Cite as: Hobbs, R. C., C. L. Sims, and K. E. W Shelden. 2011. Estimated abundance of belugas in Cook Inlet, Alaska, from aerial surveys conducted in June 2011. NMFS, NMML Unpublished Report. 7 p.

ESTIMATED ABUNDANCE OF BELUGAS, *DELPHINAPTERUS LEUCAS*, IN COOK INLET, ALASKA, FROM AERIAL SURVEYS CONDUCTED IN JUNE 2011

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Abstract

The National Marine Fisheries Service (NMFS) conducted aerial surveys of the beluga, *Delphinapterus leucas*, population in Cook Inlet, Alaska, 31 May - 9 June 2011 as a continuum of surveys conducted since 1993. Eight of the days in 2011 resulted in complete surveys of the beluga habitat in the upper inlet (north of East Foreland and West Foreland); and the remaining two days included surveys of the lower inlet. Beluga groups were dispersed by the last day of the survey (9 June) effectively excluding this day from the abundance analysis. During the remaining seven surveys of the upper inlet, 26 beluga groups were observed, and up to 12 counting passes were made per group. This season there was a fairly typical presentation of beluga groups, with two or more large groups in the Susitna area and a few smaller groups in Chickaloon Bay on each survey day. No beluga groups were found in Knik Arm, Turnagain Arm, or elsewhere in Cook Inlet. After excluding the 4 June survey because of a low estimate that was likely due to poor sighting conditions and dispersed groups, six complete surveys were considered to be of sufficient quality to use for estimation of abundance. The estimated abundance for June 2011 is 284 (CV 16%, 95% CI 207 to 389, Nmin = 248) with a ten-year trend (2001-2011) of -1.1% per year (SE = 1.1%). The trend since the management of the beluga hunt began in 1999 (i.e. 1999–2011) is -1.7% per year (SE = 0.9%).

Introduction

NMFS began comprehensive, systematic aerial surveys of the beluga, *Delphinapterus leucas*, population in Cook Inlet in 1993 (Rugh et al. 2000). Unlike previous efforts, these surveys included the upper, middle, and lower sections of the inlet. These surveys documented a decline in abundance of nearly 50% between 1994 (when systematic abundance effort began) and 1998, from an estimate of 653 whales to 347 whales (Hobbs et al. 2000a). In 1999, the Native subsistence take of belugas was regulated for the first time, and although

beluga numbers no longer declined rapidly, they have not increased in the subsequent decade. Considering how few whales were taken between 1999 and 2008 (a total of 5 whales), NMFS anticipated that the population would begin to recover. Instead, the population has continued to decline during this period (Hobbs and Shelden 2008). Accordingly, NMFS determined that Cook Inlet belugas are *endangered* as defined by the U.S. Endangered Species Act (ESA). The continued decline and endangered listing has meant it is paramount to continue these standardized aerial surveys and conduct abundance analyses of the Cook Inlet beluga stock to document any significant trends over time.

Methods

Analysis followed the methods of Hobbs et al. (2000a,b) with three notable exceptions:

1) Since 2004, the video analysis has been conducted by analysts using a Macintosh Computer based program which catalogues the individual whale images, tracks the images across the screen and provides tools for measuring image size. This computer program replaces the earlier system of using plastic transparencies to hand count whales found in the survey video. The video analysis program allows the analyst to review the video frame by frame or in slow motion play and make changes to the corresponding saved data an unlimited number of times. Each video sequence was analyzed by a primary analyst who catalogs individual whales, surfacing and diving times and measures whale images for size and color. A second analyst used the same video and corresponding data file to review the primary analyst's whale count and provide second measurements of each whale image size and color. While refinements to the program were made over this past winter, those changes were made to accommodate video resolution and streamline procedures within the program, and did not change the basic program functions; consequently it is unlikely that the program changes would have resulted in a bias in this year's analysis.

2) Only data collected during this year's survey (with the exception of surfacing interval data) were used to generate the corrections used to estimate group sizes. The observer isolation system was not available to allow the collection of independent observer data to estimate the missed group correction, consequently the missed group correction from the June 2010 survey, which had the same observers, was used.

3) The group count results of each survey day were summed and only complete survey days were used to generate an abundance estimate. For estimates of abundance derived before 2001, the inlet was divided into three sectors; an average abundance was estimated for each sector and survey (see Table 1 in Hobbs et al. (2000b)), and these estimates were summed for the overall abundance estimate (Hobbs et al., 2000b). From 2001 to 2003, an average abundance was estimated for each sector and then summed for the overall abundance estimate. Similar to estimates in Hobbs et al. (2000b), sectors on some survey days were excluded if estimates were likely to be unreliable (e.g. because of poor surveying conditions, or incomplete coverage, or if estimates were below 60% of the highest estimate for the sector during the survey period). Beginning in 2004, estimates from each survey day were summed, and only days with complete surveys of the upper inlet were used to generate an abundance estimate. This addresses the concern that whales might move from one sector to another between days during the two-week period of the surveys. Similar to the sector analysis, for

survey days with unusually low estimates (less than about 60% of the highest daily estimate) the flight paths were reviewed to determine if a group seen on other survey days could have been missed either because the area was unavailable due to weather or air traffic or because the group could have moved to an adjacent area that was not surveyed. If this was the case, these survey days were not included in the abundance estimate, thereby reducing the possibility of a downward bias in the estimate.

To calculate abundance estimates for the years 2004 to 2011, the equations in Hobbs et al. (2000b) under the heading Abundance Estimate were modified slightly to remove the sector analysis portion, and are now as follows:

$$\hat{N}_{s,y} = \sum_{i=1}^{G_{s,y}} \hat{n}_{i,s}\ , \quad Var(\hat{N}_{s,y}) = \sum_{i=1}^{G_{s,y}} Var(\hat{n}_{i,s})$$

$$\hat{N}_y = \frac{\hat{K}_y}{J_y} \sum_{s=1}^{J_y} \hat{N}_{s,y}\ ,$$

$$Var(\hat{N}_y) = \frac{1}{J_y - 1} \sum_{s=1}^{J_y} (\hat{N}_y - \hat{K}_y \hat{N}_{s,y})^2 + \frac{\hat{K}_y^2}{J_y^2} \sum_{s=1}^{J_y} Var(\hat{N}_{s,y}) + CV^2(\hat{K}_y)\hat{N}_y^2$$

Where

$\hat{N}_{J,y}$ = the estimated number of beluga in groups found in survey J of year y,

$G_{J,y}$ = the number of groups found in survey J of year y,

$\hat{n}_{i,j}$ = the estimated number of beluga in the ith group found in survey J,

$\hat{N}_y$ = the estimated number of belugas in year y,

$\hat{K}_y$ = the multiplicative correction for belugas in groups that were missed,

J_y = the number of usable surveys in year y.

The trend for the last 10 years (2001 to 2011) was estimated using weighted linear regression of the natural logarithms of the abundance estimates, with the weights being the squared inverse of the coefficients of variation (CV) of the estimates.

Results and Discussion

Eight of the survey days in 2011 resulted in complete surveys of the beluga habitat in the upper inlet (north of East Foreland and West Foreland); the remaining two days included surveys of the lower inlet. Beluga groups were dispersed by the last day of the survey (9 June), effectively excluding this day from the abundance analysis. During the remaining seven surveys of the upper inlet, 26 beluga groups were observed, and up to 12 counting passes were made per group. This season there was a fairly typical presentation of beluga groups, with two or more large groups in the Susitna area and a few smaller groups in

Chickaloon Bay on each survey day. No beluga groups were found in Knik Arm, Turnagain Arm, or elsewhere in Cook Inlet.

A total of 1,550 images of individual whales were found in 47 video sequences. Of the 26 groups, 14 had video of sufficient quality to estimate group sizes (Table 1) the remaining were estimated using corrections developed from the groups with both video and observer counts following the methods of Hobbs et al. (2000b). Glare, whitecaps, a missing part of a group, and poor image quality were the most frequent conditions that rendered video quality too poor to count. This year in particular, a last-minute change of the survey platform to an airplane that did not have opening windows resulted in having to shoot the video through a Plexiglas window.

Table 1. Estimated group sizes of groups found during the abundance surveys of Cook Inlet in June 2011. Note groups were found on June 9 but were not suitable for abundance estimation. "Source" indicates whether the estimate was derived from video counts or observer counts.

Date	Group	Number of counts averaged	Correction for beluga missed due to image size	Correction for beluga missed below the surface	Group Size	CV	Source
31-May-11	1	12			57	16%	observer
31-May-11	2	15			200	7%	observer
1-Jun-11	1	3	1.97	1.62	13	22%	video
1-Jun-11	2	3	1.98	1.17	4	36%	video
1-Jun-11	3	5	1.89	1.33	271	10%	video
2-Jun-11	1	4	1.96	1.23	22	17%	video
2-Jun-11	2	1	1.85	1.66	49	27%	video
2-Jun-11	3	5	1.90	1.43	155	11%	video
3-Jun-11	1a	8			4	14%	observer
3-Jun-11	1b	3	2.11	1.11	77	15%	video
3-Jun-11	2	1	1.92	1.22	187	24%	video
4-Jun-11	1	1			3	70%	observer
4-Jun-11	2	2	1.87	1.44	18	25%	video
4-Jun-11	3	11			4	14%	observer
4-Jun-11	4	18			68	6%	observer
4-Jun-11	5a	2			5	19%	observer
4-Jun-11	5b	1	1.80	1.29	76	26%	video
5-Jun-11	1	2	1.97	1.52	21	24%	video
5-Jun-11	2	2	1.85	1.37	23	23%	video
5-Jun-11	3	3	1.92	1.61	295	13%	video
8-Jun-11	1	2	1.39	1.84	6	36%	video
8-Jun-11	2	12			11	20%	observer
8-Jun-11	3	2			4	3%	observer
8-Jun-11	4	12			18	11%	observer
8-Jun-11	5	8			17	9%	observer
8-Jun-11	6	15			223	10%	observer

In 2011, video camera upgrades were made that improved video resolution from 720p (1280 x 720 pixels) to 1080p (1920 x 1080 pixels) and increased the field of view for the survey cameras. Although this increase in resolution should have improved image clarity, filming through the Plexiglas resulted in a net reduction in resolution. In addition, the distance from beluga groups was increased to ensure the entire group was captured in the video field of view because the cameras now had to remain level in order to reduce glare from the closed window.

These changes had the effect of reducing HD video image clarity, as well as contrast with the gray water of the inlet. As a result, the correction for belugas missed due to image size was larger than in past years. Previously, a fairly sharp cut off separated the image sizes that were found in the counting video from those that were missed (determined after review of the zoomed video). For example, in 2010, images < 4 pixels were always missed and >5 pixels nearly always seen. In 2011, some larger images (>7 pixels) were missed in the counting video. Without a clear cutoff for missed whales, the result was a larger correction factor. In the past, the sharp cutoff resulted in correction factors greater than 1.5 having large standard errors (SE) (e.g. in 2010 the SE would have been as large as 1.07 for some groups with a correction of 1.5) and these groups/video passes were not used in the abundance estimates. In 2011, corrections as large as 2.19 had a SE of < 0.27 so these passes were used in the analysis. While this was an unusual variation of the correction for beluga missed due to image size, the method was robust enough to accommodate the change.

The density of animals in the groups resulted in a density correction for two of the observers, which was significant. The correction was used with the linear correction as described in Hobbs et al. (2000b).

The independent observer aural isolation system was not available to allow collection of independent survey effort. This system isolates the observers so that when a sighting is reported the other observers are not aware until after alerted by the computer operator. Consequently no record of groups missed by one observer was available to calculate the correction for missed groups, instead the correction calculated for the same observers in 2010 (1.031; CV= 0.017) was used.

Groups found during each survey day, with the exception of 9 June, were summed to complete the total for that day (Table 2). The survey on 9 June included groups that could not be counted from video or by observers due to a dispersed group structure. After reviewing the abundance estimates, the survey on 4 June also was not used in the final estimate because of dispersed group structure (similar to 9 June) and poor sighting conditions during part of the survey day that may account for the low number of whales. The overall estimate of abundance for 2011 is 284 belugas (CV = 0.16, 95% CI = [207, 389], Nmin = 248). The ten-year trend, 2001 to 2011, is a declining trend of -1.1% per year (SE = 1.1%) (Fig. 1). The trend since the management of the hunt began in 1999 (i.e. 1999 to 2011) is a declining trend of -1.7% per year (SE = 0.9%).

This is the second lowest abundance estimate in the time series since 1994 (Fig. 1) and the lowest since the estimate of 278 in 2005. However, the 2011 estimate falls well within the statistical variation around the recent trend line and probably represents variability of the estimation process rather than a substantial decline in the population over the past year. The last-minute change in aircraft resulted in challenges for the aerial crew and the analysis. The

aerial crew was able to make adjustments to the survey protocol to accommodate the change and complete the survey successfully. The impact on the analysis occurred in the quality of the video data. The video correction methods appear to have been sufficiently robust to accommodate the change in video data quality, so the bias that may have resulted is likely to be small and well within the interannual variation of the estimates.

Table 2. Sums by day for complete surveys of the upper inlet. Data from 4-June were not used in the abundance estimate because there were poor conditions for counting some groups on that day.

Survey day	Sum of Group Sizes	CV	Used in Abundance Estimate
31-May-11	257	6.6%	yes
1-Jun-11	288	9.8%	yes
2-Jun-11	226	9.6%	yes
3-Jun-11	268	17.0%	yes
4-Jun-11	174	11.8%	no
5-Jun-11	339	11.8%	yes
8-Jun-11	279	8.1%	yes

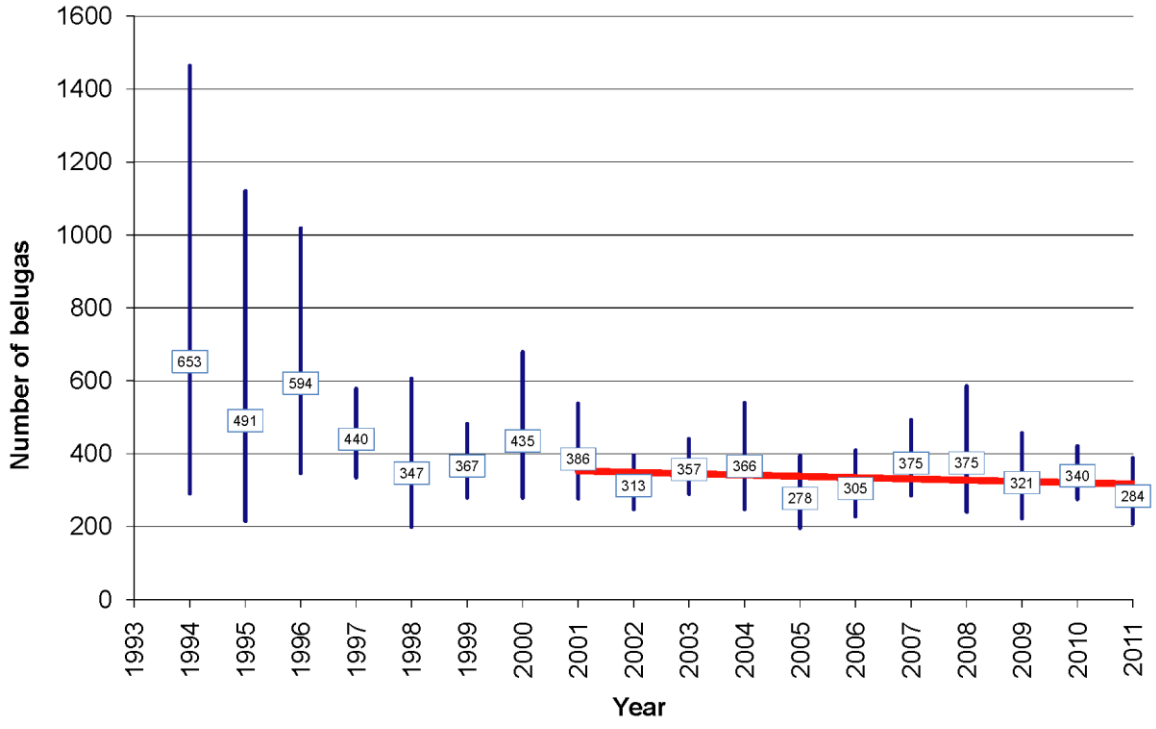

Figure 1. Abundance estimates and associated 95% confidence intervals for Cook Inlet belugas, 1994-2011. The red trend line indicates a continuing decline in abundance over the ten year period (2001-2011) of -1.1% (SE = 1.1%).

Acknowledgments—We thank our two analysts, Linda VateBrattström and Kalyn MacIntyre for their diligence and enthusiasm for an often difficult and tedious task. Janice Waite is thanked for helpful guidance, review and commentary. Phil Clapham and John Bengtson provided helpful reviews.

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