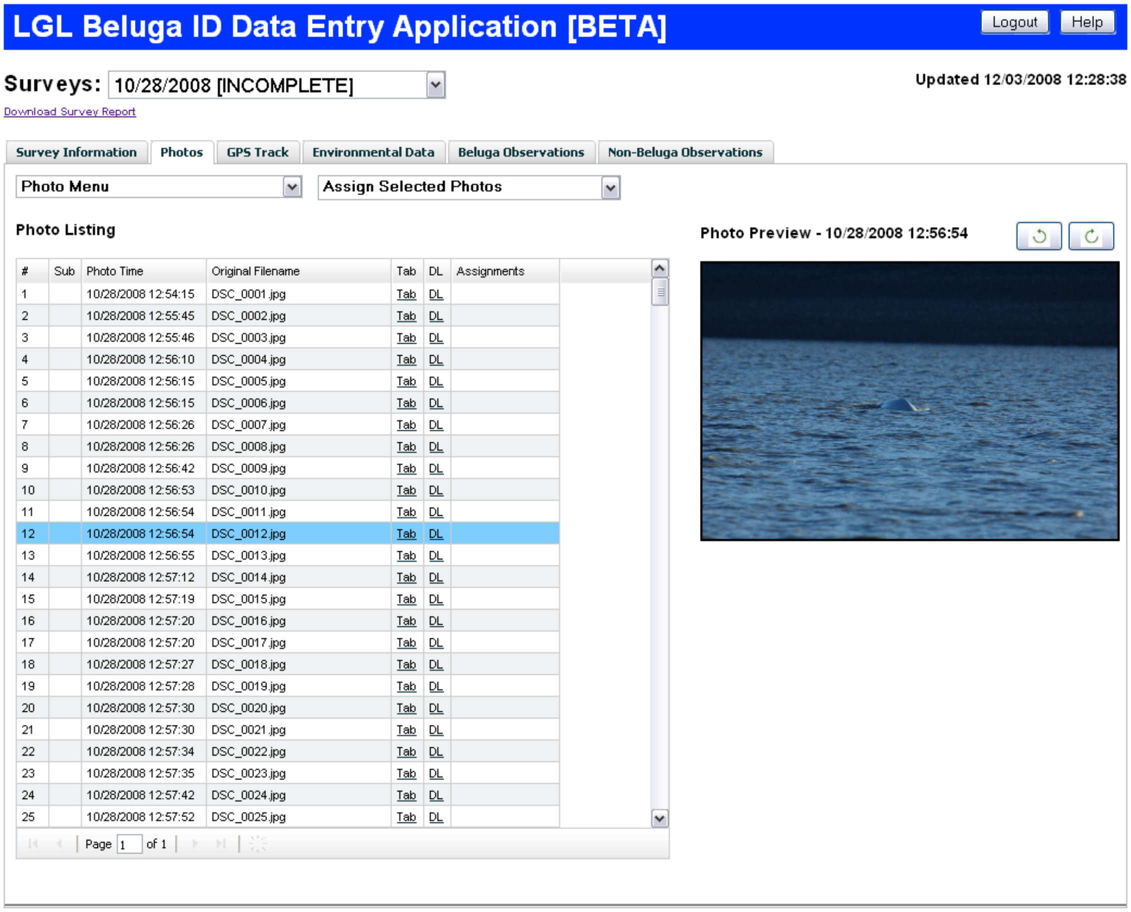


Figure A4. The field photos page in the beluga photo-id application.

In addition to data entry forms, the interface included a photo management pane. Users can scan a designated folder on the server for photos and upload them to a survey. When a batch of photos was uploaded, the application extracted metadata values such as the time the photo was taken from each photo and stored them in the database. Once the upload was complete the application began building small preview photos in the background to allow for increased user interface performance. When the upload process was complete, biologists could select photos in a grid, view previews or original photos, rotate photos, zoom in on parts of photos, apply category labels, and link photos with observation groups either manually or automatically by time.

CATALOG INTERFACE

A highly functional beluga catalog management interface was developed for the beluga identification application. This interface allowed for the creation and management of cataloged whales, potential catalog whales, and various utilitarian temporary groupings.

Users of this interface select a whale or photo group to view using a selector tool at the top of the screen. This selector tool has various criteria than can be applied to limit the whales or groups to be selected from, including whale type, body orientation, life

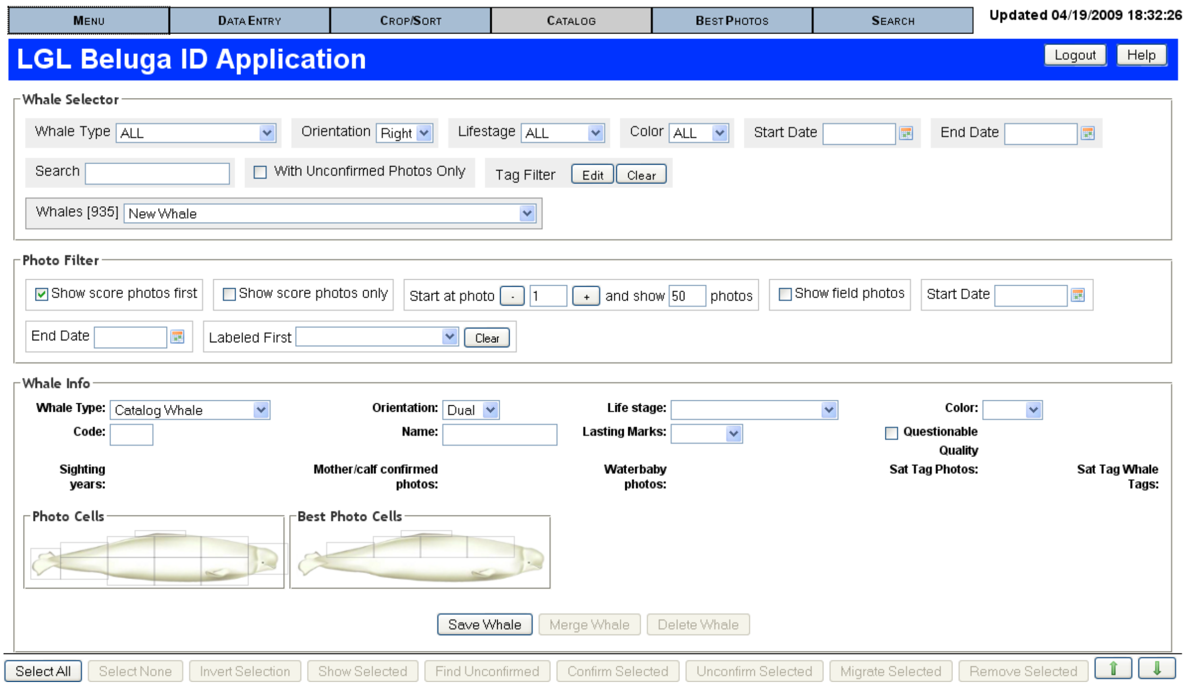


Figure A5. The individual whale information page in the beluga photo-id application.

stage (maturity), color, dates of sightings, and whale tags (see below). Once the desired criteria have been selected, users can choose a whale or grouping to view by choosing or searching the filtered list.

Once a whale or group has been selected, its information is loaded into an editable form and associated photos are loaded. The form includes all relevant whale or group data (whale type, orientation, life stage, color, code, name, presence or absence of lasting marks, and a questionable quality indicator) and also displays the sighting years and numbers of confirmed mother/calf photos, unconfirmed calf photos, and satellite tag photos as calculated from the whale or group's associated photo properties. Two diagrams which summarize which sections of the whale's body are captured in its photos are also displayed.

A photo filter toolbar is included to control the how the photos that are associated with the selected whale or group are displayed and in which order. Users can elect to show "score" photos first or only, which are photos that have been selected as the best quality photos available for a whale. Uncropped raw survey photos can also be displayed. Photos can be limited to those that fall between a specified start and end date, and photos with a selected photo label can be moved to the top of the displayed photo order.

Since a whale or group can have hundreds of associated photos and a web browser becomes unresponsive when pages grow too large, a pagination tool is used to show a defined amount of photos at one time. Users can set the number of photos to be displayed and navigate through pages of photos. All of these tools allow for a fine level of control over the way that a whale group's associated photos are displayed, which is important when analytically examining and managing the huge amounts of photos collected in the project.

An advanced photo-tagging system has been developed for this application. Biologists can create, edit, and delete custom photo-tag definitions that correspond to mark patterns commonly observed on whales. These tags can then be applied to a specific section of a whale's body or to the entire whale in general. Once the tags have been applied, they can be used in various combinations as a powerful way to search for existing animals based on mark combinations.

Photos associated to the selected whale are generally ordered by date. Various metadata are also shown along with each photo, including photo date and time, original filename, and associated beluga group count information. Controls to confirm each photo's whale association, mark a photo with a high quality "score", and add a photo label are also displayed. Finally, two diagrams that can be clicked to indicate which sections of the whale's body are captured are also displayed. The first diagram is used to indicate the presence of whale sections in a photo, and the second is used to indicate that a photo contains the best available image of a particular whale's body section.

Photos are selected by being clicked. Multiple photos can be selected, and the application support selecting ranges of photos using the shift key. Tools to select all, none, and the inverse of the current selection are also provided. Once a photo selection has been made, the selected photos can be shown in order for comparison purposes, confirmed, unconfirmed, migrated to another whale or group, or removed from the currently associated whale or group and moved back to the unmatched temporary grouping of photos.

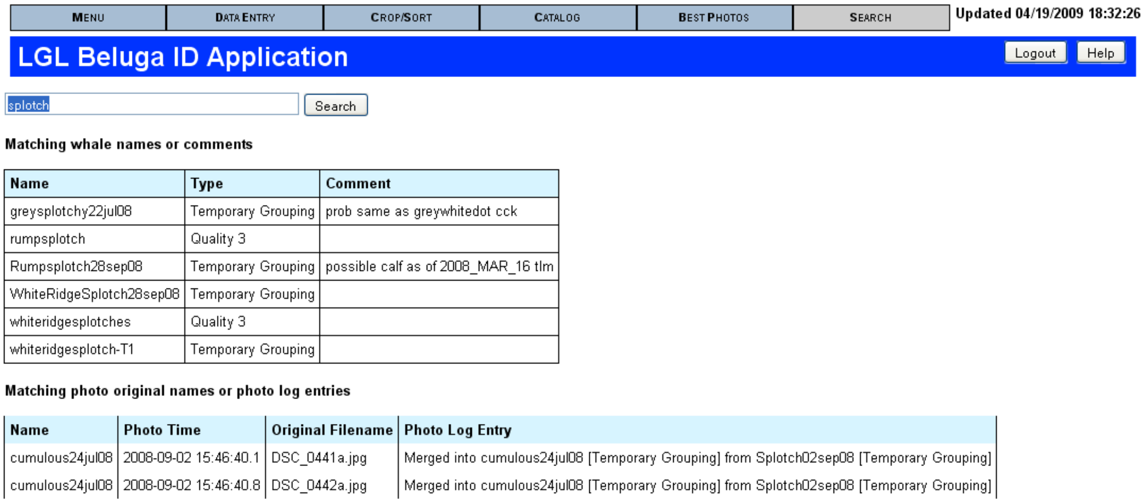
Single photos in the unmatched temporary files can be worked with in the interface in a similar way. A year, month, or date is selected from which unmatched photos will be shown. The photos can then be selected, compared with one another, and migrated to a new or existing whale or grouping.

BEST PHOTOS INTERFACE

A simple interface to display the best available photos for each individual whale folder was developed as a quick reference to be used when matching photos. Previously, project biologists manually maintained a PowerPoint® document containing reference photos for each individual. Large amounts of effort and time were required to maintain this document, search capability was limited, photo assignment changes were not captured, and file size was growing prohibitively large. The best photos interface allows biologists to select a whale's most representative photos in the catalog interface and then view them in a clean format for quick reference.

SEARCH INTERFACE

A rudimentary search interface was developed to allow for text searches of applicable whale and photo data. Whale names, whale comments, photo filenames, and



Name	Type	Comment
greysplotchy22jul08	Temporary Grouping	prob same as greywhitedot cck
rumpsplotch	Quality 3	
Rumpsplotch28sep08	Temporary Grouping	possible calf as of 2008_MAR_16 tlm
WhiteRidgeSplotch28sep08	Temporary Grouping	
whiteridgesplotches	Quality 3	
whiteridgesplotch-T1	Temporary Grouping	

Name	Photo Time	Original Filename	Photo Log Entry
cumulous24jul08	2008-09-02 15:46:40.1	DSC_0441a.jpg	Merged into cumulous24jul08 [Temporary Grouping] from Splotch02sep08 [Temporary Grouping]
cumulous24jul08	2008-09-02 15:46:40.8	DSC_0442a.jpg	Merged into cumulous24jul08 [Temporary Grouping] from Splotch02sep08 [Temporary Grouping]

Figure A6. Information page for uncataloged whale folders in the beluga photo-id application.

photo log entries (automatically created when a photo is matched to a whale or group) are searched according to an entered text string.

REPORTING

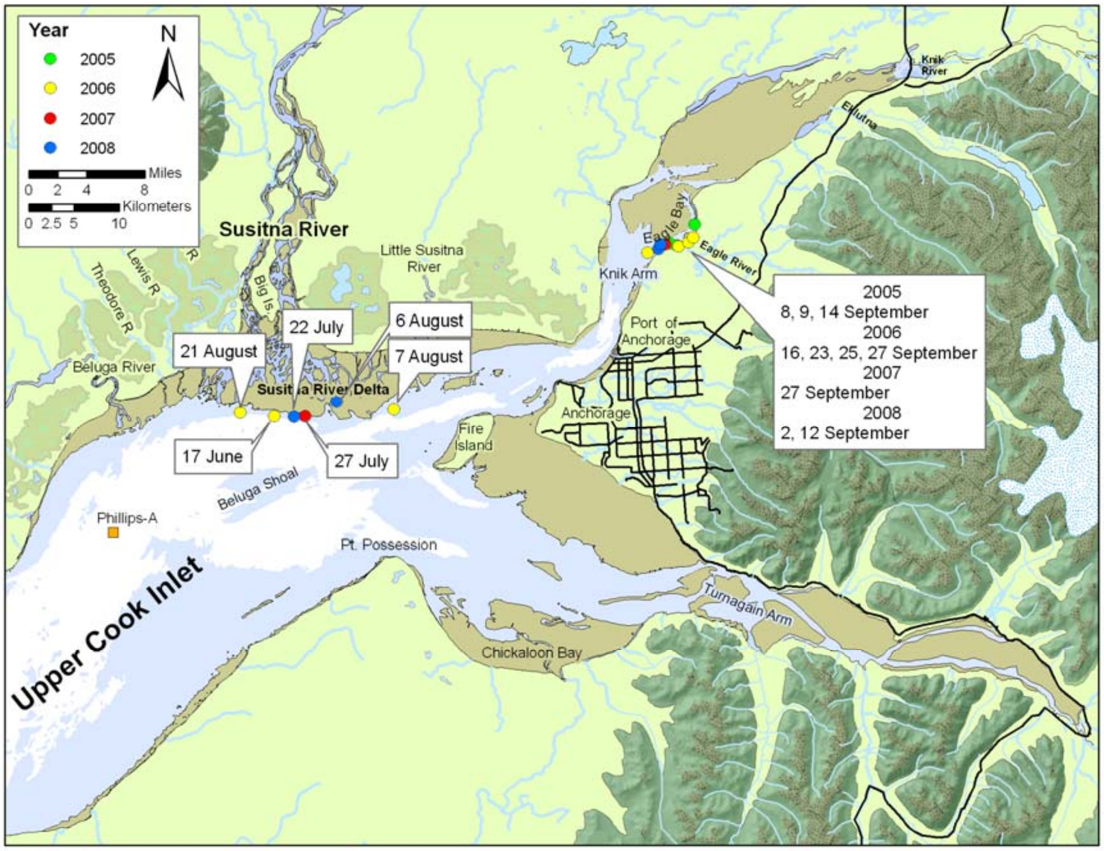
One of the greatest benefits of storing data in a database is the speed and ease with which complicated report summaries can be generated. Data validation and large scale manipulation, analysis, and correction of datasets allow for meaningful reporting. Standardized report outputs can be set up once and then generated instantly an unlimited number of times with no additional human effort. Several reports have been created for the beluga application to summarize data. These reports summarize surveys, beluga groups, individual whale attributes, whale sightings, and summaries by year. The reporting framework that has been developed allows for additional biologist requested reports to be easily added to the application.

GEOSPATIAL PROCESSING

Uploaded survey GPS tracks are now processed and stored as geospatial data within the database of the application. This allows photos to be linked to specific coordinates based on time. Survey tracks can also be plotted on maps, and a rudimentary track display has been added to the survey data entry interface. By linking survey efforts, beluga group sightings, photos, and whales with spatial and temporal information, a wide range of future analyses and data visualizations is possible.

APPENDIX B.

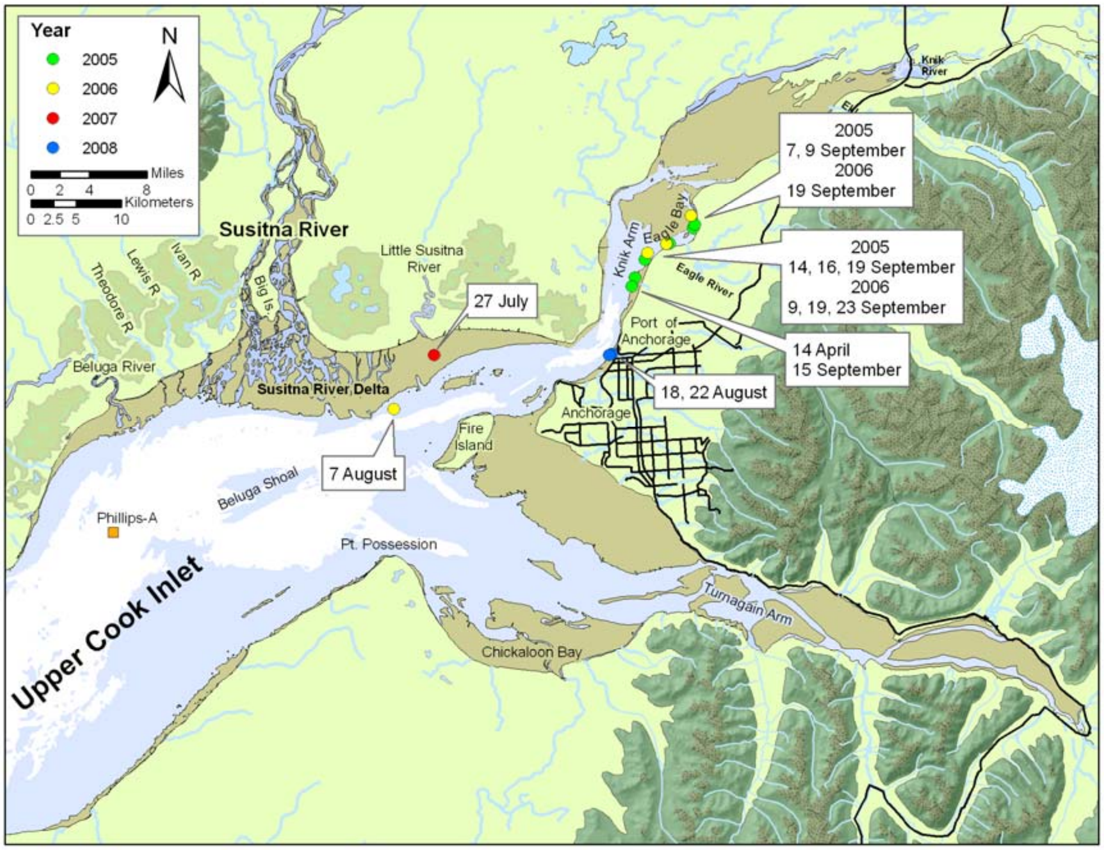
INDIVIDUAL SIGHTINGS HISTORY MAPS OF CATALOGED WHALES SEEN IN ALL FOUR YEARS OF THE STUDY, ALONG WITH A PHOTOGRAPH OF THE RIGHT SIDE OF EACH INDIVIDUAL



a.

b.

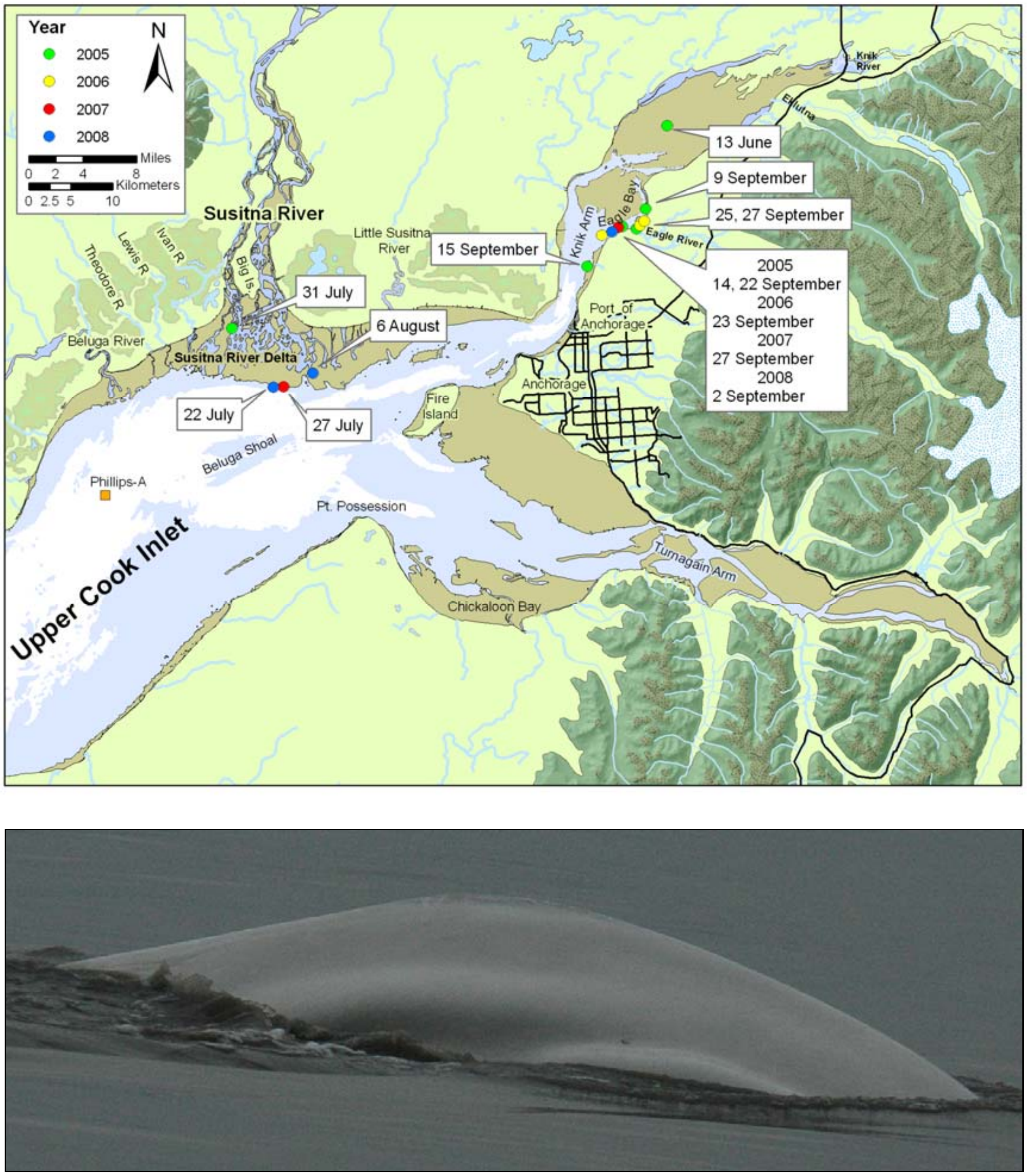
Figure B1. Sighting history (a) and photograph (b) of beluga RA 001.



a

b.

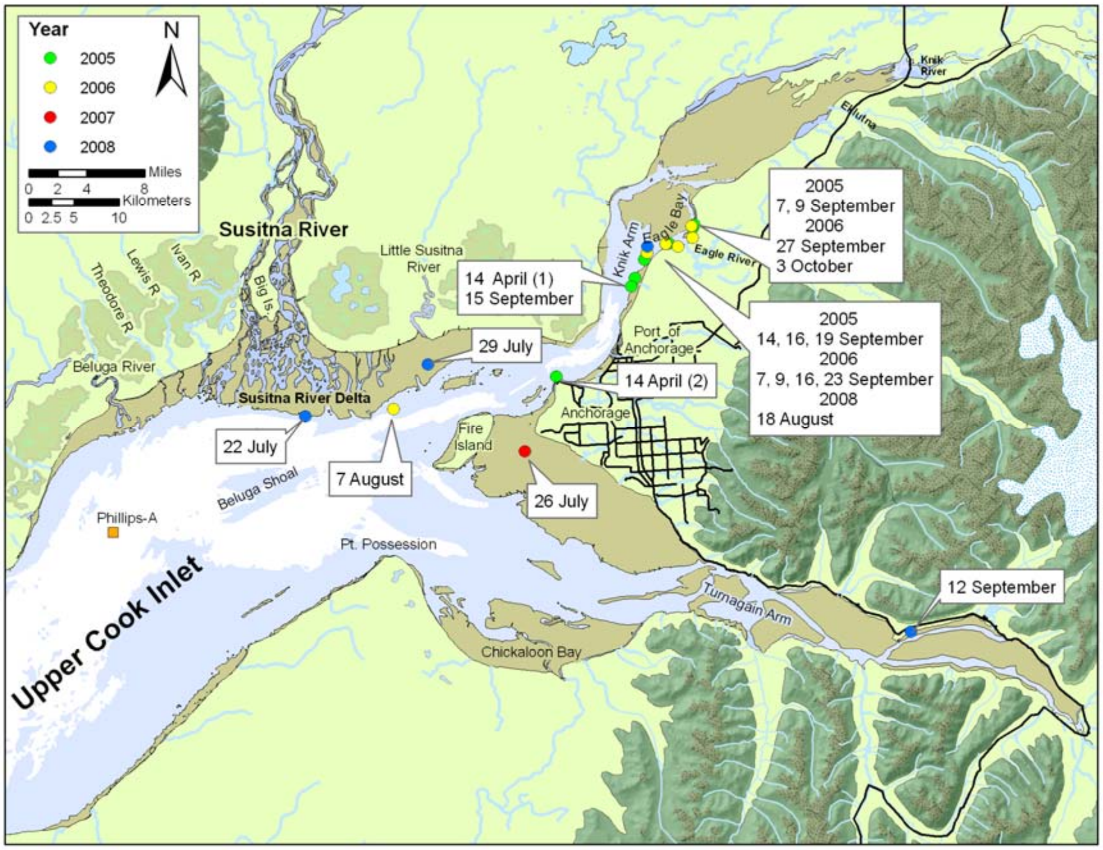
Figure B2. Sighting history (a) and photograph (b) of beluga RA 002.



a.

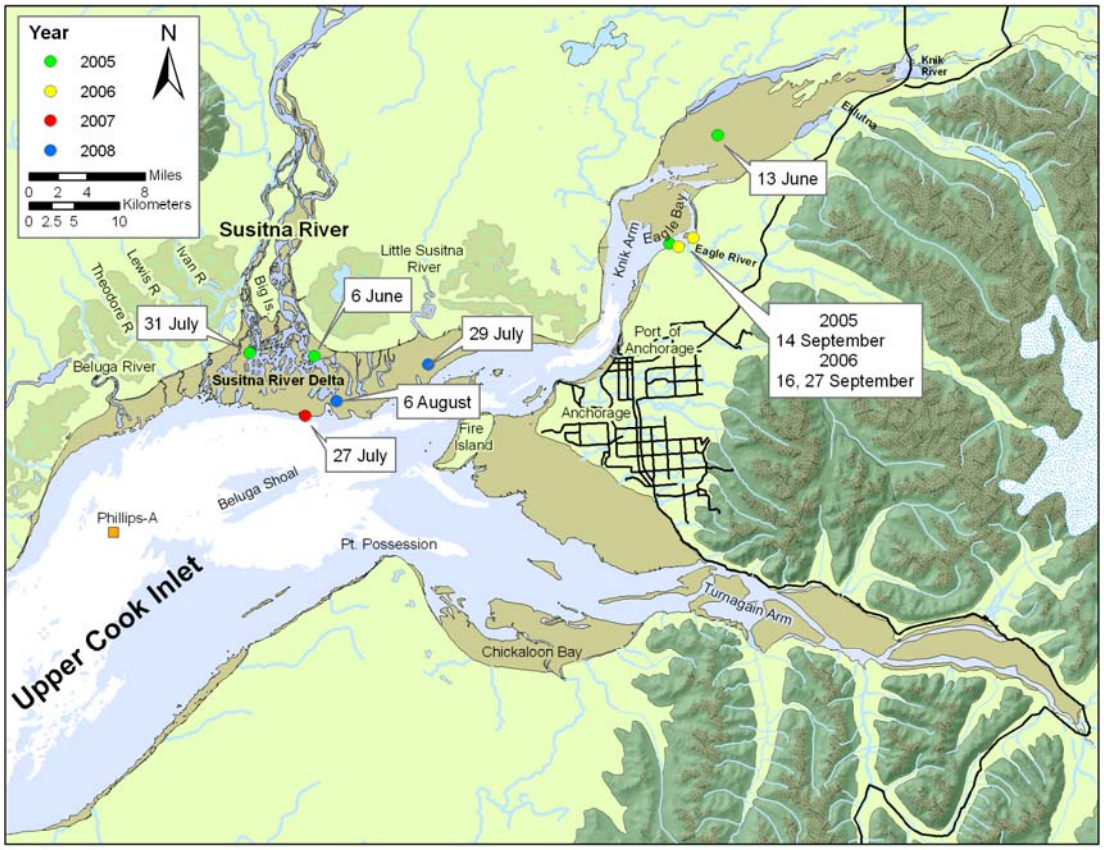
b.

Figure B3. Sighting history (a) and photograph (b) of beluga RA 009.

a.


b.

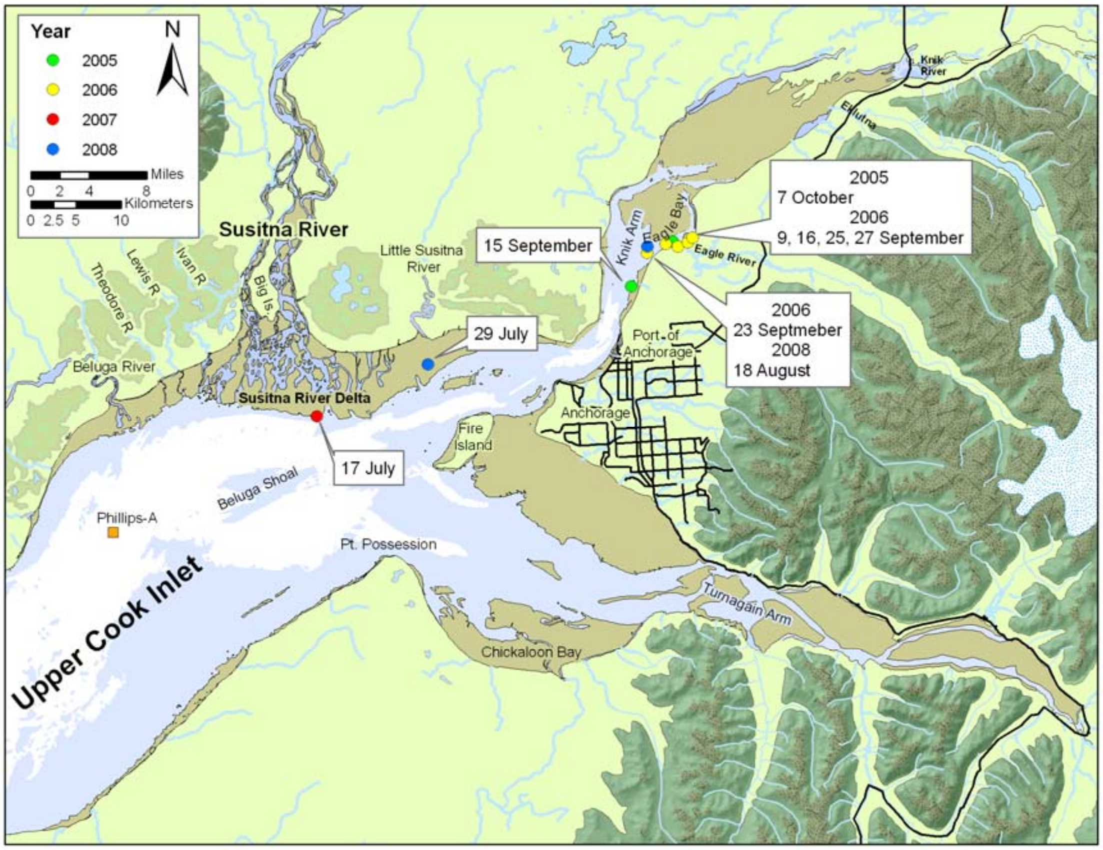

Figure B4. Sighting history (a) and photograph (b) of beluga RA 013.



a.

b.

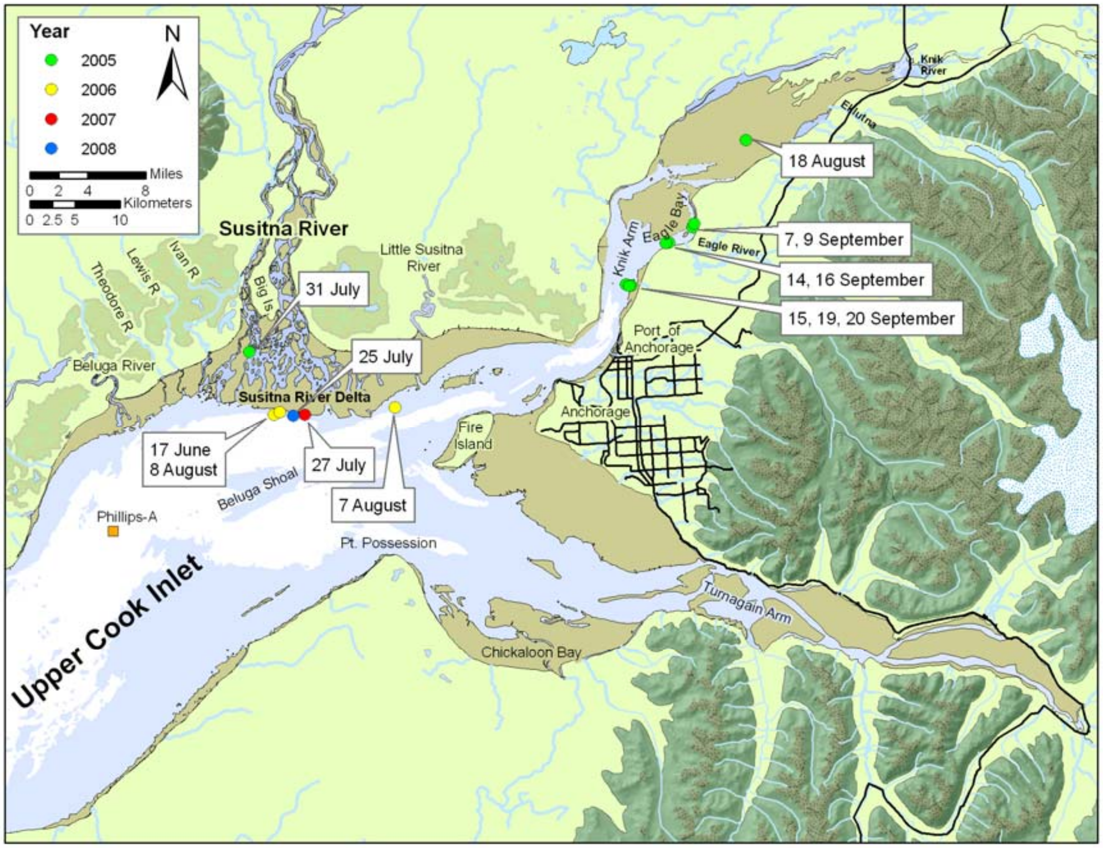
Figure B5. Sighting history (a) and photograph (b) of beluga RA 025.



a.


b.

Figure B6. Sighting history (a) and photograph (b) of beluga RA 029.

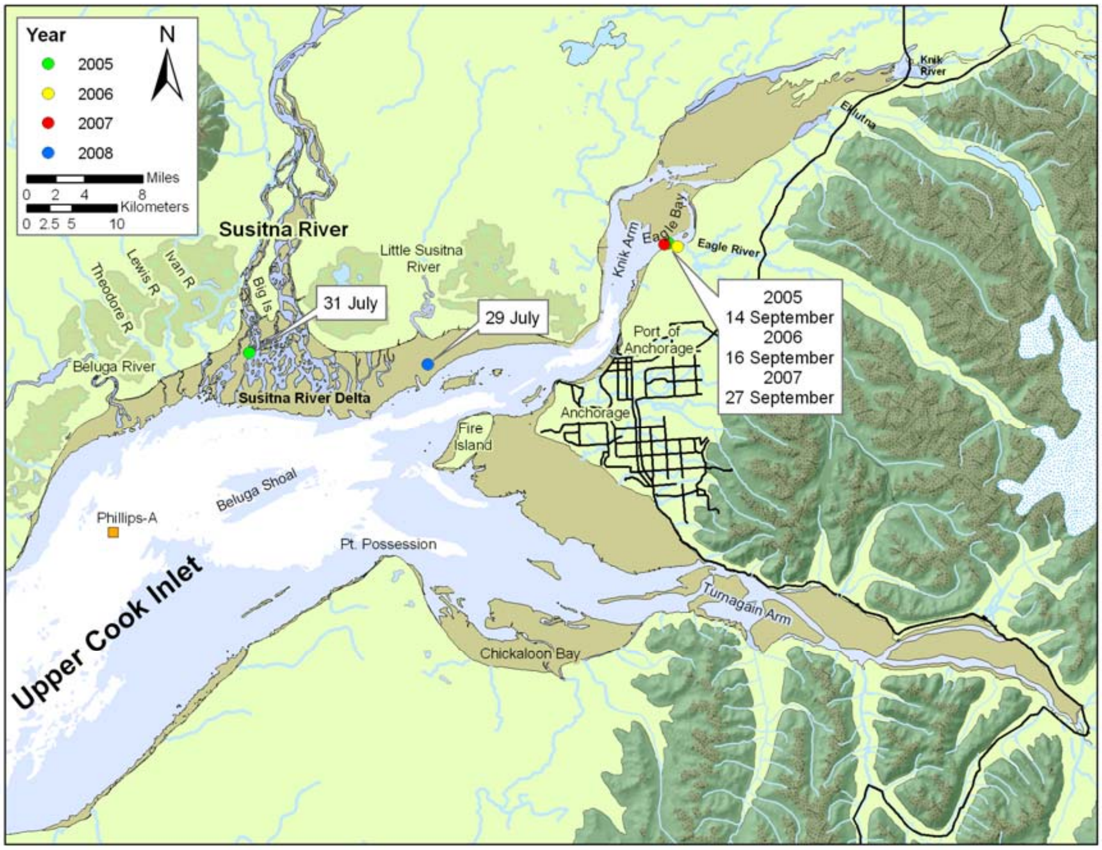


a.

b.

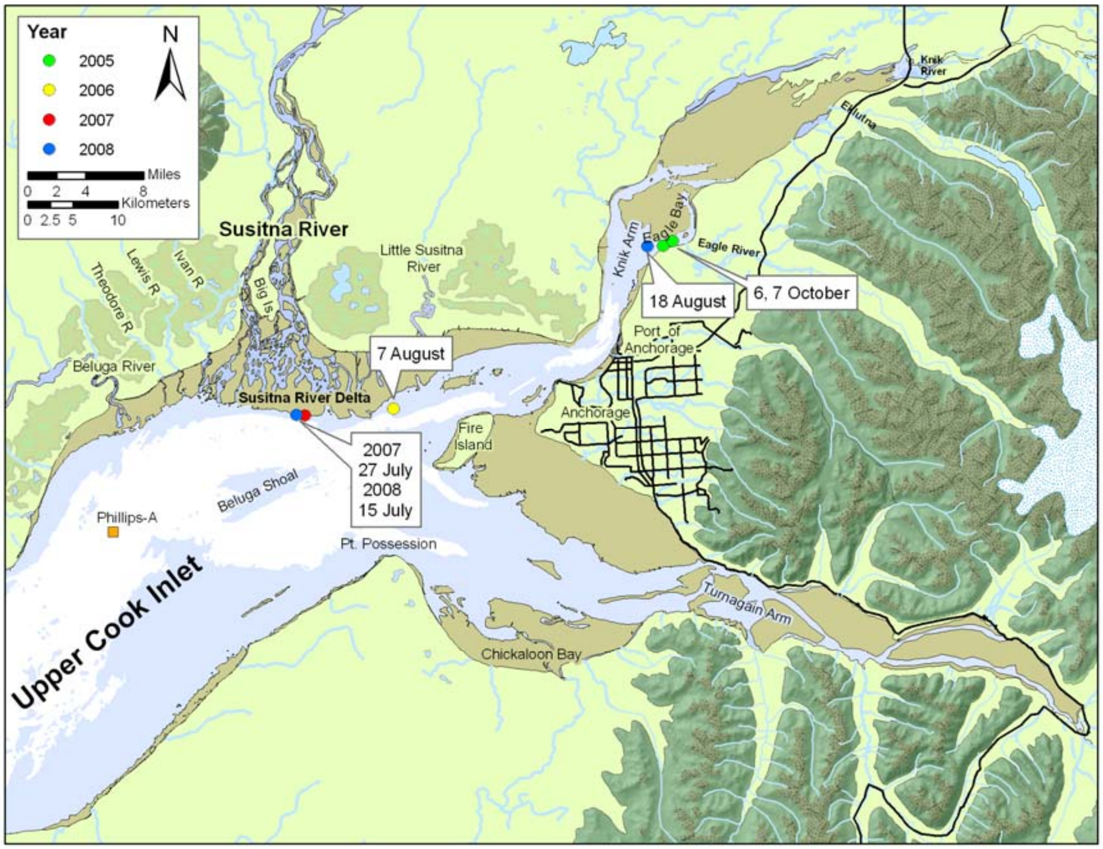
Figure B7. Sighting history (a) and photograph (b) of beluga RA 036.

a.



b.

Figure B8. Sighting history (a) and photograph (b) of beluga RA 054.

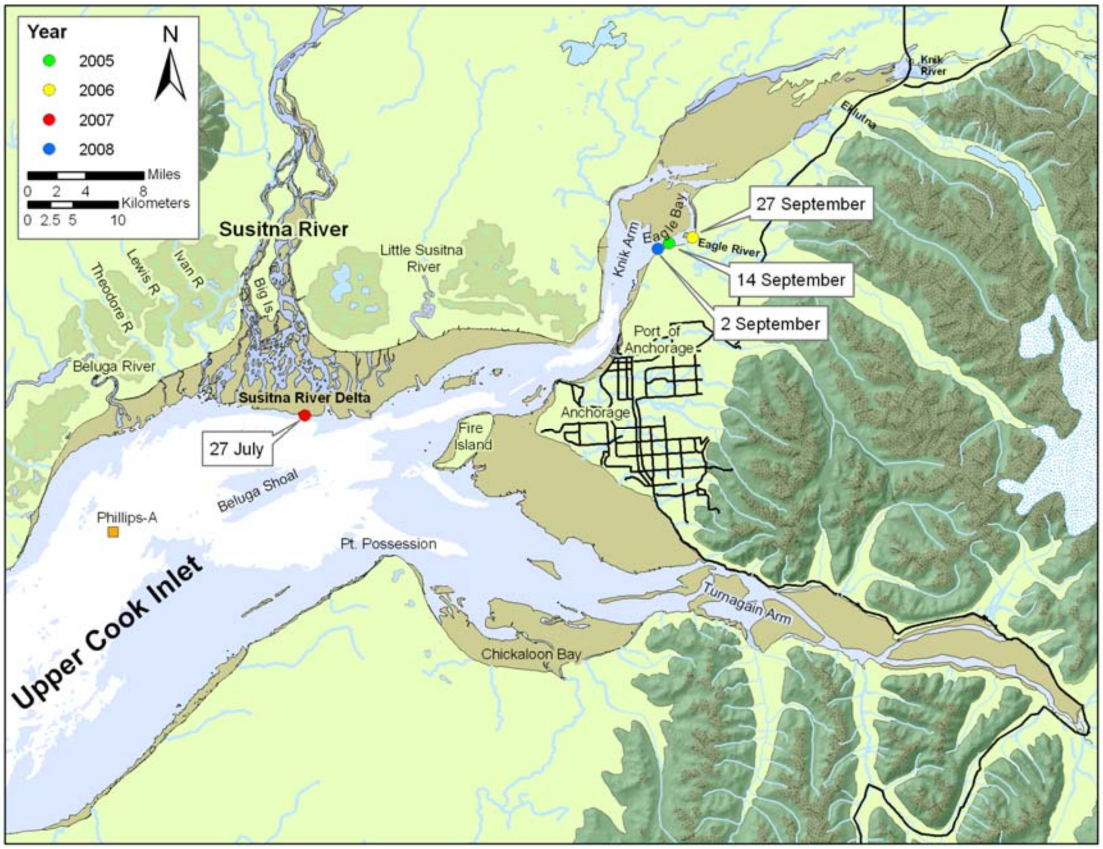


a.

b.

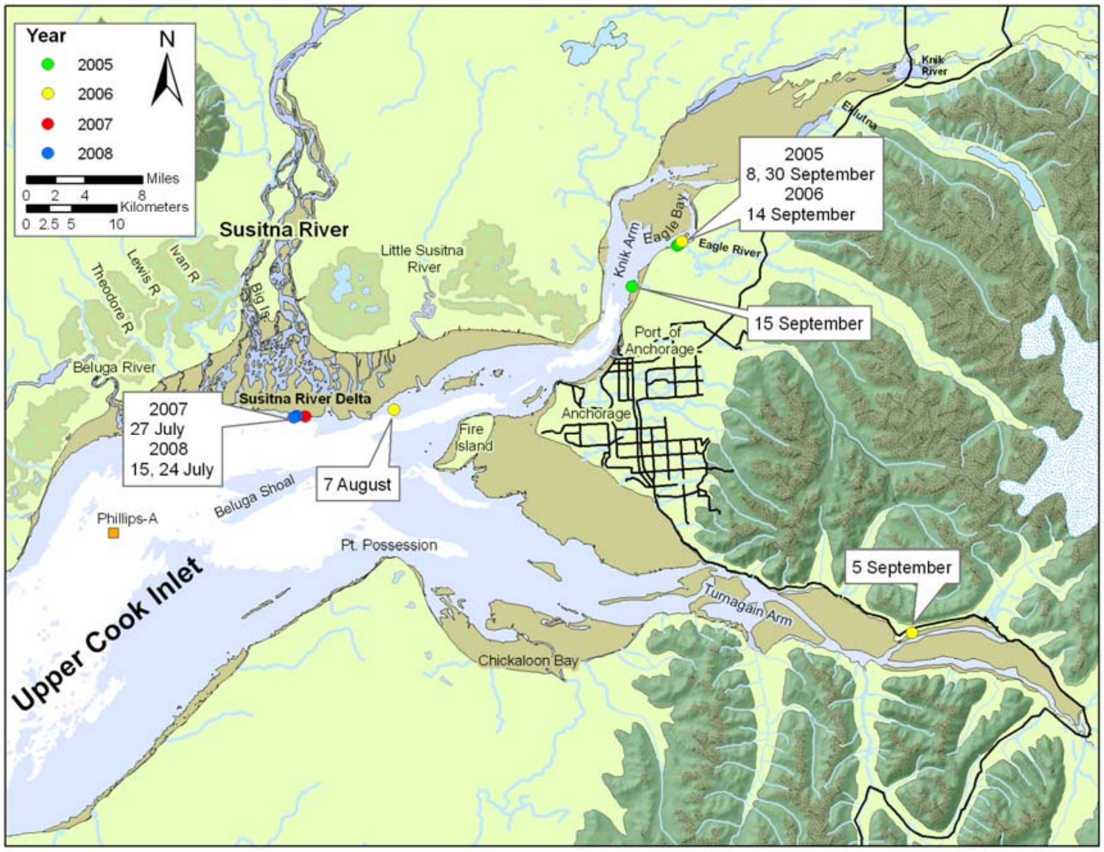
Figure B9. Sighting history (a) and photograph (b) of beluga RA 063.

a.



b.

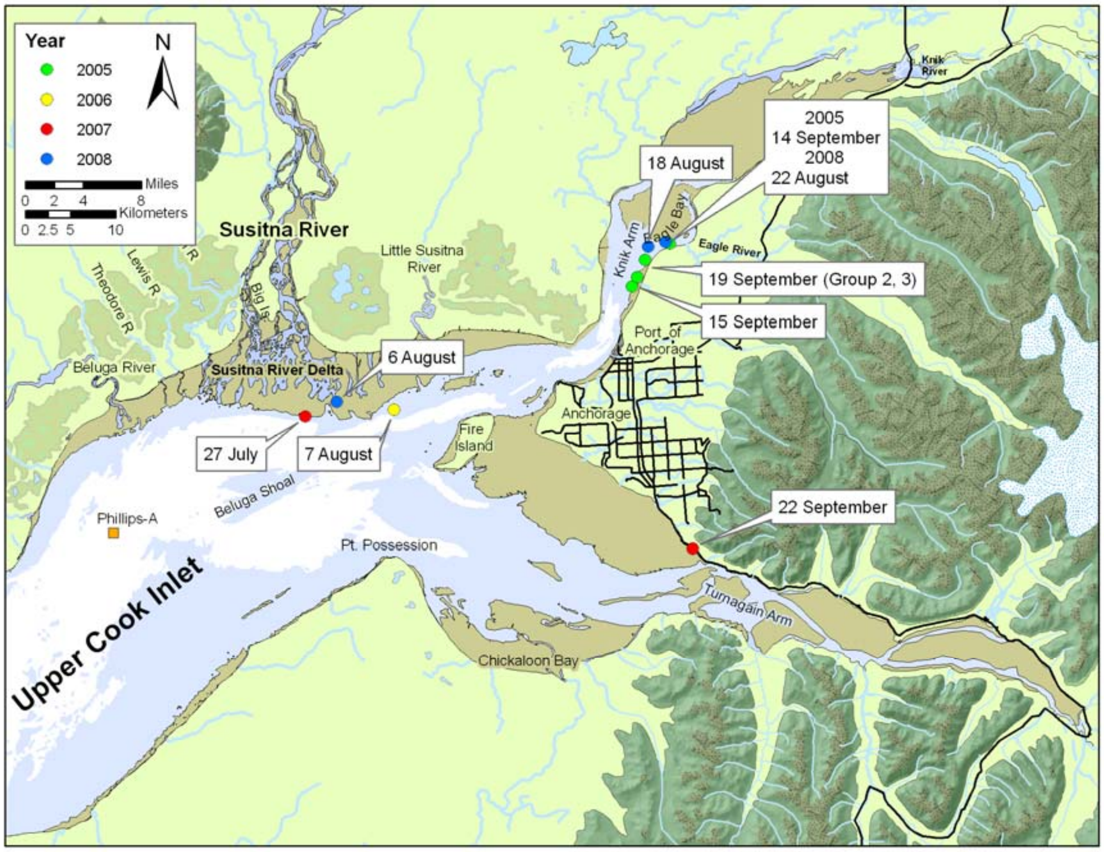
Figure B10. Sighting history (a) and photograph (b) of beluga RA 066.



a.

b.

Figure B11. Sighting history (a) and photograph (b) of beluga RA 100.

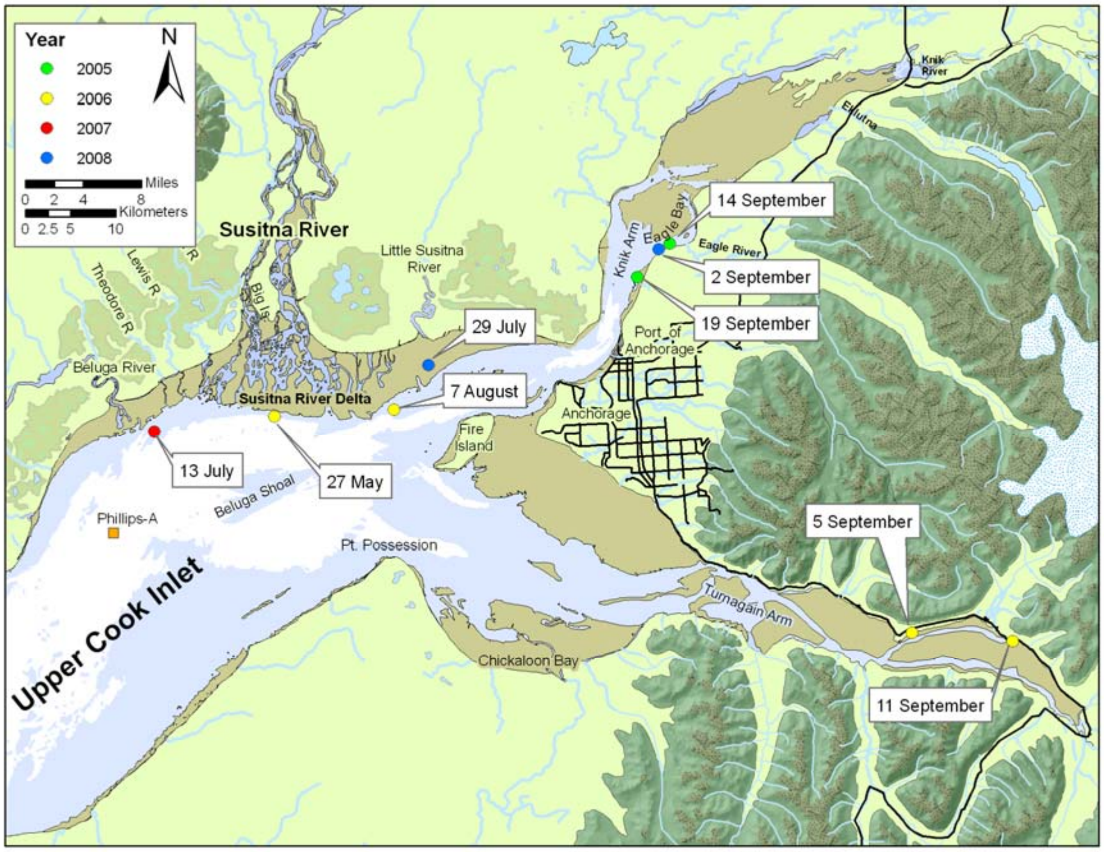


a.

b.

Figure B12. Sighting history (a) and photograph (b) of beluga RA 102.

a.



b.

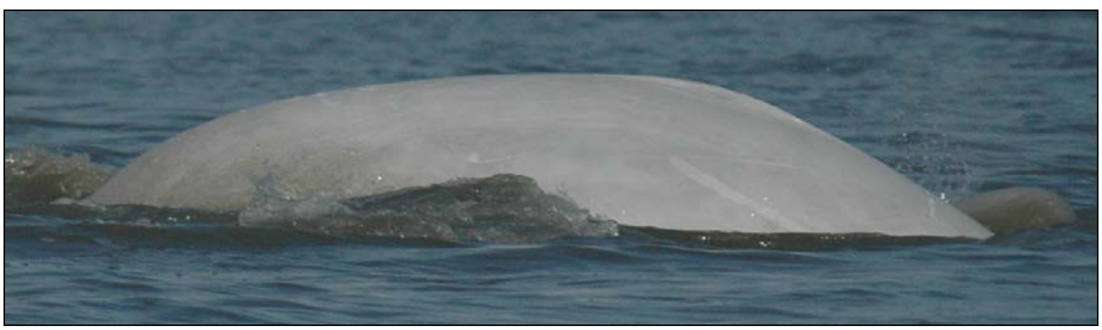
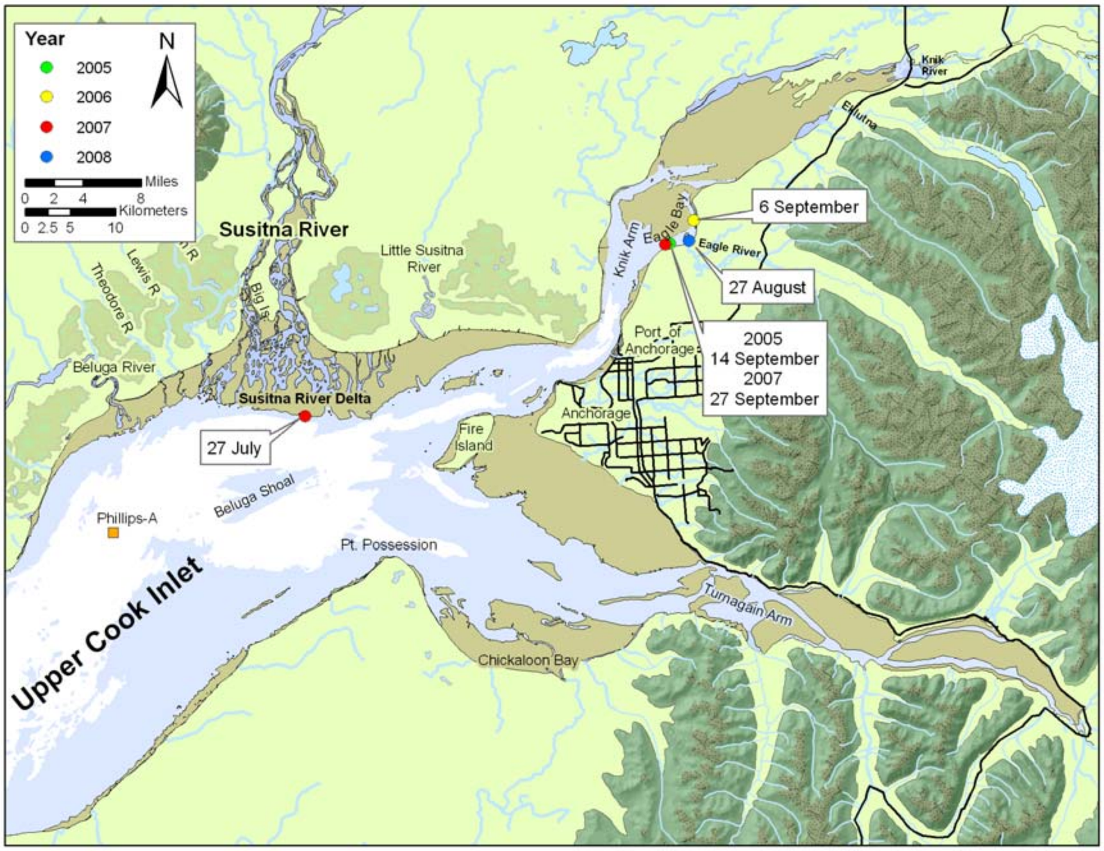


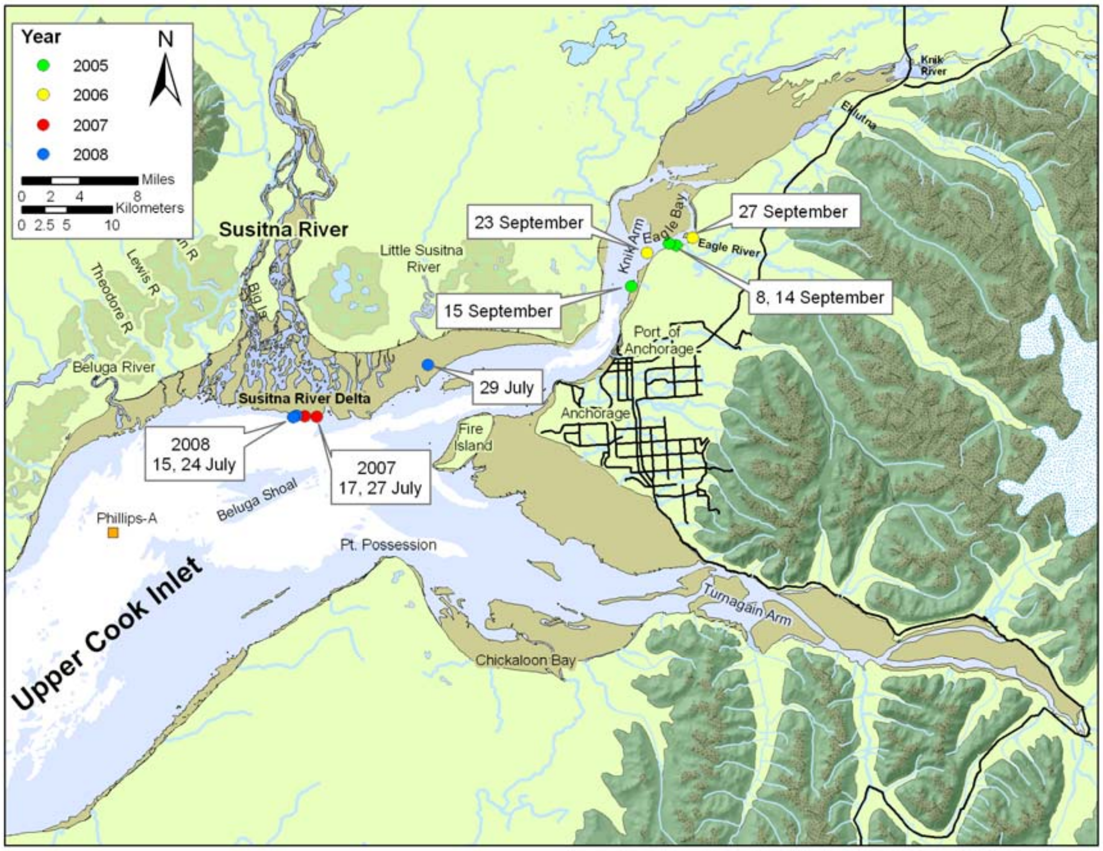
Figure B13. Sighting history (a) and photograph (b) of beluga RA 123.



a.

b.

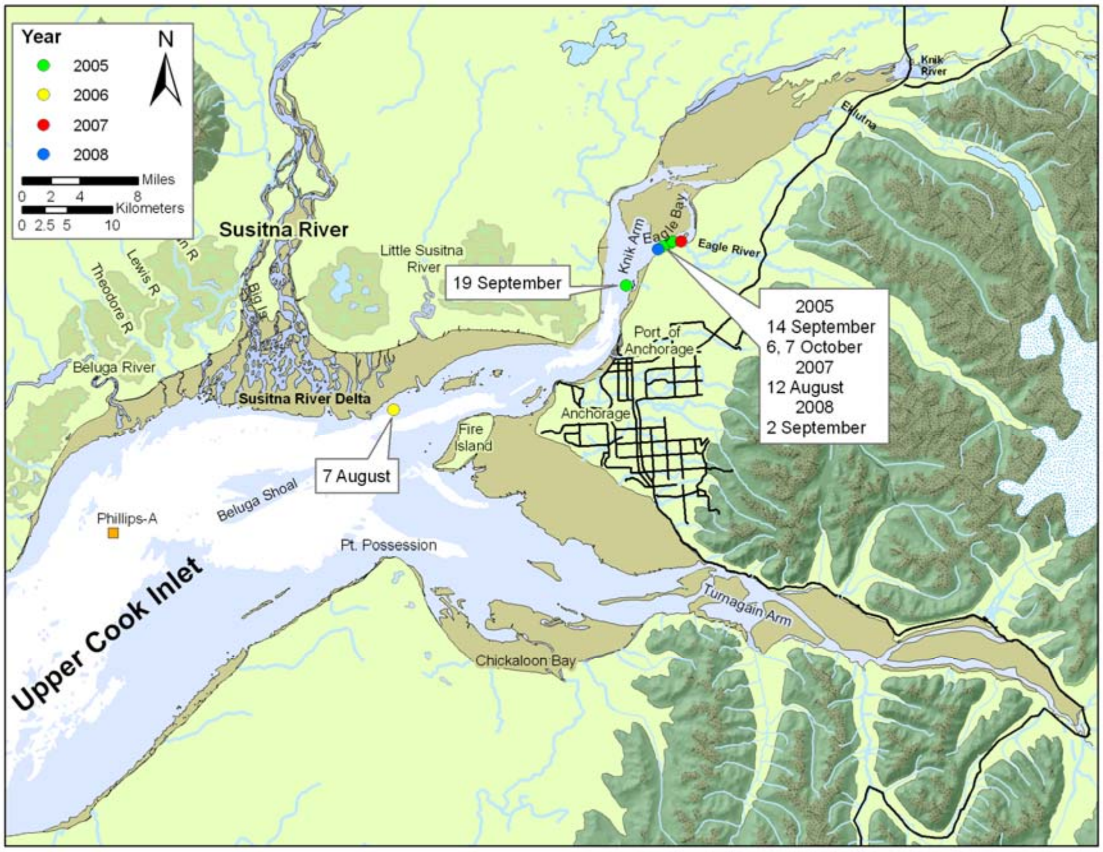
Figure B14. Sighting history (a) and photograph (b) of beluga RA 132.



a.

b.

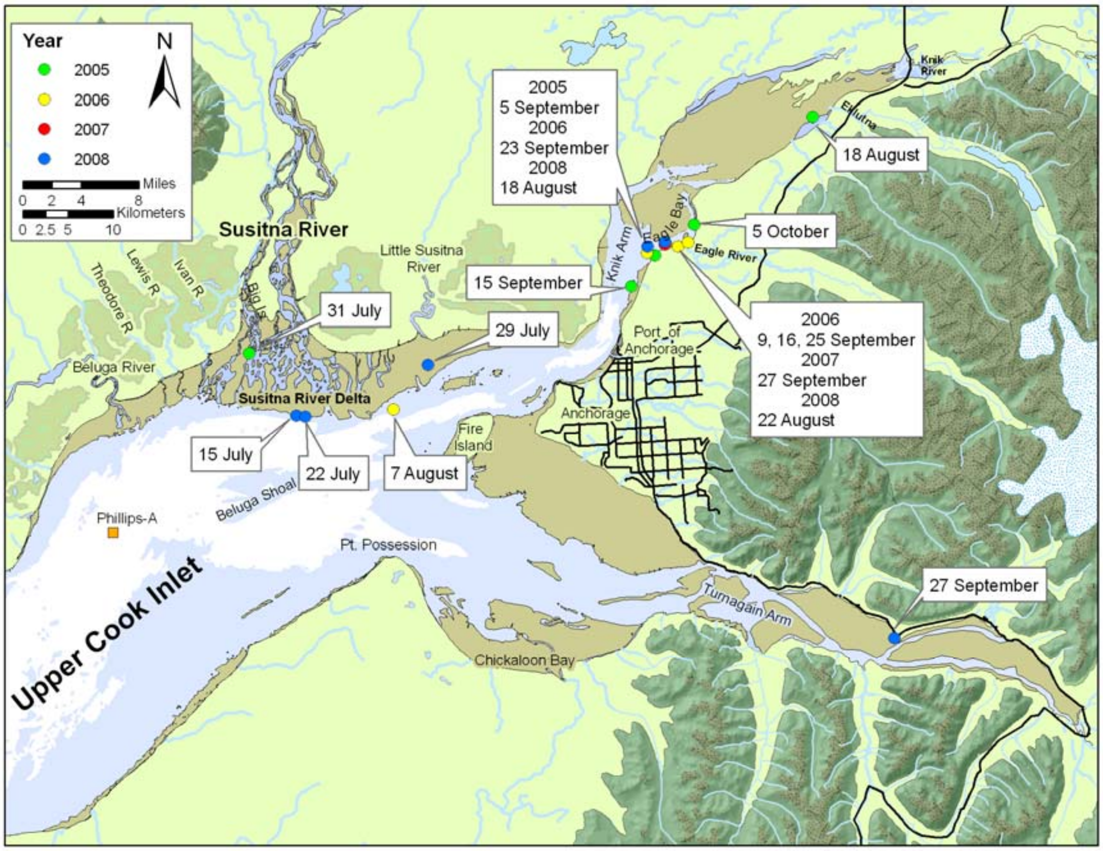
Figure B15. Sighting history (a) and photograph (b) of beluga RA 145.



a.


b.

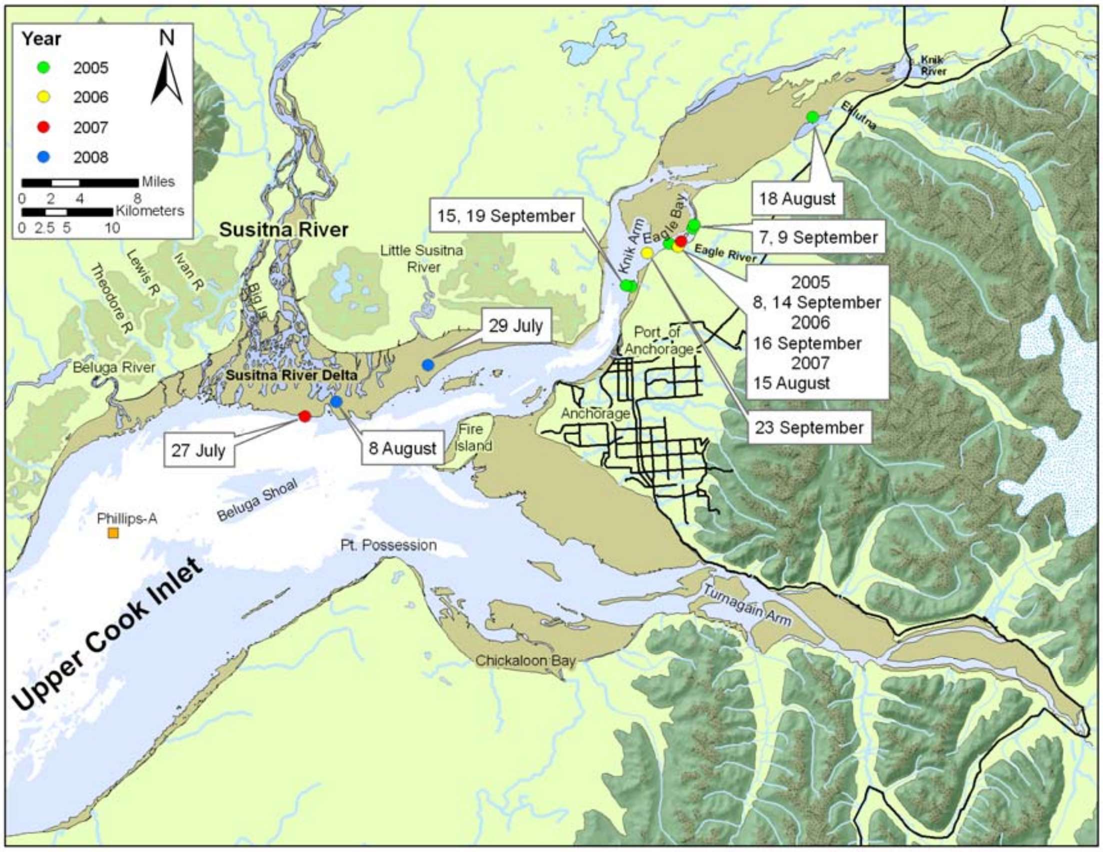
Figure B16. Sighting history (a) and photograph (b) of beluga RA 147. This beluga was tagged by NMFS sometime between 1999 and 2002.



a.

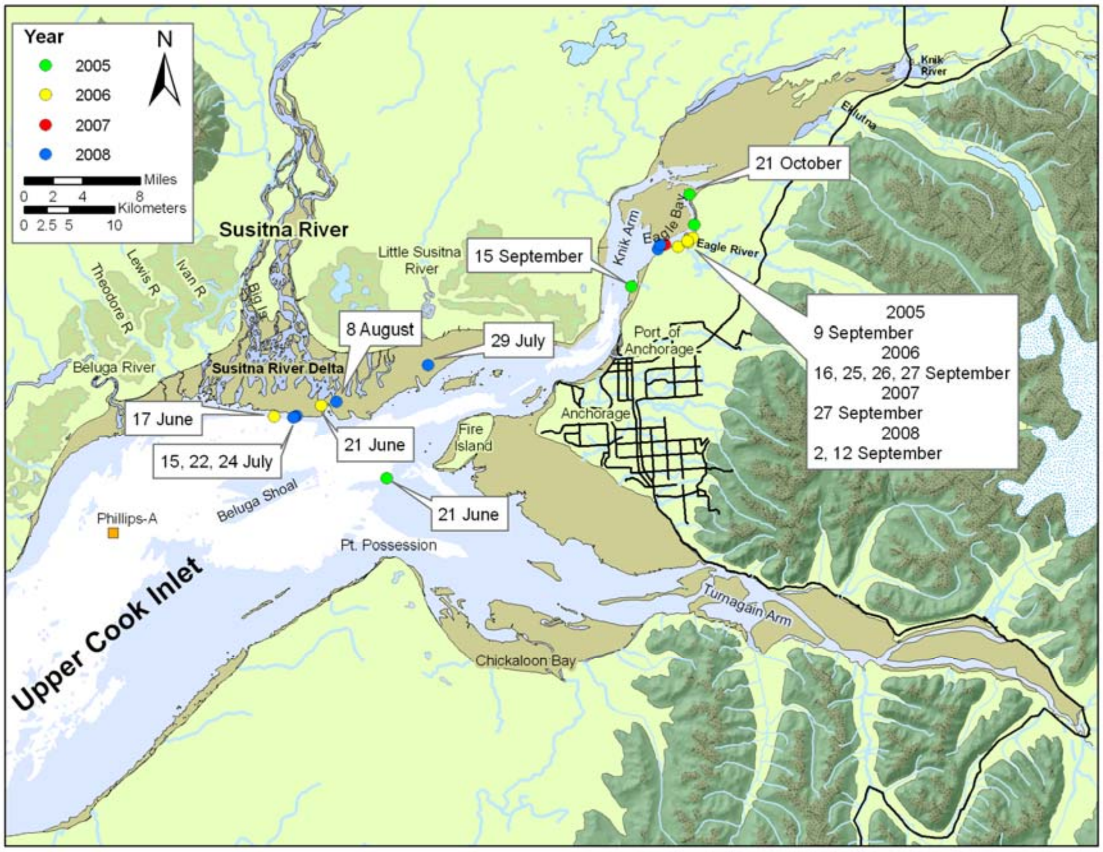
b.

Figure B17. Sighting history (a) and photograph (b) of beluga RA 148. This beluga was tagged by NMFS sometime between 1999 and 2002.

a.


b.

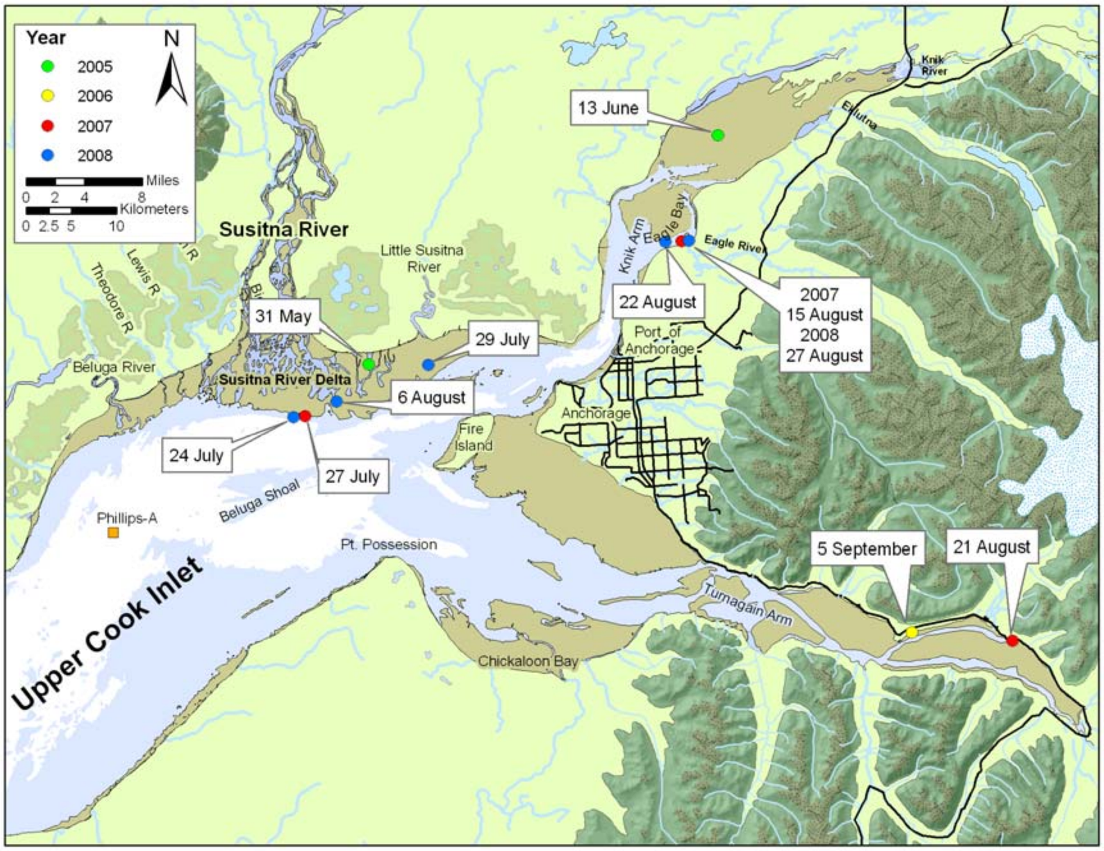

Figure B18. Sighting history (a) and photograph (b) of beluga RA 154.



a.

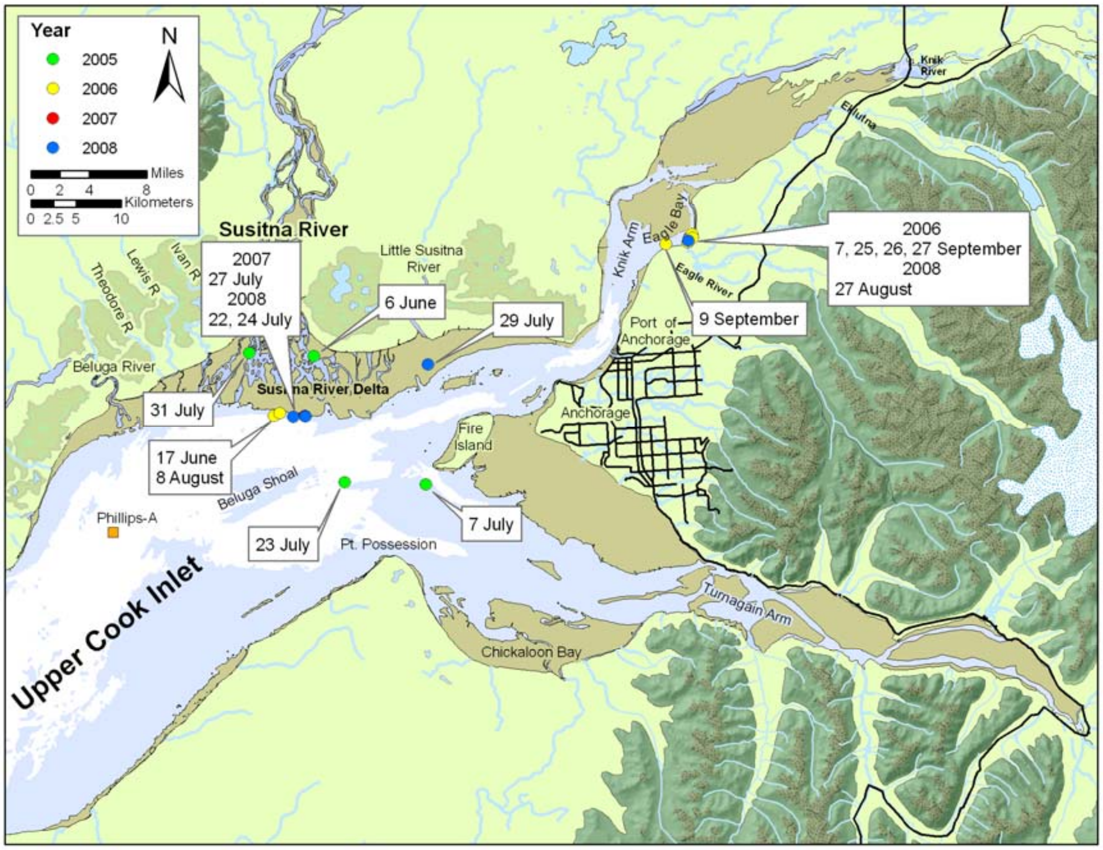

b.

Figure B19. Sighting history (a) and photograph (b) of beluga RA 155.

a.


b.


Figure B20. Sighting history (a) and photograph (b) of beluga RA 160. This beluga was tagged by NMFS sometime between 1999 and 2002.

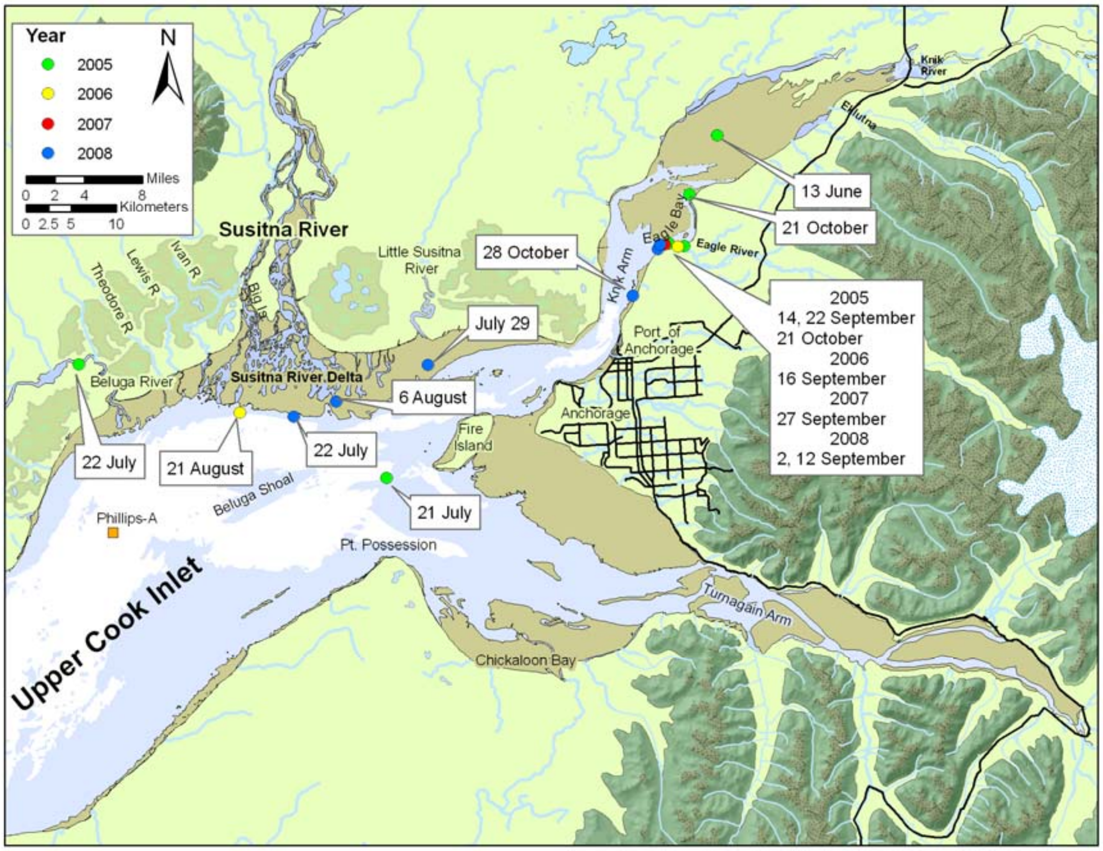


a.

b.

Figure B21. Sighting history (a) and photograph (b) of beluga RS 002.

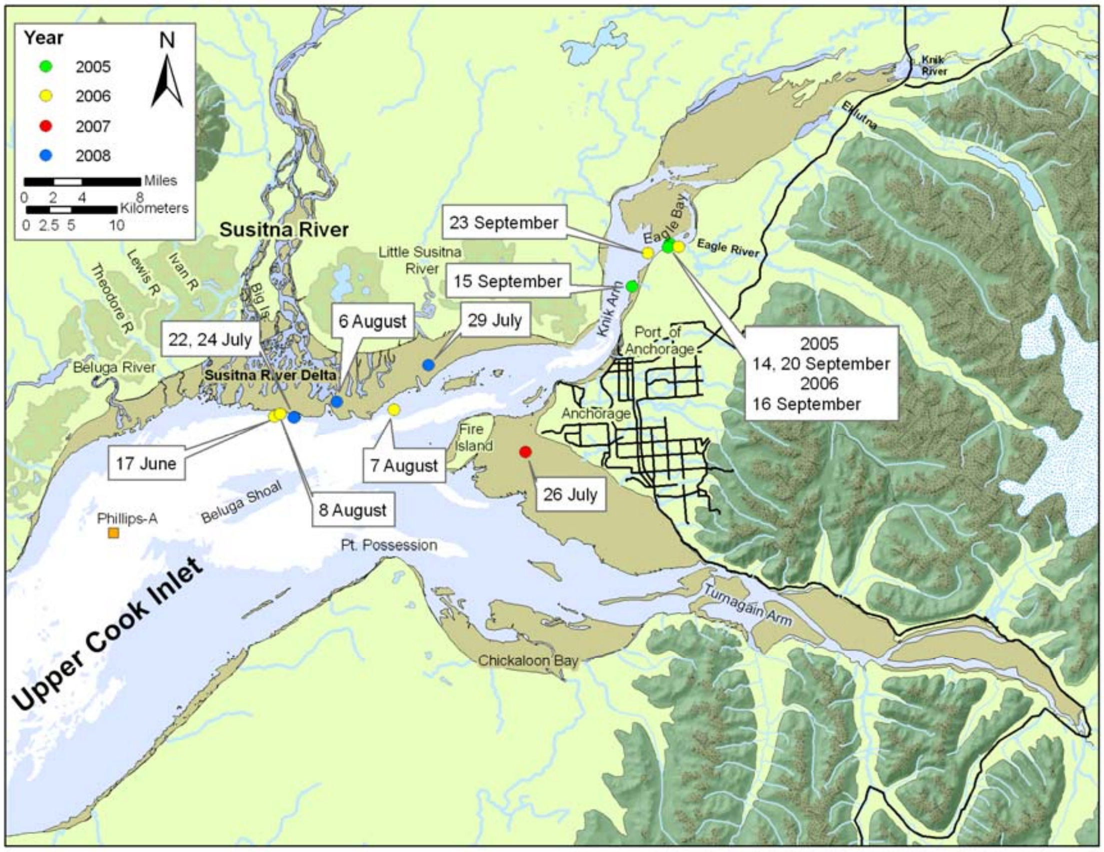
a.



b.

Figure B22. Sighting history (a) and photograph (b) of beluga RS 044.

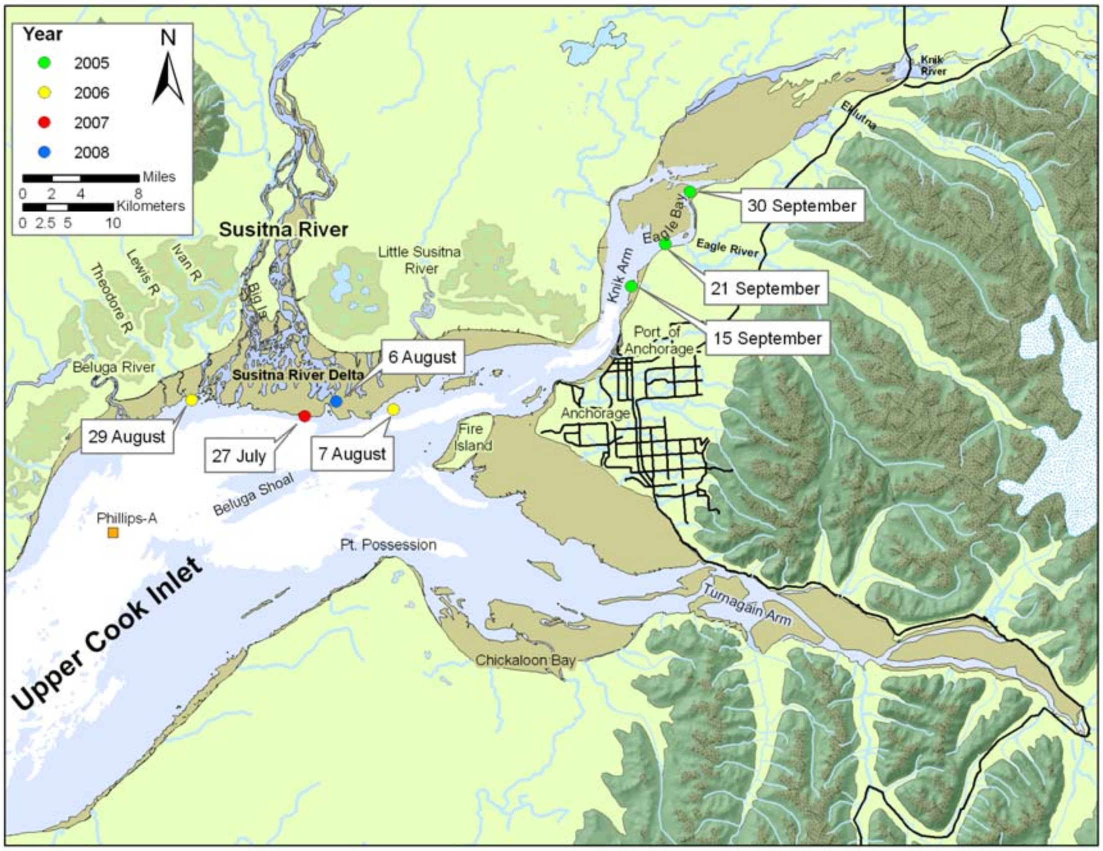
a.



b.

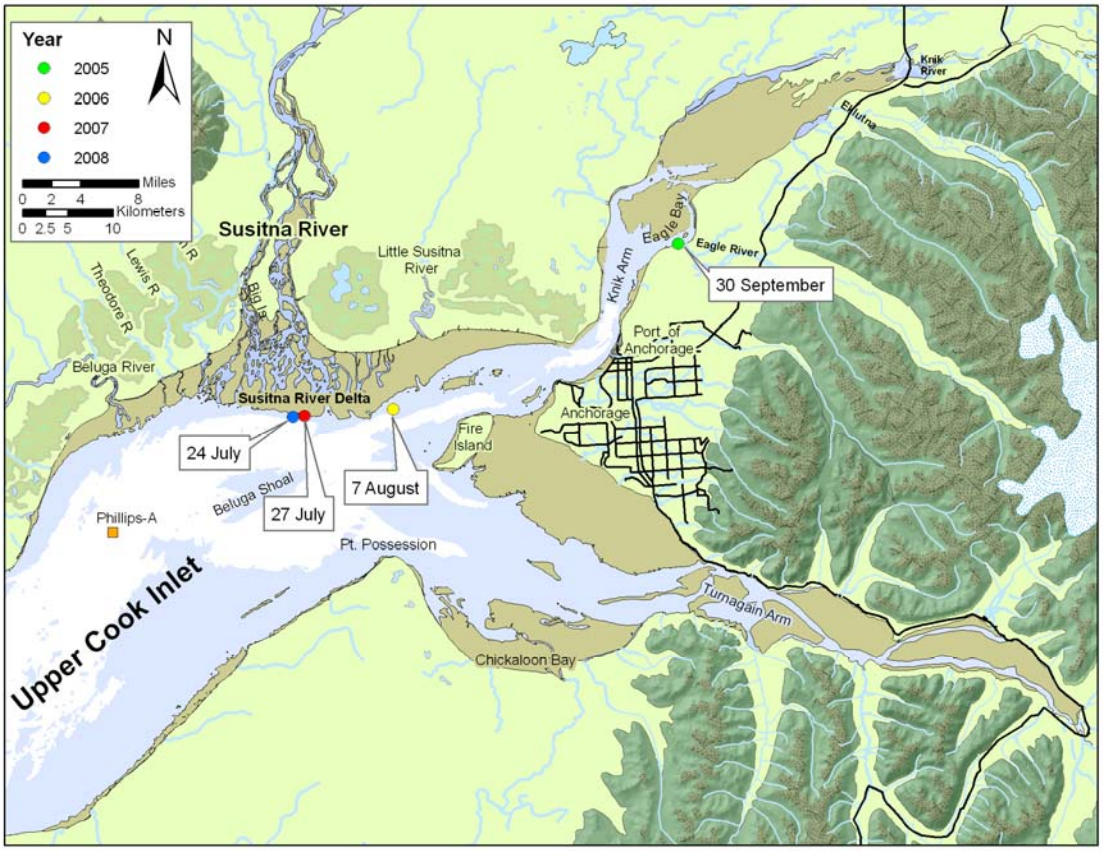
Figure B23. Sighting history (a) and photograph (b) of beluga RS 110.

a.



b.

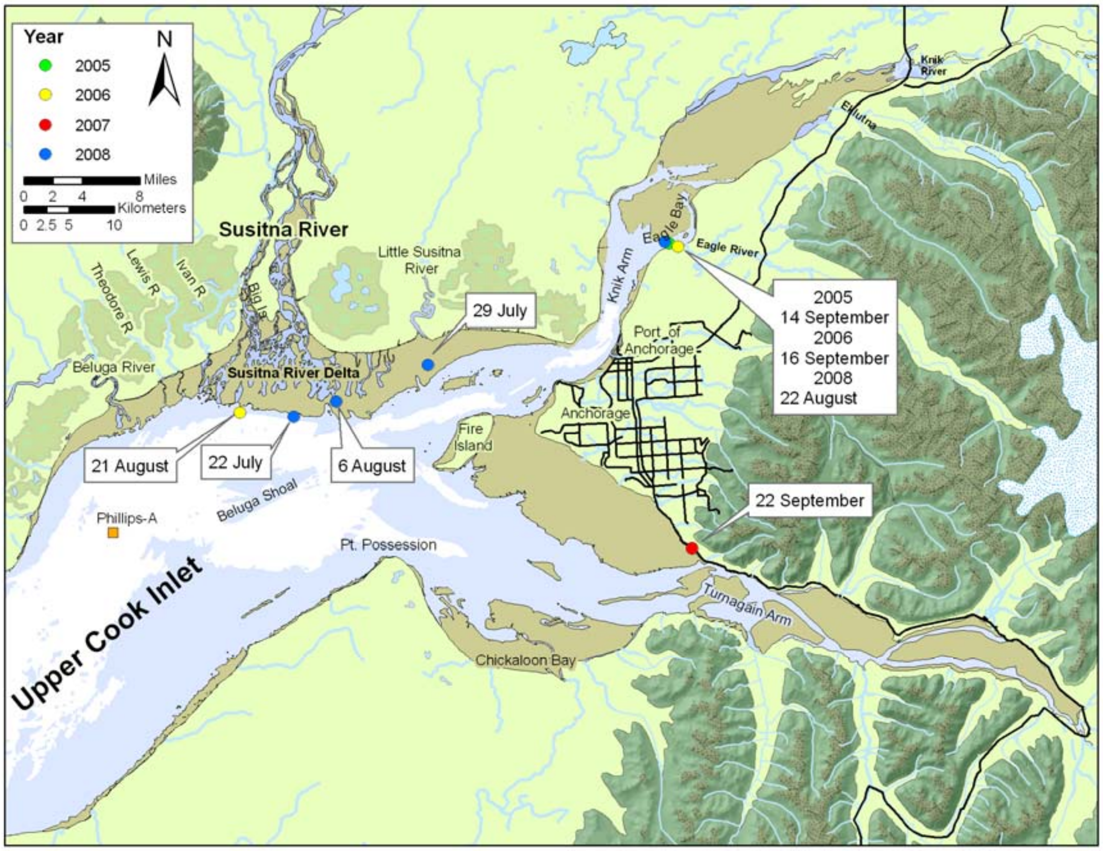
Figure B24. Sighting history (a) and photograph (b) of beluga RS 118.



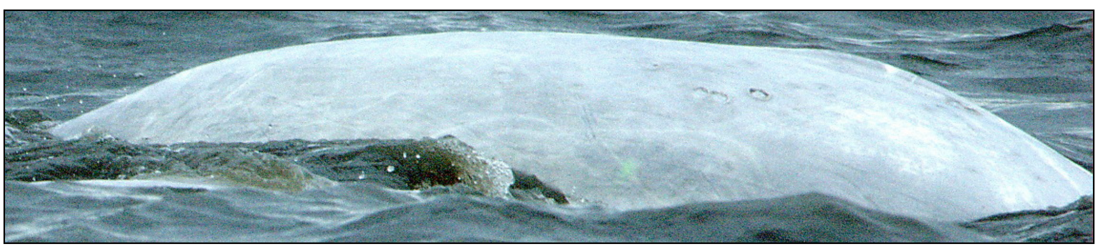
a.

b.

Figure B25. Sighting history (a) and photograph (b) of beluga RS 124.



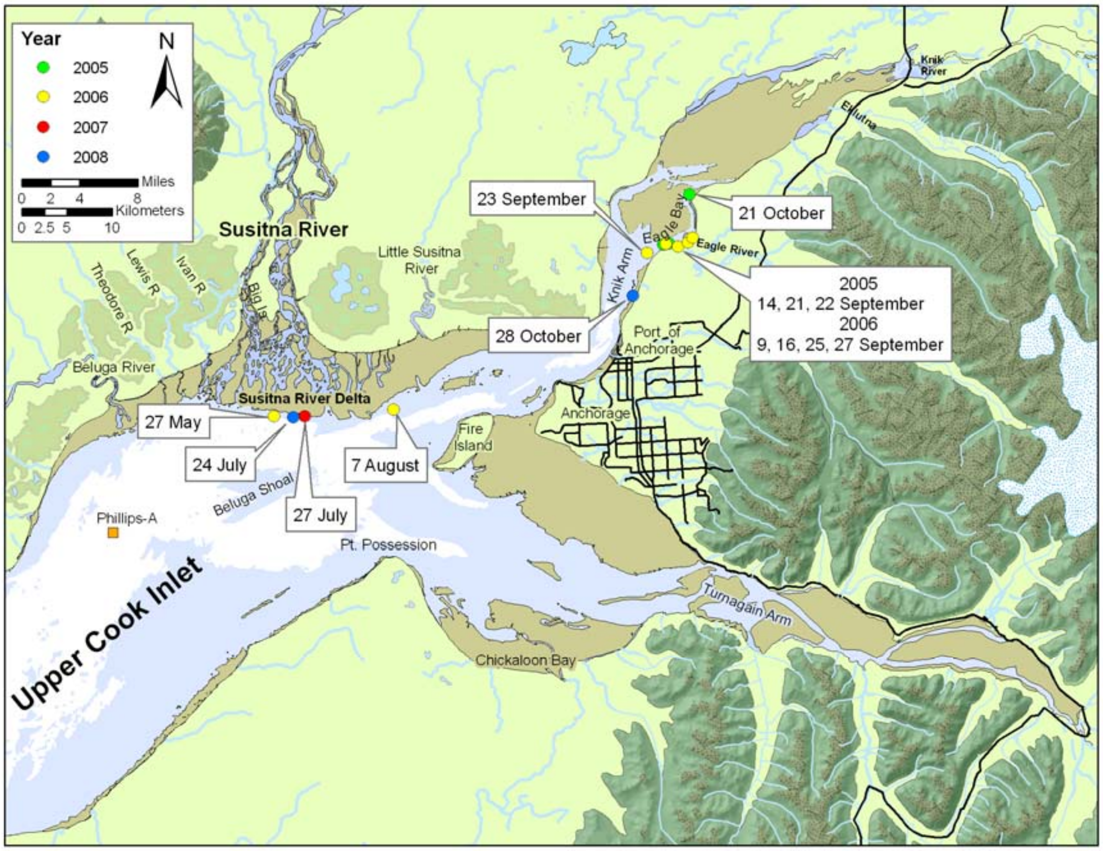
a.



b.

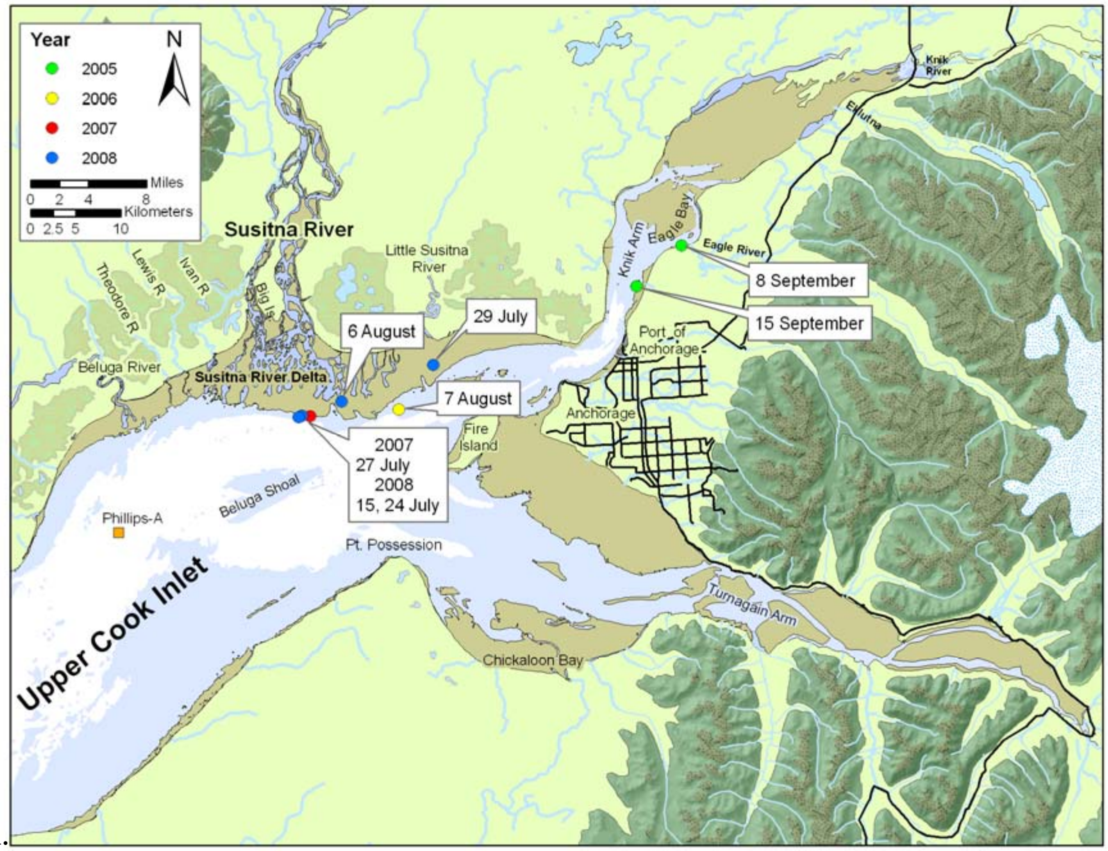
Figure B26. Sighting history (a) and photograph (b) of beluga RS 134.

a.



b.

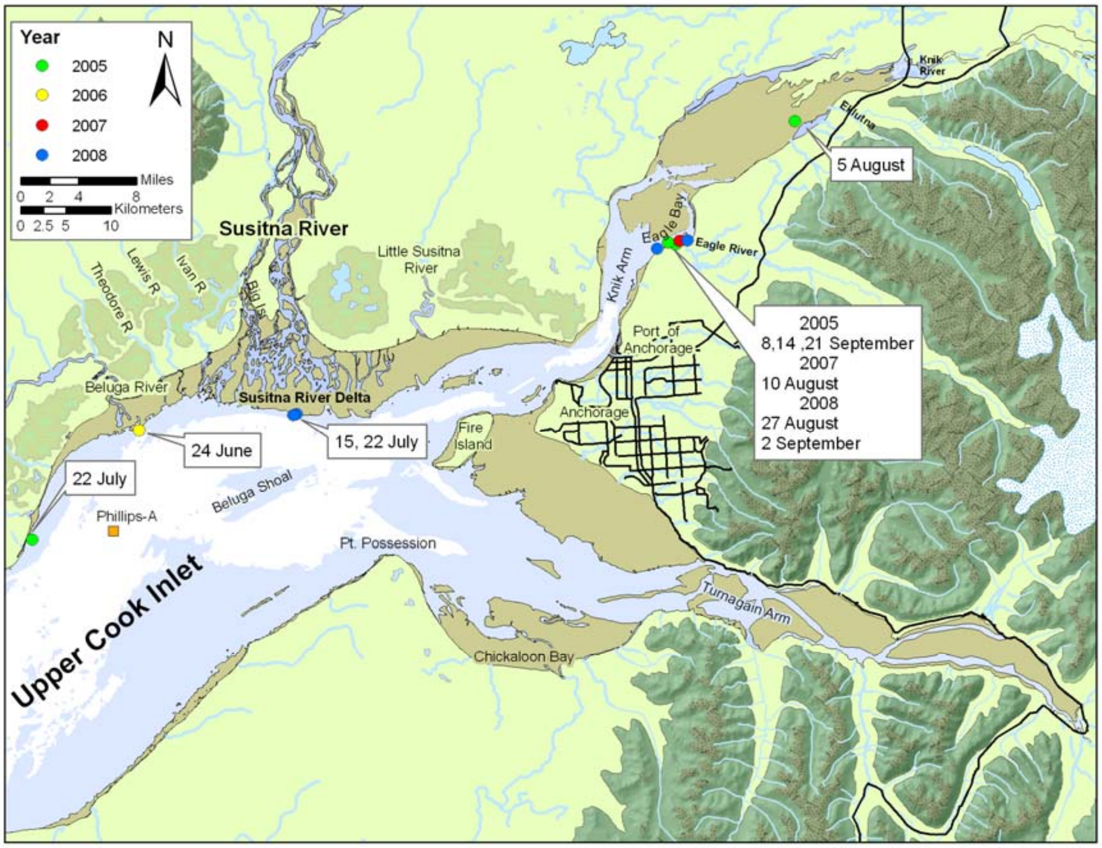
Figure B27. Sighting history (a) and photograph (b) of beluga RS 139.



a.


b.

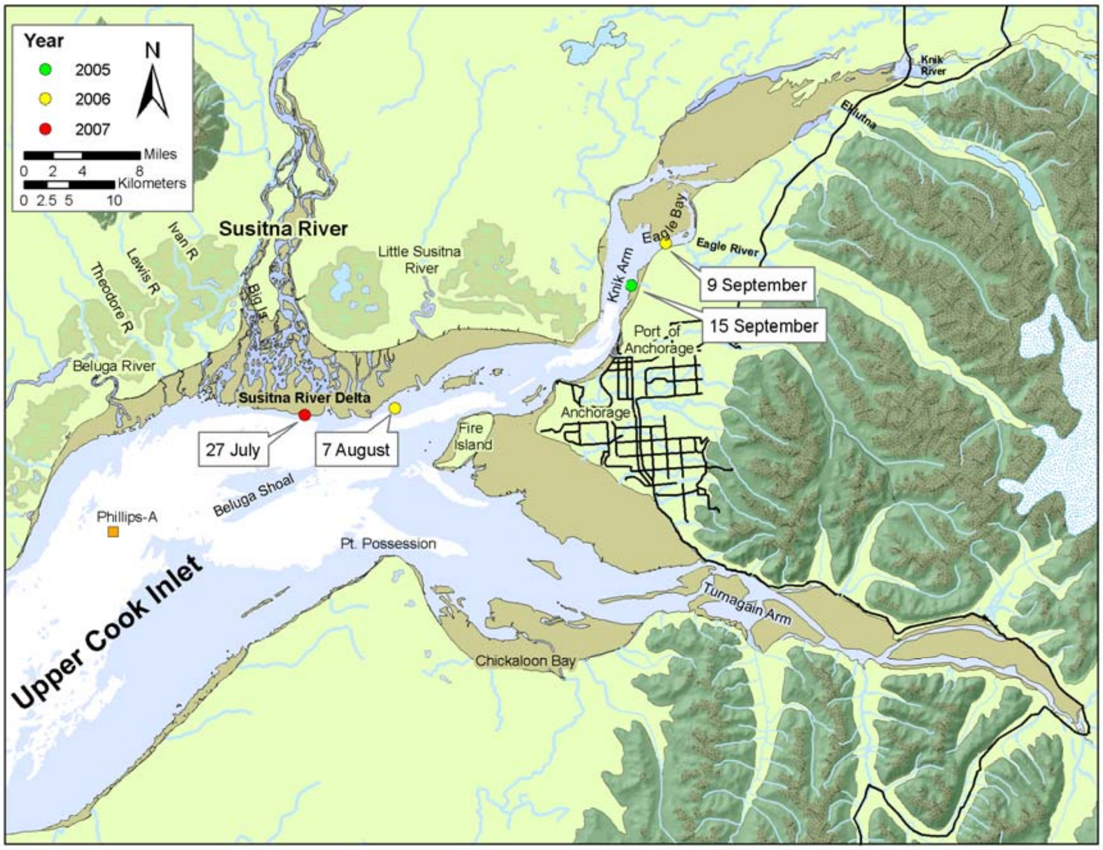
Figure B28. Sighting history (a) and photograph (b) of beluga RS 140.



a.

b.

Figure B29. Sighting history (a) and photograph (b) of beluga RS 221.



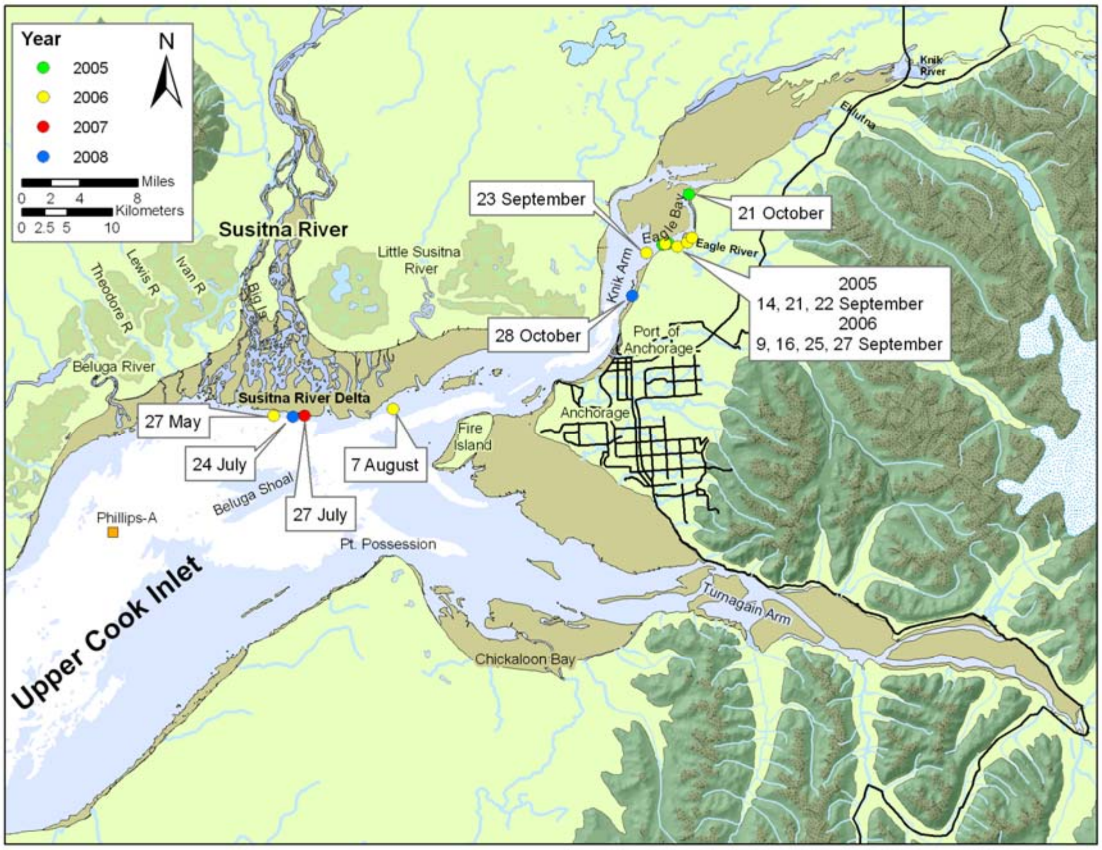
a.

b.

Figure B30. Sighting history (a) and photograph (b) of beluga RS 222.

APPENDIX C.

INDIVIDUAL SIGHTINGS HISTORY MAPS OF SATELLITE-TAGGED WHALES SEEN IN THE STUDY, ALONG WITH A PHOTOGRAPH OF THE RIGHT SIDE OF EACH INDIVIDUAL

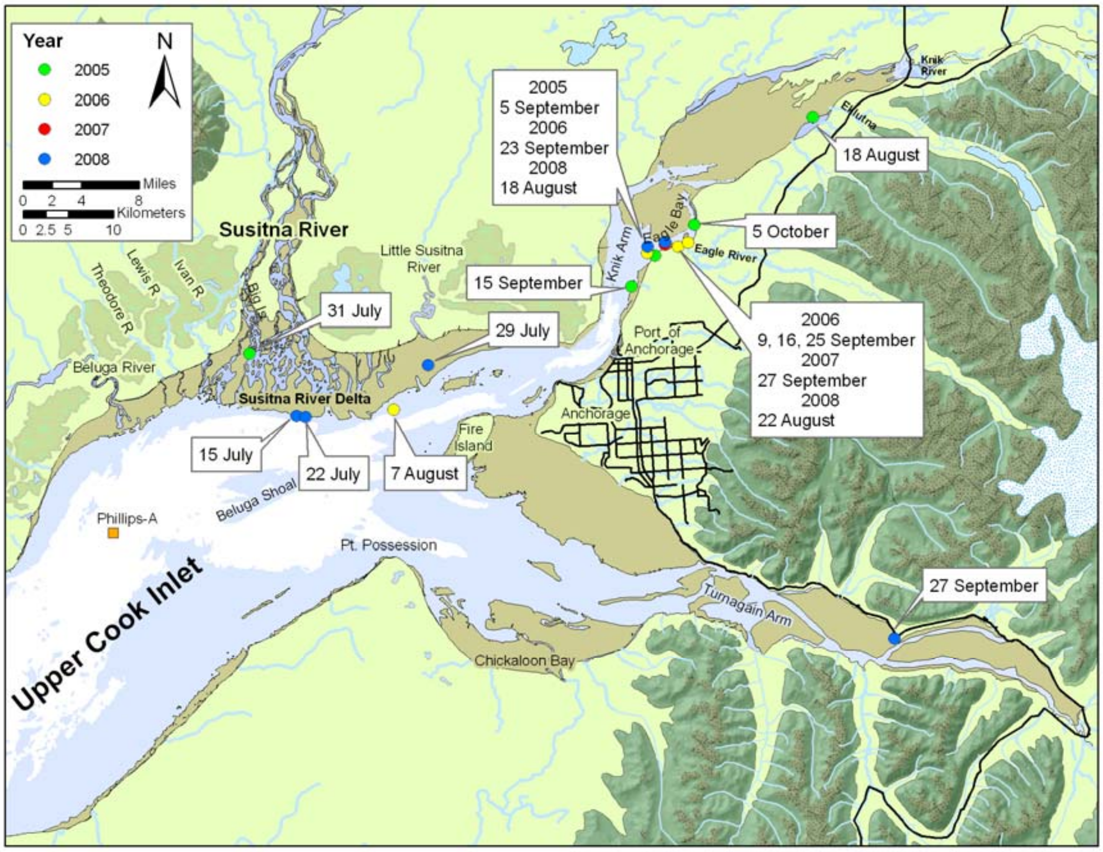


a.


b.

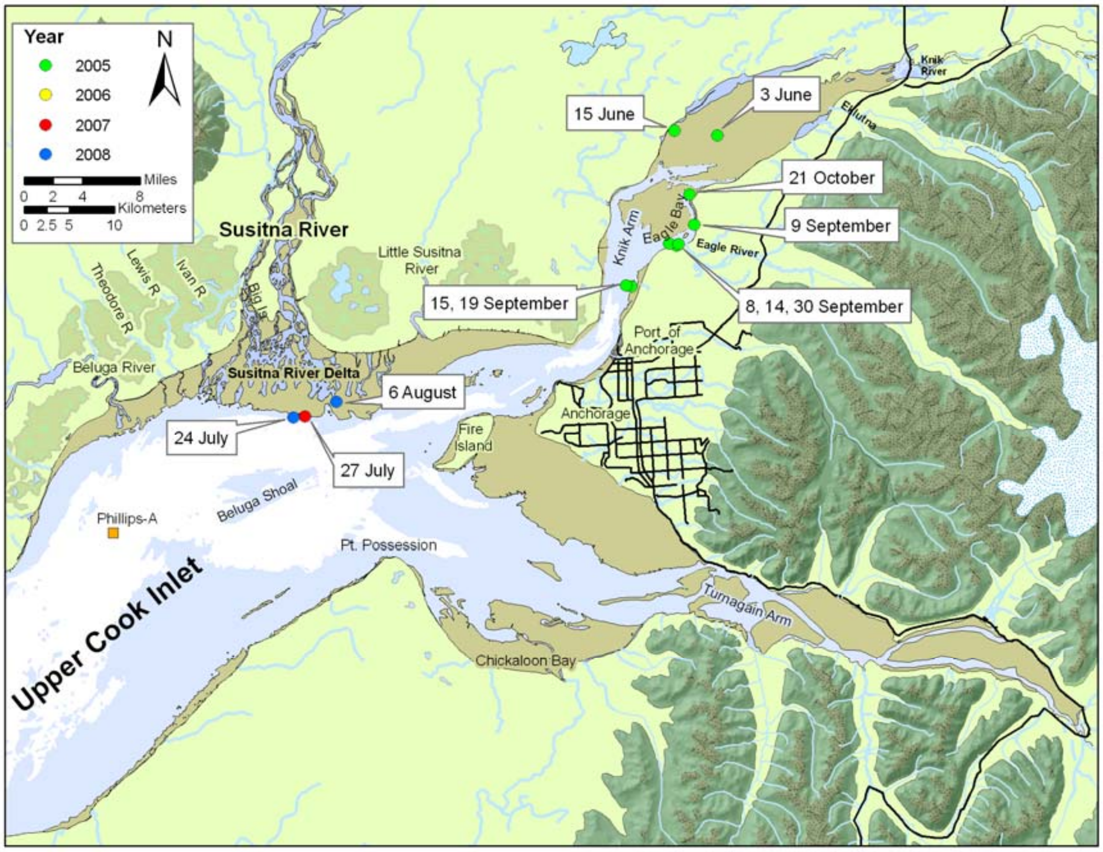
Figure C1. Sighting history (a) and photograph (b) of beluga RA 139.

a.



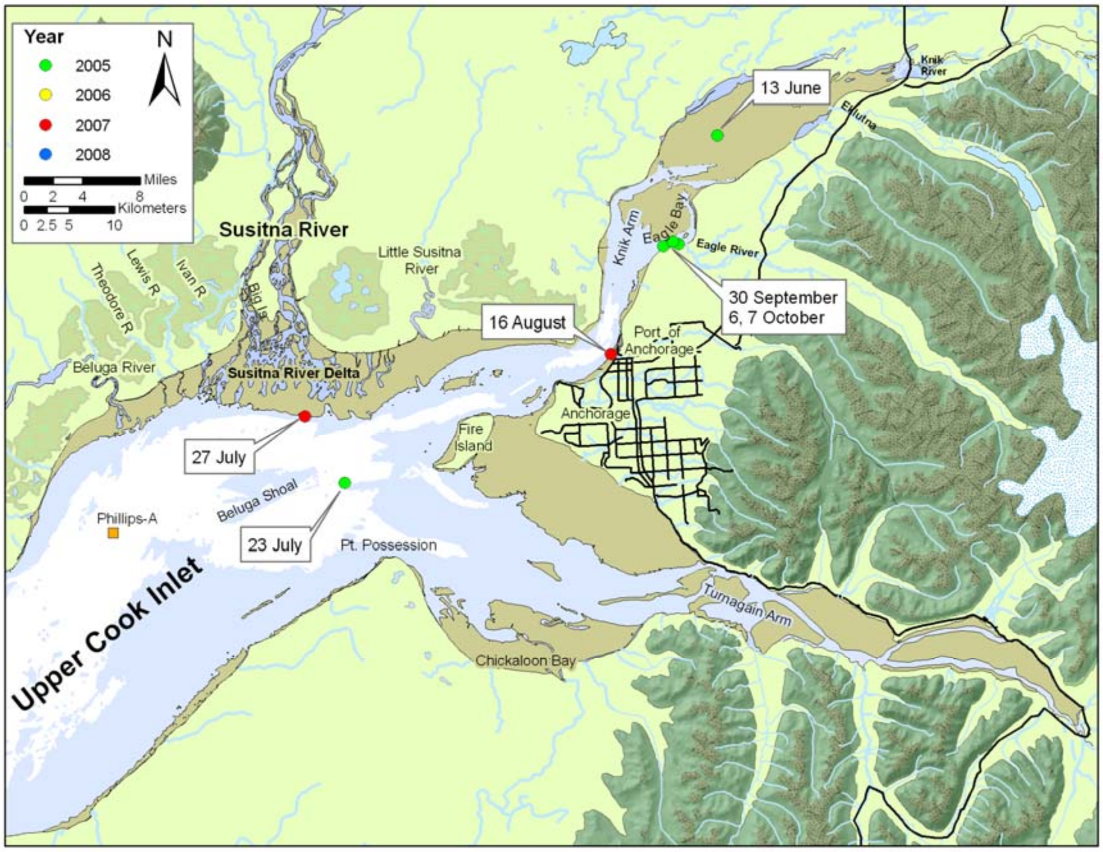
b.

Figure C2. Sighting history (a) and photograph (b) of beluga RA 148. This beluga was tagged by NMFS sometime between 1999 and 2002.

a.


b.

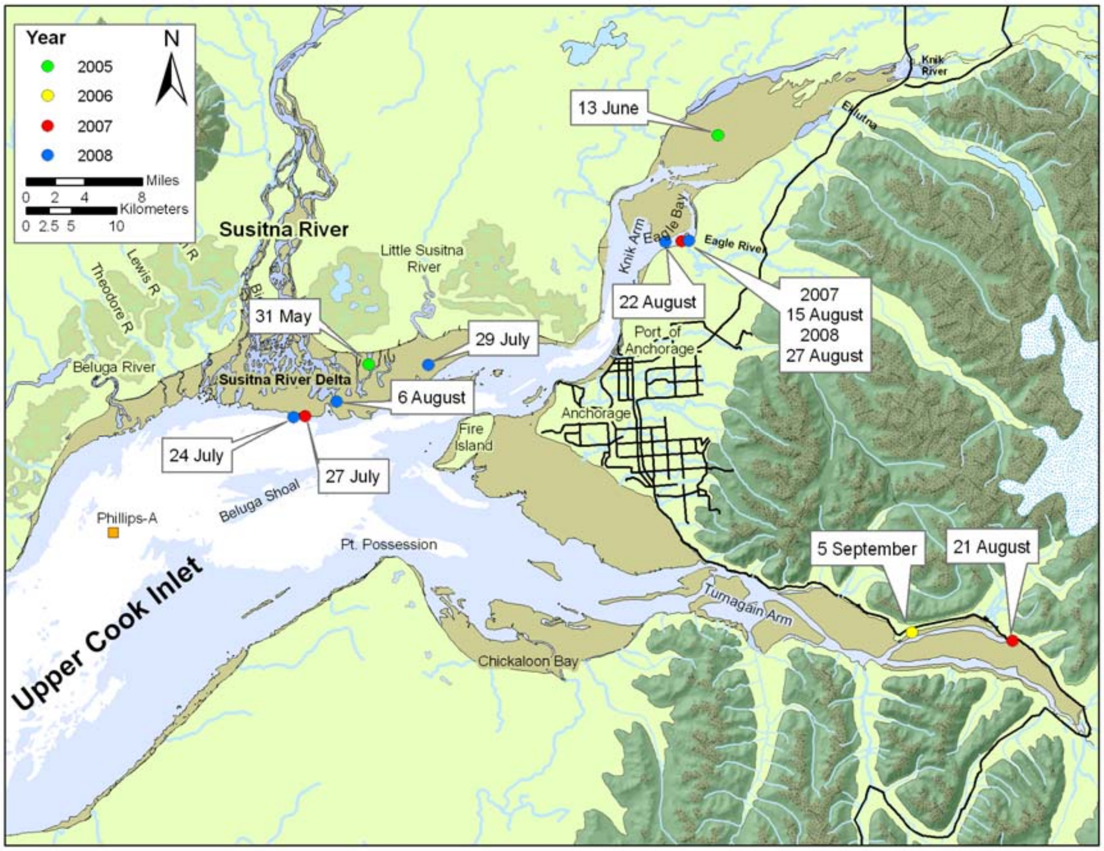

Figure C3. Sighting history (a) and photograph (b) of beluga 156.



a.


b.

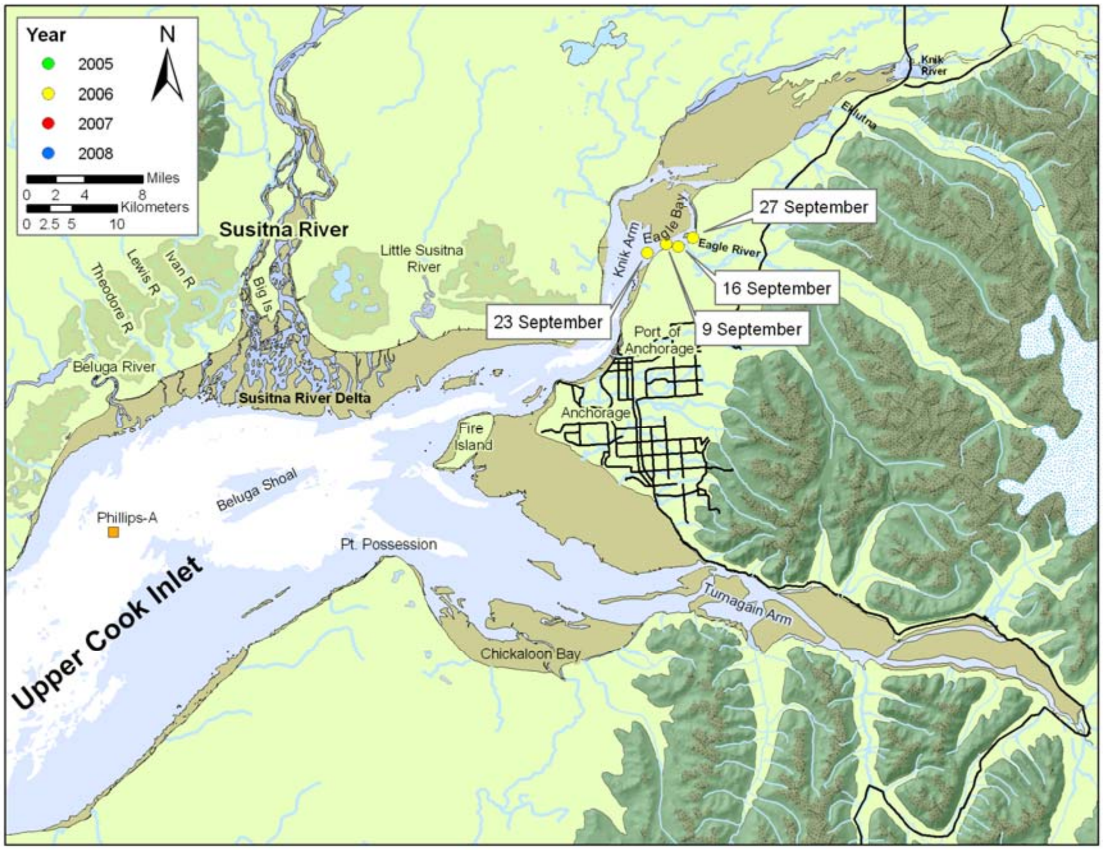
Figure C4. Sighting history (a) and photograph (b) of beluga RA 159.



a.

b.

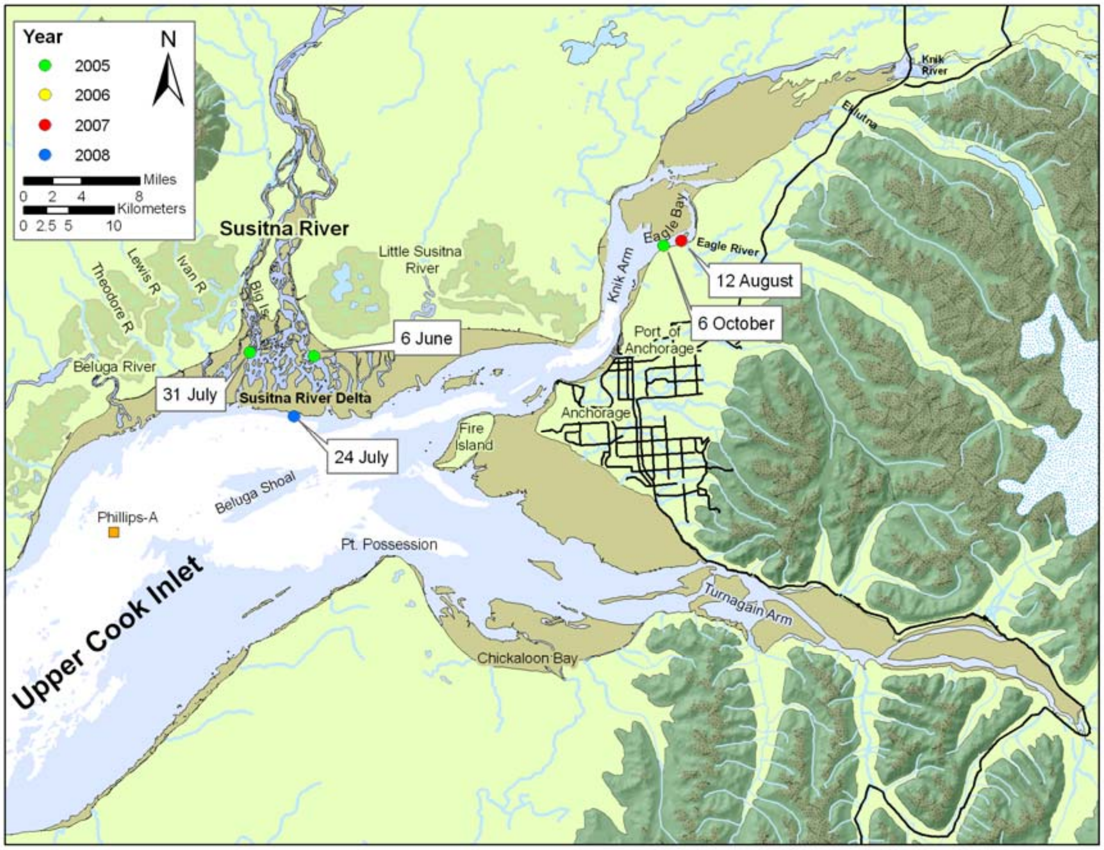
Figure C5. Sighting history (a) and photograph (b) of beluga RA 160. This beluga was tagged by NMFS sometime between 1999 and 2002.



a.

b.

Figure C6. Sighting history (a) and photograph (b) of beluga RA 161.

a.


b.


Figure C7. Sighting history (a) and photograph (b) of beluga RS 220.

APPENDIX D.

PROTOCOL FOR PHOTOGRAPHS OF BELUGA MORTALITIES FOR PHOTO-ID STUDY

Please send photos/correspondence to:
tmcguire@lgl.com, or ckaplan@lgl.com,
(907)-562 3339
LGL Alaska Research Associates, Inc.
1101 E. 76th Ave, Suite B. Anchorage, AK 99518

PROTOCOL FOR PHOTOGRAPHS OF BELUGA MORTALITIES FOR PHOTO-ID STUDY

About the Cook Inlet Beluga Photo-identification Study:

Photo-identification provides information about individual Cook Inlet beluga whales and the population as a whole, including residency/movement patterns, habitat use, reproduction, survivorship, and abundance. Over four field seasons (2005-2008) we developed a photo-catalog containing digital images of individual Cook Inlet beluga whales that were repeatedly identified during the course of the study using natural markings that persist over time. Some photographs of whales display marks indicative of infection and injury. By documenting the occurrence and frequency of these marks and attempting to identify mark sources, we can learn more about disease and injury affecting the endangered Cook Inlet beluga whale population. We photograph beluga mortalities in order to note those previously-identified whales in the catalog that have died, and also to examine possible cause of death. Continued collaboration among research projects in Cook Inlet should increase the photographic documentation and examination of disease, injury, and mortality of Cook Inlet beluga whales.

What we're looking for:

- Photos (digital preferred) of Cook Inlet belugas (wanted dead or alive)
- High resolution images (RAW or fine JPEG)
- Enough light to view contrast. Underexposing photographs by -1 will help to bring out white marks on white animals
- Minimal glare
- Photos taken at 90^{o} angle to marks or wounds
- Zoomed-in photos of marks
    - Include scale in photograph (can be a ruler, coin, pencil, hand, boot, etc) to indicate the size of the mark or wound being photographed
- Photos of entire whale, specifically the back and side(s)
- Time/date stamp- make sure camera settings are accurate, or note correct date/time when submitting the photos
- Information about where the photo was taken
- Photographer name (for credits)

What hampers photo-analysis:

- Glare – washes out parts of photo, making it hard to distinguish between marks and skin
- Lack of scale – prevents us from determining the dimensions of marks or wounds
- Low resolution – images become blurry when zoomed in
- Angled photos – make it hard to compare marks from photos taken at different angles. Profile shots of the sides of the whale are best.
- Obstructions of marks or wounds – mud, sand, and/or blood may collect in marks. Use water to rinse the area before photographing it, if possible. Bring a bucket or something to transport rinse water.

Example of a good photo:

Faint white marks (arrows) are used to identify the individual whale.
\+ high resolution to see marks, taken at a 90^{o} angle, zoomed in, reduced glare.
\- lacking: scale.

Example of a poor photo:

\- lacks scale, taken at an oblique angle, taken of the ventral side.