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INTERNATIONAL WHALING COMMISSION

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ABSTRACT

Aerial photographic surveys for bowhead whales were conducted near Point Barrow, Alaska, from 19 April to 6 June in 2011. A total of 4,594 photographs containing 6,801 bowhead whale images were obtained (not accounting for resightings). After matching, the sample size was reduced to 2,504 images of 2,123 uniquely identified bowhead whales. There were 32 between-day recaptures and 72 calves were photographed. After scoring, there were 478 marked whales (22.5%) in the photographically captured population, which is similar to years past. The interyear matching effort of the 2011 photographs is ongoing with the current focus on comparing 2011 against photos taken in the 2003 aerial abundance survey.

KEYWORDS: BOWHEAD WHALE; *BALAENA MYSTICETUS*; ARCTIC; AERIAL SURVEY; PHOTO-ID; POPULATION ESTIMATION; RECAPTURE; PHOTOGRAMMETRY

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INTRODUCTION

The photographic catalog of bowhead whales (*Balaena mysticetus*) from the Bering-Chukchi-Beaufort (B-C-B) Seas population currently contains over 21,000 images. The utility of using these aerial photographs to identify individual whales has been well documented, and applications include mark-recapture abundance estimation (Rugh 1990; da Silva *et al.* 2000; Schweder 2003; George *et al.* 2004; Koski *et al.* 2010), estimation of survival rates (Zeh *et al.* 2002), calving intervals (Miller *et al.* 1992; Rugh *et al.* 1992a), and measurement of individual growth rates (Koski *et al.* 1992, 1993).

Prior to 2011, the last concerted effort to conduct aerial surveys of the B-C-B bowhead whale population to obtain photographs for a capture/recapture abundance estimate occurred in 2003 and 2004. A primary objective of the 2003-2004 aerial surveys was to obtain a population estimate to be compared to the 2001 ice-based estimate of bowhead whales (George *et al.* 2002). Estimating abundance through a mark-recapture analysis using paired samplings (as per da Silva *et al.* 2000), provided an independent corroboration of the ice-based estimate (Koski *et al.* 2004a), with results consistent between the two surveys (Koski *et al.* 2010). In 2011, we were fortunate to successfully complete both an aerial and an ice-based survey of the bowhead whale population. Deriving and comparing abundance estimates from these two platforms in the same year provides a great opportunity to further test the aerial method of estimating abundance. Aerial photographic capture-recapture surveys will likely become increasingly important in a warming Arctic as they are less sensitive to ice conditions than the ice-based surveys (Koski *et al.* 2010). Beyond the importance of an abundance estimate, additional photographic data can be used to refine existing estimates of life-history parameters such as calving intervals, growth rates and survival rates (Koski *et al.* 2004a). This report provides a progress update on the photographic evaluations.

METHODS

The 2011 spring aerial abundance survey was conducted jointly by the North Slope Borough Department of Wildlife Management (NSB-DWM) and the National Marine Mammal Laboratory (NMML). Methodology was similar to earlier studies (Koski *et al.* 1992; Angliss *et al.* 1995). Surveys were conducted in an Aero Commander 690 with bubble windows in the two forward observer positions. The aircraft flew at an average air speed of ~217km/h (117kts) and altitude of 200m (656ft), and flew directly over bowhead whales during photographic passes. Photographs were taken with a handheld Canon Mark III-1DS digital camera affixed with a Zeiss 85mm fixed f/1.4 Planar T* lens pointed directly downward through the aircraft's ventral camera port that was covered with optical quality glass. Shutter speed was typically 1/2500th second or faster. Aircraft altitude was recorded every 2 seconds with a portable Garmin 76CSx GPS unit and a laser altimeter, both of which were saved on a laptop computer and subsequently linked, by time, to the photographic data. Additionally, Robogeo software used this information to embed latitude, longitude and altitude into the Exif metadata of each photograph post-survey. Calibration targets of known dimensions were photographed twice during the season, at the beginning and end of the survey. These calibration photographs were taken from a range of altitudes flown during survey effort. Additionally, each flight began with a photographic pass over a table of known dimensions at a set altitude of 152m (500ft) to act as a daily check of altimeter performance. Images were shared with LGL[1] who took straight-line measurements of the pixels from the tip of the rostrum to the fluke notch (Mocklin *et al.* 2010) and converted these to whale lengths.

Following the 2011 field season, we began to process the digital photographs. The basic outline of the procedure is to take the raw images and process them (crop/label) to make them uniform in appearance and thus more quickly comparable. We then evaluate how useful the images will be for matching (by scoring body zones for quality/identifiability) before starting the within day matching. After the within day matching, we eliminate duplicate photos of the same whale when the photos had a time stamp within 5 seconds, keeping only one for comparison during the between day matching. It is necessary to do this time consuming within year matching prior to interyear comparisons to know the actual number of unique whales captured in a season.

[1] LGL Limited, environmental research associates, 22 Fisher St., P.O. Box 280, King City, Ontario, L7B 1A6, Canada.

The following is a more detailed explanation of the photoanalysis process. The first step in the process is selecting the best image of each whale per photographic pass, and cropping and labeling those images to be evaluated for quality and identifiability (Rugh *et al.* 1992b). At this point we also assigned each whale a "file" (1-20 file choices) based on the amount of white pigment on the chins and peduncles (Rugh *et al.* 1992b). Once we had a complete list of images, a scoring database was created in Microsoft Access. In addition to scores for image quality and scar identifiability, we recorded feeding behavior and presence of anthropogenic scars. For both intrayear and interyear matching, our sample sizes were restricted by only searching through whales in similar files (Rugh *et al.* 1992b). We used queries in Access to do this subsampling for us. The data associated with each photograph will later be integrated into the 'Bowhead Whale Photography Database' described in Koski *et al.* (2004b). Calves were assigned a separate file code (22) and were excluded from the matching process and only matched to other calves by matching the associated cows. Once we had our working collection of useable images we began within day matching. The within day matching uses all available photographs, regardless of quality or identifiability, and matches can be made on very subtle markings, even on transient properties such as mud patterns which can persist during a day (Mocklin *et al.* 2012a). This method of matching was similar to the methods used in 2003/2004. At the end of the within day matching process we looked at all within day matches and when we found matching whales where the images had been photographed within 5 seconds of each other (therefore, duplicates), we chose one image to keep.

In 2003-2004 we conducted a 5 day look ahead matching process (DLAM), but the longest time between any recaptures was 4 days, so to expedite our matching in 2011, we decided to conduct 4DLAM. We have made one major improvement in our 4DLAM Access database in 2011. We decided to assign a "best image" when matches were made in the within day matching phase. Even though this added time on the front end of the process, it enabled us to skip associated matching images when comparing photos later on. This has saved us an enormous amount of time in the matching process. In the early days of digital matching we simply had hyperlinks for each image so it was necessary to click and view every photo. Our new matching database makes the matching process more analogous to the way we matched off prints in the past. For the 4DLAM, we looked at all images except those of useless quality (all quality "3" and identifiability "X" scores were queried out).

Once the interyear matching commenced we restricted our sample to only those images that were at least moderately marked in one zone on the body by querying out whales that had U+, U-, or X in every body zone (Rugh *et al.* 1992b). We disregarded photo quality and made selections on identifiability alone. Our interyear matching priority is to first compare 2011 to photos taken from the last major aerial abundance surveys in 2003 and 2004. As time allows, we will then compare the images from 2011 to those collected in 2005. There were two short surveys in 2005; one survey occurred in spring 2005 in the Bering Sea with a focus on stock structure issues, and another survey took place during a few days in the fall prior to whaling (Koski *et al.* 2007).

RESULTS

Flights to photograph bowhead whales were conducted on 36 of 49 days from 19 April to 6 June, 2011 (Fig. 1). The top map in Figure 1 shows all of the trackline effort and bowhead sightings in 2011. As expected, most of the whales seen were migrating through the area heading east. The bottom map in Figure 1 shows only those between-day recaptures where the whales were not headed in an obviously easterly direction. This coverage is comparable to the aerial abundance surveys in 2003 and 2004 (Table 1). The photo processing has been completed; we had 2,504 total images in the 2011 sample set (after eliminating duplicates). The intrayear matching is complete; we had 32 between-day recaptures in 2011 (1.5% of the whales were captured on more than one survey day). This is consistent with the other years; 2.5% in 2003; 0.9% in 2004 and 0.8% in 2005 (Table 1). We photographically identified 2,123 unique bowhead whales after matching (the highest of any year), compared with 1,238 in 2003 and 1,321 in 2004. There were 72 calves seen in 2011 (3.4% of all whales); 77 in 2003 (6.2%) and 111 in 2004 (8.4%). There were 478 unique marked whales in 2011 which is 22.5% of all whales (Table 1). The interyear matching is underway; we have completed matching 2011 with 2004 and are currently comparing 2011 to 2003.

All photos in 2011 were examined for anthropogenic scarring but it is very difficult to determine the source of scars from aerial photographs and we found inconsistencies among evaluator's judgments. It was decided that one person should go through all photos to eliminate evaluator bias (status: in progress). We found this to be true for the general scoring of images for quality and identifiability as well. Initially, three different people scored images and afterwards we randomly pulled a test of 50 total images from the beginning, middle and end of the project and re-scored them. There was too much variation in scores between the three evaluators so it was decided that one person should re-score all of the photos for quality and identifiability (status: completed). Despite the necessity to redo part of the scoring we are still ahead of schedule.

All photographs were measured for calibration purposes by LGL. Unfortunately, there are large errors in the length measurements that still need to be addressed. After much review, it seems that on three days in particular, there was a misalignment between the altitude data and the time photographs were taken. We think we have fixed the problem and LGL will be re-evaluating the data soon. We would like to examine length-frequency distributions with these data.

DISCUSSION

In 2003, bowhead whales passed Point Barrow steadily throughout the spring period with only one major peak of movement, which occurred on 2 May (Koski *et al.* 2004a). Overall good weather conditions in 2003 allowed for no periods longer than one day without surveying (Koski *et al.* 2004a). In 2004, similar to 2011, bowhead whales appeared to pass Point Barrow in pulses, which is typical of the spring migration (Zeh *et al.* 1993; George *et al.* 1995). The first peak in 2004 occurred on 27-28 April and the second on 11-12 May (Koski *et al.* 2004a). This is similar to the 2011 survey, which had peaks on 30 April, 4-5 May, and 12 May, with the migration rate slowing down considerably after 14 May and remaining slow with a small peak on 28 May. Unlike 2003, weather was more of a limiting factor in 2004 and 2011, resulting in several groundings of two to three day periods (Koski *et al.* 2004a, Mocklin *et al.* 2012b). As a result, the photographic sample obtained in 2003 remains the most complete data set in terms of consistent migration coverage. Despite this reduced effort when compared to 2003, the 2011 survey was the most successful in terms of number of photographs obtained and individual whales identified (Table 1). All three aerial abundance surveys (2003, 2004, and 2011) are superior to any of the past surveys, both in terms of number of photographs obtained and quality of the images.

Once the 2011 to 2003/2004 comparisons are done, as time allows we will match photos from 2005. The Bowhead Whale Feeding Ecology Study (BOWFEST) photos are another source of images that should be compared to the 2011 BAASS survey images (one match has already been made opportunistically when a cow/calf pair was photographed during BOWFEST 2011 and recognized from photographs taken during the spring 2011 BAASS survey). The BOWFEST study took place from 2007-2011 in late summer in the Beaufort Sea and 762 unique bowhead whales were photographed (Shelden and Mocklin, 2013). The photographs from 2011 should also be compared to the historic collection of photographs; especially the 1985/1986 aerial photos, however, additional funding is needed to continue this work. The more recaptures that are made, the more we can refine existing estimates of life-history parameters such as calving intervals, growth rates and survival rates (Koski *et al.* 2004a). With our new system of matching it still seems like using people to do this work is the most reliable and efficient method. The automated computer matching program is not yet capable of replacing matching by humans.

In summary, the 2011 bowhead whale aerial photo-ID survey was highly successful both in terms of photographing large numbers of bowhead whales and obtaining fairly consistent coverage of the migration. Nevertheless, whales migrating both pre- and post-survey effort were not captured during this period. The first whales that were seen by the ice-based crew were on 9 April, a full ten days prior to the start of the aerial survey; the ice-based team observed a peak in the migration on 16 April, also prior to the aerial survey (George *et al.* 2012). Whale hunters reported some whales even earlier in March. Therefore, it may be prudent to start future aerial surveys earlier than 19 April. As Koski *et al.* (2004a) points out, it is unknown whether the migration period has become more protracted as a result of an increasing population size and changes in ice conditions (George *et al.* 2004), or whether similar proportions of whales passed before the start and after the end of earlier studies. George *et al.* (2012) provide fairly convincing evidence of a trend towards migrating earlier over the past 35 years. The photographs taken in 2011 are a significant contribution to the bowhead whale photographic catalogue. The photos will also be useful for estimating health assessment parameters associated with scarring, entanglement rates in fishing/crabbing gear, and ship or propeller wounds (Reeves *et al.* 2012).

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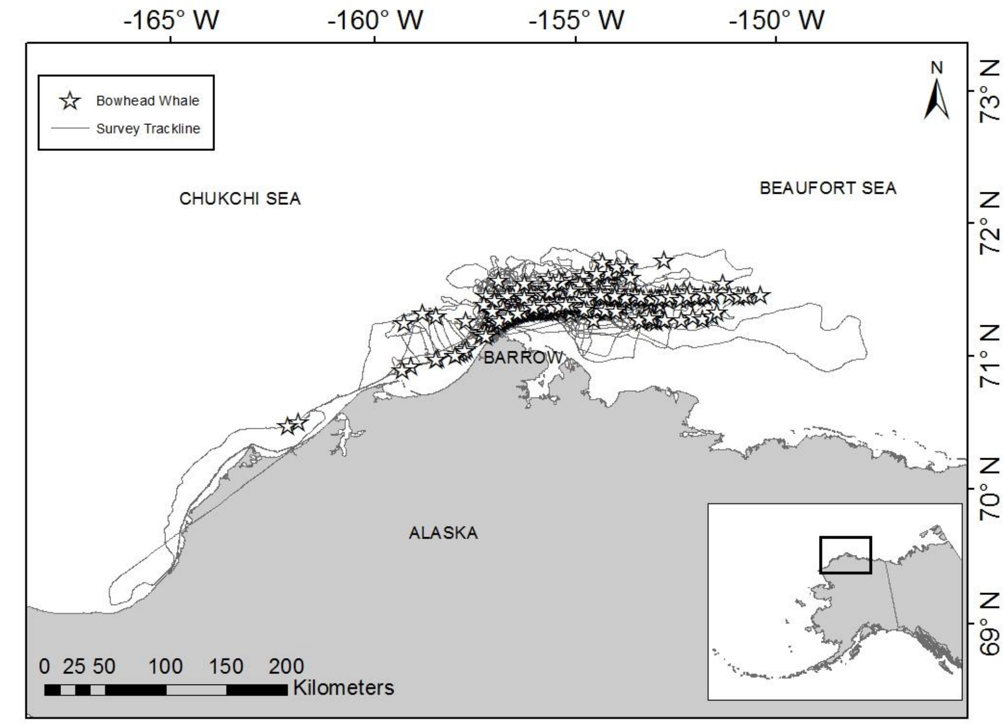

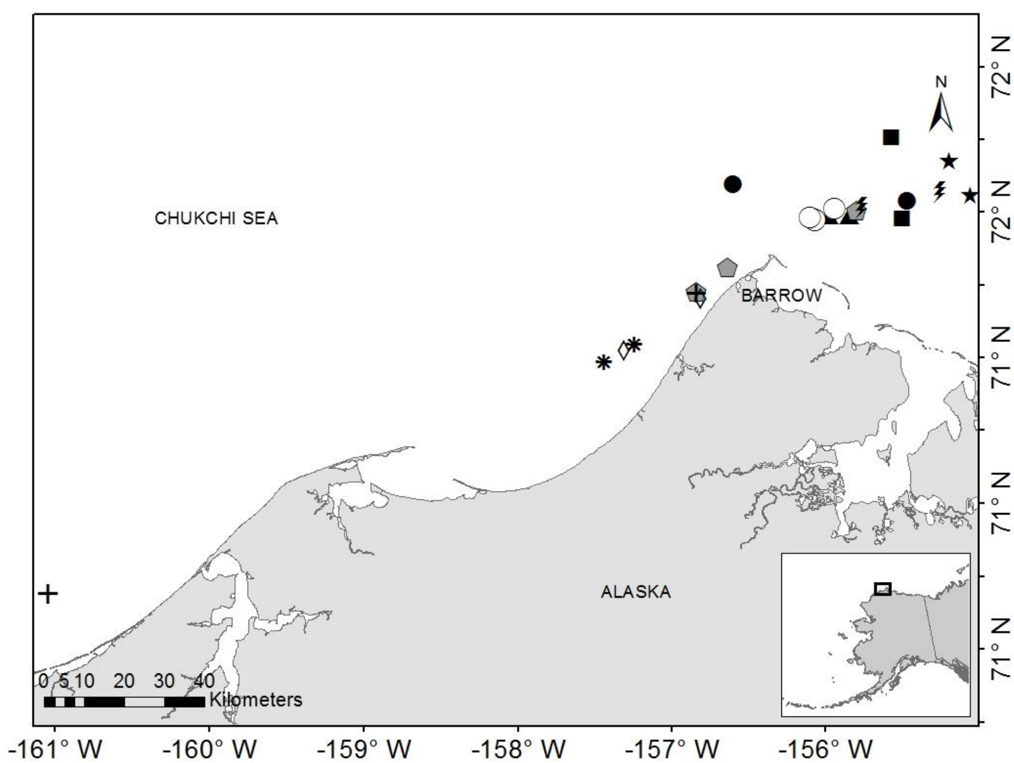

Figure 1. The top map shows all aerial survey tracks and bowhead whale sightings (stars) during the 2011 spring survey. The bottom map shows only the between day photographic recaptures of whales that were not heading in an obviously eastward direction. Symbols indicate locations of matched whales where the western-most location is the later sighting (traveled opposite of migration).

Table 1. Summary of photographic sample sizes and within-year matches from 2003, 2004, 2005 (spring and fall surveys combined) and 2011. The * denotes that the number refers to the actual number of individuals (including calves) after matching, and the percents shown are all out of the whale total (not image total).

	Beaufort Sea **12 Apr - 6 Jun** **2003**	**Beaufort Sea** **18 Apr - 7 Jun** **2004**	**Bering/Beaufort Sea** **9 Apr-2 May** **6-9 Sept** **2005**	**Beaufort Sea** **19 Apr - 6 Jun** **2011**
Days Flown	51 of 55	41 of 50	n/a	36 of 49
Total Images	1606	1975	1080	2504
Total Unique Whales*	1238	1321	994	2123
Between Day Recaptures	31	12	8	32
Percent Recaptures	2.5 %	0.9 %	0.8 %	1.5 %
Unique Calves*	77	111	0	72
Percent Calves	6.2 %	8.4 %	0.0 %	3.4 %
Unique Marked Whales*	233	325	119	478
Percent Marked	18.8 %	24.6 %	12.0 %	22.5 %