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National Marine Mammal Laboratory
7600 Sand Point Way Northeast
Seattle, WA 98115

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Population Assessment of the Beluga Whales in Cook Inlet, Alaska, June 1994
-Executive Summary-

Roderick C. Hobbs, David J. Rugh, Douglas P. DeMaster, Kim E. W. Shelden,
Janice M. Waite, Jim A. Lerczak, and Robyn P. Angliss

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE, Bin C15700
Seattle, WA 98115-0070

In June 1994, the National Marine Mammal Laboratory conducted an aerial survey and a VHF radio-tagging experiment on the beluga whale population of Cook Inlet, Alaska. The aerial survey covered the entire coastline of the inlet as well as offshore transects and three replicate surveys of the upper inlet where most whales were found. Groups of whales were counted and recorded on videotape. An abundance estimate, presented in Hobbs *et al.,* was derived from aerial survey counts (described in Rugh *et al.*), from the analysis of aerial videotape to correct for sightability bias (discussed in Waite and Hobbs), and from radio-tagging data (detailed in Lerczak). Belugas were radio-tagged using a non-invasive suction-cup attachment system. Signals from the tags were analyzed to determine beluga surfacing intervals which established the proportion of time whales were underwater and not visible to aerial observers. Surfacing behaviors were categorized and quantified based on levels of disturbance during the tagging study (reported in Shelden). Oceanographic sampling was conducted opportunistically in an effort to characterize beluga whale habitat (reported in Shelden and Angliss). Photographs and videotapes taken during vessel operations were analyzed to determine the feasibility of photo-identifying beluga whales (reported in Waite). Seven papers comprise the body of this report. These papers were submitted as working documents to the 5-7 April 1995 research workshop of the Alaska Beluga Whaling Committee. They were also submitted as working documents to the May 1995 meeting of the International Whaling Commission. After the 1995 field season, papers on abundance, tagging methods and behavior will be submitted to peer-reviewed publications. We will be applying the methods developed in the 1994 season to results from aerial and vessel surveys conducted in 1995 to finalize the abundance estimate. Currently, the abundance of beluga whales in Cook Inlet is estimated to be 747 whales (CV=0.19).

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Preliminary Estimate of the Abundance of Beluga Whales in Cook Inlet Based on NOAA's June 1994 Aerial Survay and Tagging Experiments

Roderick C. Hobbs, Janice M. Waite, David J. Rugh and James A. Lerczak

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way, NE
Seattle, WA 98115

Abstract

Abundance of beluga whales in Cook Inlet was estimated from aerial survey counts corrected for subsurface animals (availability) and animals at the surface that were missed (sightability). The correction method involved replicate, timed observer counts of groups and analysis of simultaneous video footage. Availability was corrected using the formula of McLauren (1961) and sightability was corrected using the ratio of group size estimates from the video to group size estimates from observers. The correction factor for sightability was 2.45 (CV=0.14) and abundance was estimated at 747 whales (CV=0.19).

Introduction

Abundance of beluga whales in Cook Inlet has been estimated by several authors to be somewhat more than 300 animals. In some cases these are the maximum sum of visual counts and represent minimum abundance estimates. In other cases an estimate of total abundance has been made by multiplying the counts by a correction factor to account for the animals that were presumed to have been missed (see Shelden 1994 for review). None of these surveys were designed specifically to estimate total abundance of beluga in Cook Inlet, but they do provide useful information on distribution, behavior, ecology and minimum abundance. Drawing on the observations and insights from these studies, a survey method for an absolute abundance estimate of the Cook Inlet beluga was designed. An accurate abundance estimate depends on:

1) Locating all of the large schools and getting accurate counts for each.
2) Correcting counts for subsurface whales that were missed during the count (availability bias).
3) Correcting counts for whales at the surface that were missed during the count (sightability bias).
4) Estimating the size and number of groups missed.

Although field methods and analyses were designed to satisfy all four criteria, the 1994 field season did not yield a sufficient sample size to estimate the fraction of the population in missed groups. Instead the highest abundance estimate is used with the assumption that on that day no groups were missed. The analysis does include the two corrections for missed animals (#2 and #3) which are applied to estimate group sizes for the groups that were encountered.

Background

During late spring and throughout the summer, large aggregations of beluga whales are found in the mouths of rivers on the northwest shore of Cook Inlet. These whales are also found in other areas of the inlet, usually near shore or in shallow areas offshore. On rare occasions individuals are seen offshore in deep water. Large tidal fluctuations in Cook Inlet and broad tidal flats result in strong tidal currents and significant changes in the shoreline through a tidal cycle. Beluga whales move with these tidal fluctuations to remain in fairly shallow water. Beluga whales have also been sighted considerable distances up rivers such as the Big Susitna River and the Kenai River. Behavior within a group will vary from milling about to moving in a closely packed and unidirectional manner. Because Inlet waters are extremely turbid and essentially opaque, belugas are seen from the air as white or gray backs in a field of brown when at the surface and cannot be seen when below the surface. The high contrast between the white adult whales and their background make them easy to identify at a distance both visually and on film or video tape.

Field Methods and Results

The approach to designing the aerial survey was to take advantage of the highly aggregated population that is seen in June and July. This involves an accurate count of the few large groups that are found, and a survey of the remaining area to document how many individuals occurred outside the large groups. Several strata were considered in the aerial survey: 1) River and tidal regions including river mouths and deltas, 2) inner coastline (i.e., the shore side of coastal transects away from river and tidal areas), 3) outer coastline (i.e., the offshore side of coastal transects away from river and tidal areas), 4) shallow offshore waters, and 5) deep offshore waters. Complete surveys of the first three strata were planned and completed as far south as Cape Douglas and Elizabeth Is. (south of Seldovia) with a repeat of these strata in the upper inlet (north and east of the Forelands). The fourth and fifth strata were subsampled in a sawtooth pattern covering the open water areas as far south as the entrance of the Inlet. All of the coastline of Cook Inlet (1307 km) was surveyed, and 1129 km of offshore trackline were completed (Figure 1). Thus, 100% of the strata where beluga whales were expected to be found was surveyed and, assuming a 3 km strip width, approximately 37% of the surface area of Cook Inlet was surveyed at least once (see Rugh *et al.* 1995 for details).

A total of 26 sightings were made of the 19 groups that were encountered. Counts ranged from 1 to over 150 individuals per group. There are more sightings than groups because some groups were sighted independently by more than one observer. Portions of the upper inlet were resurveyed two or three times so that several of these sightings are considered resightings of the same groups. Also, the whale groups have been observed to move about from day to day, some times breaking into subgroups and later reforming. To account for this the individual groups have been collected into geographical sections. The sections were: 1) Northwest, including the Beluga River, the Susitna Rivers and Knik Arm; 2) Northeast, including Turnagain Arm, Chickaloon Bay, Point Possession down to East Foreland; 3) Southeast, including the shoreline south of East Foreland; and 4) Southwest, including the shoreline south of the West Foreland.

Two counting methods were employed, visual counts by two observers and counts made from video tapes. The visual counts and video recordings were made using a standardized method referred to as the racetrack method (see Withrow *et al.* 1994 for details). A racetrack-shaped path was flown around the group. Counts and corresponding video recordings were made from the port windows as the plane passed by the group along the straight sides of the racetrack. Start and stop times were recorded and a time stamp was recorded on the video. This method allows repeatable counts with essentially the same presentation of the group and a measure of time spent counting. Racetracks were typically 2 to 4 kilometers from end to end and 1 to 2 kilometers across. The judgment of the pilot was relied on to insure that the entire group passed on the port side but not too distant for acceptable counting conditions. Observers graded the conditions during each count and the process continued until each of the two observers had made four counts under acceptable conditions. Each observer recorded his or her counts independently and counts were not discussed among observers during the survey. To further maintain independence the counts were entered into the database by a non-member of the aerial crew (see Rugh *et al.* 1995 for details).

Counts of whales were made from video tape using a video editing deck and a high resolution monitor. All whales within single video frames, 0.5 sec. apart, were marked on transparent plastic sheets. Successive sheets were compared and new surfacings identified and counted. The video count was then the sum of all animals on the first sheet and new surfacings from the subsequent sheets. The counting time in seconds was determined from the time stamp on the video tape (see Waite and Hobbs 1995 for details).

Time at the surface was determined from video tapes using the editing deck. Each whale on an individual video frame was followed forward and backward frame by frame to determine the beginning and ending of time at the surface. A total of 108 surfacings on four different frames were used for this analysis, providing a time at the surface of 3 sec. per surfacing (rounded to the nearest second) (see Waite and Hobbs 1995 for details).

Surfacing interval, the length of time for one breathing cycle, was determined from a VHF radio tagging experiment. Over seven hours of surfacing data were collected from two whales tagged with suction cup attached radio tags (see Lerczak 1995 for details). On review, it was determined that the second whale had a much clearer record than the first. The surfacing of the first whale had been recorded by hand only. The signal from the second whale had been recorded on tape and could be checked in the laboratory. Two observers reviewed the tapes of the second whale independently. The correspondence between their records was high. Although the record of the first whale is of lower quality, for the purpose of this analysis, the average of surfacing intervals from these two animals were used. The average surfacing interval was 29 seconds (CV=0.21).

Analysis Methods

Abundance Estimate

A group size estimate can be calculated from a count by multiplying by the surfacing interval and dividing by the average time spent at the surface for an individual whale added to the time spent counting by the observer (after McLauren 1961). The surface time is added to the counting time in order to account for whales that are at the surface when counting begins. Therefore,

$$\hat{n}_{g,p,o}=\frac{T_i c_{g,p,o}}{T_s+t_{g,p}} \qquad (1)$$

where,

$\hat{n}_{g,p,o}$ is the estimated size of group g on pass p by observer o.
$c_{g,p,o}$ is a count of surfacings in group g made during pass p by observer o.
T_i is the mean surfacing interval (i.e. the time spent under water added to the time at the surface).
T_s is the mean time spent at the surface during a surfacing.
$t_{g,p}$ is the time spent counting group g during pass p.

This method assumes that all animals that are at the surface during the counting period are counted and that animals that surface more than once can not be identified as such and would therefore be counted more than once. Because the observers are instructed to count all surfacings this approach is reasonable; however, it should be noted that an animal would only be counted twice if it were at the surface twice during the time period that a particular piece of water was being observed. This formula was also used for the group size estimates made from the video. If the video was a 'single point' count, $t_{g,p}$ was the elapsed time from the first frame of a pass counted to the last frame counted. For a 'scan' count from video $t_{g,p}$ was the time required for an object to cross the screen (see Waite and Hobbs 1995 for details).

The group size estimates from the airborne observer counts were typically lower than those from the video tape. The group size estimates from the video tape are thought to be representative of the true group size so a correction factor was devised to correct the observer counts for missed animals. This correction factor is the ratio of video group size estimates to the observer group size estimates from individual passes where both the observer counts were of acceptable quality and video footage was of acceptable quality (see Waite and Hobbs 1995 for details). The correction was formulated as,

$$k_{ov}=\frac{\sum_{P_{ov}}\hat{n}_{p,v}}{\sum_{P_{ov}}\hat{n}_{p,o}} \qquad (2)$$

where,

k_{ov} is the multiplicative correction factor for animals at the surface that were missed during observer counts.
P_{ov} is the set of passes on groups of belugas with good observer counts and good video footage.
$\hat{n}_{p,o}$ and $\hat{n}_{p,v}$ are the group size estimates for pass p from the averaged observer counts and video counts respectively, calculated using equation (1).
This formula weights the correction factor to be most accurate for large groups where a bias would have the greatest impact on the abundance estimate. This formulation will , also, have a

lower variance than an average of ratios calculated from individual passes.

To account for variation in time spent counting from one pass to the next a group size was estimated for each group by multiplying the sum of the total counts by the observer to video correction factor and the surfacing interval and dividing by the sum of the time that animals remain at the surface and the time spent counting. Surfacing rate was then

$$\hat{n}_g = \frac{k_{ov} T_i \sum_{OP_g} c_{g,p,o}}{\sum_{OP_g} \left(T_s + t_{g,p}\right)} \qquad \textbf{(3)}$$

where,
$\hat{n}_g$ is the estimated size of group g from several observer-passes.
OP_g is the set of observer-passes on group g that resulted in a count with a quality rating of fair, good or excellent. On some passes both observers made counts with acceptable quality ratings, each of these counts is included separately in this set.

The formula in equation (3) weights the observer counts by the time spent counting and should result in a lower variance than an average of group size estimates calculated separately for each count (i.e. equation (1) applied to each count separately).
The abundance in each section of the inlet on a given day is computed as the sum of the estimated number of whales in each of the groups encountered on that day within the section.
Therefore,

$$\hat{N}_{s,d} = \sum_{G_{s,d}} \hat{n}_g \qquad \textbf{(4)}$$

where,
$\hat{N}_{s,d}$ is the estimated abundance in section s on day d.
$G_{s,d}$ is the set of groups seen in section s on day d.

Because some groups may be missed on some days and there is little likelihood that groups are counted twice, the largest daily abundance estimate for each section, $\hat{N}_s$, is used as the abundance estimate for that section

$$\hat{N}_s = \max\left[\hat{N}_{s,d}\right] . \qquad \textbf{(5)}$$

The abundance estimate for the entire inlet, $\hat{N}$, is the sum of the abundance estimates for the four sections, thus,

$$\hat{N} = \sum_{S} \hat{N}_s \ . \qquad \textbf{(6)}$$

Variance Estimate

The variance of k_{ov} follows from the variance of a ratio given in Snedecor and Cochran (1973), so that

$$\mathrm{var}(k_{ov}) = \frac{m_{P_{ov}}}{m_{P_{ov}} - 1} \frac{\sum_{P_{ov}} \left[\hat{n}_{pv} - \hat{n}_{po} k_{ov}\right]^2}{\sum_{P_{ov}} \left[\hat{n}_{po}\right]^2} \qquad \textbf{(7)}$$

where,

$m_{P_{ov}}$ is the number of passes in P_{ov}.

The estimation formula for group size is essentially a weighted average of the surfacing rate (i.e. $c_{g,p,d}/(T_s+t_{g,p})$) from individual observer-passes weighted by $(T_s+t_{g,p})$ multiplied by T_i and k_{ov}. Following Seber (1973), the variance of this weighted average is then,

$$\mathrm{var}(\hat{r}_g) = \frac{\sum_{P_g} \frac{1}{T_s + t_{g,p}} \left[c_{g,p} - \hat{r}_g \left(T_s + t_{g,p}\right)\right]^2}{\left(m_{P_g} - 1\right) \sum_{P_g} \left(T_s + t_{g,p}\right)} \qquad \textbf{(8)}$$

where,

$\hat{r}_g = \hat{n}_g/(T_i\, k_{ov})$ is the average surfacing rate for group g.

m_{P_g} is the number of observer-passes in P_g .

Noting that, $cv(\hat{x}) = \sqrt{var(\hat{x})} \ / \ \hat{x}$, the variance of a group abundance estimate is derived. using the delta method (cf. Buckland, et al. 1993) to be as follows:

$$\mathrm{var}(\hat{n}_g) = \hat{r}_g^2 T_i^2 k_{ov}^2 \left[cv^2(\hat{r}_g) + cv^2(T_i) + cv^2(k_{ov})\right] \ . \qquad \textbf{(9)}$$

The variance of a geographical section on a given day is the sum of the variances of the groups in that section on that day,

$$\mathrm{var}\left(\hat{N}_{s,d}\right) = \sum_{G_{s,d}} \mathrm{var}(\hat{n}_{s,d}) \qquad \textbf{(10)}$$

The variance for the section is the variance of the largest single day abundance in that section,

$$\mathrm{var}\left(\hat{N}_s\right) = \mathrm{var}\left(\max\left[\hat{N}_{s,d}\right]\right) \tag{11}$$

and the variance of the abundance estimate for the inlet is the sum of the variances for the sections,

$$\mathrm{var}\left(\hat{N}\right) = \sum_{S} \mathrm{var}\left(\hat{N}_s\right) . \tag{12}$$

Results

Of the 19 groups sighted in the aerial survey, 16 had sufficient data to be included in the abundance estimate. The three groups that were discarded were all seen on 2 June 1994. These could not be used because, due to a computer failure, the time spent counting could not be determined. The sections that these sightings occurred in were surveyed on other days, so no areas were missed. However, a small group, seen in Turnagain Arm on 2 June, was not seen on subsequent days, possibly due to poor sighting conditions. The estimated group sizes were calculated for the observer and video counted passes (Table 1). The correction factor for animals at the surface, k_{ov}, was calculated as 2.45 (CV=0.14). Group size was then estimated for the 16 observed groups (Table 2). A CV could be calculated for all groups except one which was not counted on multiple passes by more than one observer. This group had just 4 animals so it would not make a significant contribution to the CV of the final abundance estimate.

Cook Inlet was divided into four sections based on the distribution of sightings and survey effort and the assumption that animals did not cross the inlet in significant numbers during the five days of the survey. The group abundances were summed by date and section (Table 3), and the largest daily abundance was used for each section in the total abundance estimate of 747 beluga whales (CV=0.19). The corresponding maximum daily counts (Rugh *et al.* 1995) are included for reference.

Discussion

Although this abundance estimate does not explicitly account for missed groups, by choosing the survey day with the highest estimated abundance, it is quite possible that all groups were seen that day. This dependence on a single best day of surveying is problematic for repeatability from year to year and for the analysis of trends in abundance. Examining Table 3 it is clear that without the survey on 4 June, the abundance would have been estimated at around 450 animals. It is unclear from our survey record why this difference occurred. It is possible that a large group was missed on each of the other days. It is also a possibility that the large groups seen on 4 June were dispersed into smaller, more easily missed groups on the other days or they had moved out of the nearshore environment.

It is clear from the magnitude of the correction for observer group size estimates from the video group size estimated that a significant number of beluga are missed by the observers. One possibility is that the observer's eye is drawn to the white backs of the adults while the lower contrast, gray juveniles are missed. A second possibility is that an observer can only effectively count in an area somewhat smaller than the area covered by a typical group. The time spent counting any portion of the group is then only a fraction of the time spent counting the whole group. In either case, using the video analysis to develop a correction factor resolves this problem. It is important to note that this correction factor is directed at a different problem than the one used by Frost et al. (1985). Theirs is meant to correct for animals missed in small groups while surveying in passing mode. In passing mode, the observers have only a few seconds to find and count all of the animals in a group as the plane passes. Animals will be missed if they do not surface during those few seconds. The multiple approaches used in the Cook Inlet survey allows ample time to determine the extent of the group. Also, the aerial counting times are as long or longer than the surfacing interval of a typical beluga, so each animal is available at the surface to be counted at least once.

This abundance estimate is closely tied to the typical surfacing interval of a beluga whale. The surfacing interval estimate used here is from two whales clearly a larger sample size is necessary for this important parameter.

Acknowledgments

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Table 1. Group size estimates from observer counts and video counts used to develop the observer to video correction factor.

Date	Group	Pass	$\hat{n}_{g,p,o}$	$\hat{n}_{g,p,v}$
6-1-94	1	2	78	232
6-1-64	1	6	91	245
6-1-94	1	8	54	173
6-1-94	1	10	102	225
6-1-94	2	2	53	247
6-4-94	3	2	83	304
6-4-94	3	3	82	202
6-4-94	4	4	300	469
6-5-94	2	3	10	41
6-5-94	3	5	21	20
6-5-94	5	3	25	54
6-5-94	7	3	7	11
Total			908	2223

Table 2. Group size estimates for the groups included in the abundance estimate.

Date	Group	Total passes	Average time (sec.)	Average count	$\hat{n}_g$	cv($\hat{n}_g$)	Site
6-1-94	1	13	23	71	193	0.26	Big Susitna River
6-1-94	2	12	47	127	180	0.28	Big Susitna River
6-3-94	1	6	42	10	15	0.29	Pt. Possession
6-3-94	2	3	21	3	9	0.25	Kachemak Bay
6-3-94	3	2	25	5	13	0.29	Kachemak Bay
6-4-94	1	4	35	2	4	0.26	Iniskin Bay
6-4-94	2	4	22	59	167	0.27	Iniskin Bay
6-4-94	3	6	25	82	210	0.26	Big Susitna River
6-4-94	4	5	20	106	323	0.37	W. of Little Su. R.
6-5-94	1	1	11	1	5	0.21	Pt. Pos./E. Forel.
6-5-94	2	5	26	11	27	0.29	Beluga River
6-5-94	3	8	25	15	39	0.32	W. of Big Su. R.
6-5-94	4	6	16	9	36	0.30	W. of Big Su. R.
6-5-94	5	7	58	80	94	0.31	W. of Big Su. R.
6-5-94	6	6	40	145	240	0.26	Little Susitna R.
6-5-94	7	8	62	15	16	0.28	Chickaloon Bay

Table 3. Group sizes and estimated abundances by section and for the entire Cook Inlet. The coefficient of variation is included below each estimate in parentheses. The maximum counts for each section are included for reference.

Section	Location	1 June	3 June	4 June	5 June	N	Rugh et al. 1995 Maximum Count
Northeast	Turnagain Arm	---	---	---	---		
	Chickaloon Bay	---	---	---	16	21	30
					(0.28)	(0.28)	
	Pt. Possession	---	15	---	5		
			(0.29)		(0)		
Southeast	Kachemak Bay	---	22	---	---	22	9
			(0.20)			(0.20)	
Southwest	Iniskin Bay	---	---	4	---	4	2
				(0.26)		(0.26)	
Northwest	Beluga River	---	---	0	27		
					(0.29)		
	Big Susitna R.	374	---	377	168	700	408
		(0.19)		(0.19)	(0.20)	(0.20)	
	Little Susitna R.	0	---	323	240		
				(0.37)	(0.26)		
Total						747	449
						(0.19)	

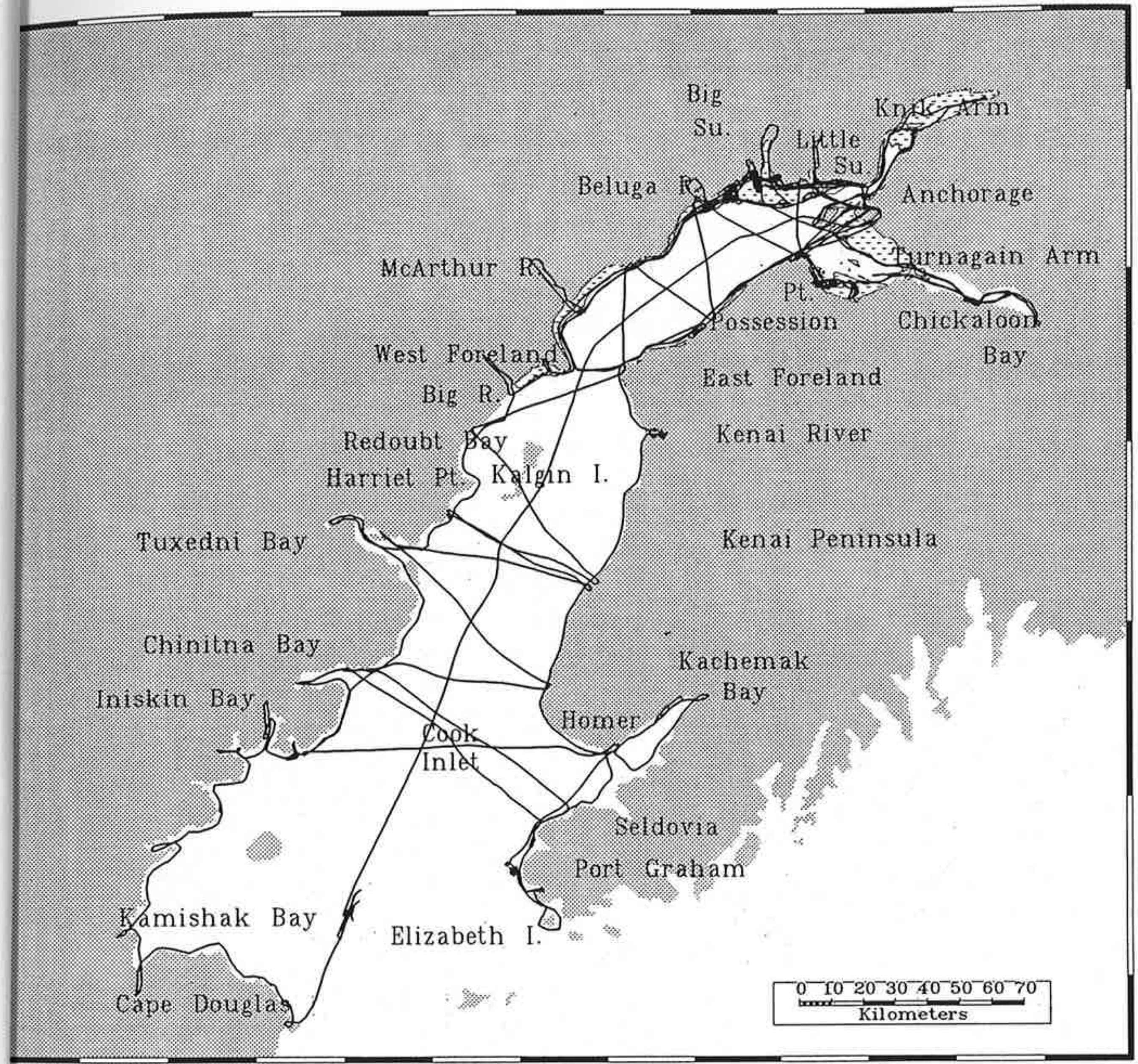

Figure 1. Aerial tracklines flown during the June 1-5 1994 beluga whale surveys, Cook Inlet, AK.

Aerial Surveys of Belugas in Cook Inlet, Alaska, June 1994

David J. Rugh, Robyn P. Angliss[1], Douglas P. DeMaster, and Barbara A. Mahoney[2]

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115, U.S.A.

Abstract

The National Marine Mammal Laboratory (NMML), in cooperation with the NMFS Alaska Regional Office, conducted an aerial survey of the beluga whale population in Cook Inlet, Alaska, during 1-5 June 1994. This provided a thorough coverage of the coasts around the entire inlet (1307 km), including 1129 km of offshore transects. Therfore 37% of Cook Inlet was searched, and all areas where belugas were expected to be during this season were searched one or more times. The 25.2 hr survey was flown in an Aerocommander at 267 m (800 ft) altitude and 170 km/hr (90 kt). Throughout this survey, a dual independent observer test was conducted on the coastal (left) side of the plane (where most sightings occur), and a single observer and computer operator/data recorder were on the right side. Beluga groups were counted visually and were also videotaped for more controlled counts later. The sum of the maximum aerial estimates was 449 beluga whales. Group counts ranged from 1 to 165 animals. Dual counts showed all groups of over 85 animals were seen by both observers, but groups of less than 85 were rarely seen by more than one observer while on transect. Most (70%) of the sightings occurred 1-2 km from the aircraft ($\bar{x} = 1.46$ km). The largest groups (91% of the belugas) were seen in the upper Inlet near the mouth of the Big Susitna River, which is typical for June.

Introduction

Aerial surveys are the established method used to collect distribution and abundance data for beluga whales in Cook Inlet (Klinkhart 1966; Calkins *et al.* 1975, 1984; Murray and Fay 1979; Withrow *et al.* 1994). Traditionally, visual counts or estimates have been used to enumerate groups seen from the air, but they lack repeatability and have no direct measure of accuracy except through tests of independent, paired observers. However, there have been no documented tests of dual counting of beluga whales where two observers with nearly identical aerial views made independent searches and counts of whale groups. Barlow (1987, 1993), Øien (1990), Butterworth and Borchers (1988) and others have had independent observers search for cetaceans

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[1] Office of Protected Resources, NMFS, 1335 East-West Hwy., Silver Spring, Maryland 20910, U.S.A.

[2] Anchorage Protected Resource Management Division, NMFS, 222 West 7th St., Box 43, Anchorage, Alaska 99501, U.S.A.

from ships. Rugh *et al.* (1990, 1993) conducted shore-based double counts of gray whales. Crete *et al.* (1991) made double counts from aircraft in surveys for polar bears, but paired observers did not have identical viewing areas. Forney and Barlow (1993) used a partially independent observer design for aerial surveys of cetaceans in which a second observer called out sightings only if they were missed by the primary observer, but the paired observers did not have identical viewing areas. We chose a survey design close to that recommended by Hiby and Hammond (1989) in which paired, independent observers have nearly identical search areas, and their counts are not compared until the research project is complete. Although we did break from the trackline each time a group of beluga whales was reported, it was only after the group was well behind the beam line.

A technique to standardize the way beluga whales were counted, referred to as the race track method, was introduced during the July 1993 survey to improve the consistency of effort among observers and to include replicate counts made between successive aerial passes over the same group (Withrow *et al.* 1994).

Objectives

The objectives of the aerial surveys in 1994 were to: 1) make a complete search for beluga whales around the perimeter of Cook Inlet; 2) conduct sawtooth transects through the center of Cook Inlet; and 3) circle groups of belugas for video documentation and aerial estimations of group sizes. The aircraft was also available to support the vessel-based tagging operation by searching out beluga groups or by helping locate lost radio tags (Lerczak, 1995). In general, aerial survey procedures adopted for this study were similar to those used in previous studies (e.g., Withrow *et al.* 1994). The only significant difference between this study and previous studies was the use of two observers on the same (nearshore) side of the aircraft, each doing independent searches and counts of belugas, and the reliance on videos to provide post-season counts of whales (Waite and Hobbs, 1995). Summary counts from the aerial effort, in combination with correction factors developed through tests such as the paired observer effort, video documentation, and surface timings based on tagged whales, were used by Hobbs *et al.* (1995) to estimate the total number of beluga whales in Cook Inlet.

Aerial Survey Methods

Survey Aircraft

The survey aircraft , an Aero Commander 680 FL (N7UP), had twin-engines, high-wings, 10 hr flying capability, and a five-passenger seating capacity. There were bubble windows at each observer position, maximizing the search area. An intercom system allowed communication among the observers, data recorder, and pilot. A selective listening control was used to aurally isolate the two left observer positions. Positional data were determined through the aircraft's Global Positioning System (GPS) interfaced with the laptop 386 computer used to enter sighting data.

Aerial Tracklines

Coastal surveys were conducted on a trackline 1.5 km offshore. The objective was to find beluga whales in shallow, nearshore waters where they typically have been seen in June (Calkins 1984). The trackline distance from shore was monitored with an inclinometer such that the waterline was generally 10° below the horizon while the aircraft was at the standard altitude of 800 ft (246 m) used throughout these surveys. Ground speed was approximately 170 km/hr (90 knots). This coastal survey included searches up rivers until the water appeared to be less than 1 m deep, based on the appearance of rapids and riffles.

In addition to the coastal surveys, a sawtooth pattern of transects was flown through the offshore areas of the inlet. This trackline was designed to cross over shore at points approximately 30 km apart starting from Anchorage and zigzagging to the southern limits of Cook Inlet (between Cape Douglas and Elizabeth Island; Fig. 1). Also, a trackline was flown down the center of Cook Inlet to include a search over several shoals.

Because of the broad geographical range of these surveys, and because tide heights in Cook Inlet are highly variable from place to place, we did not attempt to synchronize the aerial surveys with the predicted low tide at any particular point.

Aerial Records

General descriptions of the aerial operations (startup and shutdown times, names of participants, survey accomplishments, etc.) were kept in a master log maintained by the aerial project principal investigator or delegate. All other data and comment records were entered into the onboard computer. These data entries included routine updates of percent cloud cover, sea state (Beaufort scale), glare (on the left and right), and visibility (on the left and right). Each start and stop of a transect leg was reported to the recorder. Observer seating positions were recorded each time they were changed, generally every 1-2 hr to minimize fatigue.

Search Technique

Observers searched forward and laterally, but not behind the wing line. When away from shore, the search typically focused on a zone approximately 4° to 8° below the horizon (2-4 km from the aircraft) and 10° to 60° to the left (or right) of the trackline. This zone was considered to be an area with a relatively good probability for detecting whales. Between this search zone and the aerial trackline, whales were considered to be close enough to be detected by peripheral vision; that is, areas close to the aircraft did not need to receive as concentrated a search as those at a distance. However, areas outside of the focal zone were glanced at frequently anyway, partially as a check of sighting cues and partially for visual relief. As viewing conditions deteriorated (higher sea states, fog, etc.), the focal zone came closer to the aircraft.

The search area for observers on the shore side of the aircraft was bounded by the shoreline 1.5 km (10°) from the trackline. The steepest angles observers could search were 81-86°, depending on the height of the observer relative to the window frame, but typically there may have been little search effort expended at angles exceeding 75° (0.07 km off the trackline). This would mean there was a 0.14 km (140 m) wide blind zone along the trackline. When the search was concentrated in the typical viewing area, 10° to 60° off the trackline 2-4 km ahead of the aircraft, there would have been reduced effort within 0.4 km of the trackline, possibly lowering sighting rates in a 0.8 km wide swath under the aircraft.

Sighting Records

Immediately on seeing a beluga group, each observer reported the sighting to the recorder. As the aircraft passed abeam of the whales, the observer informed the recorder of the species, inclinometer angle, whale travel direction, and notable behaviors (feeding, splashing, etc.). With each sighting, the observer's position (left front, left rear, etc.) was also recorded. The recorder repeated these entries back to the observer to confirm accuracy. An important component of the effort by the two observers on the left was that they not cue each other to their sightings. They had a visual barrier between them, and their headsets did not allow them to hear each other, but they could be heard by the recorder, and the recorder was able to selectively confirm their sighting information. As these data were being entered, the aircraft continued past each whale group until it was out of sight; then the aircraft returned to the group and began the circling routine. If one observer missed seeing a group on transect, there was no cue to the sighting until the aircraft turned to circle the group. The pilot and data recorder did not call out whale sightings or in any way cue the observers to the presence of a whale group.

Counting Techniques

The race track method consisted of a long oval flown around the longitudinal axis of a whale group with turns made well beyond the ends of the group. Whale counts were made on each pass down the long axis of the oval. Because groups were circled at least two times, there were four or more separate counts per group. Counts began and ended on a cue from the left front observer, starting when the group was close enough to be counted and ending when it went behind the beam line. This provided a record of the duration of each counting effort. The paired observers made independent counts and wrote down their results along with date, time, pass number, and quality of the count. The quality of a count was a function of how well the observers saw the group (considered "poor" if glare, whitecaps, or distance compromised the counting effort). These notes were not exchanged with anyone else on the aerial team until after all of the aerial surveys were completed. This was done to maximize the independence of each observer's estimates.

Typically, counting techniques were initiated by a quick check of the perimeter of the group to assess the distribution; then a rapid tally was made from left to right across the whale group, mentally registering each animal as fast as possible or counting by fives or tens. Large groups were counted on a single visual pass across the group without looking back except slightly to include new surfacings close to the counting focus. This gave only a few seconds of search time on any particular beluga location. Dispersed or small groups allowed slightly longer counting efforts because it was easier to keep track of surfacings. Generally counts consisted of the number of visible whale backs, but on occasion, wakes, mud plumes ("contrails"), or other obvious indications of a whale's presence, were included in a count (and noted in comments). The effort was to maximize the accuracy of the count, not the precision.

While circling whale groups, the right front observer moved to the left front seat and used a video camera through an open window to document the beluga group. The camera was set on manual focus and operated at maximum useable shutter speeds (1/1000). Date and time were recorded directly onto the video image. Magnification was adjusted to keep the entire beluga group in view, except when recording dispersed groups which were better documented by maintaining the camera in a constant magnification and set position.

Accuracy Check

During the survey, the computer operator made frequent checks of entries for accuracy. Following each flight, data were examined carefully for apparent errors (appropriate GPS updates, readable comments, etc.), and any additional notes written by observers were entered. The survey trackline was mapped as part of the quality control of the location data.

Analysis

Video images have been collected in previous seasons (Withrow *et al.* 1994), but the images lacked sufficient quality, duration, and coverage to allow an accurate count of belugas. In 1994 video coverage was more systematically and rigorously pursued. These video images were reviewed, and counts were made to compare to the infield counts (see Waite and Hobbs, 1995). Analysis of both the aerial counts and counts from the video tapes are described in Hobbs *et al.* (1995).

The distance between the location of the aircraft when an initial sighting was made and the location of the whale group gave an indication of the observer's effective search perimeter. The whale group location was treated as a point half way between two GPS positions recorded at "end counts" when the whale group passed abeam of the aircraft while flying racetrack patterns. However, if the two "end counts" were greater than 3 km apart, the distance to initial sighting was not used in the analysis as the group was considered to be too dispersed to have a meaningful location of the first sighting.

Results

Survey Effort

A total of 25.2 hrs of aerial surveys were conducted around Cook Inlet 1-5 June 1994. All of these surveys (8 flights ranging from 1.5 to 5.4 hours) were based out of Anchorage with refueling stops in Homer when we surveyed the lower inlet. Visibility and weather conditions rarely interfered with the survey effort; during only 1.1 hours (5% of the total effort) did one or more observers consider the visibility poor or worse.

The first survey, on 1 June, targeted the river mouths of the Susitna Rivers, an area where beluga whales have been found during previous surveys. This was in part a test of our survey techniques and in part an effort to find whales for the crew doing radio tagging. On 2 and 5 June we flew duplicate, thorough coastal surveys of the perimeter of upper Cook Inlet north of East and West Forelands, including Knik Arm, Turnagain Arm, and the lower portions of the MacArthur, Beluga, and Susitna Rivers. On 3 June the survey covered the east shore of Cook Inlet as far south as Seldovia, including the lower portions of the Kenai River and Kachemak Bay; it then zig zagged 14 times across the inlet back to Anchorage. On 4 June the survey trackline went south down the center of Cook Inlet to Cape Douglas and north along the west shore to

Chinitna Bay where we crossed the inlet for a refueling stop in Homer. We then returned to the west shore of Cook Inlet and continued north along the coast to Anchorage, including surveys well up Tuxedni, Big, and West Fork Rivers.

The composite of these aerial surveys provided a thorough coastal coverage of Cook Inlet (1307 km) for virtually all waters within 3 km of shore (Fig. 1). The 1129 km of offshore aerial transects meant we searched 3387 sq km, assuming a 3 km wide transect swath. Of the 19,863 sq km surface area of Cook Inlet, our coastal plus offshore tracklines covered 7308 sq km, which means approximately 37% of Cook Inlet was surveyed. However, the aerial surveys covered 100% of the coastal area in which beluga whales were expected.

Aerial Estimates of Beluga Group Sizes

Aerial counts of beluga whales are shown in Table 1 and Figure 2. These counts were the highest counts made by either of two observers on multiple passes over a group. Group sizes ranged from 1 to 165 (in Table 1 some groups were combined by location). The consistency of resightings between days, particularly the whales near the Susitna Rivers and whales in Chickaloon Bay, allowed us to combine results among the survey days. Maximum counts from each location were used, assuming whales did not travel long distances between days.

Double Counts

All four of the observers had experience in aerial surveys of beluga whales prior to this project. Their sighting rates were compared for periods when they were paired on the left side of the aircraft (Table 2). Of 12 group sightings, observer A saw 9 and missed 3; of 7 groups, B saw 5 and missed 2; of 6 groups, C saw 2 and missed 4; of 7 groups, D saw 7 and missed none. In summary, 16 group sightings were recorded of which only 7 groups were seen by both observers, and 9 were missed by one of the two observers. The mean size of groups missed by an observer was 26 (ranging from 1 to 85); the mean size of groups seen by both observers was 124 (ranging from 22 to 165). All groups of over 85 whales were seen by both observers, but of groups of less than 85 whales, only one (10%) was seen by both observers.

Distance to Initial Sighting

Distances between the aircraft and a beluga group at the moment of the initial sighting varied considerably (Table 2). The minimum sighting distance was 0.00 km (first seen under the aircraft), the maximum was 3.19 km, and the mean was 1.46 km (n=16; sd = 0.75). Most (70%) of the initial sightings occurred between 1 and 2 km from the aircraft.

Behavioral Observations

Behavioral observations are necessary to develop background information for the tagging study and identify possible stratification criteria for the abundance estimates.

Group size - In most cases, beluga whales were found in large groups, particularly near the Susitna Rivers where there was usually 70-165 whales counted in a group. Only the pair of whales in Iniskin Bay, an adult and young (possibly a calf), were well away from other whales. The animals near the Susitna Rivers were typically in dense groups. These whales were in such shallow water that their wakes were sometimes visible. In some lighting conditions, it appeared that every whale in the group was making a visible surface disturbance. Aerial counts at such times - and when mud plumes occurred behind each whale - were considered to represent most of the whales in a group. Other groups, such as those in deeper waters near Pt. Possession/ Chickaloon Bay and in Kachemak Bay, were fairly disperse, and their relatively deep dives provided fewer sighting cues.

Aerial harassment - Beluga whales made no apparent reactions to the survey aircraft. This is consistent with observations in other years (Withrow *et al.* 1994) and may be due to habituation to the dense air traffic in the area. Our aircraft was not a novel stimulus: during most of our surveys in Upper Cook Inlet, many other aircraft were in view at any one time.

Aerial observations of vessel harassment - When one of the NOAA tagging boats approached a dense group of whales on 1 June, the whales changed from multidirectional to unidirectional surfacings until the boat stopped motoring, then the group quickly returned to multidirectional surfacings. Initially, the group appeared as a densely packed circle, but when the boat entered the group, the circle became a crescent arched around the boat; however, the integrity of the group did not seem to be broken, and they did not make an effort to leave the area even with the boat only a few tens of meters away. This is remarkably different from Fraker's (1978) observations of belugas swimming rapidly from a barge in tow 2.4 km away. See Shelden (1995) for descriptions of beluga responses to vessel approaches as seen from the vessel.

Tidal influence - Group behavior might be tidally influenced. We observed a large, dense group (Group 2 on 1 June) 1.5 km offshore in the mouth of the Big Susitna River nearly 9 km from the shelf break (beyond which the bottom is not exposed at low tide). There was a 4 km long comet-like trail of animals traveling from the main group to deeper water just after the peak of high tide. Otherwise all groups were seen close to shore, generally within 1 km of the apparent shoreline.

Discussion

Methods

Survey methods for the 1994 study were refined from those developed in 1993 (Withrow *et al.* 1994). Cook Inlet was surveyed more thoroughly and included tracklines further up rivers and further south to the southernmost limits of Cook Inlet. The survey width was considered to be 1.5 km wide on each side of the aircraft, instead of 1.0 km wide as in 1993. Time of the initial sighting of a whale group was recorded, which allowed sighting range distances to be calculated. A paired, independent observation effort was conducted systematically throughout the 1994 study, and whale counts were kept independent. Systematic video coverage allowed for laboratory analysis of group size and surfacing behavior.

Whale Distribution

During both our 1993 and 1994 aerial surveys, large concentrations of belugas (91% of our aerial counts in 1994) occurred in the northwest corner of Cook Inlet, between the Beluga and Little Susitna Rivers (Fig. 2). This concentration apparently lasts from mid-May to mid-June (Calkins 1984) and is very likely associated with the migration of anadromous fish, particularly eulachon (*Thaleichthys pacificus*) (Calkins 1984; 1989). We consistently found a smaller group (approximately 20 whales) between Chickaloon Bay and Pt. Possession. Other small groups (2-10 each) were found in Turnagain Arm, Kachemak Bay, and Iniskin Bay. The latter two sightings were well south of the southernmost sighting made in 1993 (in Redoubt Bay). Other's surveys in June (Calkins 1984) also found the majority of animals were in the northwest corner of the inlet, with some (26 animals) seen in Redoubt Bay and others (25 animals) south of Kasilof River. Calkins (1979:40) indicated that belugas were "seen throughout the year in the central and lower Inlet." Others (Harrison and Hall 1978) made sightings even further south near Kodiak Island in March and July. Murray and Fay (1979) also found belugas near Kodiak Island, as well as in Shelikof Strait, south of Prince William Sound, and in Yakutat Bay. Leatherwood *et al.* (1983) recorded one beluga near the southwest entrance of Shelikof Strait on 6 August 1982, but no other belugas were seen by this project on the north or south shores of the Alaska Peninsula. Some sightings have been made in Prince William Sound in March (Harrison and Hall 1978) and Yakutat Bay in May (Calkins and Pitcher 1977) and September (R. Ream, NMFS, NMML pers. commun.), perhaps as occasional visitors from Cook Inlet (Calkins 1989). These sightings indicate that at least some of the time there are beluga whales in the northern Gulf of Alaska outside of Cook Inlet. However, no sightings of belugas were made during many intensive aerial surveys around the Alaska Peninsula (Brueggeman *et al.* 1989; Frost *et al.* 1983; Harrison and Hall 1978; Leatherwood *et al.* 1983; Murie 1959; NMFS unpubl. data) supporting the hypothesis that the Cook Inlet stock is isolated from stocks in the Bering Sea and that the Cook Inlet stock is not widely dispersed.

In both of our survey years, 1993 and 1994, we made no sightings of belugas in deep water well away from shore. The furthest offshore sighting was a group 2.2 km from shore, but they were over the shallow shelf where water is listed as less than 1 m deep at lower low tides (NOAA Nautical Chart #16660). In every case, beluga whales were seen on the shore side of the aircraft during transects; sometimes whale groups were so large they were seen from both sides, but no group was entirely on the open water side of our tracklines. The approximate 140 m-wide blind zone below the aircraft was probably insignificant in the general sighting effort.

Aerial counts ranged from 1 to 165 whales per group, with many (47%) of the sightings in groups of more than 70 animals. The sightings were generally of white backs as the whales arched during a surfacing, although surface disturbances were included in the counts. Small, dark gray animals, such as calves or yearlings were probably underrepresented in the aerial counts (see Hobbs *et al.* (1995) for calculations of number of animals missed in the aerial counts). The number of beluga whales at the surface was inconsistent between aerial passes. This was in part due to changes in visibility, such as glare, but also due to changes in the amount of time the group was counted. Although there was not a constant number of animals in view, as might be expected if there was a random surfacing rate, we did not observe an apparent synchrony in surfacings either. Calkins (1979) describes waves of three sub-groups surfacing in synchrony within a larger group such that the first group is resurfacing as the third group submerges. We did not see any patterned surfacings of this sort.

Double Counts

In 1993 some effort was made to compare observers during aerial surveys; however, the data cannot be treated as independent searches because the paired observers were able to interact.

While circling whale groups, 2-4 observers made independent estimates of group size, but all could hear the others' estimates after they were made, possibly influencing sequential effort. Also, group sizes were estimated separately by the left and right observers when the aircraft changed its flying pattern from counterclockwise to clockwise, but the number of animals in view would have changed between passes, so these dual counts of a group are not as comparable as dual counts from the same aerial pass.

In 1994 more rigorous testing of paired observers showed that beluga groups were missed by single observers. As might be expected, small groups were missed more often than large groups. This was also documented by Barlow (1993) when he had independent observers search for cetaceans from a ship. In our study, both observers saw groups of over 85 whales, but the probability of both observers detecting groups of less than 85 whales was only 0.10. The impact of this low sighting rate is diminished by the apparent low proportion of beluga whales in small groups during the June survey period.

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Table 1. Summary of high counts of beluga whales made during aerial surveys of Cook Inlet in June 1994. Dashes indicate no survey, and zeros indicate that the area was surveyed but no whales were seen. Asterisks show which counts were used in the summary count (right column).

	Flight dates					
Location	1 June	2 June	3 June	4 June	5 June	Count
Turnagain Arm	---	*7	---	---	(a)	7
Chickaloon Bay	---	18	---	---	*22	23
Pt. Possession	---	0	14	---	*1	(b)
Kachemak Bay	---	---	*9	---	---	9
Iniskin Bay	---	---	---	*2	---	2
Beluga R.	---	0	---	0	*20	(c)
Big Su R.	222	165	---	180	*228	408
Little Su R.	0	0	---	143	*160	(c)
Totals	222	190	23	325	431	449

(a) Visibility was compromised due to local winds.

(b) Counts included in Chickaloon River count.

(c) Counts included in Big Su River count.

Table 2. Distance to initial sighting of a group of beluga whales. An underline indicates which observer first saw a group. An x indicates which observers missed a sighting while on transect. Group size is the maximum estimate made by any observer.

Date	Group	Location	Group size	Front obsv	Rear obsv	Distance (km)
6/1/94	1	Big Su R.	84	B[1]	---[1]	1.16
	2	Big Su R.	138	D[2]	C[2]	---[3]
6/2/94	1	W of Big Su R.	165	A	B	---[3]
	2	Turnagain Arm	---[4]	A x	B	0.00
	2	Turnagain Arm	7[5]	A	B	1.46
	3	Chickaloon Bay	18	A	B x	1.51
6/3/94	1	Pt. Possession	14	C x	A	1.44
	2	Kachemak Bay	3	C x	A	1.05
	3	Kachemak Bay	6	C[2]	A[2]	0.80
6/4/94	1	Iniskin Bay	2	D[2]	A[2]	0.56
	2	W of Big Su R.	85	A x	D	1.67
	3	Big Su R.	95	A	D	1.65
	4	W of Little Su R.	143	A	D	2.67
6/5/94	1	Pt. Possession/ East Foreland	1	B x	A	1.90

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[1] Observations made from the right side of the aircraft.

[2] Entries not used in the inter-observer comparisons because mikes were on, allowing for open communication.

[3] The group was too dispersed to establish initial sighting distance.

[4] No counts were made on the first survey past this group.

[5] This group was revisited on a return down Turnagain Arm, therefore it is not included in the analysis of missed groups.

	2	Beluga River	20	B	A x	1.45
	3	W of Big Su R.	70	C x	D	3.19
	4	W of Big Su R.	13	C x	D	1.24
	5	W of Big Su R.	145	C	D	---[3]
	6	Little Su R.	160	C	D	1.68
	7	Chickaloon Bay	22	A	B	---[3]

Table 3. Pairings of observers during aerial surveys over Cook Inlet, showing the number of beluga whale groups seen by one or both of a pair of observers, and (parenthetically) indicating the total number of hours spent observing simultaneously.

	Observers			
	A	B	C	D
A	---	7 (5.3)	2 (3.4)	3 (5.4)
B	---	---	0 (2.4)	0 (2.0)
C	---	---	---	4 (4.4)
D	---	---	---	---
Hours surveyed while paired	14.2	9.7	10.2	11.8
Groups seen	9	5	2	7
Groups/hour	0.6	0.5	0.2	0.6
Total seen by both observers	12	7	6	7
Groups missed	3	2	4	0
Percent missed	25	29	67	0

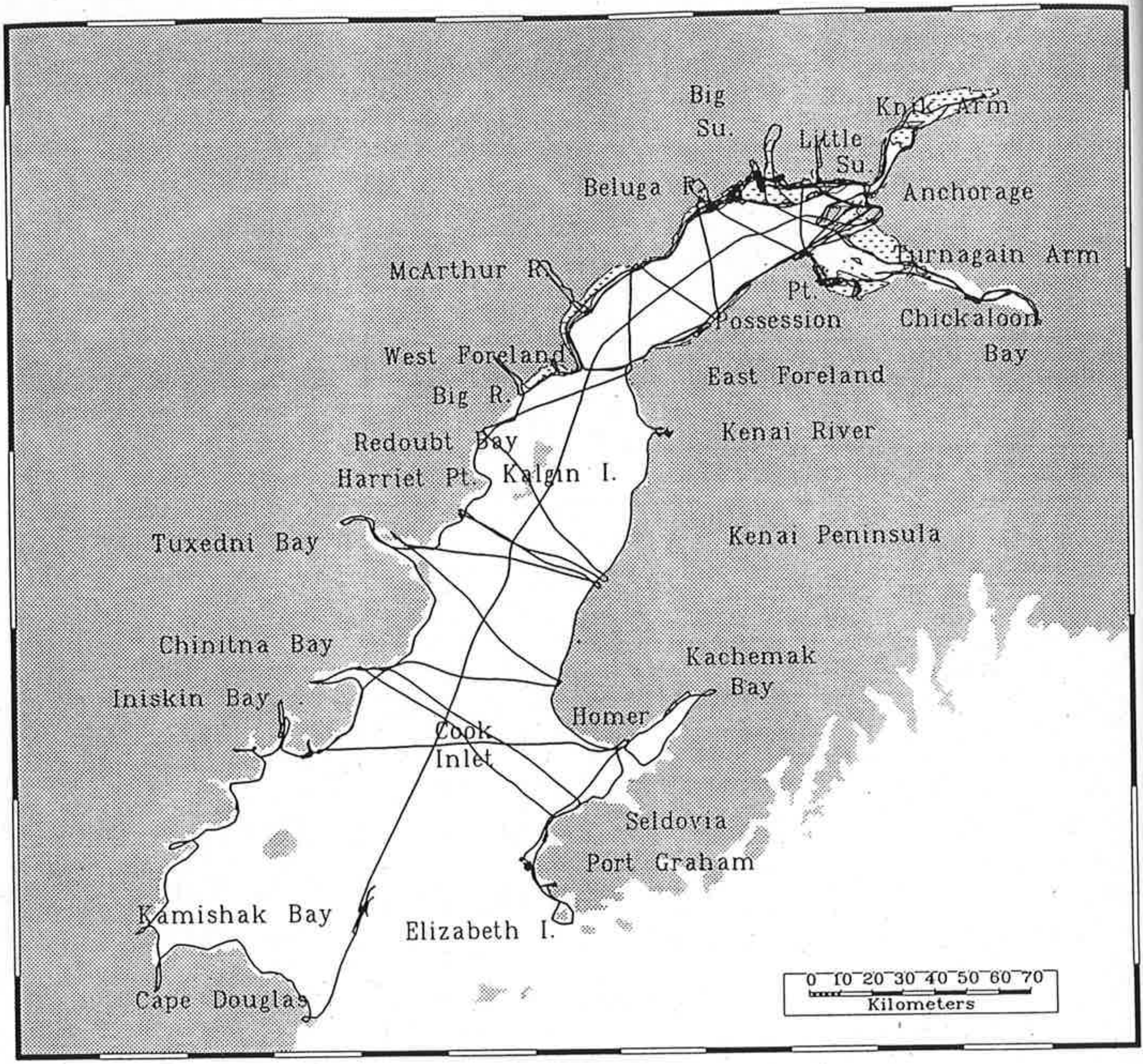

Fig. 1. Aerial survey tracklines for 1-5 June 1994 covering the coastal and offshore areas of Cook Inlet. Dashed areas indicate mud flats exposed at low tide.

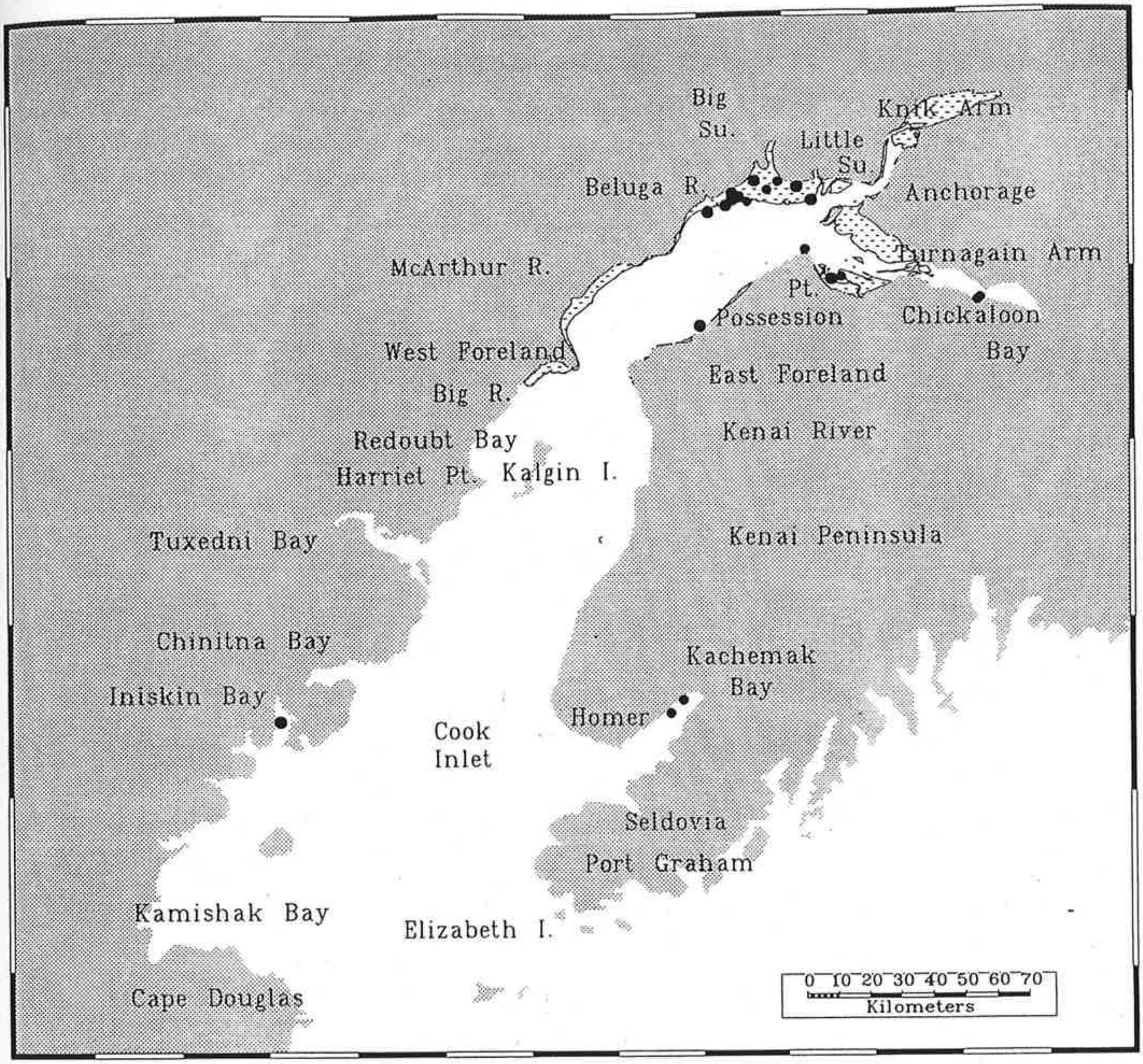

Fig. 2. Beluga whale groups seen during aerial surveys of Cook Inlet 1-5 June 1994.

Group Count Estimates and Analysis of Surfacing Behavior of Beluga Whales from Aerial Video in Cook Inlet, Alaska, 1994

Janice M. Waite and Roderick C. Hobbs

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115, U.S.A.

Abstract

Videotapes of beluga whale groups were collected during aerial survey work in Cook Inlet, Alaska, from 1-5 June 1994. From these aerial videotapes, thirteen whale groups were counted to correct counts made by airborne observers. These correction factors were then used in the abundance estimate in Hobbs *et al.* (this report). In addition, the aerial videos provided the time that whales spent at the surface (190 whales were measured from five different groups), a variable in the correction for whales under the surface during a count. The color and size of whales on the monitor screen were also measured (155 from three groups). Surface times were not significantly different between two passes of the same whale group for all three color categories, but were significantly different for two of the three color categories between whale groups. The surface times of the different color groups were compared to surface times of different color groups measured in videotape taken during vessel work. Surface times measured from the vessel were significantly different from one aerial group, but not from another. The proportion of color groups was also compared to the proportion of color groups from a photograph of a stranded beluga whale group. There was a similar proportion of gray animals in the aerial video and in the stranding photograph. Because of this and because surface times were not shorter than measured in the vessel video, it appears that all or most whales are being counted in the aerial video. However, because these results are based on small sample sizes, and comparisons are made between very different views of whales, more analysis needs to be done before we can be confident about the proportion of whales that are seen in the aerial video.

Introduction

During the 1994 aerial survey of Cook Inlet (Rugh *et al.* 1995), video records were collected concurrently with observer counts of beluga whale (*Delphinapterus leucas*) groups. Over 45 minutes of video tape recording (hereafter referred to as video) was taken. From these tapes several types of analysis have been conducted, including:

- Accurate counts of all visible surfacings in a group over a measured period of time.

- Accurate measurement of time whales were visible at the surface (start to end of a surfacing).
- Apparent size estimates of whales as seen in the aerial video.
- Color classification for whales as seen from the aerial video.

Group size estimates based on aerial video counts are considered to be accurate when corrected for animals below the surface or animals that have surfaced twice during a count. These can then be compared to the observer's counts made during the aerial survey to devise a correction factor for animals that were available at the surface but missed during a count.

To correct for animals under the surface during a count and animals that surfaced twice during a count period, an average time visible at the surface was needed (see Hobbs *et al.* 1995 for more detail). The aerial video provides a precise way to measure the time that whales spend at the surface. The surface times measured in the aerial video represent the same vantage point as an observer during an aerial count.

Small whales or whales whose color may be camouflaged against the color of the water are more likely to be missed in the aerial counts and in counts made from aerial video. The size and color of animals in a group can also be measured from the aerial video. In addition to aerial video, beluga whales were videotaped from a vessel during tagging operations (Shelden 1995) and an aerial photograph of a mass stranding on the Susitna River delta was obtained. Vessel video analysis provided surface time data for different color classes of beluga whales in Cook Inlet, while analysis of the stranding photograph provided an estimate of the proportion of gray to white animals in a group. By comparing the surface times of the different color categories in the vessel and aerial video, it may be possible to evaluate whether a portion of the beluga whale population is not represented in the aerial analysis.

Methods

Counting beluga whales

To count from the videotape, a video cassette recorder capable of advancing and reversing the tape frame by frame and a Panasonic monitor were used. Each frame corresponds to 1/30th of a second. Groups were counted in two different ways according to group size. For small groups, whales were counted directly from the monitor screen as the video played at regular speed. Independent counts were made by three different people, and an average was used. For large groups, whale locations were "captured" by stopping the video every 0.5 seconds (15 frames). Transparency sheets placed on the monitor screen allowed marks ('dots') to be made for each visible beluga whale. The sheets were then examined by placing one on top of the next and determining which whales were resighted from one sheet to the next. If a new dot appeared, it was marked as a new whale. Each sheet was checked by a second person, and any discrepancies about whether dots represented new animals or were resightings were discussed until an agreement was made. The number of whales on the first sheet plus the number of "new" whales on each successive sheet were then added to derive a total count for the pass.

This method of counting beluga whales from video was developed in several steps of learning. Two people viewed an aerial pass together with open discussion about which dots represented actual beluga whales. Then a second count was made by three people independently (including the two who had made the first count together). This count was then examined sheet by sheet (every half-second) by all three reviewers. Discrepancies between reviewers were discussed, and a consensus was made concerning whether a dot on the screen could be considered a whale or not. We found that a bird could be mistaken for a beluga but learned through this process how to distinguish them.

The aerial video was taken in two different ways. For some passes, the camera was pointed at the group and was moved to keep the whales in the field of view until they were out of sight. For other passes the camera was held perpendicular to the trackline and scanned across a group (Figure 1). To determine a correction factor, the time spent counting was needed. This was determined differently depending on how the video was taken. For the 'single point' groups, the amount of time that the group was in view was used. For the 'scanned' groups, we measured the amount of time an object on the water was in view across the screen during the pass.

Time at the surface

To measure the time that whales were visible on the surface, a sample of whales from different passes were examined. Transparency sheets from the group counts were used to ‘grab’ a random group of whales (one or two sheets were used depending on the length of the pass). The dots on these sheets were copied onto new transparency sheets, and each dot was numbered. It was then possible to follow each whale using the slow frame-by-frame mode on the video cassette recorder from the time the whale appeared to the time it disappeared. Counter numbers were used to determine the time spent at the surface for each whale. Because there are 30 video frames per second, the error in timing was at most 0.07 seconds.

Whale size (magnitude) and color scale

To determine the distribution of apparent whale sizes visible from the aerial video, each whale that was measured for time at the surface was also measured for visual size and given a color rating. The halfway point in each whale's time at the surface was determined, and measurements were taken at that time for each whale. A plastic metric ellipse template was used as a scale for size. The template was reduced by half using a photocopier to match the range of sizes of the whales. Each ellipse was classified with an angle (describing the shape of the ellipse from almost a circle to a flat oval) and a size (the length of the major axis). The template was held up to the monitor screen for each whale, and a best match was determined. Two independent assessments were made. Using the angle and size for each whale, the magnitude, *m*, (area in mm^2 on the screen) was calculated for each whale:

$$\sin(a) b^2 \frac{\Pi}{4}$$

where a = the angle, and b = the size in mm. The area was calculated for both independent measurements and these were averaged for each whale. To determine a color rating for each whale, three color shades were used: white, gray, and dark. Two independent assessments were made. If there was a disagreement, the two reviewers discussed the color and came to an agreement.

Stranding photograph

On 14 June, 1994, a group of approximately 190 beluga whales stranded on a mud flat near the Big Susitna River mouth. A photographer from The Anchorage Daily News took an aerial photograph which included most of the stranded individuals (186 total). We obtained a 10 x 15 print of the photograph. From the photograph, an assessment of the distribution of sizes and colors was possible. Each whale in the photograph was given a size rating from four size categories (small, medium, large, and very large) and a color rating from four color categories (dark gray, light gray, off-white, and white). Two independent assessments were made, differences were discussed, and a consensus reached for each whale. It was then possible to compare the relative frequency of gray animals to white animals in this large group of beluga whales to the color distributions found in the aerial video of large beluga groups.

Comparison of aerial and vessel video

Beluga whale surfacing behavior was also analyzed from videotape taken from boats during tagging operations (Shelden 1995). Whales were classified into three categories based on coloration and behavior: white animals, gray animals, and head lifts. Surface times were measured for each whale. A t-test was used to compare all surface times measured from the vessel video to all surface times measured from two different groups in the aerial video. Next, the three color categories classified in the vessel analysis were paired to and compared to the three color categories classified in the aerial analysis.

Results

Video counts

A total of thirteen passes were counted using aerial video (Table 1). Passes that were lacking a count time during the aerial survey (due to computer failure in the field) and passes that were rated as poor quality on the video were not counted (see Rugh *et al.* 1995 for rating descriptions). Three out of eight passes with a 'fair' rating were counted. Of the thirteen passes counted, four were counted directly from the screen (without use of transparencies) and nine were counted by "capturing" whales every half a second using transparency sheets on the screen.

Time at the surface

Of the thirteen passes counted from video, five were sampled for the length of time whales were visible at the surface. Average times per pass ranged from 1.91 ± 0.12 sec to 2.99 ± 0.10 sec (Table 1). Two of the five were different passes of the same group (6/1/94, Group 1). The mean surface time for these two passes did not differ significantly (t-test, P = 0.18). The surface times from this group were used in the equation to derive a correction factor for missed whales under the water surface (Hobbs *et al.* 1995) because we felt that the video for this group was the best for measuring surface times. Other groups were further from the plane and so less clear.

Of these five passes, three were measured for whale magnitude and color (Table 1). Two of these were different passes of the same group (6/1/94, Group 1, Passes 2 and 6, Big Susitna River), and the third was a group counted on a different day (6/4/94, Group 4, Pass 4, west of the Little Susitna River). For each of these three passes, surface times were split into the three color categories (white, gray, and dark). Surface times from each color class were compared between passes. First, the two passes from 6/1/94, Group 1 were compared. No significant differences were found for all three color categories (t-test; $P = 0.61$, $P = 0.46$, and $P = 0.81$, respectively). Because the surface times from the two passes of 6/1/94, Group 1 were not different, these two passes were pooled and then compared to the third pass. The white and gray color categories were significantly different between 6/1/94, Group 1 and 6/4/94, Group 4 (t-test; $P = 0.055$ and $P = 0.002$, respectively), but the dark color category, a smaller sample, was not ($P = 0.11$).

Magnitudes

Differences in magnitudes (i.e., size of an animal) were tested between the two passes of the same group for all colors combined and then for each color category separately. Pass 2 and Pass 6 (6/1/94, Group 1) were significantly different overall (t-test, $P = 0.04$). Magnitudes of white whales and dark whales were not significantly different (t-test, $P = 0.70$ and $P = 0.69$, respectively), but magnitudes of gray whales between passes were significantly different ($P = 0.02$).

The whales from the two passes of 6/1/94, Group 1 were combined and their magnitudes were compared to 6/4/94, Group 4. Overall, there was a highly significant difference between groups (t-test, $P = 7.29 \times 10^{-7}$). Broken down by color, white whales from the two groups were significantly different in size ($P = 0.04$), but grays and darks were not different ($P = 0.53$, and $P = 0.55$, respectively).

Relationship between surface times and magnitudes

Surface times were plotted against magnitudes for the two passes of 6/1/94, Group 1, combined. Each beluga whale color classification was plotted separately (Figure 2). Each color group was clustered, but clusters overlapped between groups.

Stranding photograph

Of the 186 whales counted in the stranding photograph, 180 were rated for color and size. It was not possible to judge the size of the remaining six because they were partially obscured by other whales and/or water. The distribution of colors for the 180 stranded beluga whales was nearly uniform between the four color categories (Table 2). Combining the two gray categories and the two white categories produced nearly equal numbers of gray and white animals (48% to 52%). Four times as many medium and large whales were found as small and very large whales. There was an obvious relationship between size and color (Figure 3), with small and medium whales comprising most of the dark and light gray whales, and large and very large whales comprising most of the off-white and white whales.

Comparison of vessel and aerial video

The surface times of all whales measured in the vessel video and all whales measured in the aerial video of Group 1 from 6/1/94 were significantly different (t-test, $P = 3.59 \times 10^{-8}$) (Table 3). Broken down by color category, vessel whites and aerial whites, and vessel grays and aerial grays were significantly different ($P = 2.00 \times 10^{-4}$, $P = 1.02 \times 10^{-6}$, respectively). The surface times of vessel head lifts, however, were not significantly different than aerial dark whales ($P = 0.10$).

The surface times of all whales measured in the vessel video and all whales measured in the aerial video of Group 4 from 6/4/94 were not significantly different (t-test, $P = 0.11$) (Table 3). In addition, all three color comparisons were also not significantly different (vessel whites and aerial whites: $P = 0.48$; vessel grays and aerial grays: $P = 0.35$, and vessel head lifts and aerial darks: $P = 0.97$).

Discussion

Aerial video proved to be a valuable tool for examining counts made from aircraft. By using the stop motion feature of a video cassette recorder, it was possible to get a very precise count of a beluga group. These counts were used in the abundance estimate derived in Hobbs *et al.* (1995). For large groups, the aerial video count was almost always much higher than the airborne observer count (Rugh *et al.* 1995) , although these counts have not been corrected for time spent counting and so do not imply group size estimates. It was very difficult for an observer to see and count each individual whale. Therefore, observers made assessments by quickly tallying whales as best as they could, or by counting in fives or tens (Rugh *et al.* 1995). Data from video counts indicate that for these large groups too many whales were present for observers to mentally register, and therefore, negatively biased counts were made. Interestingly, small group counts (less than 50 whales) were larger from the aircraft than from the video. Observers had more time to count individuals in small groups, and so counts were more likely to be accurate. Video counts may have been lower for these small groups because the whales may have been spread out over a large area making it difficult to capture all whales on video.

In making corrections from video analysis, it was necessary to have a measure of what portion of a group of whales were actually visible. The stranding of the whales in the Susitna River delta gave an unexpected opportunity to accurately quantify the proportion of different colored animals in one large group. Approximately half of this group was comprised of gray whales and half white whales. The proportion of beluga whales in the Canadian Arctic estuaries was found to be similar, with 42% white whales (Smith *et al.* 1994). For Group 1 from 6/1/94, more than 50% of the group was classified as gray or dark, suggesting that all animals were visible. On the other hand, it is possible that white animals appeared gray in the video due to resolution limitations of the monitor. To test for this, surface times were compared to surface times measured from the vessel video. Surface times from Group 1 (6/1/94) and Group 4 (6/4/94) were actually longer in the aerial video than the vessel video; however, Group 4 surface times were not significantly different from the vessel times. This indicates that animals were not being missed in the aerial video. Surface times may have appeared shorter in the vessel video because animals were hidden by small waves, where they would still be visible from the air.

The measure of surface times was necessary as a component in the correction factor for animals missed (those underwater during all or part of a count) and for animals counted twice during a pass. We found differences in surface times between whale groups, although two passes from the same group had similar surface times. There are several possible reasons for these differences: The behavior of the animals may have been different between groups (or in the same group on different days). Whales may have faster surfacing times when they are active (feeding or traveling) than when at rest. However, it was difficult to determine the behavior of a whale group from the air, other than being clumped or spread out. Surface times may also be different between groups due to differences in distance from the aircraft. The further the group is from the aircraft, the smaller whales would appear. They would, therefore, be less distinct for measuring surface times. The brightness of the day and the sea condition may also have affected how well animals were seen. These weather conditions affect how whales contrast against the background water color. There could also have been a difference in the brightness settings of the video monitor during analysis. Because the surface times of the two passes from the Group 1 were not significantly different, the analysis methods were probably consistent between passes.

Differences in surface times and proportions of colors and size were found between Group 1 (6/1/94) and Group 4 (6/4/94). The differences were consistent with Group 4 being further from the camera so that the beginning and ending of surfacings were most likely lost due to low resolution of the camera. Animals may have appeared darker as a function of increased distance from the camera. Surface times were shorter in Group 4 and there was a much higher proportion of gray and dark animals.

Acknowledgments

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Table 1. Type of video and count made for aerial passes, counts from video, elapsed time, time at surface, whale magnitude on screen, and ratio of whale colors for each pass.

Date	Group	Pass	Type of video	Method of counting	Count	Elapsed Time (seconds)	Mean time at surface in seconds (SE)	Mean size (magnitude) in mm^2 (SE)	Ratio of colors (white:gray:dark)	Sample sizes for measurements
6/1/94	1	2	Point	Sheets	127.7	12.93	2.77 (0.14)	3.67 (0.18)	15:25:7	47
6/1/94	1	6	Point	Sheets	156	15.50	2.99 (0.10)	4.22 (0.18)	25:32:4	61
6/1/94	1	8	Point	Sheets	149	22.00				
6/1/94	1	10	Point	Sheets	190	21.50				
6/1/94	2	2	Point	Sheets	145	14.00				
6/4/94	3	2	Point	Sheets	178	14.00	2.82 (0.19)		7:10:4	21
6/4/94	3	3	Point	Sheets	132	15.93				
6/4/94	4	1	Point	Sheets	158	19.23				
6/4/94	4	4	Scan	Sheets	123	11.50	1.91 (0.12)	3.10 (0.11)	6:20:21	47
6/5/94	2	3	Scan	Screen	16	17.60				
6/5/94	3	5	Point	Screen	15.7	19.80				
6/5/94	5	3	Point	Screen	29.3	31.47	1.99 (0.11)			14
6/5/94	7	3	Scan	Screen	6	25.43				

Table 2. Number (and percentages) of stranded belugas in each color and size category.

	Whale Size				
Color	Small	Medium	Large	Very large	Total
Dark Gray	20 (11%)	23 (13%)	1 (1%)	0	44 (24%)
Light Gray	1 (1%)	36 (20%)	9 (5%)	0	46 (26%)
Off-white	0	10 (6%)	30 (17%)	2 (1%)	42 (23%)
White	0	6 (3%)	28 (16%)	14 (8%)	48 (27%)
Total	21 (12%)	75 (42%)	68 (38%)	16 (9%)	180

Table 3. Mean surface times (seconds) of beluga whales from aerial and vessel video.

	Aerial				Vessel		
	6/1/94, Group 1		6/4/94, Group 4				
Color	Mean (SE)	Sample size	Mean (SE)	Sample size	Color/ Behavior	Mean (SE)	Sample size
White	3.22 (0.11)	40	2.83 (0.15)	6	White	2.71 (0.07)	21
Gray	2.86 (0.10)	57	2.32 (0.23)	20	Gray	2.17 (0.08)	18
Dark	1.83 (0.30)	11	1.26 (0.14)	21	Head lifts	1.26 (0.10)	13

Radio-Tagging of Belugas in Cook Inlet, Alaska, June 1994

James A. Lerczak
National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115, U.S.A.

Abstract

As part of the June 1994 field studies to assess the status of the Cook Inlet stock of beluga whales, radio transmitters were deployed on whales, using suction cup tags. Tagging operations took place on the extensive tidal delta of the Big and Little Susitna Rivers. A total of four whales were successfully tagged, and two of these tags stayed on long enough for data to be collected. The data were used to determine the mean time between dives and the mean time at the surface per surfacing. This information was necessary to establish a correction factor for sub-surface whales missed during aerial surveys.

Introduction

Beluga whales (*Delphinapterus leucas*) occur in large, tightly grouped pods in the northern portion of Cook Inlet during the late spring and early summer (Hobbs *et al.* 1995). The largest groups (300+ whales) appear to occur on or near the broad delta of the Big and Little Susitna Rivers (Fig. 1). The National Marine Mammal Lab (NMML) has conducted aerial surveys of these whales in the entire Cook Inlet for the past two years during this time period (Rugh *et al.* 1995). Counts from these surveys have been used to establish an abundance estimate for this stock (Hobbs *et al.* 1995).

The waters of the upper inlet are extremely turbid. Secchi depths are typically less than 20 cm (Shelden and Angliss 1995). Thus, sub-surface whales are not at all visible to aerial observers, and counts must be corrected for the fraction of whales that remain below the surface during aerial passes. To determine this correction factor, the mean inter-surfacing time and the mean time at the surface per surfacing are required (Hobbs *et al.* 1995).

VHF radio-tagging studies were conducted on belugas in Bristol Bay by Frost *et al.* (1985) to obtain data on the diving characteristics of these whales. Like the whales of upper Cook Inlet, the tagged Bristol Bay belugas occurred around extensive tidal mud flats in extremely turbid waters. Behavioral differences between the Bristol Bay and Cook Inlet stocks, however, are not known. Further, the diving behavior of any particular stock is likely to change seasonally. It is, therefore, important to obtain dive data that is representative of the whales being surveyed by the aerial observers. To ensure that this occurred, the NMML conducted similar tagging studies on the whales at the Big and Little Susistna Rivers delta at the same time the June 1994 aerial surveys were being flown.

For their tagging studies, Frost *et al.* (1985) used an instrument pack that was bolted directly to the dorsal ridge of the whales. The transmitters deployed in Cook Inlet were attached using suction cup tags. Suction cups have been used for the attachment of instrument packs onto wild cetaceans by several investigators (killer whales: Baird and Goodyear 1993, Baird 1994; humpback whales: Goodyear 1989; Hector's dolphins: Stone *et al.* 1994; and gray whales: Duffus 1995). With these tags, attachment is relatively easy and requires a minimum amount of harassment to the whales.

Methods

The tags used in this study were designed by Cetacean Research Technology, Seattle, Washington. The suction cup and transmitter saddle mount (Fig. 2) were formed from silicone as a single unit by an injection mold process. Two polyurethane sleeves were placed into the setting silicone around the bottom of the saddle. Plastic tie-straps were fed through the sleeves and around the transmitter to secure it to the tag. Closed cell foam (not shown in Fig. 2) was used to give the tags positive buoyancy. The foam was placed on top of the transmitter and symmetrically around the plastic accessory ring so that the tag floated with the antenna pointing upward. This allowed for a signal to be received after the tag was released from the animal so that the tag could be recovered and re-used. A tapered hole was molded through the transmitter mount and into the suction cup. A small water soluble gelatinous plug was placed into this hole so that suction was maintained. Suction was broken when this plug dissolved. This provided a time release mechanism for the tags. In a controlled lab environment, suction was maintained for 10-14 hours.

The tags were further tested on captive belugas at the Point Defiance Zoo, Tacoma, Washington. Tags were placed just left of the dorsal ridge of two whales (a 900 kg male and 450 kg female). The whales were then sent through their training exercises which included rapid swimming around the tank and breaching. Both tags remained attached to the animals during the exercises and were removed by the trainer after being on the male for 2.25 hours and the female for 1.75 hours.

The VHF radio transmitters (model 5A, Advanced Telemetry Systems, Inc., Isanti, Minnesota) used in this study had frequencies within the range of 164 and 168 MHz and a power output of 6 milliwatts (6 V x 1 mA). Pulses were transmitted at a rate of 400 pulses per minute and had a nominal width of 20 ms. An eight inch 210 lb steelon flexible antenna was used. Transmitters were heavily encapsulated, giving them a cylindrical shape with a diameter of approximately 29 mm and a length of approximately 100 mm. The total weight of the tag and transmitter package was approximately 185 gm.

In the field, tags were attached to whales using a telescoping (8 to 16 feet) aluminum pole. This was accomplished from a 16 foot rigid-hulled inflatable boat in shallow waters (3 to 6 feet), where the wakes from the rostrum and tail flukes could easily be tracked to allow taggers to be close to the whales when they surfaced (see Shelden 1995).

Results

Tag Deployment

A total of 4 tags were successfully deployed (June 4, 9, 11 and 15), and two tags (June 4 and 9, DL4 and DL9 respectively) stayed on long enough for surfacing data to be collected.

Figure 1 shows the location of tag deployment for all four tags and the movements of the vessel as it followed the groups with which DL4 and DL9 were associated. As tagging operations occurred very quickly and the water was too turbid to observe the whales through, the ability to assess the size and coloration of the tagged whales was limited. DL4 appeared to be completely white, but smaller than the larger whales seen in the area. DL9 appeared to be almost completely white, with a small amount of grayish mottling. It also seemed to be adult size, but not as big as the larger whales seen. The tag on DL9 was placed on the center of the back near the dorsal ridge. The tag on DL4, however, was placed on the tail stock.

Diving Characteristics

For DL4, surfacing data, as received from the audio output of a radio receiver, were recorded real-time in a log book. For DL9, the audio signal from a receiver was split to a head-set and a tape recorder. Surfacing data was recorded in the log book and on audio tape. Real time data logging and tape recording occurred essentially at the same time, though slightly more time was spent tape recording since data logging had to be stopped each time other tasks needed to be performed. Therefore, the two data sets are not independent. The tape recorded data set served as a permanent record that could be carefully scrutinized. The logged data of DL9 was compared to this taped data to assess its quality and, thus, the quality of the DL4 logged data set for which there was no tape recorded data.

For the majority of the time, clear surfacing signals were heard over a fairly low background noise level. On occasion, however, a continuous background signal from the transmitter was heard. This background signal was lower in intensity and higher in pitch compared to the signal from surfacings. Tests showed that the transmitters occasionally continued to transmit with a continuous signal like this while completely submerged. This was assumed to occur when the transmitter was in fresh water and the antenna was not completely shorted Though no CTD casts were performed during these tests, casts made at other times gave salinities ranging from approximately 0.1 to 16 ppt (Shelden and Angliss 1995).

Useable blocks of log book data were determined from log book notes describing signal quality and strength as well as the position of the boat with respect to the whale group. Useable blocks of data from tapes were determined from log book notes as well as tape quality assessments. Generally, blocks of time were kept for analysis if the background noise level was clean and surfacings could clearly be heard above the background. Blocks of time where surfacing signals were low in intensity relative to background (probably because the boat was too far from the tagged animal) were not used. Blocks in which the continuous high-pitched signals occurred and were high enough in intensity to swamp the surfacing signals were also not used. To ensure that blocks of time were not so short that the data would be biased in favor of shorter surfacing intervals, only blocks long enough to contain several long dives were used. The cut-off chosen was 10 minutes. Within acceptable blocks of time, surfacings were designated as either definite or questionable. Definite surfacings were high in intensity, low in pitch (as compared to the continuous, high-pitched, background signals occasionally heard) and long in duration (approximately 1-2 seconds). Questionable surfacings were, generally, low in intensity and short in duration (less than 0.5 seconds). They were often higher in pitch than the definite surfacings (similar to the high-pitched background signals). These signals could not be definitively interpreted as surfacings. Similar short, sporadic signals were occasionally heard while testing the transmitters when the tag was known to be submerged.

From the tapes, the times of surfacing signals (with respect to the real time noted at the beginning of each tape side) were digitized using a program with which a person listening to the audio tapes could strike a hot key to grab a computer time for each surfacing heard. The time for the center of the surfacing interval was used. Separate hot keys were used to distinguish definite from questionable surfacings. A second program was used to obtain the duration of each surfacing signal. Two hot keys were used to mark the beginning and end of the signal from a surfacing. For this, the tape speed was reduced to the lowest speed allowed by the tape deck so that the error associated with the time to respond to the onset and end of a surfacing signal could be minimized with respect to the signal length. Tapes were listened to and data was digitized independently by two people.

The pattern of surfacing times from the end of each tape side in the digitized record were matched to the patterns from the log book to obtain a real time for these surfacings. By doing this, the surface interval times, stretched in length by the slow speed of the tape deck, could then be adjusted to real time. Even when the tape deck was run at normal speed, the digitized surfacing times occurred slightly earlier than the log book times (on average, 29 seconds per 45 minutes of tape, or approximately 1%). This was likely due to a slight difference between recording and playback tape speed. The surfacing time record from each tape was adjusted to account for this.

The signals within acceptable time blocks were analyzed, first, with all surfacings (both definite and questionable) included and, secondly, with only definite surfacings included (analysis types A and B respectively). In this way, the significance of the questionable surfacings could be assessed. The median, mean, standard deviation and the 2.5th and 97.5th percentiles of the distributions of inter-surfacing times as well as the shortest and longest times were calculated. These values are summarized in Table 1a. The mean inter-surfacing times for whales DL4 and DL9 are designated as $T_{i,DL4}$ and $T_{i,DL9}$, respectively.

For all sets of data, the mean and standard deviation of the inter-surfacing time distributions are significantly greater for DL4 than for DL9. The distribution for DL4, therefore, has a broader high dive time tail. This can clearly be seen in the attached histograms (Fig. 3a-h) as well as in the much higher 97.5th percentile for DL4. The mean and standard deviations vary significantly for DL4 between the analysis in which all surfacings (definite and questionable) are included and only definite surfacings are included. For DL9, however, the mean differs only slightly between the two analysis types and does not differ significantly between the log book and tape data. For the tape data, the standard deviation does increase significantly when only definite surfacings are included. The median is very stable and is only slightly higher for DL4. The 2.5th percentiles are all comparable. However, the 97.5th percentiles of DL4 are 1.2 to 2.3 times greater than those of DL9, depending on which data sets and analysis types are being compared.

The mean inter-surfacing time (T_i) used in the correction factor for sub-surface whales must reflect the diving characteristics of both whales studied. Therefore, the average is taken for the two whales. For DL4, the log book data set was used. For DL9, the tape recorded data set was used and $T_{i,DL9}$ was average of the values obtained from the two listeners:

$$T_i = \frac{1}{2}(T_{i,DL4} + T_{i,DL9})$$

T_i was calculated using the data from both analysis types. The results are summarized in Table

$$\mathrm{var}(T_i) = \frac{1}{2}[(T_i - T_{i,DL4})^2 + (T_i - T_{i,DL9})^2] + \frac{1}{4}[\mathrm{var}(T_{i,DL4}) + \mathrm{var}(T_{i,DL9})]$$

1b.

For the analysis of the duration of surfacings, a single tape side was chosen on which essentially no questionable signals occurred. From this tape side, a sample size of 125 surfacings were recorded. A summary of the statistics for the time at the surface for the two tape listeners is presented in Table 2. Histograms of the distributions of time spent at the surface for the two listeners are shown in Figure 4. The distribution from listener A is narrower and has a significantly higher mean. Figure 5 compares the surface times from listeners A and B for the same surfacings. These times are clearly correlated -- i.e. both listeners were able to distinguish long surfacings from short surfacings. Therefore, the two listeners were able to record a relative measure of the surfacing lengths. However, interpretations of the onset and ending of the signals were different, leading to the differences in the distributions.

Discussion

Inter-surfacing Times

Several factors, likely, contributed to the differences in the observed diving characteristics of the two tagged whales. These are listed below in their probable order of significance.

It is likely that surfacings have been missed in the logged data of DL4. This is suggested by the peaks at 47.5 seconds and 77.5 seconds in Figures 3a and b. The first peak probably corresponds to two surfacings being interpreted as one and the second peak probably corresponds to three surfacings being interpreted as one. The fact that the log book data and tape data of DL9 are very similar under analysis type B suggests that not many definite surfacing signals were being missed by the log book recorder. The slight differences under analysis type A suggest that some questionable signals were being missed. The tag on DL9 was placed on the center of the back near the dorsal ridge. This area is very likely to break the surface when an animal surfaces (though it may not when the animal only exposes its blow hole to breath -- see Shelden 1995 for a description of this behavior). Therefore, the probability of getting definite surfacing signals from the transmitter when the animal surfaces is high. The tag on DL4, however, was placed on the tail stock, an area less likely to break or come close to the surface as the animal surfaces. Thus, it is possible that, on occasion, only a faint signal or no signal at all was transmitted when this animal surfaced.

It is also probable that the diving characteristics of the two whales were different. Though the groups (perhaps the same group) these whales were associated with appeared to exhibit similar overall behavior (sporadic milling/traveling), individuals within the groups were certainly not behaving exactly the same as the others. Physiological differences as well as behavioral conditioning differences between these whales probably caused differences in diving patterns. In addition, the slight differences in environmental conditions the whales were exposed to might contribute to diving pattern differences. The tags were deployed on different days (though at similar times of the day) and at different locations (DL4 was deployed near the mouth of the Little Susitna and DL9 was deployed on the western side of the Big Susitna delta). Data was collected on DL4 roughly two hours before and after high tide, whereas, data collection on DL9 started roughly at low tide and continued for about three hours.

Whales were observed surfacing very frequently (about every 10 seconds) immediately after being stressed by the tagging vessel. The typical time for a whale to return to normal respiration behavior was not determined. Data collection on DL4 was started roughly 2.5 hours after the tag was deployed, whereas, data collection began on DL9 only about 10 minutes after tag deployment. Therefore, DL4 had more time to recover from the stress of being tagged and the data collected on it might be more representative of normal diving behavior.

Finally, some bias may have been introduced to these results by ignoring blocks of time in which continuous, high-pitched signals were heard in the background. We interpreted these blocks as being periods when the animals were swimming in very low saline water so that signals were being transmitted even when the animals were under water. It is possible that the animals behavior is affected by the salinity of the water. It is also possible that the animal's behavior itself was a partial cause of the continuous signals -- e.g. at these times, the whales may have been swimming or resting continuously at or near the water surface.

Time at Surface

The duration of the transmitter signal for each surfacing probably does reflect some measure of the time spent at the surface by a whale. Quick surfacings probably have a short signal duration, and long surfacings probably have a long signal duration. However, the duration of transmitter signals most likely does not give the total time the whale is at the surface for any surfacing. The whale's rostrum is probably exposed before the transmitter antenna breaks the surface and the lower back and tail stock probably remain exposed after the antenna has re-submerged. This is confirmed by Waite and Hobbs 1995 and Shelden 1995 who determined mean time at the surface for surfacings from aerial and boat video records. Using this visual method, the mean time at the surface was approximately one second greater than the mean determined by using the transmitter signal (3 seconds compared to1.8 seconds).

Conclusion

An unbiased sample of times between surfacings for Cook Inlet beluga whales is extremely difficult to obtain without the use of remotely sensed tags. Visual tracking of individual whales is very difficult because of the highly turbid water of the inlet, the irregular swimming patterns of the whales, the lack of obvious markings on whales, and the large groups (>100) the whales are often found in. Only short continuous visual records of surfacings can be obtained before whales are either lost or confused with other whales. Such records are biased towards short dive times, because whales are often lost during longer dives. With radio tags, long, continuous and unbiased dive records can be obtained.

The diving behavior of the entire population of Cook Inlet belugas is clearly not well characterized by the diving characteristics of two whales. The sample size must be increased to understand the range of behavior from whale to whale and from different environmental conditions within the inlet. More testing of the tag performance in the highly dynamic conditions of the upper inlet will provide more confidence in distinguishing definite surfacing signals from transient signals caused by tags passing through varying water masses.

Finally, radio signals from surfacings do not provide a good means for determining the time spent at the surface by the whales. Measurement of the time a surfacing whale is visible at the surface from a video record is a much more direct and effective method.

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Tape Listener	Analysis type*	statistics for inter-surfacing times (seconds)							total time (hours)	sample size
		median	mean	standard deviation	longest	shortest	97.5th percentile	2.5th percentile		
whale tagged on June 4, 1994 - DL4										
log book data										
	A	18	26.8	24.7	182	4	102.5	8.0	3.4	460
	B	19	35.1	41.4	356	4	133.2	8.0	3.4	348
whale tagged on June 9, 1994 - DL9										
log book data										
	A	17	21.9	17.4	185	7	69.8	9.0	1.61	265
	B	17	22.1	17.6	185	7	69.8	9.0	1.61	263
tape data										
1	A	17.2	20.8	12.0	89.4	6.9	57.2	9.0	1.96	338
	B	17.1	23.0	19.5	144.2	6.9	88.7	8.9	1.96	306
2	A	17.1	21.2	14.2	140.2	6.6	62.5	9.3	1.99	338
	B	17.1	23.4	20.9	184.2	6.6	88.8	9.1	1.97	302

*A = all surfacings included (definite and questionable), B = only definite surfacings included

Table 1a. Statistics for inter-surfacing times for DL4 and DL9.

Analysis Type	mean inter-surfacing time using the data from both whales					
	$T_{i,DL4}$ (seconds)	var($T_{i,DL4}$)	$T_{i,DL9}$ (seconds)	var($T_{i,DL9}$)	T_i (seconds)	var(T_i)
A	26.8	1.33	21.0	0.51	23.9	8.87
B	35.1	4.92	23.2	1.34	29.2	36.97

Table 1b. Mean inter-surfacing time.

tape listener	**statistics for time at surface for DL9**		
	average (seconds)	**standard deviation (seconds)**	**sample size**
1	1.88	0.28	125
2	1.70	0.33	124

Table 2. Statistics for time spent at surface per dive for DL9 only. Only a single side of one tape was used for this analysis (approximately 45 minutes in length).

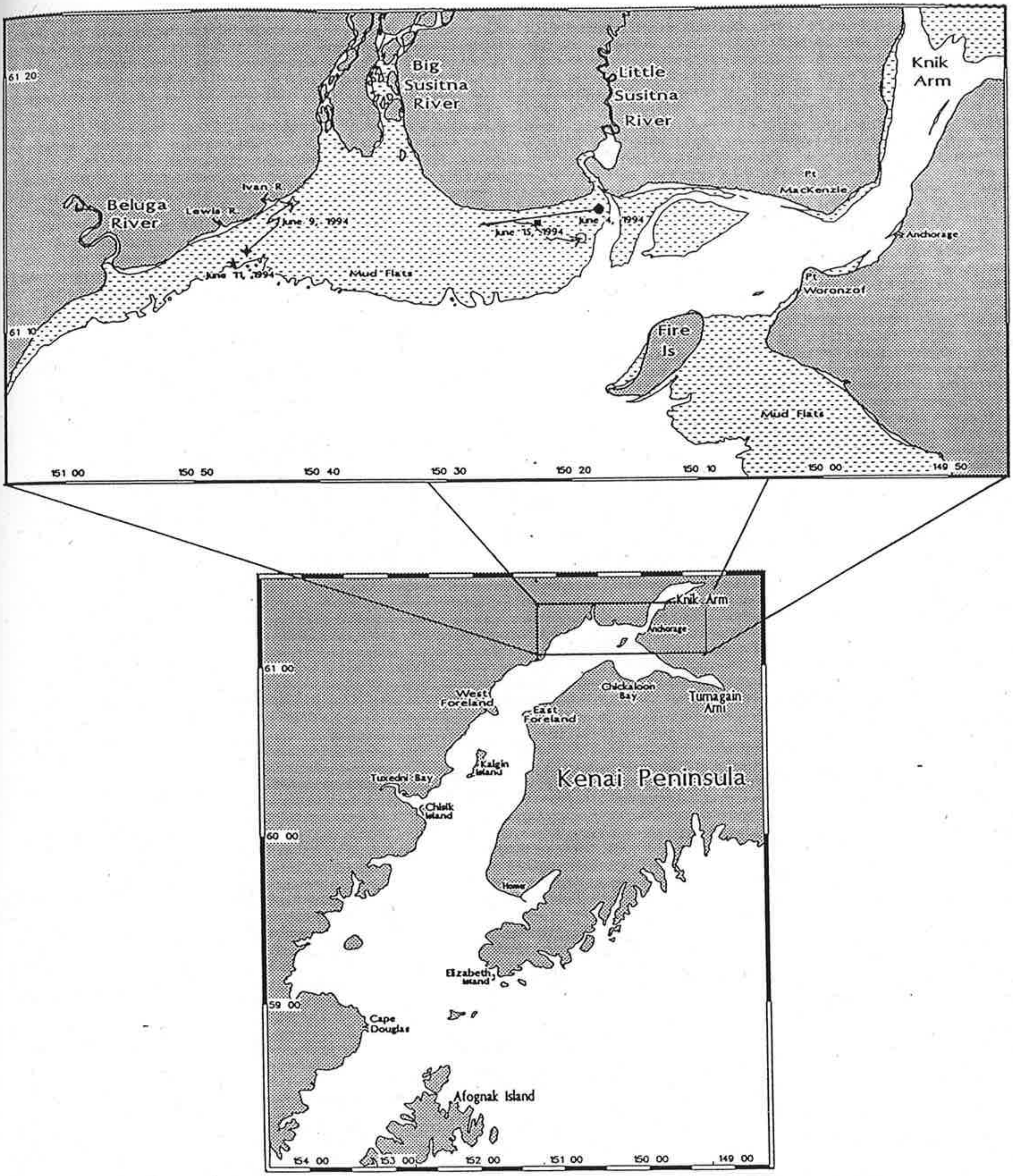


Figure 1. June 1994 radio tagging survey. The initial locations of the four successfully tagged Whales are shown as points. The location of the survey boat while monitoring DL4 and DL5 are shown as arrows from the initial location to the location where monitoring ceased.

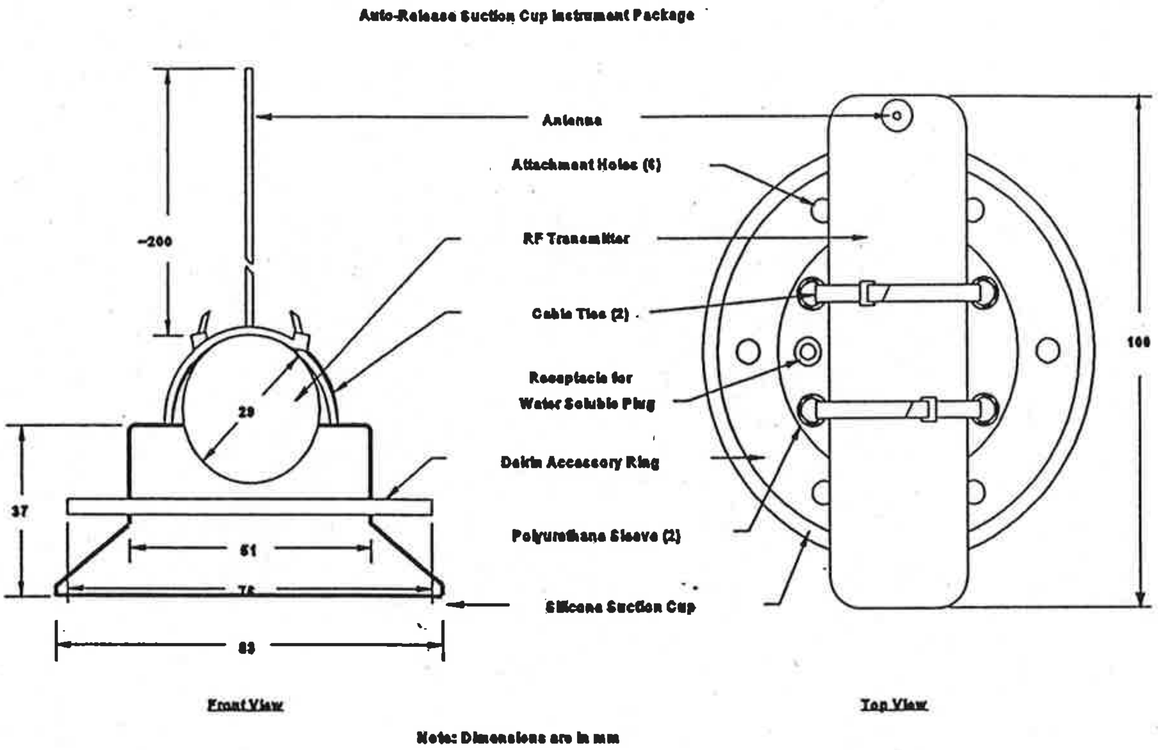
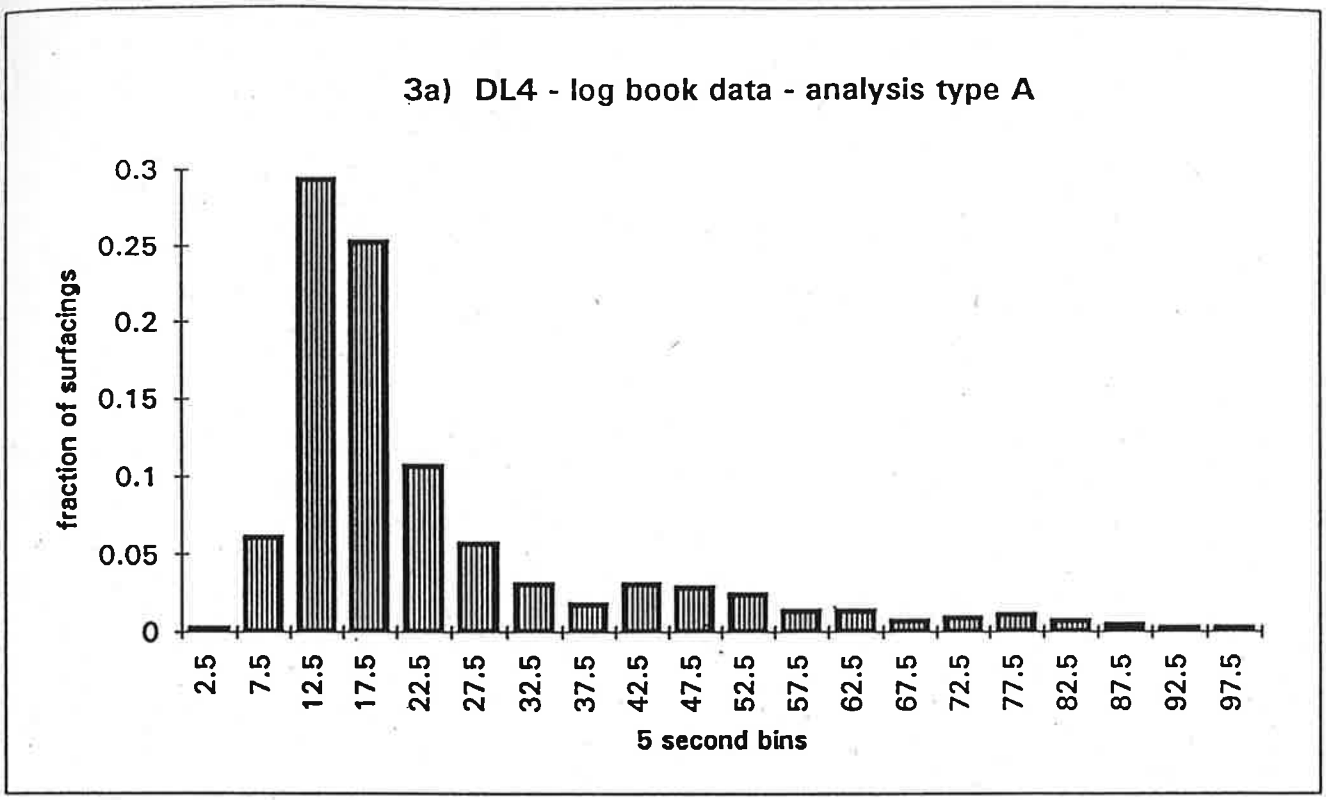


Figure 2. Schematic of suction cup tag and VHF radio transmitter. The closed foam used for floatation is not shown.



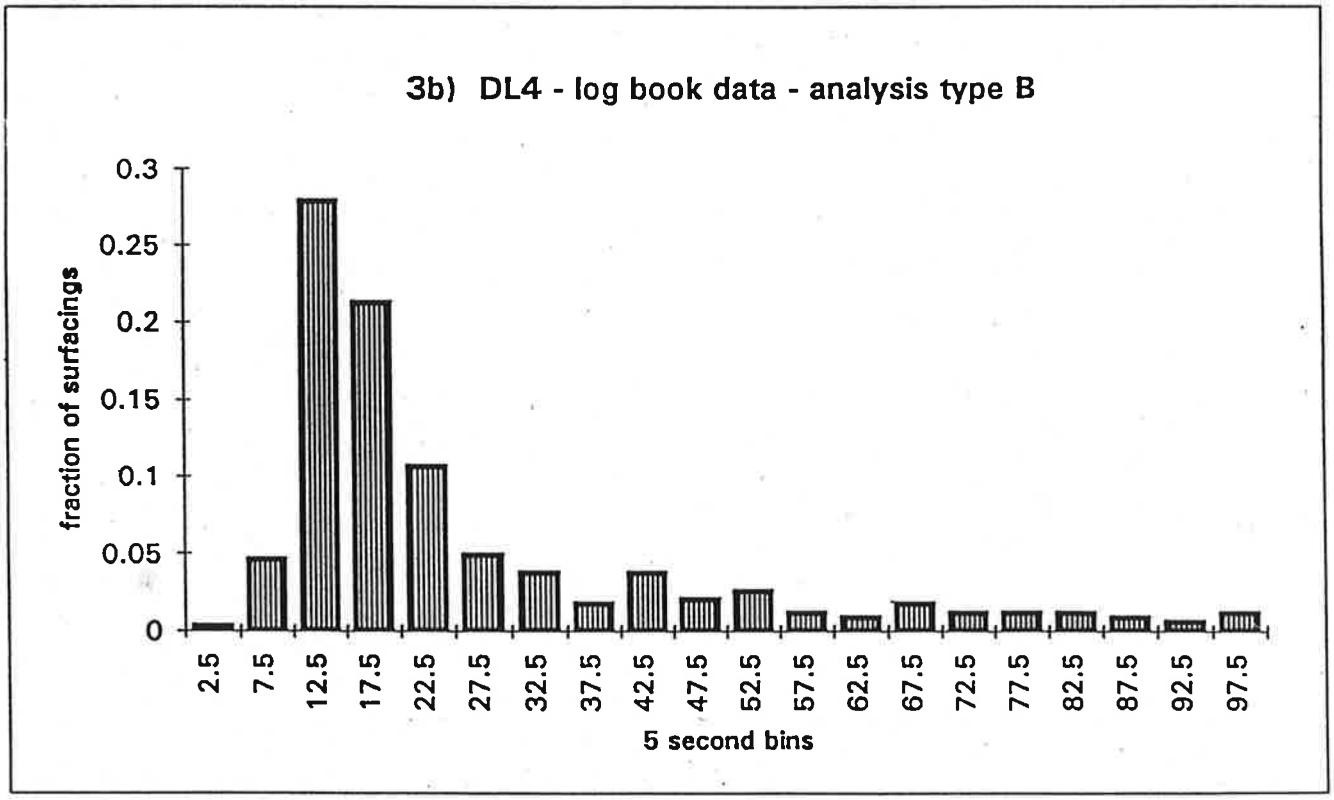
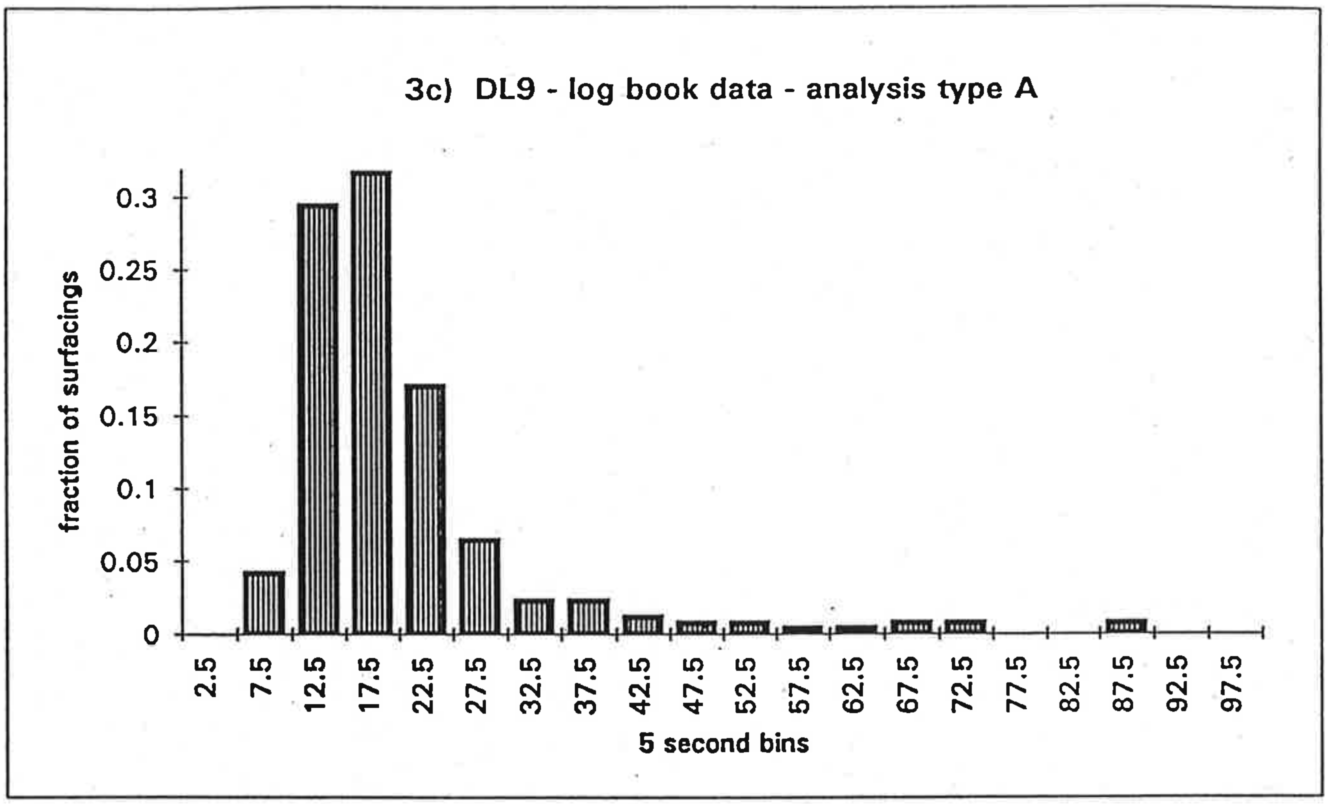


Figure 3a-b. Inter-surfacing time distribution from log book data for DL4 using analysis types A and B, respectively.



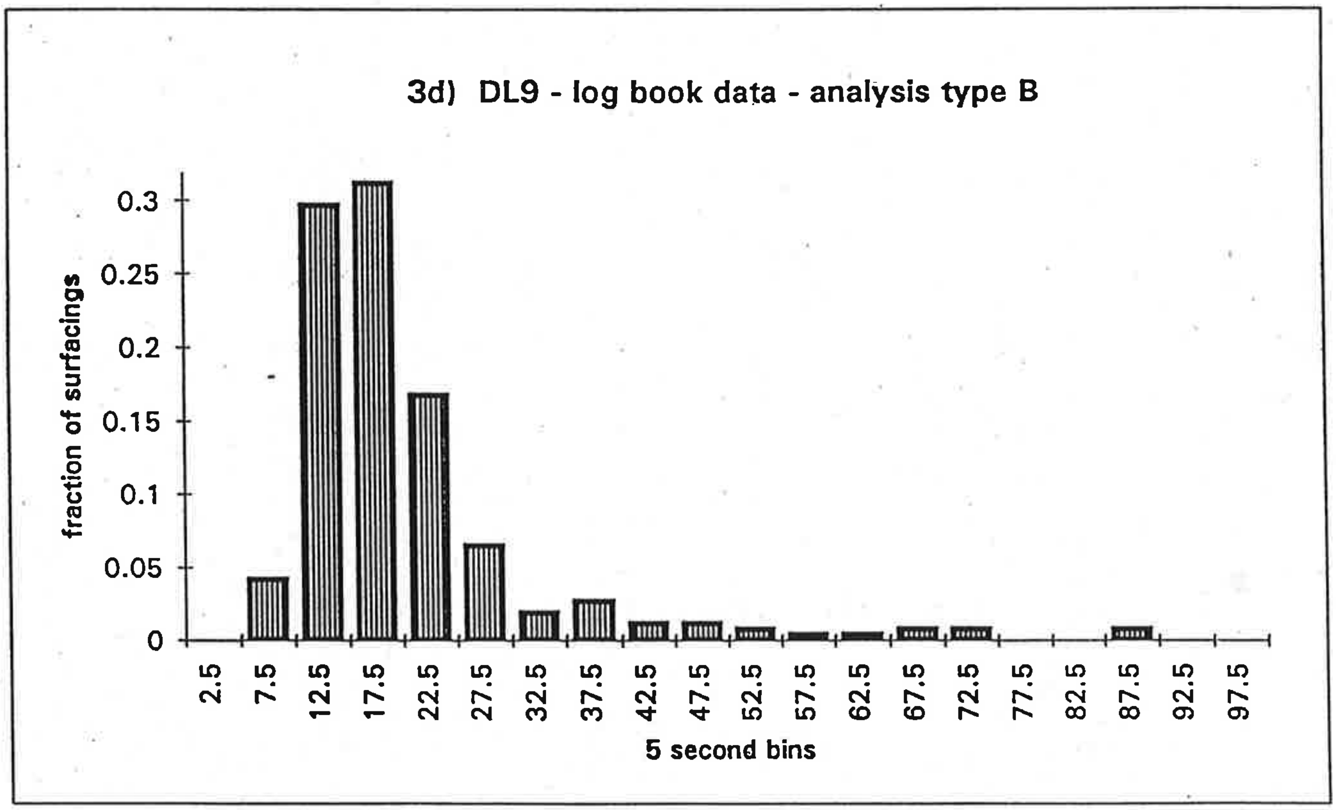
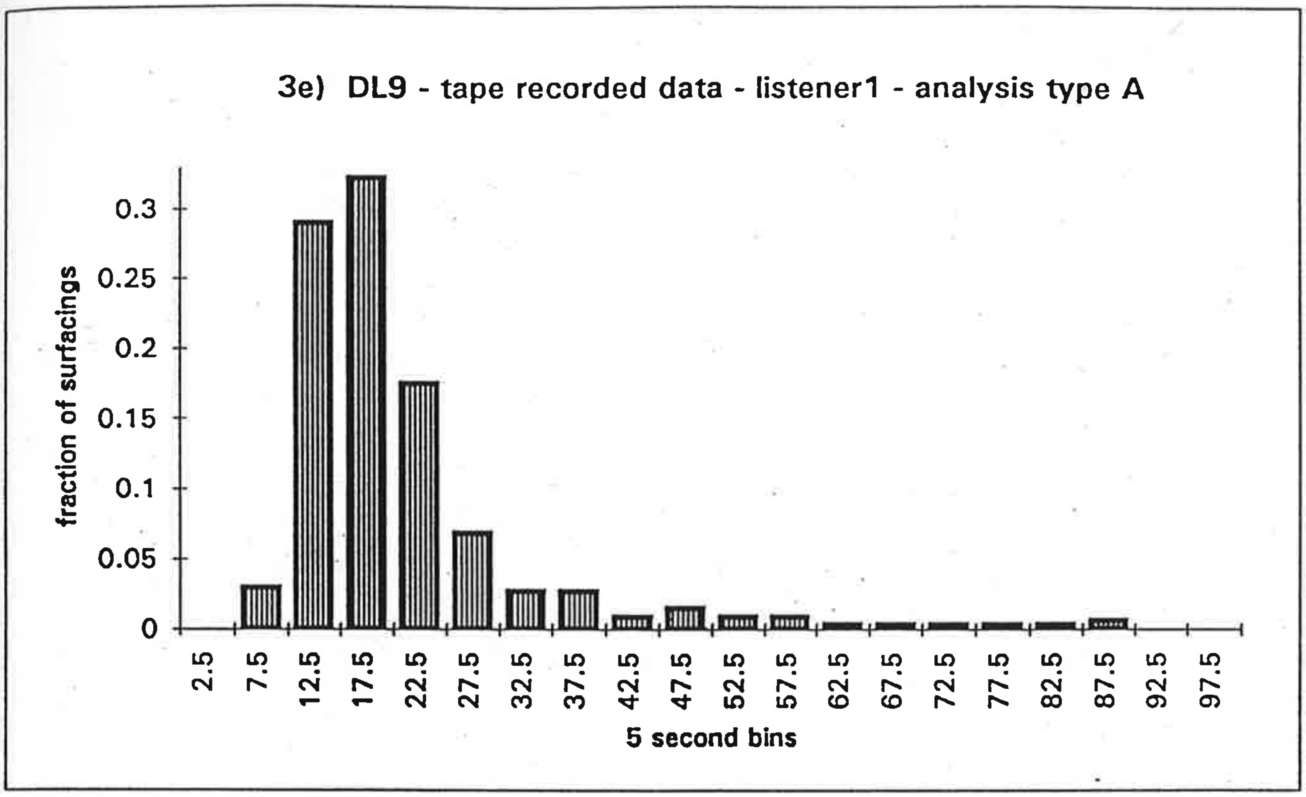


Figure 3c-d. Inter-surfacing time distribution from log book data for DL9 using analysis types A and B, respectively.



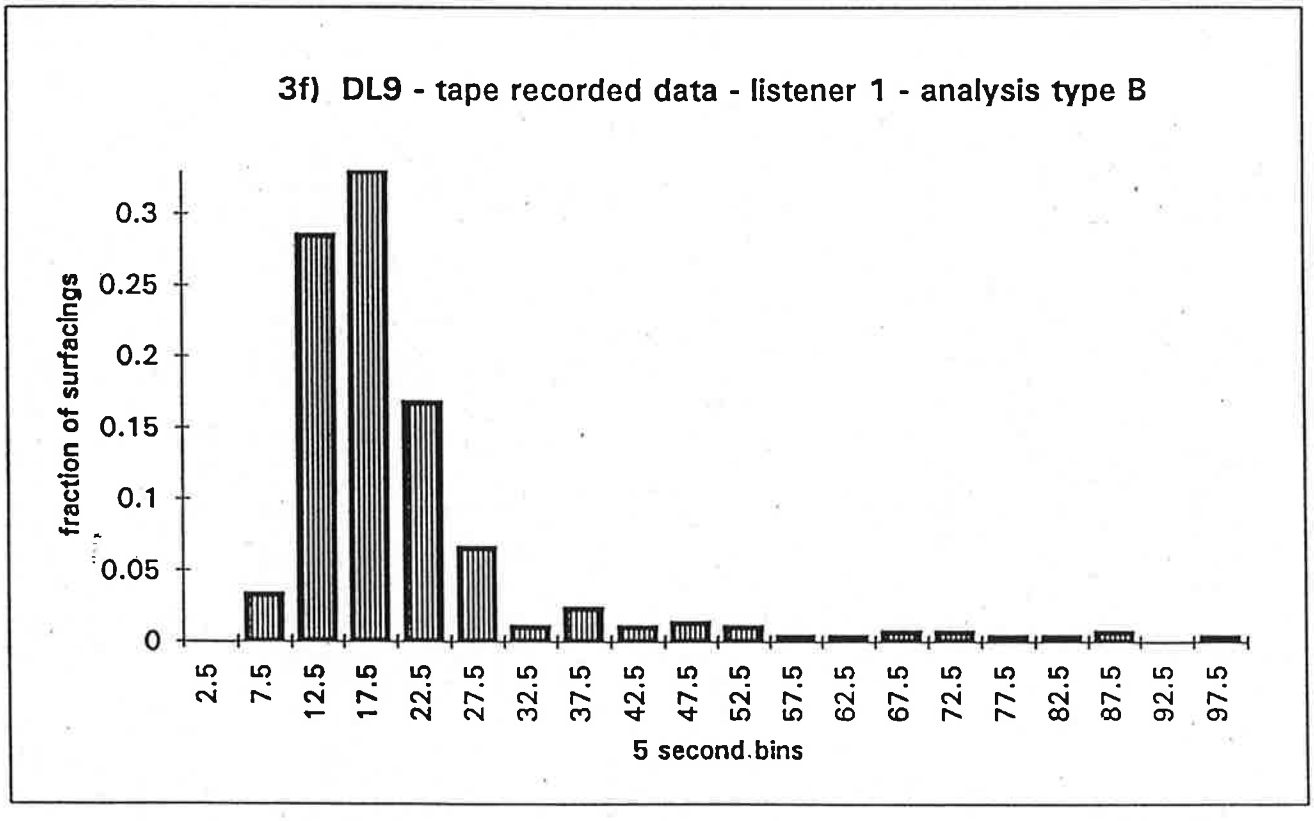
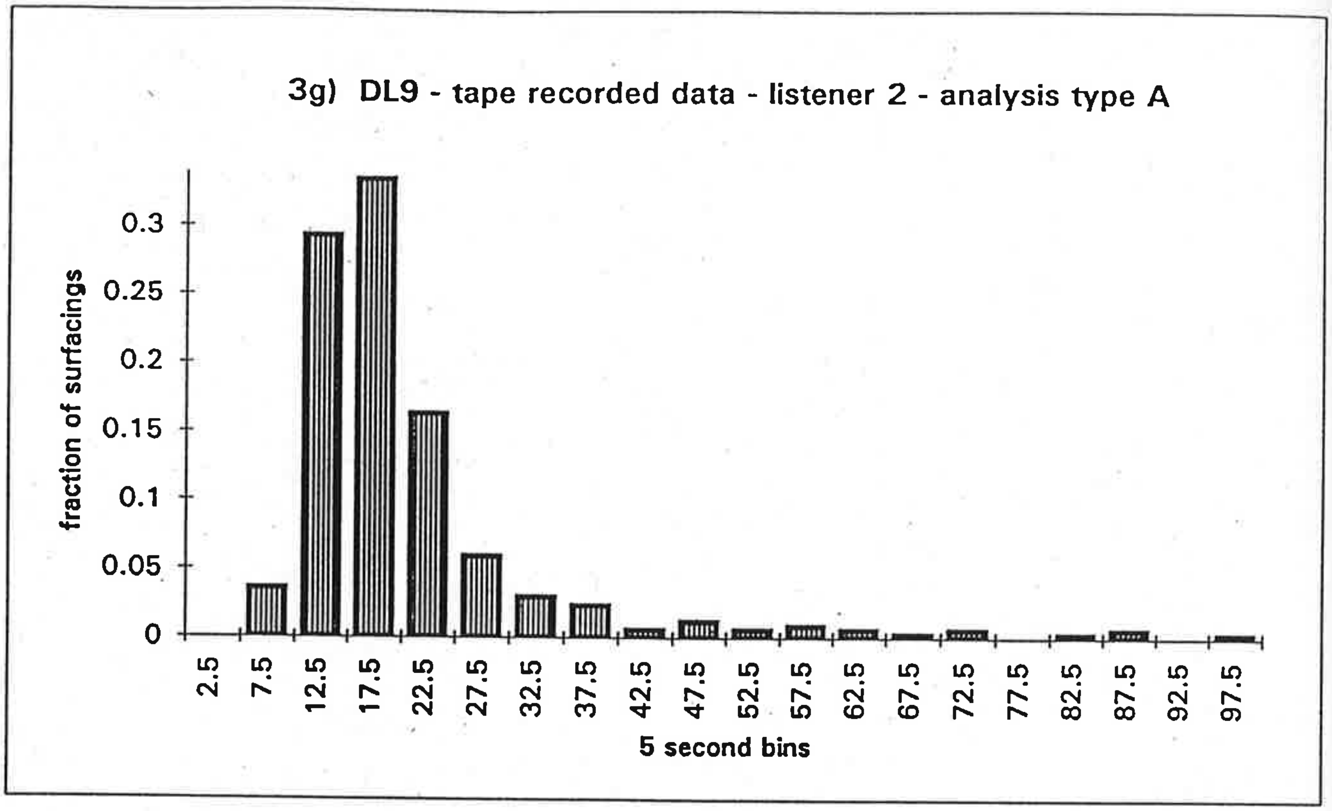


Figure 3e-f. Inter-surfacing time distribution from log book data for DL9 using analysis types A and B, respectively. Tapes digitized by listener 1.



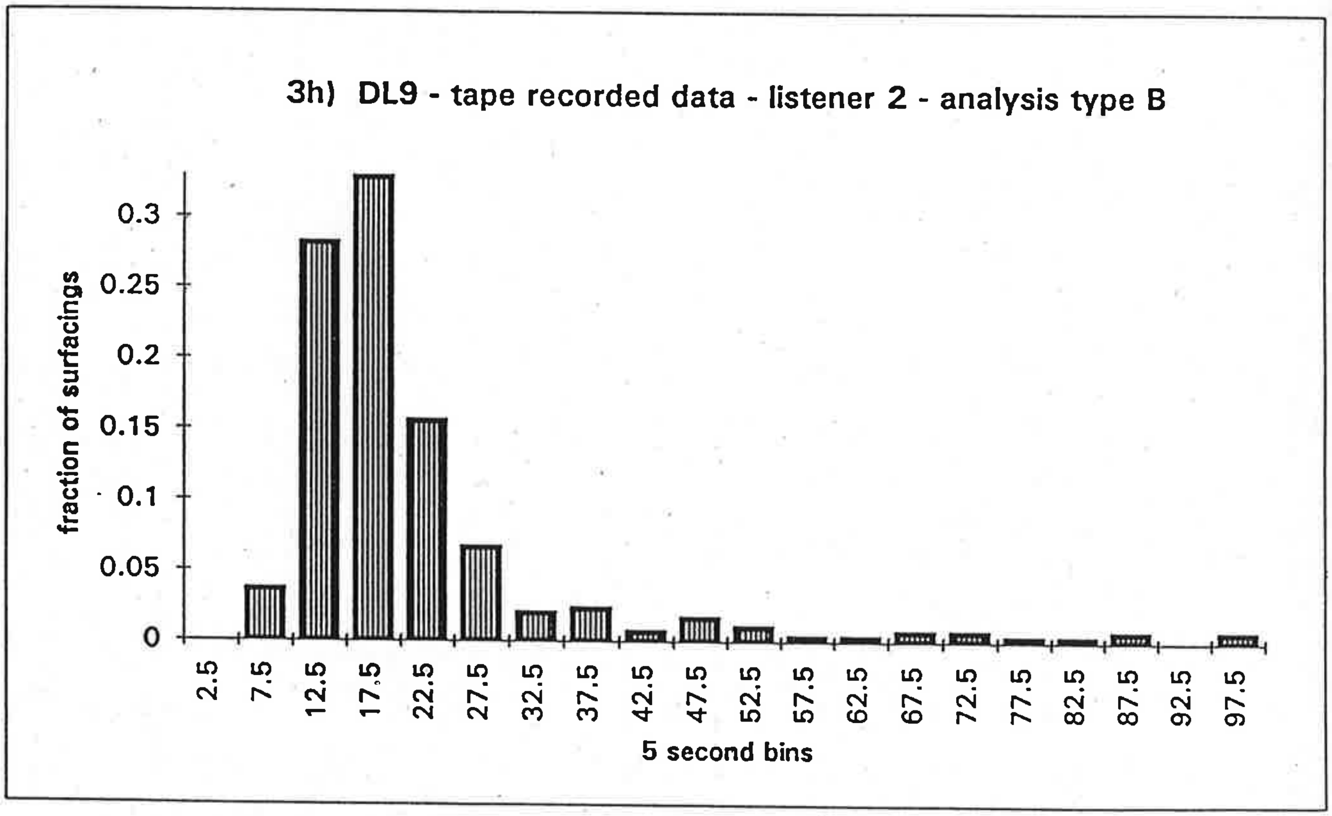
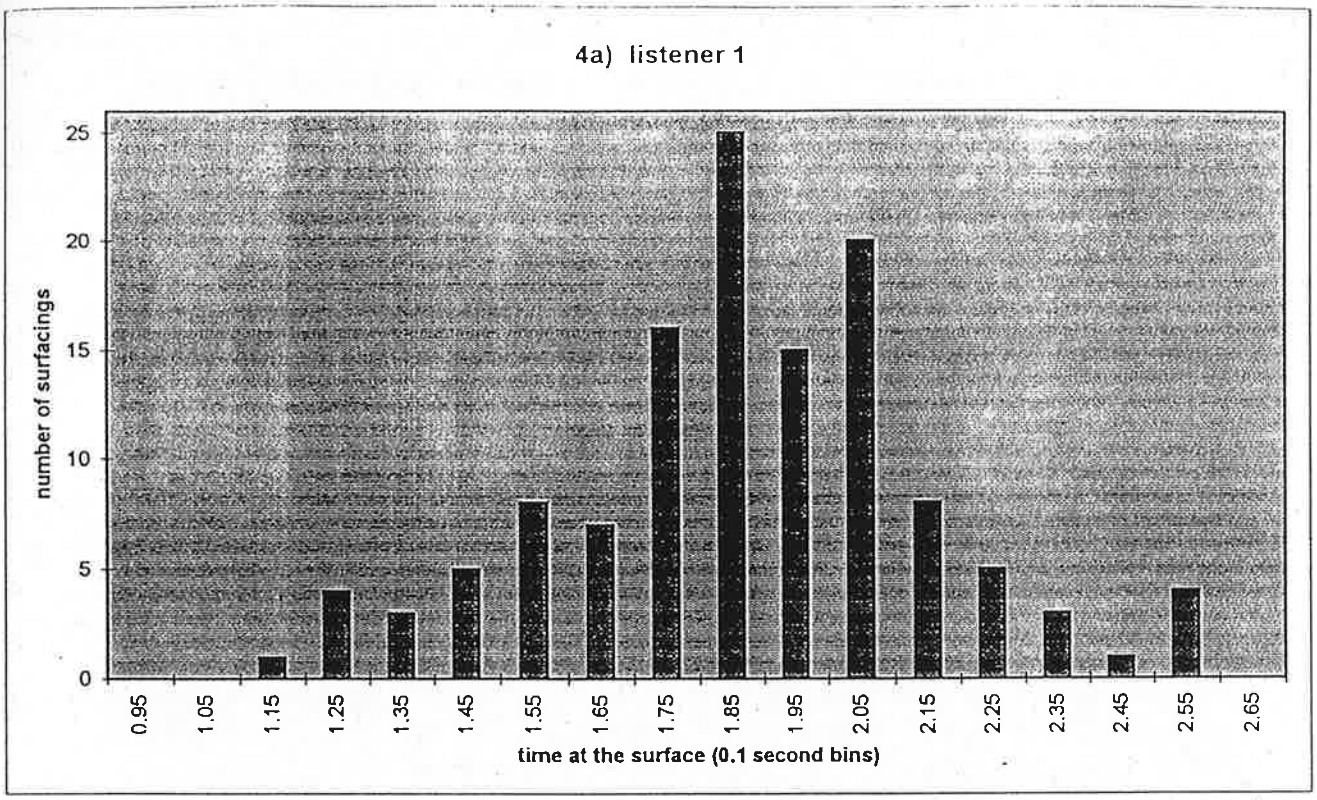


Figure 3g-h. Inter-surfacing time distribution from log book data for DL9 using analysis types A and B, respectively. Tapes digitized by listener 2.



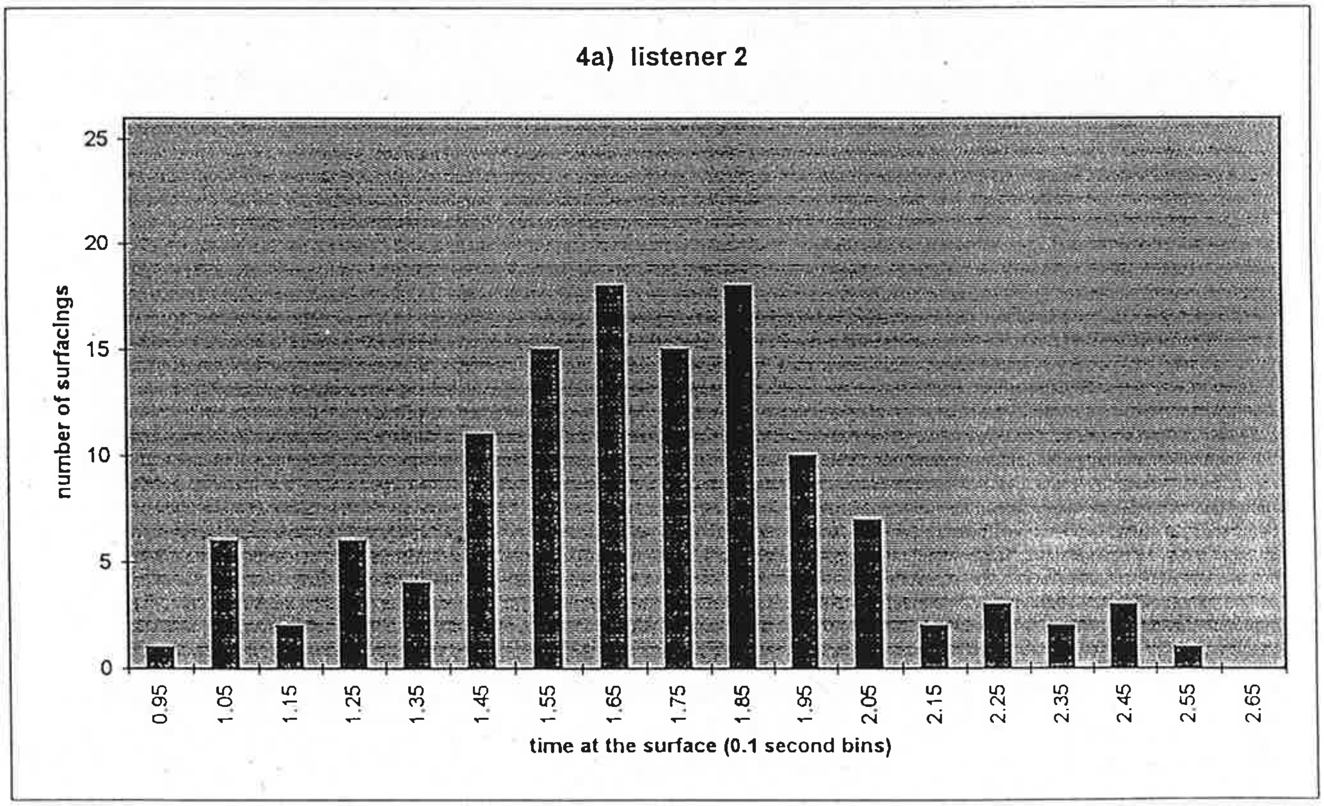


Figure 4a-b. Distribution of time spent at the surface (duration of transmitter signal) for DL9. Data digitized by listeners 1 and 2, respectively.

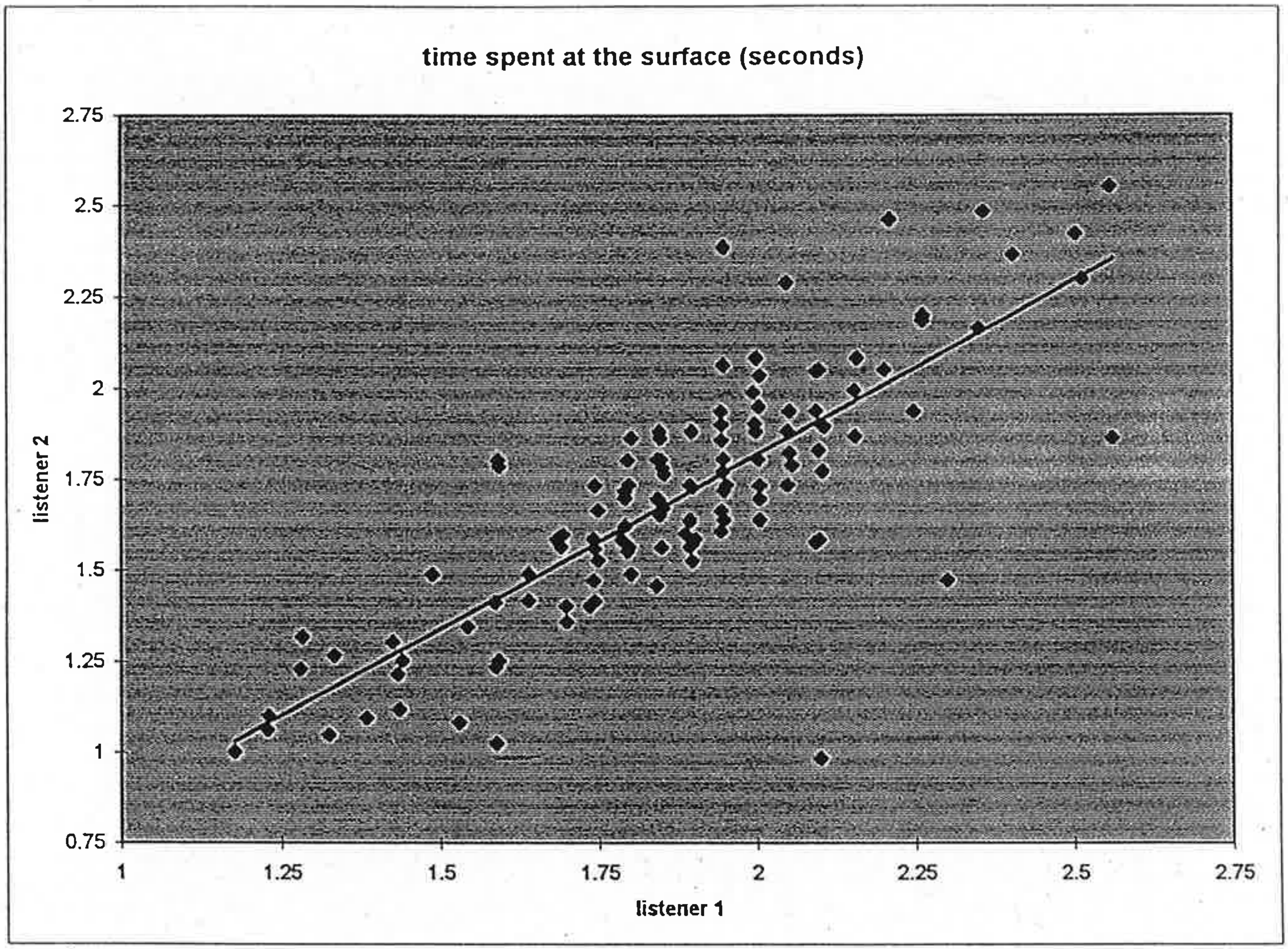


Figure 5. Time spent at the surface for each surfacing (N = 125). Listener 2 vs Listener 1. The bold line is a linear regression of the data.

Impacts of Vessel Surveys and Tagging Operations on the Behavior of Beluga Whales (*Delphinapterus leucas*) in Cook Inlet, Alaska, 1-22 June 1994

Kim E. W. Shelden

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way N.E., Bin C15700
Seattle, WA 98115-0070

Abstract

In June of 1994, the National Marine Mammal Laboratory conducted a vessel survey of beluga whales in the northwest corner of Cook Inlet, Alaska. The focus of the survey was a radio-tagging study of a portion of the population found near the Susitna River delta. The impacts of the methods used to tag and study beluga whales from vessel platforms were examined. Using techniques similar to those employed by native hunters, beluga whales were isolated from their groups and pursued. Surfacing behaviors were categorized and analyzed based on initial reactions to tagging attempts, duration of tagging attempts, and whether the animals were in undisturbed or actively pursued groups. Behaviors were broken down into two categories: head lifts and slow rolls. The amount of time an animal was visible at the surface during each type of behavior was also examined. Based on analysis of videotaped pursuits, belugas were more likely to head lift during an approach and tagging sequence than to slow roll. In undisturbed groups, times at the surface were significantly different between head lifting and slow rolling animals, and between juveniles and adults displaying slow rolling behavior. Reactions to disturbance were consistent with those observed in other studies. Despite hunting pressures and tagging activities, belugas never abandoned the study area. Site tenacity, demonstrated by this species in other regions, is apparent in the Cook Inlet population.

Introduction

An absolute abundance estimate is necessary in order to make management decisions regarding the population of beluga whales that seasonally occupies Cook Inlet, Alaska. In 1994, aerial surveys, oceanographic sampling, and radio-tagging studies were conducted to obtain raw counts of beluga groups, characterize beluga habitat, and quantify surfacing behaviors, respectively. This report focuses on the methods we used for tagging and studying belugas from vessel platforms, and the impacts these techniques might have had on individuals and groups of whales. In particular we needed to evaluate how our presence may have affected surfacing rates of tagged whales. These surfacing rates represent the amount of time the average whale would be visible to observers conducting aerial surveys, an important component in the development of a correction factor for the number of animals seen during aerial surveys (Hobbs *et al.*, this report). Different levels of disturbance and lengths of recovery time may influence the types of surfacing behaviors observed.

Methods

Survey Location and Research Platforms

Vessel surveys for beluga whales were conducted in the waters of Cook Inlet, Alaska, from 1-22 June 1994 by the National Marine Mammal Laboratory (NMML). The focal area for these surveys was the Susitna River delta located approximately 35 km west of Anchorage (Fig. 1). Research vessels were a 6 m (20 ft.) Boston whaler[1] with twin 100 hp propeller engines and a 5 m (16 ft.) Avon rigid-hulled inflatable with 70 hp propeller engine. Operations were based out of Anchorage, where vessels were deployed each survey day at Ship Creek.

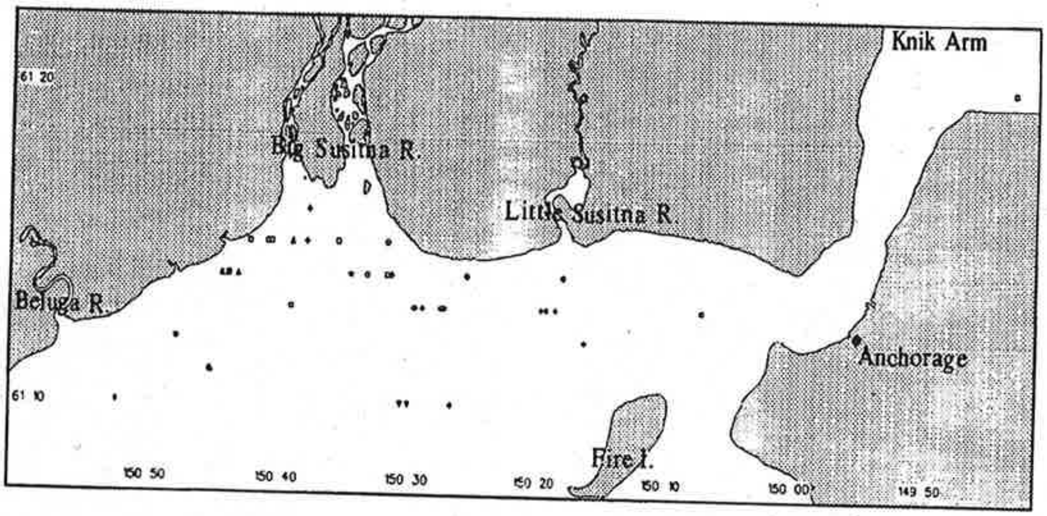


Figure 13. June 1994 survey area. Symbols indicate vessel locations during beluga whale observations (distance to whale groups are not indicated).

For most of the survey, the Boston whaler served as the research platform for oceanographic sampling and radio-tag monitoring while the smaller Avon was used for tagging whales. Generally the crew divided into two teams. One team was comprised of a driver, video camera operator, and 1-2 taggers in the Avon. The other team was made up of a driver, oceanographic samplers, and a tag monitor in the Boston whaler.

Tagging Operations and Equipment

Once a beluga group was located, the crew took up their positions in each vessel. GPS position, Beaufort sea state, water depth, and weather condition were noted at the time of the sighting, and a rough estimate was made of the size of the beluga group. When time allowed,

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[1] Reference to trade names does not indicate endorsement by the National Marine Fisheries Service.

the group was plotted on a chart form developed for the survey. Vessel position (i.e., GPS location) was noted at the center of the circular chart; lines and circles radiating out from the center noted magnetic bearing and approximate distance, respectively, from the whale group(s) to the vessel. A 7x50 binocular with reticles and a compass helped determine distances from and expanse of the beluga groups. The presence (or absence) of hunters was also documented.

During tagging operations, one or two of the crew were stationed in the bow of the Avon, each outfitted with a suction cup tag clamped to an adjustable pole (4.6 m (15 ft.) maximum length). Tags consisted of a VHF radio transmitter, flotation device, and silicon suction cup. Each tag had a gel plug detachment system that would release the tag after the plug dissolved (see Lerczak, this report, for a detailed description of the tagging system). Preparations usually took place at a distance of approximately 300 m from the whale group with vessels lashed together and engines off. Tagging operations commenced when the Avon driver moved the vessel toward the whale group. The Boston whaler and its crew remained behind, staying within visual range while conducting oceanographic sampling and setting up tag monitoring equipment.

Tagging bouts consisted of an approach on a group, isolation of an individual, and a maximum of three tagging attempts on an individual ending with either a successful deployment and withdrawal from an animal, or an unsuccessful deployment and search for a new animal. The first three survey days (1-3 June) were spent developing tagging methods. The team experimented with fast approaches; slow, steady approaches; and circumventing a group, then stopping engines and waiting for the whales to move past. This met with limited success, with belugas only surfacing within approximately 4.5 m (15 ft.) of the vessel before moving away. On the fourth survey day a local beluga hunter joined the team and provided training in beluga hunting techniques.

Our tagging methods were modified based on this training. Tagging events were scheduled just after low tide. Hunters have determined that it was easier to track the whales when they were in very shallow water. In water <2 m deep whales created "bow waves" as they swam, a small wave in front of the head and a larger wave in front of the flukes. The motion of the flukes also caused circular upwellings or "footprints" on the surface. The hunters used these cues to isolate and follow a whale. The hunting vessel is driven into the wave formed by the flukes, and the animal is followed until it surfaces in front of the vessel in the wave created by its head. This method worked extremely well in shallow water; however, when an animal moved into water >2 m deep, the wave collapsed, which made further tracking impossible. Similarly, if Beaufort sea states were >2, waves made by whales were lost in the confusion of wind-created waves.

To minimize disturbance, each group was studied prior to tagging to determine the best approach direction. At this time, the number of visible whales was estimated and locations recorded. The Avon was driven rapidly toward the edge of the group and an animal would be chosen as a function of proximity to the vessel and consistency in visibility of its "wave ". Small juveniles, identified by their gray skin color, were avoided. The selected animal was then followed as it broke away from the group. Isolation of an individual occurred within seconds and was either due to the individual moving away from the group or to the group distancing itself from the tagging operation. Tagging bouts averaged about 2.7 minutes (max.

10 minutes) from the time an individual was isolated to the time the pursuit ended. After 4 June, tagging bouts were documented by a fourth observer on the tagging vessel using a hand held video camera.

Laboratory Analysis

Video recordings of tagging operations were examined in order to determine the amount of time spent isolating and tagging each beluga whale. The level of harassment during tagging was defined in terms of the number of animals "taken". A "take" indicates that an animal or animals deviated from what might be considered normal behavior. Individual whales isolated from the group and pursued during tagging operations were considered to be "taken by harassment". Individual(s) were classified as "taken incidental to harassment" when they reacted strongly (e.g., rapidly swimming away with sufficient speed to create a wake and white water) to the presence of the vessel as it approached to isolate a single animal for tagging operations. A tagging approach was defined as the isolation and pursuit of an individual whale. Interruption of the pursuit for any reason (e.g., retrieval of a dislodged tag), resulted in a new tagging approach. If the approach was on the same individual it was logged as a second or third attempt. A maximum of three tagging approaches were allowed for each individual.

The surfacing behaviors of harassed and undisturbed whales were examined using video footage obtained in the field. Two types of surface behavior were observed - "slow rolls" and "head lifts". A "slow roll" is a surfacing where an animal's head appears then recedes; the back first appears as a thin line on the surface before it arches high out of the water as the whale dives. The lateral indentations along the lower side of the body between the dorsal ridge and caudal peduncle are usually visible during the highest point in the arch. The flukes are rarely observed to break the surface. A "head lift" is similar to the beginning of the "slow roll" behavior: the head appears above the surface then recedes; however, it is not followed by the appearance of the back. In the analysis, "slow roll" behavior was divided into two color categories representing juveniles (gray) and adults (white). Because of the difficulty in determining the color category of individuals displaying "head lift" surfacing behaviors (i.e., the visual cue is small and video image resolution is poor during stop action), this behavioral category was not divided.

Surfacing intervals were obtained from radio-tagged animals by following animals immediately after tagging and logging each visible surfacing or recording radio signals (see Lerczak This report for a description of radio-signal monitoring and analysis). Surfacing intervals were also gathered during focal animal studies in which an untagged animal's surfacings were recorded for as long as the identified animal could be tracked. Only video records were reviewed for this analysis because written logs did not provide the exact moments the animals appeared and disappeared from view.

Results

Whale Reactions to Tagging Operations

Whale responses to our vessel activity did not vary, although we tried different approach methods. Once the vessel approached within approximately 10 m of a whale, it would move rapidly away from the vessel creating a wave, sometimes cresting in a whitecap. From videotapes of tagging bouts where initial approaches were recorded (25 of 50 recorded segments), 92% of the time belugas demonstrated "head lifting" surfacing behavior (only revealing the top of their heads to breathe) when the vessel began its rapid approach for tagging.

The initial burst of speed observed at the start of each tagging bout lasted for only a short period of time (ranging from less than 1 minute to 2 minutes) after which the beluga began to surface more frequently. Once an animal tired, the vessel driver could follow it at a slower pace. At the termination of a tagging bout, whether or not a tag was attached, the whale usually moved away from the vessel without "slow rolling" at the surface until it was at distances roughly >10 m away from the vessel. Though not quantified, these behaviors are substantiated by field observations made after 93 tagging attempts.

During tagging pursuits, 85% (n=27) of the whales isolated for tagging bouts initially reacted by "head lifting" on the first surfacing. Individuals isolated for tagging varied in the amount of time they spent "head lifting" and "slow rolling" during a chase sequence. Only 15% of the animals approached (n=27) were observed to "slow roll" throughout the entire bout, while 59% exhibited only "head lift" behavior (Table 1). The remainder, 26%, exhibited almost equal preference for the two types of surfacing behavior. Because the duration of a tagging bout was relatively short (average 2.7 minutes), usually only 1-3 surfacings occurred before the bout was terminated.

When engines were off, belugas did not appear to avoid the boats. Whales

Table 1.

Whale #	Number of Head Lifts	Number of Slow Rolls
1	1	0
2	2	1
3	1	1
4	1	1
5	0	1
6	1	0
7	3	0
8	1	0
9	1	0
10	1	0
11	1	0
12	1	1
13	1	0
14	1	0
15	3	0
16	0	3
17	1	1
18	3	0
19	3	0
20	2	0
21	1	1
22	1	0
23	2	0
24	0	5
25	0	7
26	2	0
27	1	1

surfaced as close as 4.5 m and would approach within 2 m or go under the vessels as evidenced by bubbles, "footprints " at the surface, or images moving across the depth sounder. Whales observed beyond 4.5 m would raise their backs above the surface in a high arch ("slow roll") prior to diving. This was apparently a more casual and typical surfacing behavior than was the "head lift", which was a rapid surfacing that minimized the length of time and amount of body area above the water surface.

Harassment of beluga whales during tagging operations was categorized two ways: as those animals that were "taken by harassment" and those that were "taken incidental to harassment" (Table 2). A total of 93 individuals were isolated from their group and pursued during tagging operations. Other individuals (n=77) within the group that reacted strongly to the presence of the vessel, did so only when the vessel was within 10-20 m.

Table 2.

Date	Number of Individuals Taken by Harassment	Number of Individuals Taken Incidental to Harassment[2]	Approximate Distance from Animals at Time of Disturbance[2]	Number of Approaches on an Individual Isolated for Tagging[2]
6/1/94	0	20	10-20 m	0
6/2/94	0	10	10-20 m	0
6/3/94	8	10	10-20 m	1-2
6/4/94	8	5	10-20 m	1-2
6/9/94	14	4	10-20 m	1-2
6/11/94	28	15	10-20 m	1-3
6/13/94	5	1	10-20 m	1
6/14/94	14	5	10-20 m	1
6/15/94	12	7	10-20 m	1-3
6/17/94	4	0	10-20 m	1-2
Total	93	77	-	-

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[2] Based on observations made in the field and video footage of tagging bouts where initial approaches were recorded (n=25).

Despite our presence and the presence of hunters in the area, the belugas never left the immediate survey area during this study. Animals would move 300 to 500 m away from our tagging operation, but once the Avon stopped approaching whales, they would return to within 100 m of the vessel within a short period of time. Beluga groups were present within the Susitna River delta throughout the survey period. Prior to the last 2-3 days of tagging operations (before 15 June), beluga whales were found in large, clumped groups (>50) often surfacing in multiple directions. Thereafter, the animals were more dispersed in groups ranging from 1-20 individuals.

Duration of Tagging Bouts

Between 3 and 17 June 1994, a total of 93 individual beluga whales were isolated for tagging . Of these 93 tagging attempts, 50 were video taped. Analysis of the tape revealed that the average amount of time spent isolating and attempting to tag an animal was 2.7 minutes (CV=0.85, n=50). Only 4 of the 93 attempts resulted in successful deployments of tags. For those attempts captured on video tape, successful tagging attempts averaged 5.5 minutes in length (CV=0.53, n=3). The 47 failed attempts logged on tape were categorized as to the reason tag attachment was unsuccessful. The video record was not complete in 14% of the attempts so the reason for failure in these cases was considered unknown.

The greatest percentage of failures (30%) was due to the animal entering deep water (>2 m in depth). This resulted in the wave collapsing, leaving the tagging team with no visual cue to the whale's location. The average amount of time spent on an attempt, prior to the whale entering deep water, was 2.2 minutes (CV=0.99, n=15). The second highest failure rate (18%) was due to poor attachment of the tag. Tags would dislodge prematurely from the jab stick after coming into contact with the whale at an improper angle or if the pole tip dipped into the water while underway (n=9). Other reasons included: aborting the attempt because the animal was too small or an adult was accompanied by a calf (n=4); aborting the attempt after three unsuccessful approaches had been made (n=4); unable to stay with an animal because it was too evasive (n=3); the whale was lost in low contrast lighting (n=3); or, the wake of the boat was confused with the wake from the whale (n=2).

Surfacing Behaviors of Undisturbed Beluga Whales

Video tape obtained during vessel operations was further analyzed to determine the amount of time undisturbed individual animals were visible at the surface. Both types of surfacing behavior were quantified. Time at the surface for each color category was compared for those animals exhibiting "slow roll" behavior. Juveniles (gray animals) averaged 2.25 seconds at the surface (CV=0.14, n=36) while adults (white animals) surfaced for an average of 2.55 seconds (CV=0.14, n=70). Times at surface were significantly different between gray and white individuals (Fig. 2; t-Test =4.5, d.f.=79, $p << 0.001$). On average, white individuals were at the surface 12% longer than gray animals.

Color categories were combined and averaged in order to compare "slow roll" behavior to "head lift" behavior. As expected, the amount of time spent at the surface during a "head lift" ($\bar{x}=1.02$ seconds, CV=0.37, n=28) differed significantly from the time spent at the surface during a "slow roll" ($\bar{x}=2.45$ seconds, CV=0.15, n=106) (t-Test=17.9, d.f.=132, $p<<0.001$). During a "slow roll", animals were at the surface 58% longer than those "head lifting".

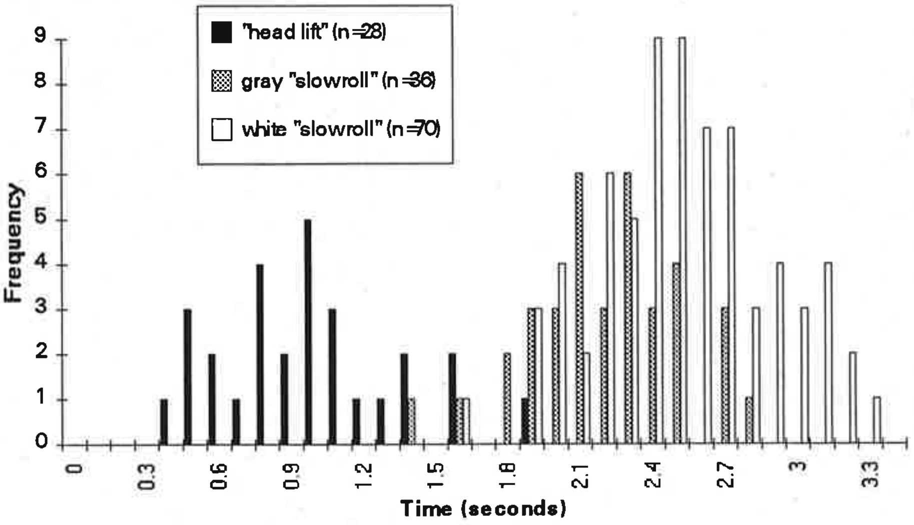

Figure 2

Variation in Surfacing Behaviors of Video-Tracked Individuals

Time at the surface was calculated from video footage of an undisturbed adult beluga accompanied by a calf. The pair were not accompanied by any other belugas, enabling the field crew to track them continuously on video for 2 one-minute segments and 1 six-minute segment during the 16 minute encounter. The observation team attempted to keep the vessel a distance of 100 m away so as not to disturb the pair. Although no "head lift" surfacings were observed, 7 complete "slow roll" surfacings were captured on video for the adult and 8 for the calf. The average amount of time spent at the surface was 2.77 sec. (CV=0.08) for the adult and 1.42 sec. (CV=0.23) for the calf. Adult/calf surfacings were not always synchronized. Only 8 possible sequential surfacings were available for the adult and 6 for the calf (Fig. 3). Some calf surfacings were not captured on video (the audio portion of the tape indicates the calf was at the surface though it was not visible on the videotape). Reasons for missed calf surfacings include: difficulty in judging where the next surfacing will occur; the brevity of time spent at the surface; the calf surfacing on the far side of the adult; or the lack of contrast between calf and water making it difficult to discern from the background.

Video footage was also available of a recently tagged, and therefore harassed, whale. For the entire length of the video segment (5.25 minutes), only "head lift" surfacing behavior was observed. Time at the surface averaged 1.34 seconds (CV=0.23, n=28; Fig. 4). The average amount of time spent below the surface was 9.63 seconds (CV=0.26, n=26). Toward the end of the tracking time, the amount of time spent below the surface appeared to increase, although the time at the surface did not appear to change (Fig. 4). One surfacing was not captured on film as evidenced by the gap before the last 3 surfacings (audio data from the tape placed the animal at the surface, though it was not in the field of view of the camera).

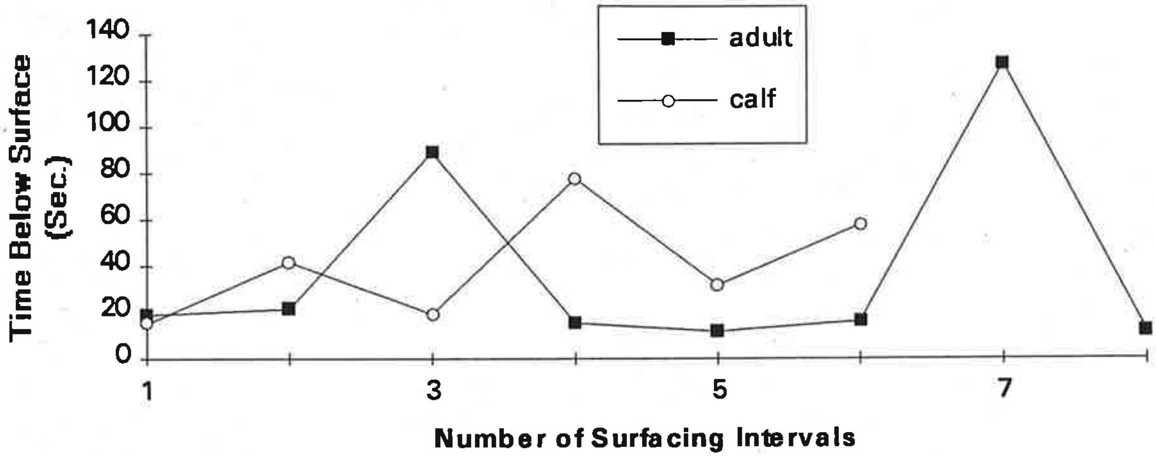

Figure 3

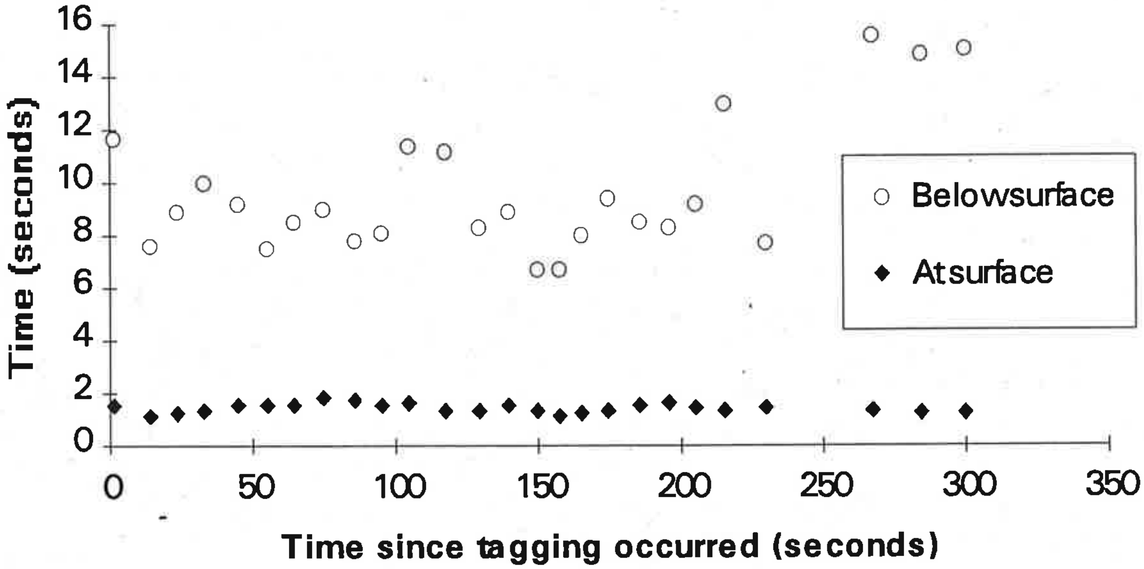

Figure 4

Because of this, 2 dives were removed from the data because the precise time that one dive ended and the other dive started could not be determined reliably. The amount of time spent at the surface prior to and just after a dive appeared to vary more for shorter dives than longer dives (Fig. 5), but this has not been tested statistically to date. Tracking terminated when the suction-cup tag released prematurely from the whale.

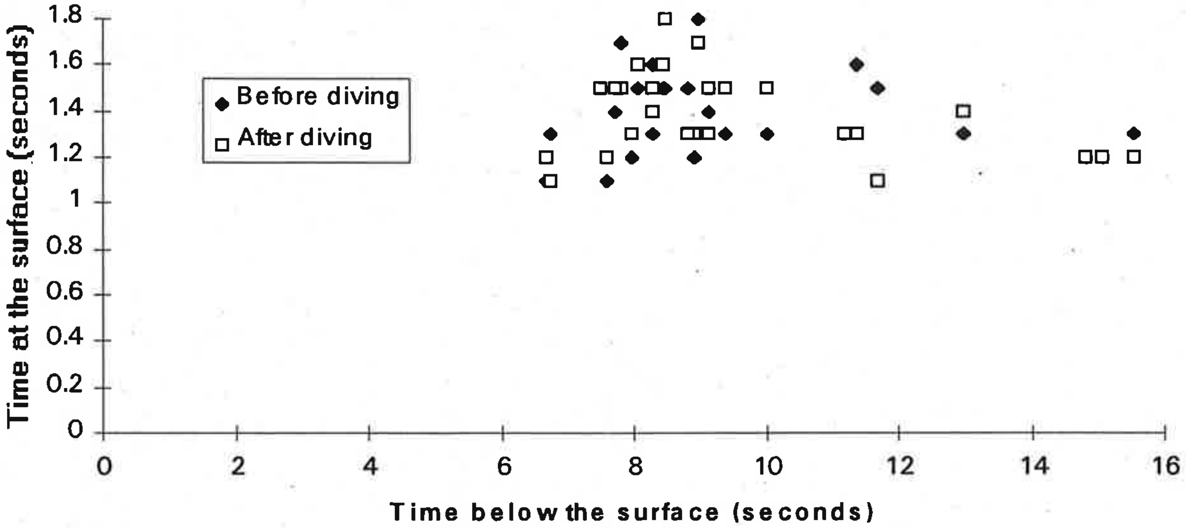

Figure 5

Discussion

The presence of beluga whales in Cook Inlet was first documented in the published literature in 1963 (Klinkhart 1966). During this time, belugas have been subjected to oil drilling and seismic operations, potential interactions with commercial and subsistence fisheries, heavy vessel traffic, low-flying aircraft, and annual subsistence hunts. In spite of this, belugas continue to occupy the upper inlet each summer and have been observed to remain in the inlet throughout all seasons (Calkins 1984). In other regions these whales have demonstrated a strong attachment to certain estuaries, a behavior referred to as site tenacity or fidelity (Finley 1982; Finley *et al.* 1982; Caron and Smith 1990). Belugas continue to return to these estuaries after a disturbance (i.e., hunters, vessel and/or aircraft traffic). Surprisingly, adults accompanied by calves were usually the first to return. This site fidelity behavior seems to be demonstrated by the belugas in Cook Inlet as well.

It is not known why beluga groups appeared to be more dispersed near the end of the field season (mid-June). This type of dispersal is usually not observed until later in the summer after a season of hunting and with the end of fish spawning runs (Calkins 1984; B. Mahoney, pers. comm.). Belugas have been observed in dense aggregations at river mouths during these fish runs (Calkins 1984). Large herd formations have been shown to be associated with heavy concentrations of food organisms in a small feeding area (Bel'kovich 1960). According to the Alaska Department of Fish and Game, spawning runs of king salmon (*Oncorhynchus tshawytscha*) were particularly poor in June, especially in the Susitna river systems (Medred 1994). Eulachon (*Thaleichthys pacificus*) runs appeared to have ended by 9 June because we no longer saw large numbers of dying fish in the Susitna region. This decline in available prey might be one explanation for the early dispersal of belugas because vessel and hunting activities did not appear to affect group structure prior to this time.

Belugas remained in the survey area throughout the field season. On two days when hunting coincided with our tagging operations (3-4 June), whales were observed to move away, up and downstream, but never to fully abandon the river delta. Belugas appeared to recover quickly from disturbance as evidenced by the responses we observed to our vessel activity. Caron and Smith (1990) reported the return of belugas to areas previously disrupted by hunting activities or motor traffic in as little as 2 hours time after a disturbance. However, this recovery time varied significantly between identified individuals (ranging from 33 h. to 574 h.).

According to Kleinenberg *et al.* (1964), though easily alarmed by loud noises, belugas are not shy and have often been seen swimming close to large and small vessels. On a number of occasions, after unsuccessful tagging attempts, we would turn off the engines and observe the whale groups. At such times, the belugas typically surfaced within 4.5 m of the vessel. If we ran the vessel parallel to a moving group then stopped ahead of it, the whales would initially move away. However, within a few minutes, they would return to their original course and surround the vessel as they passed by. On two occasions (4 June), we observed hunters using this same method to get close to the whales.

Because we used methods similar to those used by the hunters to approach and tag whales, similar reactions to our presence would be expected. Caron and Smith (1990) described the reactions of belugas to hunting methods used in the Nastapoka Estuary, eastern Hudson Bay. As hunting vessels rapidly approached, many animals would leave the estuary. However, others did not react to the vessels until they had approached to within 500-1000 m. Pursued whales would either porpoise through the water or only reveal the tops of their heads to breathe ("head lifting") as they fled. Though we did not observe "porpoising" behavior, animals did flee rapidly, and only revealed their heads at the surface when first pursued. Fleeing from disturbances has also been documented for belugas hunted in Russian waters (Kleinenberg *et al.* 1964). Animals appeared less frequently at the surface, rapidly changed course, and moved away from the source of the disturbance. In terms of a hunted animal, a head lift presents a smaller target.

One tagged animal we were able to track for a short period of time continued to exhibit head lift behaviors until we lost sight of it. A factor that will need to be considered in future studies is the amount of time it takes an animal to recover from tagging. Because we were unable to visually track radio-tagged whales for long periods of time, it is not known when normal surfacing behaviors resumed. We did note a change in the behavior of the individual whale mentioned above. This animal had been pursued for 5.4 minutes. Approximately 4 min. after tagging, the whale began to make longer dives (Fig. 4) as it approached a group of belugas. Unfortunately, the tag released prematurely and once within the beluga group, the animal could not be distinguished from the other whales. These longer dives may reflect the return to a normal swimming pattern. Short dive intervals following a tagging event may be the result of oxygen debt, and once sufficiently aerobic, the animal may remain submerged longer.

Head lifting behavior appeared to be correlated with disturbance. Although, Smith *et al.* (1994) observed this behavior frequently when belugas were in shallow water and when large numbers of animals occupied an area, in the undisturbed groups we studied under the same conditions, fewer animals were observed head lifting. From videotape recordings obtained during vessel operations, we noted that during slow roll surfacings adult belugas took an average of 0.3 seconds longer to submerge than juveniles. Slow rolling animals were also at the surface an average of 1.43 seconds longer than animals displaying head lifting behavior. Considering the amount of body area exposed during a surfacing, one would expect head lifting animals and the smaller, slow rolling juveniles to disappear from view more rapidly than the larger, white adults. The distance of the animal from the vessel during a surfacing may have influenced whether the whale slow rolled or head lifted. Although attempts were made to limit the sampling area to a distance from the vessel where both behaviors could be easily observed and whales were unlikely to be disturbed, it is probable that the sample was biased toward slow rolling animals that were white (adults), which were far easier to see than head lifting by adults or the behaviors of gray individuals. Analysis of video recordings from the aerial surveys was also affected by these biases (Waite and Hobbs, this report).

Video footage of an "undisturbed" adult with calf consistently showed the animals displaying slow roll behavior (Fig. 3). This does not necessarily mean that the pair were not bothered by our presence. During one tagging encounter that involved an adult with a calf (Table 1, no. 24 and 25), both animals surfaced this way the entire time. For an adult with a calf this type of surfacing may be necessary. Traveling this way, the adults body experiences increased drag while the calf gains an energetic benefit (Kelly 1959; Lang 1966). In this respect, a younger animals can maintain speed with an adult (Fish 1993). Despite our presence, neither cow/calf pair separated. Adults with calves may be a special case and are not usually targeted for hunting or tagging.

By studying undisturbed beluga groups and tracking known individuals (undisturbed and harassed), we were able to quantify the amount of time animals were spending at the surface during different surfacing behaviors. In turn, this information can be compared to data collected from aerial videotapes (Waite and Hobbs, this report) and radio-tag signal recordings (Lerczak, this report). These comparisons are presented in Waite and Hobbs (this report). If head lifting behavior is influenced by level of disturbance, the difficulty will be in determining at what level a large proportion of the group will display this behavior. Correction factors for population counts may need to be developed for harassed and undisturbed groups as well as groups occupying shallow and/or deep water habitats. Further documentation of these surfacing behaviors will be necessary to better quantify levels of harassment and recovery times.

Acknowledgments

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Characterization of Beluga Whale (*Delphinapterus leucas*) Habitat through Oceanographic Sampling of the Susitna River Delta in Cook Inlet, Alaska, 11-18 June 1994

Kim E.W. Shelden and Robyn P. Angliss[1]

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way N.E., Bin C15700
Seattle, WA 98115-0070

Abstract

In June of 1994, the National Marine Mammal Laboratory conducted an abundance study of the beluga whale population in Cook Inlet, Alaska. An important aspect of this study was to characterize the physical habitat that belugas occupied and examine potential impacts the environment might have had on tag performance. Results from oceanographic samples collected over the Susitna River tidal flats show a fresh water environment with large suspended sediment loads. By comparison, areas sampled offshore of the flats had significantly higher salinity ranges and lower turbidity levels. All sampling sites had salinity levels lower than 32 ‰. Suspended sediment loads ranged from 4 to 205 mg/l. Water temperatures (10°-13°C) were fairly constant for all stations. Extremely low salinity levels in areas where belugas were found affected the salt water switch on the tag transmitter resulting in signal emissions when submerged. Salt water stratification within the water column may have produced detectable differences in signal intensity with depth; however, in very shallow areas, oceanographic sampling results showed minimal stratification. No strong correlation between any one physical factor (salinity, turbidity or temperature) and beluga distribution could be found, though thermal benefits have been described in the published literature for similar estuarine environments. These results may be confounded by the small number of sites sampled in areas occupied by belugas. Current velocity, water depth, and prey distribution may more strongly influence beluga aggregations.

Introduction

The oceanography and hydrography of much of upper Cook Inlet (defined as the areas north of East and West Forelands) has been described by the US Army Corps of Engineers (1993; Smith 1993). Cook Inlet is a macro-tidal estuary with an immense influx of fresh water and with tidal ranges ranking the second highest in North America (US Army Corps of Engineers 1993). The hydrography of the area is heavily influenced by the fresh water

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[1] Current address: National Marine Fisheries Service, Office of Protected Resources, 1335 East-West Highway, Silver Spring, MD 20910.

discharged by the Matanuska, Knik, and Susitna Rivers. River discharge and sediment load are highest during the summer months following the melt of snows in the surrounding watershed. Much of the sediment settles out as extensive tidal flats at the mouths of the Susitna Rivers and in Knik and Turnagain Arms. The mean tidal height at Anchorage is 7.9 m (25.9 ft), and the mean flood and ebb currents at Anchorage are 6.5 km/h (3.5 kts) and 5.7 km/h (3.1 kts), respectively. Wave height is limited by both fetch and water depth. However, standing waves, caused by tidal currents in opposition to wind-generated waves are particularly hazardous to small boat traffic.

Temperature and salinity profiles in upper Cook Inlet typically show well-mixed brackish water (US Army Corps of Engineers 1993). Micro-scale fresh water lenses with low suspended sediment load have also been reported (Smith pers. comm.). Temperature and salinity stratification has occurred in the immediate vicinity of river mouths. Salinities on the tidal flats near the Port of Anchorage generally range from 4 to 5 ‰ (Everts and Moore 1976), and salinity offshore of the tidal flats ranges from 9 to 13 ‰ (Kinney *et al.* 1968; US Army Corps of Engineers 1993). Water temperature is typically 14-17° C.

The observed suspended sediment concentrations in upper Cook Inlet are extremely high: concentrations in Knik Arm are occasionally above 3000 mg/l, and concentrations above 1,000 mg/l are frequently observed (US Army Corps of Engineers 1993). Because of a Coriolis-induced trend, the waters of the west coast of the inlet are generally fresher and more turbid while east coast waters are relatively clear and saltier. Previous studies (Naidu *et al.* 1992) determined that most suspended sediment in July consisted of roughly 50% clay-sized and 50% silt-sized particles with occasional trace amounts of fine sand.

Species assemblages of phytoplankton, zooplankton, and intertidal and subtidal benthic invertebrates in upper Cook Inlet are not particularly diverse due to high suspended sediment load, burial of benthic organisms by silt, high current velocities, ice scouring, low temperatures, and low and fluctuating salinity. Eulachon and adult and smolt salmon transit through upper Cook Inlet en route to riverine spawning grounds. The presence of marine mammals in the area is probably related to the temporal distribution of the prey species.

Beluga whales typically frequent the upper portions of Cook Inlet during the early summer. Information about the physical habitat of this area is important to this study for two reasons: 1) beluga whales may be found more frequently in some physical settings and 2) the salinity of the water may affect the performance of the radio tags attached to the animals. Oceanographic samples were taken during the 1994 beluga whale study in Cook Inlet, Alaska, to further define the animals' habitat.

Methods

Oceanographic measurements were taken at two types of sample sites; opportunistic sites that were close to beluga whale groups and fixed stations that were each assigned a waypoint number. Fixed stations consisted of an offshore array of sampling sites set 5.5 km apart along the 3 fathom (5.5 m) depth contour from west to east (Waypoints 1-7) and a nearshore array set 0.9 km apart following the 150°32'W longitude line from north to south (Waypoints 8-11). Attempts were made to conduct repeat sampling at fixed stations at different times in the tidal cycle. Consecutive station (Stn.) numbers were assigned each day, each new day beginning where the previous survey had ended.

Four types of samples were collected at each station: water samples for surface salinity and turbidity levels, secchi disk depth measurements, CTD casts to profile salinity, temperature, and density levels within the water column, and benthic samples to characterize bottom substrate. In addition to this data, time at sampling, position (latitude and longitude), Beaufort sea state, and tidal activity were recorded.

The salinity and turbidity of the water samples was analyzed by the School of Oceanography, University of Washington. CTD cast data were saved on a microchip within the CTD and downloaded into the field data acquisition system at the end of the survey. Temperature, salinity, and density profiles were created for each station sampled. To reduce the likelihood of cross-contamination between sampling sites, a second CTD cast was made at each site and compared to the previous cast. Gross morphological descriptions of the benthic samples were made for each site, however, the samples have not undergone grain size analysis at this time. Water depths at each site were approximated based on depths obtained from CTD casts, benthic grabs, and the vessel depth recorder. Depths obtained from CTD casts were only used when strong currents did not displace the sampling equipment.

Results

From 11 to 18 June, a total of 19 stations were sampled (Fig. 1). This included opportunistic sites (n=4) and repeat sampling of some of the fixed stations (n=15). All four types of samples were collected at each station except for the fixed stations at Waypoints 8-11 where only CTD casts and water samples were obtained.

Surface salinity levels obtained from the water samples ranged from 0.062 ‰ to

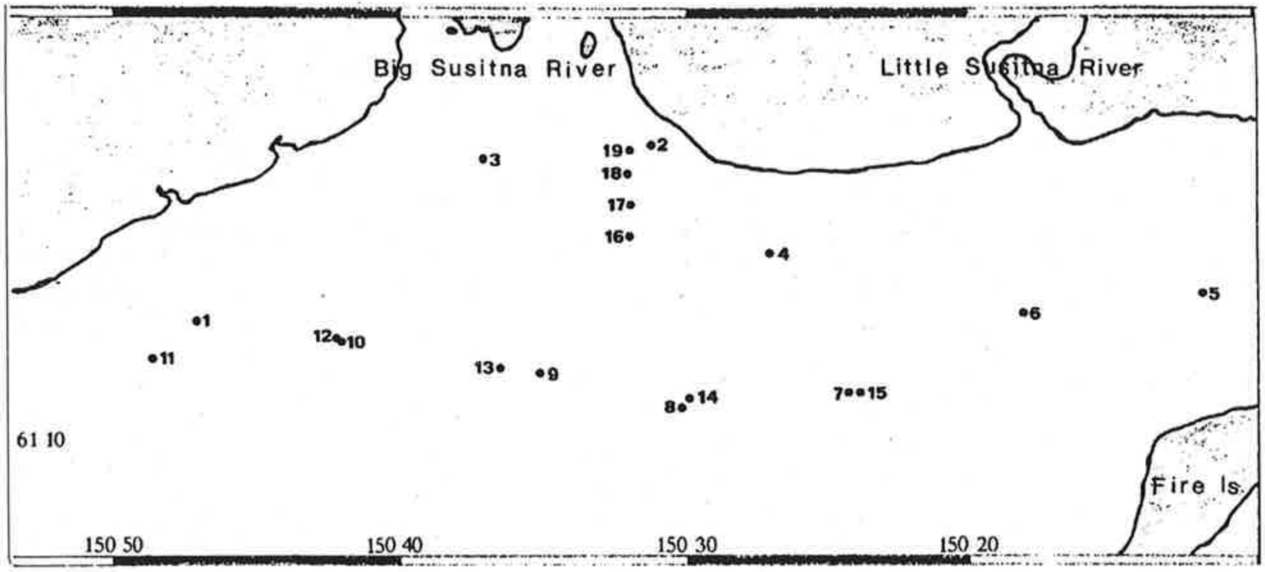

Figure 1. June 1994 survey area. Sample sites are noted by Station number.

15.777 ‰ ($\bar{x}$=7.0 ‰, CV=1.0; n=19). These results compared favorably with those obtained from the CTD casts, showing an average difference of -0.49 (paired t-Test; t-value=-1.63, d.f.=18, p=0.12) (Table 1). Based on these numbers, fresh water predominated throughout the water column for all stations (<32 ‰). CTD profiles showed salinity, temperature, and density to be fairly uniform throughout the water column except at Stations 11 and 13 where water density and salinity increased with depth by 7 $(kg/m^3)^2$ and 8-11 ‰, respectively. Surface water turbidity results ranged from 4 mg/l to 205 mg/l ($\bar{x}$=80.3 mg/l, CV=0.78; Table 2). Secchi disk depth measurements ranged from 5 cm to 37.5 cm ($\bar{x}$=14.4 cm, CV=0.64; Table 2).

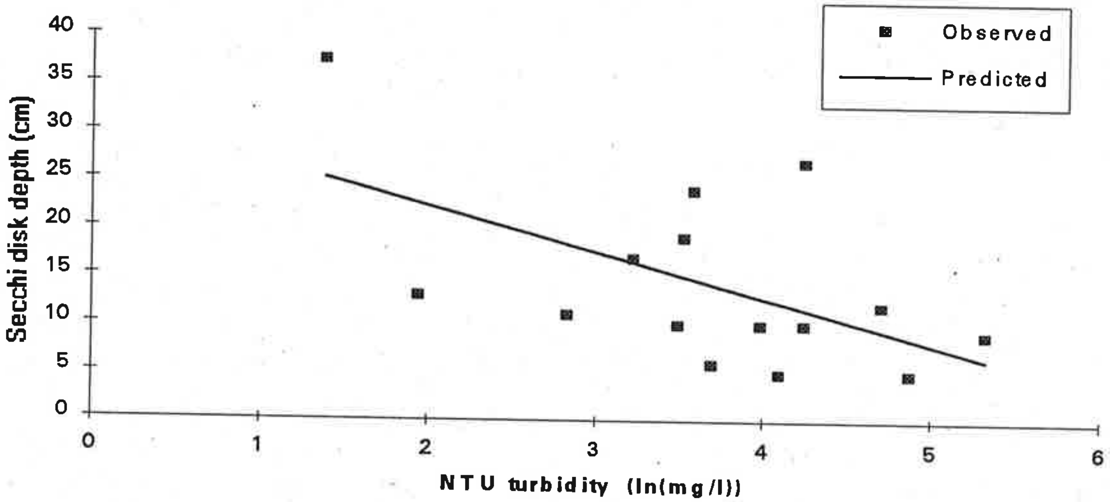

Figure 2

Turbidity and secchi disk results were plotted against one another (Fig. 2) and by sampling site (Fig. 3). As turbidity increased, secchi disk depth was found to decrease in most cases (ANOVA; p=0.03). When tested together, salinity did not affect secchi measurements at all (ANOVA; p=0.6) while turbidity levels strongly influenced secchi measurements (ANOVA; p=0.0001).

Gross morphological examination of benthic samples found that most were composed of fine sediment or sand. In addition some contained organics such as wood, small stones, and in two cases what was described as a "slimey mud" (Table 3). Water temperatures were fairly constant for all stations, ranging from 10° to 13°C.

Of the four stations sampled in close proximity to beluga groups, surface salinity ranged from 0.06 ‰ to 14.00 ‰ ($\bar{x}$=4.29, CV=1.54), turbidity ranged from 40 mg/l to 70 mg/l ($\bar{x}$=56, CV=0.22), and secchi disk measurements from 5 cm to 10 cm ($\bar{x}$=7.7, CV=0.34). Water depth at these stations was approximately 2-3 m. Other stations sampled in shallow water or at low tide (<5 m in depth; n=7) had a surface salinity range of 0.07 ‰ to 3.00 ‰ ($\bar{x}$=0.55, CV=1.94), a turbidity range of 70 mg/l to 205 mg/l ($\bar{x}$=147.8, CV=0.28), and secchi disk measurements from 5 cm to 27 cm ($\bar{x}$=13.7, CV=0.86; n=3). Average changes in salinity and density within the water column in shallow water stations were 0.6 ‰ and 0.2 $(kg/m^3)^2$, respectively. This does not include the profiles obtained from Stations 11 and 13 where wide fluctuations in salinity and density were noted. Stations sampled in deep water or at high tide (between 7 m and 25 m in depth; n=7) had a surface salinity range of 10 ‰ to 15 ‰ ($\bar{x}$=13.8, CV=0.15), a turbidity range of 4 mg/l to 110 mg/l ($\bar{x}$=37, CV=0.92), and secchi disk measurements from 10 cm to 37.5 cm ($\bar{x}$=18.6, CV=0.52). Salinity and density profiles showed an average change of 2.5 ‰ and 1.9 $(kg/m^3)^2$, respectively, with increased depth. Data from one station (#8) were not included in the analysis because depth measurements were not obtained during oceanographic sampling.

Only four sites were sampled twice during the field season. Waypoints 3 (Stn. 7) and 4 (Stn. 8) were first sampled on 14 June and Waypoints 5 (Stn. 9) and 6 (Stn. 10) on 15 June. All four waypoints were sampled again on 18 June (Stns. 15, 14, 13, and 12, respectively). Sampling that took place on 14 June occurred during the ebbing tide, all other samples were collected as the tide was flooding. Turbidity levels were higher at all four waypoints on 18 June. Secchi measurements also reflected the increase in suspended sediment load at all four waypoints. Considerable differences were noted between the salinity and density profiles

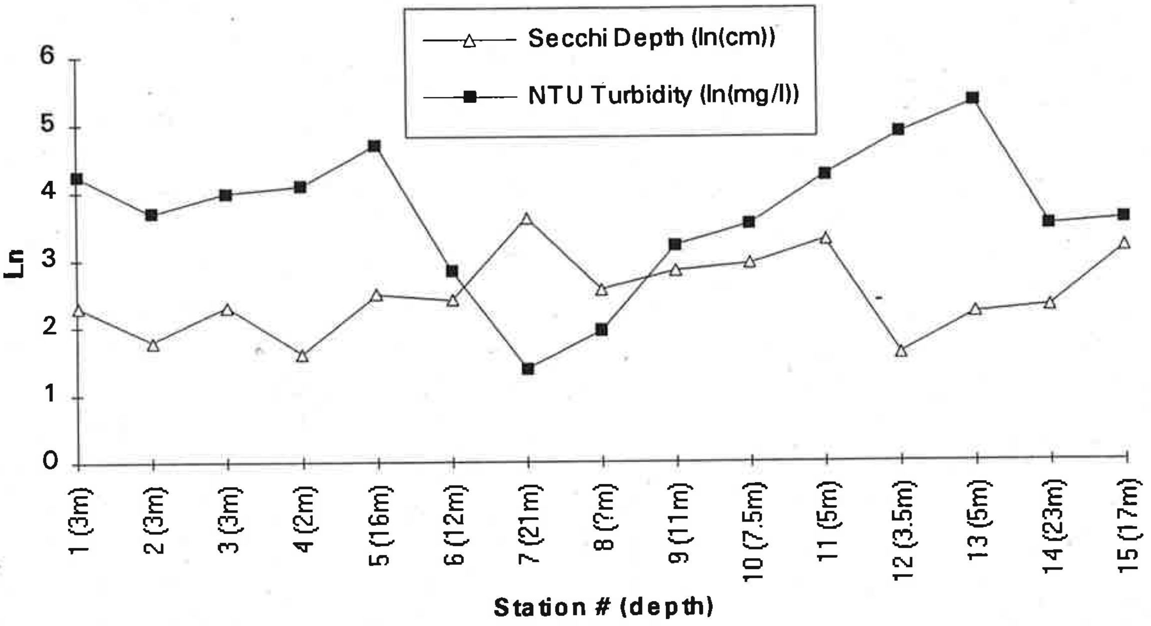

Figure 3

obtained for Waypoints 5 and 6 on 15 June and 18 June. The water was much fresher (0.2-1 ‰ versus 15 ‰) and density much lower (0.4 (kg/m^3)^2 versus 11 (kg/m$^{3\,2}$)) on 18 June. Water depth for both sites was approximately 4 m deeper on 15 June.

Weather conditions varied spatially and temporally. Beaufort sea states tended to increase throughout the survey day, independent of site location (Table 4). High velocity currents encountered during mid-tide sampling events would often affect the submerging direction and rate of the secchi disk, CTD, and benthic grab. Anchoring the vessel increased the impact of these currents on the collecting equipment. In some instances, even with the vessel unanchored and under power, sampling was interrupted while the vessel repositioned back to the original site (displacement from the site ranged from a distance of 0.5 km to 1.5 km at speeds ranging from 0.5 kts to 1.5 kts). All attempts to sample were aborted after 18 June due to poor weather.

Discussion

Oceanographic samples collected in Cook Inlet during the 1994 field season provide preliminary information on the outer edge (3 fathom depth contour; Waypoints 1-7) of the Susitna River delta and sites occupied within the delta by beluga groups (Stations 1-4 and Waypoints 8-11). Results from our samples are similar to those obtained during previous studies of the inlet. In waters offshore of the Susitna tidal flats, salinity ranged from 10 to 15 ‰. Prior results for regions off the Port of Anchorage tidal flats yielded salinity ranges of 9 to 13 ‰ (Kinney *et al.* 1968; US Army Corps of Engineers 1993). Over the Susitna tidal flats, salinity levels ranged from 0.07 to 3 ‰ compared to 4 to 5 ‰ for tidal flats near the Port (Everts and Moore 1976). The large volume of fresh water entering the inlet from the Susitna River system might be the primary reason salinities are lower in this region than near the Port of Anchorage. Water temperatures were fairly constant for all stations, ranging from 10° to 13°C. These temperatures are slightly lower than those typically recorded in the inlet which may be a function of sampling site or time of year that the samples were taken. Temperatures of 14° to 15° C are usual for July (Smith 1993).

During the end of the ebb tide as flood tide was just beginning, we found a large shift in salinity and density levels at two of the westernmost stations (Station 11 and Station 13; Table 2). Both stations were 5 m deep. Station 11 had a secchi measurement of 27 cm and turbidity at 70 mg/l, while Station 13 was 9 cm and 205 mg/l (the highest recorded), respectively. At Station 12, which was between the two, water depth was 3.5 m, secchi depth was 5 cm, and turbidity was 130 mg/l, but salinity and density were uniform throughout the water column. It may be possible that the heavier "salt" water was being channeled around Station 12 (a sandbar) into Stations 11 and 13, which were deeper. It could not be determined if the salt water was exiting or entering the Susitna delta. Other anomalies similar to this were not detected in the data. Differences were noted between waypoints (3, 4, 5, and 6) that were sampled 3-4 days apart. Water depth, tidal stage, and wind levels may have played a role in the changes that were observed. However, few replicate samples were obtained for each site, and in some cases none. More thorough sampling throughout the tidal cycle will be necessary before any conclusions can be made regarding what is normal and what is anomalous.

Suspended sediment loads were lower than those frequently observed in the upper inlet (1,000 mg/l; US Army Corps of Engineers 1993). In shallow water (<5 m in depth), turbidity levels averaged 148 mg/l compared to deeper water (between 7 and 25 m) where surface sediments averaged 37 mg/l. Secchi disk measurements for these water depths averaged approximately 14 and 19 cm, respectively. As expected, turbidity levels strongly influenced secchi depth. Depth, current, bottom topography, river outwash, and wind may have affected our results. Benthic sediments collected at deep water sites tended to contain finer particulate matter, stones, and wood debris while those collected at shallow sites consisted of sand or mud. Strong currents, wind, and high sea states encountered during sampling may have produced more mixing in the shallower water thereby increasing sediment load. Salinity and density results obtained from CTD casts were fairly uniform in shallow water (excluding Stations 11 and 13; Table 2). At deeper sites, changes within the water column were more noticeable at some sites with density and salinity levels increasing with depth. This might suggest more thorough mixing in shallower waters. However, analysis of the bottom substrate has not been completed at this time and sample sizes are fairly small.

The task of collecting oceanographic samples in 1994 was complicated by the environmental conditions mentioned above. Strong tide-influenced currents and high Beaufort states could have affected sampling results by dragging the CTD and benthic casts away from the station and compromising secchi disk measurements because it would not sink correctly. Also strong currents caused the vessel to drift away from the station requiring sampling to stop until the vessel could be repositioned. Because we were unable to complete an entire sampling array within one day or resample stations throughout the tide cycle, further comparisons between sampling stations were not made. From our samples there did not appear to be any cross-contamination between CTD samples (i.e., no residual water in the CTD carried from site to site). We resolved this problem by sampling twice at each site and comparing the two samples for anomalies. Sediment load did not appear to affect salinity in water bottle samples. No significant differences were found between surface salinity levels obtained from water bottle samples and those from CTD casts.

The relationship between certain physical factors and beluga occupation of upper Cook Inlet has not been explored. Much of the literature on belugas and their use of coastal estuaries focuses on the movement of these animals relative to tides (summarized in Kleinenberg *et al.* 1964). Where water levels have been noted to fluctuate markedly, inshore migrations primarily occur during high tide. In Russian waters, the highest numbers of belugas were found to migrate along the shore during the high spring tides (Kleinenberg *et al.* 1964). Penetration into rivers and movements inshore during these tides is principally driven by the availability of prey species. In Canadian waters, (i.e., Nastapoka Estuary), herd position was also found to correlate with tide (Caron and Smith 1990). Beluga groups would move into the upper reaches of the estuary during flood tide and recede during ebb tide. Other factors that favored occupation of the upper estuary included large herd size, long periods without disturbance, high waves, strong northerly winds, high river water temperature, and clear water. Hansen (1987) found that whale abundance and distribution within the Churchill River estuary was positively correlated with maximum estuarine temperatures and increased temperature differences between the estuary and outlying coastal waters, but only during high tide.

In June 1994, water temperatures ranged from 10° to 13°C in Cook Inlet. Temperature did not appear to vary with depth or with location within the inlet. This temperature range is consistent with those described for other warm water estuaries utilized by belugas. Studies conducted in Canadian estuaries at the time of beluga occupation found temperatures ranged from 10° to 18°C, while surrounding waters registered 0° to 7°C (summarized in Watts *et al.* 1991). Adult beluga, occupying the Churchill River, were found to occur more frequently in warm water sites than immature animals (Watts *et al.* 1991). The authors suggest that warmer waters may be providing a thermal advantage to adults undergoing seasonal molt. In Cook Inlet, we did not observe any clear evidence of molt. We were also unable to determine the proportion of adults to juveniles from aerial and vessel videotapes because of the turbid waters. However, on 14 June, 186 belugas live-stranded in the Susitna River delta. Aerial photographs showed that 48% of the group consisted of juveniles (gray coloration; including calves) (Waite and Hobbs this report). The consistency of the temperatures observed in both deeper, faster-moving offshore water and shallow, nearshore water suggests that water temperature alone does not influence beluga distribution within the inlet. The tidal flats do, however, provide some protection from the strong currents that predominate in the central inlet.

Samples obtained from stations close to beluga groups and in shallow water areas likely to be occupied by belugas, tended to have lower salinity and more suspended sediment. Beluga groups were generally found near river mouths (Beluga R., Big Susitna R., and Little Susitna R.). Fresh water discharge and sediment loads from these rivers strongly influences the hydrography of the upper inlet, particularly during the summer months (US Army Corps of Engineers 1993). It seems improbable that belugas benefit from a turbid, freshwater habitat. Belugas seem as likely to be found in clear water estuaries (Bel'kovitch and Shchekotov 1990; Caron and Smith 1990; Smith *et al.* 1994) as turbid habitats (Bel'kovitch and Shchekotov 1990; Smith *et al.* 1994). In the Churchill River study area, no significant correlation was found between whale abundance and turbidity or salinity levels (Hansen 1987). Whale distribution was also not influenced by turbidity levels, though a high negative correlation was found between beluga distribution and salinity levels during high tides. In these cases, salinity and temperature were collinear. Hansen (1987) suggests that temperature is the most influential oceanographic factor affecting beluga distribution.

Because salinity levels were so low in the areas occupied by belugas in Cook Inlet, the salt water switch on the radio tags did not appear to activate completely. This resulted in the tag emitting a signal when submerged. The intensity of the signal might have been affected by stratification within the water column, however, stratification was minimal in shallow areas where belugas were found (see Lerczak (this report) for a more detailed description of radio tag design and function).

Because our sample sizes are so small, it is difficult to find any strong correlations between any one physical factor and beluga distribution. As mentioned in previous publications, occupation of coastal areas, particularly near river mouths, is more likely to be driven by the availability of prey items (see Shelden, this report). Tides and resulting water depths may be the greatest limiting factor in terms of beluga distribution within the river deltas. When interpreting the echolocation strategies of beluga whales, Bel'kovitch and Shchekotov (1990) believed differences in echolocation series between belugas found in the White Sea and the Amur Estuary were caused by prey size, behavior, and hydrological factors, such as water clarity, current speed, and depth. Amur belugas hunt in an area similar to the Susitna delta. Water and Secchi depths in Amur ranged from 1-5 m and 20-40 cm, respectively. Spawning fish, such as salmon, utilized a 3-5 m deep channel to migrate upstream. In the areas surrounding this channel, water depth was 1-2 m. Channels such as this are also present in the Susitna delta. Belugas hunting salmon in similar environments formed large compact groups ranging from tens to hundreds of individuals (Bel'kovitch and Shchekotov 1990). Similar group formations have been observed in the east and west tributaries of the Big Susitna River, and in the mouths of the Little Susitna River and the Beluga River (Withrow *et al.* 1993; Rugh *et al,*.this report). In Cook Inlet, oceanographic factors may influence beluga assemblages indirectly by affecting the distribution of prey items, or directly only in terms of currents and water depth.

Acknowledgments

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Table 1. Results from CTD casts made during oceanographic sampling in Cook Inlet, Alaska, June 1994. Water sample salinity results are included by way of comparison.

Station #	Station Type	Water Depth (m)	Temperature (°C)*	Density Sigma-T (kg/m^3)^2	Salinity (ppt)†	Water Sample Salinity (ppt)
1	opportunistic	1.35	11.8338-12.1392	2.2133-3.8556	3.5946-5.5752	2.943
2	opportunistic	1.87	10.9488-11.2035	-0.2578 to -0.2197	0.1862-0.2137	0.171
3	opportunistic	0.99	12.5065-12.5353	-0.5147 to -0.5125	0.0575-0.0606	0.062
4	opportunistic	1.99	11.3306-11.3941	10.7593-10.8536	11.6690-14.5582	14.395
5	Waypoint 1	9.95	11.4553-11.8322	11.0959-11.5538	13.6482-15.4692	15.127
6	Waypoint 2	11.44	10.9192-11.3773	9.0479-12.0388	11.8328-16.0066	15.777
7	Waypoint 3	19.39	10.1750-10.7743	12.0402-12.7254	16.0454-16.7386	15.675
8	Waypoint 4	20.39	10.2177-11.4475	9.7351-12.6373	12.9648-16.6286	15.106
9	Waypoint 5	7.46	10.4113-11.1246	11.3090-12.5138	15.1194-16.5059	15.257
10	Waypoint 6	7.96	10.6566-11.1773	11.6796-12.0548	15.5947-15.9694	15.539
11	Waypoint 7	3.48	11.3830-11.9487	2.8703-9.3857	4.3420-12.4358	3.863
12	Waypoint 6	0.78	11.4039-11.6551	-0.4545 to -0.2812	0.0172-0.2099	0.219
13	Waypoint 5	3.48	11.8381-12.0630	0.4831-8.9331	1.6710-12.1886	0.382
14	Waypoint 4	15.91	12.1740-12.8980	6.1831-10.4940	9.0344-14.3016	10.828
15	Waypoint 3	13.43	12.6107-12.8506	8.7074-10.5183	12.1213-14.3944	12.054
16	Waypoint 11	1.49	13.0333-13.0628	-0.5623 to -0.5536	0.0837-0.0921	0.092
17	Waypoint 10	1.33	12.0778-12.9456	-0.5852 to -0.4884	0.0112-0.0851	0.086
18	Waypoint 9	1.23	12.1996-12.8164	-0.6037 to -0.5056	0.0149-0.0702	0.074
19	Waypoint 8	0.72	11.9997-12.6277	-0.5528 to -0.4898	0.0115-0.0669	0.073

* Temperature became colder with depth

† Density and Salinity usually increased with depth, particularly within the first three meters.

Table 2. Surface salinity and NTU turbidity results from water samples and secchi disk depth measurements taken in Cook Inlet from 11 to 18 June 1994, during beluga whale tagging operations (tides are noted as: E=ebb, F=flood, SH=slack high, SL=slack low).

Station #	Station Type	Distance to beluga whales	Tide	Approx. Water Depth (m)*	Secchi Disk Depth (cm)	Salinity (ppt)	NTU turbidity (mg/l)
1	opportunistic	0.3km N.	E	3.0	10 est.	2.943	70
2	opportunistic	1-2km N.	SH	3.0	6 est.	0.171	40
3	opportunistic	0.3km N.	E	3.0	10 est.	0.062	54
4	opportunistic	1km W.	F	2.0	5.0	14.395	60
5	Waypoint 1	-	F	16.0	12.0	15.127	110
6	Waypoint 2	-	SH	12.0	11.0	15.777	17
7	Waypoint 3	-	E	21.0	37.5	15.675	4
8	Waypoint 4	-	E	-	13.0	15.106	7
9	Waypoint 5	-	F	11.0	17.0	15.257	25
10	Waypoint 6	-	SH	7.5	19.0	15.539	34
11	Waypoint 7	-	SL	5.0	27.0	3.863	70
12	Waypoint 6	-	F	3.5	5.0	0.219	130
13	Waypoint 5	-	F	5.0	9.0	0.382	205
14	Waypoint 4	-	F	23.0	10.0	10.828	33
15	Waypoint 3	-	F	17.0	24.0	12.054	36
16	Waypoint 11	-	F	2.0	-	0.092	150
17	Waypoint 10	-	F	1.5	-	0.086	150
18	Waypoint 9	-	F	1.0	-	0.074	160
19	Waypoint 8	-	F	1.0	-	0.073	170

* water depth approximations were based on depths obtained from CTD casts, benthic grabs, and the vessel depth sounder.

Table 3. Gross morphological results of benthic samples obtained from 19 oceanographic stations during beluga whale surveys conducted in Cook Inlet, Alaska, June 1994.

Station #	Station Type	Approx. Water Depth (m)*	Gross Morphology of Benthic Samples
1	opportunistic	3.0	fine sediment
2	opportunistic	3.0	sand
3	opportunistic	3.0	sand
4	opportunistic	2.0	sand
5	Waypoint 1	16.0	wood debris, metallic sediment (gold?), and sand
6	Waypoint 2	12.0	metallic sediment and sand
7	Waypoint 3	21.0	fine sediment and organic matter (wood bits)
8	Waypoint 4	-	fine sediment, sand, and organic matter (wood bits)
9	Waypoint 5	11.0	sand, small stones, clay (?), and organic matter (wood bits)
10	Waypoint 6	7.5	fine sediment
11	Waypoint 7	5.0	slimey mud
12	Waypoint 6	3.5	fine sediment, sand, small stones, and wood debris
13	Waypoint 5	5.0	fine sediment, slimey mud, and organics
14	Waypoint 4	23.0	fine sediment, small stones, and wood debris
15	Waypoint 3	17.0	fine sediment and sand
16	Waypoint 11	2.0	(not sampled)
17	Waypoint 10	1.5	(not sampled)
18	Waypoint 9	1.0	(not sampled)
19	Waypoint 8	1.0	(not sampled)

* water depth approximations were based on depths obtained from CTD casts, benthic grabs, and the vessel depth sounder.

Table 4. Tide levels and sea states during oceanographic sampling in Cook Inlet, Alaska, June 1994.

Date: June 1994	Elapsed Time of Oceanographic Sampling		Approximate Location of Oceanographic Sampling (including initial GPS position)	Tidal Range During Sampling		Beaufort Sea State During Sampling	
	Start	End		Start	End	Start	End
11	13:40	13:56	Station 1 (opportunistic); (61°11.96N, 150°47.07W)	13.63'E	12.23'E	1-2	1-2
13	09:25	09:50	Station 2 (opportunistic); (61°15.02N, 150°31.26W)	22.96'F	24.48'F	1	1
	11:02	11:27	Station 3 (opportunistic); (61°14.78N, 150°37.07W)	27.50'F	27.60'E	1	1
14	08:28	08:53	Station 4 (opportunistic); (61°13.14N, 150°27.05W)	14.27'F	16.68'F	0-1	0-1
	09:55	10:19	Station 5 (Waypoint 1); (61°12.52N, 150°11.88W)	21.45'F	23.02'F	0-1	0-1
	10:30	10:50	Station 6 (Waypoint 2); (61°12.10N, 150°18.06W)	23.64'F	24.65'F	0-1	0-1
	10:55	11:11	Station 7 (Waypoint 3); (61°10.81N, 150°24.12W)	24.87'F	25.54'E	0-1	0-1
	12:50	13:12	Station 8 (Waypoint 4); (61°10.57N, 150°30.12W)	25.63'E	24.31'E	2	2
15	11:23	11:38	Station 9 (Waypoint 5); (61°11.18N, 150°35.09W)	23.07'F	23.82'F	3	3
	11:57	12:12	Station 10 (Waypoint 6); (61°11.67N, 150°42.05W)	24.65'F	25.22'F	4	4
18	08:23	08:41	Station 11 (Waypoint 7); (61°11.39N, 150°48.54W)	8.66'E	7.14'E	2	2
	09:19	09:34	Station 12 (Waypoint 6); (61°11.70N, 150°42.16W)	4.40'E	3.45'E	1	1
	10:04	10:26	Station 13 (Waypoint 5); (61°11.21N, 150°36.47W)	2.09'E	1.60'F	1	1
	10:46	11:14	Station 14 (Waypoint 4); (61°10.68N, 150°29.89W)	1.55'F	2.28'F	2	2
	11:27	12:06	Station 15 (Waypoint 3); (61°10.80N, 150°23.84W)	3.01'F	6.60'F	1	1
	12:49	12:54	Station 16 (Waypoint 11); (61°13.48N, 150°31.95W)	11.68'F	12.24'F	2	2
	12:59	13:03	Station 17 (Waypoint 10); (61°13.98N, 150°31.99W)	12.79'F	13.23'F	2	2
	13:10	13:13	Station 18 (Waypoint 9); (61°14.49N, 150°32.03W)	13.96'F	14.27'F	2	2
	13:20	13:24	Station 19 (Waypoint 8); (61°14.95N, 150°31.92W)	14.97'F	15.36'F	2-3	2-3

Photo-identification of beluga whales in Cook Inlet, Alaska: a feasibility study

Janice M. Waite

National Marine Mammal Laboratory
Alaska Fisheries Science Center, NMFS, NOAA
7600 Sand Point Way NE
Seattle, Washington 98115, U.S.A.

Abstract

In June 1994, studies were conducted by the National Marine Mammal Laboratory (NMML) to determine the abundance of beluga whales in Cook Inlet, Alaska. In conjuction with the population studies, a study was conducted to determine the feasibility of using vessel-based photo-identification of individual whales as a tool for identifying different groups of beluga whales. A total of thirteen rolls of film were developed and examined. From these, 273 whales were examined and 49 (18%) had some kind of visible mark. Seven whales were reidentified, but only from multiple photographs taken within a single surfacing. One whale was reidentified from two photographs taken minutes apart. Because no whales were reidentified between days, and because marks usually were were no more than subtle scratches, photo-identification of beluga whales is not considered a feasible method for distinguishing different whale groups.

Introduction

Photo-identification has been used as a tool for studying many different aspects of cetacean biology including population size and vital parameters (i.e, birth and mortality rates), movements, and social organization (see International Whaling Commission, Special Issue 12). Beluga whale research in Cook Inlet could benefit from photo-identification if individual whales could be re-identified hours or days between photographs. It is possible that different groups in Cook Inlet consist of different parts of the population (age/sex classes), as has been found in the Canadian Arctic (Smith *et al.* 1994). If there are segregations by age or sex , there may also be differences in surfacing behaviors among groups. Such differences could affect correction factors being developed for population abundance calculations (Hobbs *et al.* 1995). If group segregation became evident, studies such as tagging efforts (Lerczak 1995) would need to sample different groups appropriately. For photo-identification to be useful, individual beluga whales must have distinct marks that would allow them to be identified over time. In addition, a large percentage of a group would need to be photographed on each sample day to ensure that identifiable individuals in a group were not missed. A photo-identification study was conducted in June 1994 to determine the feasibility of identifying individual beluga whales in Cook Inlet.

Methods

Two vessels were used for photographing beluga whales: a 5 m Avon rigid hull inflatable boat with a 70 hp engine and a 6 m Boston Whaler with twin 100 hp engines. Attempts were made to position the boats alongside whales to photograph their dorsal ridge as they surfaced. We found that the whales could not be easily or predictably approached in this manner. It was sometimes possible to follow single whales or pairs of whales to obtain photographs, but typically whales would dive and change direction upon the approach of a boat. Instead, when we moved the boat in front of a group and turned off the engine, whales surfaced nearby. It was still difficult to photograph individuals because they rarely surfaced in a predictable manner, but this method provided the best opportunity to get within photographic range of the whales. Photographic bouts were conducted opportunistically when tidal states limited tagging effort (Lerczak 1995, Shelden 1995), and were variable in length.

A Nikon 8008 35 mm camera with a 70 - 210 mm zoom lens and a Minolta 7000 camera with a 60 - 200 mm zoom lens were used. Five types of film were tested: Fuji 400 print film; Kodak 200 and 400 print film; Fuji 400 slide film; and Kodak Ektachrome 200 slide film. The print film was processed at a photography lab in Anchorage to provide feedback during the project and the slide film was processed in Seattle after the field season.

In the laboratory, the number of whales in each photograph that were close enough to be examined and the number of those which had visible marks were recorded. Sketches were drawn of marked animals and an attempt was made to match individuals.

Results

A total of thirteen rolls of film were developed and examined. The Fujicolor print film had better contrast than the Kodak print film. It was not possible to make an objective comparison between the print film and the slide film because of differences in lighting conditions.

A total of 273 whales were counted in these photographs. Of these, 49 (18%) had some kind of visible mark. Markings included both dark and white lines (34), dark or white spots or splotches (8), what appeared to be healed wounds (3), and indentations on the back (2). Marks were found on both gray and white animals, although scars and indentations were only found on white animals. Seven individuals were reidentified from frame to frame (two or more shots of the same surfacing), and one whale was matched between surfacings (but during same photographic bout).

Discussion

Although marks were found on approximately one-fifth of the whales photographed, few of the marks appeared to be unique enough to reliably reidentify individuals over time. Photo-identification studies of cetaceans are typically conducted with species that either have a prominent dorsal fin with varying shapes and the possibility of nicks - such as killer whales and bottlenose dolphins (Bigg 1982, Balcomb *et al.* 1982, Scott *et al.* 1982) - or species that have prominent color patterns that exhibit individual variation, such as humpback whales (Katona *et al.* 1979). Beluga whales have neither. Therefore, it would be necessary to rely on scratches or prominent scars. Large wounds have been found to persist over years in other delphinids (Würsig and Jefferson 1990), but the number of evident wounds found during our study was small (3 out of 49). Although lines and dots were found on beluga whales, they may not last over time. Furthermore, many of these were white marks on a white body. Such marks may need particular lighting conditions to be seen more than once. This would greatly decrease opportunities to reidentify an individual.

Another problem encountered during analysis was the difficulty in determining which side of the beluga whale was photographed . For other species, such as killer whales, photo-identification efforts concentrate on one side only (Bigg *et al.* 1987). This provides a standard so that an animal that does not have symmetrical markings from the right to the left side will not be recorded as two individuals. But beluga whales lack a dorsal fin or other evidence of direction of travel in a still photograph. Infield notes or supplementary video coverage would be necessary to record which side of each whale was being photographed.

It is unknown whether beluga groups in Cook Inlet stay together, mix with other groups, or change membership over time. Studies in the Canadian Arctic, using whale length classification, found small groups of males separate from mother/calf groups, and a seasonal difference in the proportion of mothers, juveniles and calves (Smith *et al.* 1994). It is possible that some well-marked individuals in Cook Inlet could be resighted over several days, but without knowing their social organization, it would be impossible to draw any conclusions about group identity . To understand the group dynamics of beluga whales in Cook Inlet through photo-identification, a large percentage of the population would need to be identifiable and resighted over many years. Results from this study show that there are not enough well-marked individuals to accomplish this.

The difficulties we found in getting close enough to photograph beluga whales and the lack of well -defined marks indicate that photo-identification studies are not practical at least for our purposes. To obtain any information applicable at a stock management level, a long-term dedicated study would need to be conducted. Such a study could possibly produce insights into beluga group dynamics. But within the time frame of our study, the limitations are too great to produce useful results.

Recommendations

Photo-identification could be worth pursuing if a dedicated, long-term study was planned. In our study, we were only able to photograph whales opportunistically during tagging efforts. The ability to identify even a few individuals could help us understand some of the social dynamics (were different groups comprised of different subsets of the population, did they mix, etc.) and movements of the beluga whales within Cook Inlet.

Several factors could improve the photographic effort. A longer lens (300 mm or longer) might increase the ability to detect identifiable marks. Black and white film might help reveal marks as well. Multiple shots would provide increased opportunities of catching optimal lighting across a whale mark.

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