Review of bowhead whale aerial photographic studies in 2003-06

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ABSTRACT

Aerial photographic surveys were conducted near Point Barrow, Alaska, from 12 April to 6 June in 2003, from 18 April to 7 June in 2004, from 6 to 9 September 2005, and 1 to 6 September 2006, and in the Bering Sea, Alaska, from 9 April to 2 May 2005. The 2003 survey was the most complete photographic coverage of the spring migration past Barrow of any survey to date, and the 2004 survey was also thorough except that poor weather resulted in poor coverage of the mother/calf migration late in the season. Approximately 1,157, 1,443 105, 81, and 454 photographs containing 1,606, 1,975, 114, 173 and 967 images were obtained in the respective seasons. The number of different marked whales with acceptable quality photographs to recognise between-year matches was 179 in 2003, 275 in 2004 and 71 in spring 2005. Within-year and between-year matching has been completed for the 2003–2005 spring photographs, and the databases are nearing completion. Eleven whales were matched between the 2003 and 2004 spring migrations, three whales were matched between 2003 and spring 2005, one was matched between spring 2004 and September 2005, and no matches were found between spring 2003 and September 2005. The photographs from these studies will permit calculation of a population estimate required for the AWMP management procedure and comparison with the estimate from ice-based counts in 2001 (George *et al.*, 2004) and better precision in the calculation of bowhead whale life-history parameters. Stock structure analysis will be applied to resighting rates of bowheads photographed in April 2005 in the Bering Sea (early in the spring migration), through the spring migration near Barrow, during September near Barrow (which is prior to the main fall migration out of the Beaufort Sea), and in late summer in the Beaufort Sea (the primary feeding area).

KEYWORDS: BOWHEAD WHALE; *BALAENA MYSTICETUS*; ARCTIC; NORTH PACIFIC; ALASKA; PHOTO-ID; POPULATION ESTIMATION; PHOTOGRAMMETRY; RECAPTURE; MIGRATION TIMING

INTRODUCTION

The photographic database of the Bering-Chukchi-Beaufort Seas (BCBS) population of bowhead whales (*Balaena mysticetus*) contains 12,192 images for the years before 2001 (Koski *et al*., 2006). About 86% (10,437) of these images were obtained during slightly more than a decade of relatively intensive photographic surveys from 1982 to 1992. About 54% of the 10,336 images that have been classified for image quality to date are of adequate quality to determine if the whales are marked. All of the images in the database, but particularly the better quality images, have provided useful information on life-history parameters including calving intervals (Miller *et al*., 1992; Rugh *et al*., 1992a), growth rates (Koski *et al*., 1992, 1993), population structure (Davis *et al*., 1983; Koski *et al*., 1993, 2006; Angliss *et al*., 1995), population size (Rugh, 1990; da Silva *et al*., 2000; Schweder, 2003) and survival rates (Whitcher *et al*., 1996; Zeh *et al*., 2002). On-going studies continue to use these data to further describe various parameters of bowhead whale life history and population dynamics.

The size of the bowhead photographic database has increased to the point where collection of new photographs results in a relatively high probability of re-sighting a previously photographed marked whale. This

is because the proportion of the population that has been photographed has increased, and consequently, the likelihood of photographing a whale that has been photographed during previous studies has increased dramatically. Thus new photographs at this time provide much more information on individual whales than the same number of photographs did during the early years of bowhead whale photography studies. This point is emphasized by the substantial information provided by the relatively small photographic effort during the 1998-2000 bowhead feeding study (15 new inter-year re-identifications spanning 4 to 15 years among photographs of 70 different marked whales).

Aerial photographic studies were conducted during the spring migrations of 2003–2005 and prior to the fall migrations of 2005 and 2006. The major objective of the 2003–2004 aerial photography project was to obtain a population estimate as specified in the AWMP (Aboriginal Whaling Management Procedure) (10-year intervals) and one which can be compared to the 2001 ice-based census of bowheads (IWC, 2003; George *et al*., 2004). The major objective of the 2005 spring project was to determine if some whales that migrate through the northern Bering Sea in spring do not pass Barrow (George et al. 2005). The aerial survey projects in September 2005 and 2006 were to provide information on feeding aggregations of bowheads near Barrow before the main migration from the eastern Beaufort Sea had reached the Barrow area.

Mark-recapture analysis of the 2003–2004 photographs (as done by da Silva *et al*., 2000) will provide a completely independent abundance estimate to compare to the best available estimate from visual counts and acoustic recordings made by ice-based observers near Point Barrow (George *et al*., 2004; Zeh and Punt, 2004). If the CV is "acceptable", the estimate may be used in the AWMP strike-limit algorithm (SLA) for giving management advice (IWC, 2003). The aerial photography approach to estimating abundance is less sensitive to vagaries in ice cover than is the ice-based survey, yet both methods have provided similar abundance estimates (both roughly 6,700) with similar accuracy: SE = 1,450 - 1,915 for ice-based results and SE = 1,696 - 2,017 for photographic results (da Silva *et al*., 2000) in 1985 and 1986 when there were multiple samples from the both Barrow and the Beaufort Sea. Secondary objectives of the project were to obtain a length-frequency distribution of the population to compare with earlier length-frequency distributions estimated by Angliss *et al*. (1995) and Koski *et al*. (2006) and to obtain additional photographic data that can be used to refine existing estimates of life-history parameters such as calving intervals, growth rates and survival rates.

The recapture rates and sizes of recaptured whales in the Bering Sea in 2005 will be compared to the corresponding recapture rates and sizes in the photographs from Barrow in 2003 and 2004. Differences in the recapture rates or the sizes of whales that are recaptured will be used to assess whether different bowheads are present in the two different areas. In addition, the timing of passage past Barrow will be compared to timing past St Lawrence Island for whales that are photographed in the two areas. The timing information may provide hints about different stocks or sub-populations, if they exist.

Other objectives of the current studies were to expand the photographic collections at NMML and LGL to obtain images that were not present at both locations and to update the database with data that were missing in earlier versions. We are currently developing a computer-assisted matching program to increase the efficiency of finding matches both within season and between studies.

METHODS

The 2003–2005 aerial photographic studies were conducted jointly by LGL Limited (LGL), the North Slope Borough Department of Wildlife Management (NSB-DWM) and the National Marine Mammal Laboratory (NMML) with support from the Minerals Management Service (MMS). The field and laboratory methods were similar to those of earlier studies (Koski *et al*., 1992; Angliss *et al*., 1995) and are described in Koski *et al.* (2005).

Following the 2003 and 2004 field seasons, the film was developed, labelled, duplicated and stored in acid-free archive sheets for future analyses. The data documenting each photograph were entered into an Excel spreadsheet for future integration into the "Bowhead Whale Photography Database" described in Koski *et al*. (2006). Images obtained in 2003 and 2004 were digitized at 4000 dots per inch; most of the digitized images were cropped and printed to nearly fill 12.7cm × 17.8cm (5in. × 7in.) colour prints (Table 1), which are suitable for comparing photographs to identify matches (Rugh *et al*., 1992b). All printed images were checked against the original film transparencies and the data files to ensure that all were scanned and printed.

Researchers at LGL and NMML have shared all subsequent tasks. NMML researchers have taken the lead on scoring images for photo quality and identifiability (as per Rugh *et al.*, 1998). NMML researchers did within-year matching of images from 2004 for verification of the same effort at LGL. Researchers at both NMML and LGL provided final determination of within-year matches. LGL researches have taken the lead on within-year matching for all 2003–2005 studies, assembling the database, and measuring whales. Both groups have done matching to find between-study matches independently and after both groups have completed their matching efforts, match results are compared and discussed and final match determinations are made.

RESULTS

Sample sizes

Aerial photographic surveys were conducted near Point Barrow, Alaska, from 12 April to 6 June in 2003, from 18 April to 7 June in 2004, from 6 to 9 September 2005, and 1 to 6 September 2006, and in the Bering Sea, Alaska, from 9 April to 2 May 2005. The 2003 survey was the most complete coverage of the spring migration past Barrow obtained to date, and the 2004 survey was also thorough except that poor weather resulted in poor coverage of the mother/calf migration late in the season. Approximately 1157, 1443, 105, 81 and 454 photographs containing 1606, 1975, 114, 173 and 967 images were obtained in the respective seasons.

Analyses of Photographs

Table 1 shows the progress on each of the general tasks as of 1 March 2007. The images from all studies prior to 2006 have been scanned, cropped, printed, scored for identifiability and image quality and filed. Within-study comparisons have been completed for photographs collected in 2003–2005. The 2003 to 2004 and 2003 to spring 2005 between-study matches have been finalized. The between-study matching for spring surveys in 2004 to 2005 has been completed by LGL and will soon be conducted by NMML. An upcoming objective will be to process the September 2006 images for inclusion in the photographic database.

Computer-assisted Matching Program

Funds have been supplied by MMS to develop and test a computer-assisted matching program for bowhead whales similar to programs used for dolphins and gray whales. The personnel assigned to this program developed the earlier programs "Finscan", a widely distributed photo-identification system for identifying individual marine animals by notch patterns in dorsal fins (Markowitz *et al.*, 2003); "Flippermatch," a program for photo-identification of Steller sea lions (*Eumetopias jubatus*); and software for identifying sea otters (*Enhydra lutris*) by scarring patterns on the nose; and for identifying gray whales (*Eschrichtius robustus*) by scarring patterns on the flukes (Hillman *et al.*, 2003). The fluke scarring has characteristics closest to the marks seen on bowhead whales, and it is that program that will be modified and adapted to the present need. The bowhead matching specialists at NMML and LGL will conduct testing of the new system and help with the fine tuning of the program.

Funds to start work on the matching program became available in early February 2007. We have scanned the images that were used by Rugh et al. (1998) for evaluating the scoring of photo quality and whale identifiability, and that collection of photographs will be used for developing the program. The computer-assisted matching program will be evaluated by searching the 2004 photographs for matches with 2003 photographs, a task that has already been completed by the biologists at LGL and NMML using traditional manual matching methods.

Population Estimate

Within-season matches have been completed for 2003 (by LGL) and 2004 (independently by both LGL and NMML) and between-season matching has been done independently by both groups. We feel that additional verification of the 2003 versus 2004 matching should be done. That verification will be accomplished using the computer-assisted matching program described above. Photo quality was better in 2003 and 2004 (0.144 and 0.283, respectively, useable photos with marked whales/photo) than in studies conducted 1981–2000 (0.122/photo). A reliable population estimate should be possible using these photographs and mark-recapture methods as applied by da Silva *et al*. (2000). Funds have been secured to further refine this mark-recapture model.

Stock Structure Analyses

Both LGL and NMML have completed matching of the 2003 spring photographs with the 2005 spring and fall photographs, and the 2003 spring photographs with the 2004 spring photographs. LGL has completed matching 2004 spring photographs with 2005 spring and fall photographs, but finalization of those between-project matches cannot be confirmed until NMML has completed the same tasks. The between-study matches were confirmed, and the database was updated for the 2003 to 2004 and 2003 to 2005 spring and fall matches. This will permit preliminary examination of recapture rates at Barrow vs. the Bering Sea. Matching of 2003-2005 images with earlier years will not be started until funds become available

Preliminary results suggest that we will not be able to detect the existence of a second stock among our photographs from the Bering Sea. Only three matches were found between the 2003 spring and 2005 spring photographs (0.042 recaptures/marked whale), and a similar recapture rate (0.040 recaptures/marked whale) was found between 2003 and 2004 (11 matches). Although the whales in the 2005 spring photographs were well marked, high winds reduced the quality of the photos, and only 0.081 useable photos with marked whale/photo

were obtained. This is lower than the 0.122/photo in 1981–2000, and much lower than in 2003 and 2004. Therefore, sample sizes may be too small to rigorously compare resighting rates between sample sets.

No matches were found between spring 2003 and fall 2005 photographs and one match was found between spring 2004 and fall 2005.

Database

The data fields in the photography database (BOWPHOT) are being filled in for each of the recent studies as analyses are being conducted. Thus the data will be available for preliminary analyses shortly after the matching and validation matching are completed.

DISCUSSION

Delays in obtaining funding prevented matching to be completed in time to meet the IWC data submission requirements for the 2007 bowhead whale comprehensive stock assessment (4 November 2006). However, good progress has been made on analyses of the 2003–2005 photographs. All first priority tasks have been completed except finalization of the database which cannot be done until all matching is completed, and some second and third priority tasks (whale length measurements) have been completed. Within-season verification matching is complete for only one of the four studies (2004) and is not expected to be conducted for the other three studies in the near future except, perhaps, through the testing of a new computer matching program. Other analyses of these images are well underway at both NMML and LGL. Between-study matching has been completed for all combinations of 2003, 2004 and 2005, but verification matching for 2004 to 2005 spring remains to be done. Between-study matches have been verified and finalized for 2003 to 2005 spring and 2003 to 2004 spring images. This will allow a preliminary estimate of population size as well as a preliminary examination of recapture rates between photographs obtained at Barrow in the spring migrations in 2003 and 2004 and with those in the Bering Sea in spring 2005. Preliminary results suggest that we will not be able to detect the existence of a second stock among our photographs from the Bering Sea. Nonetheless, we note that the recapture rates of whales photographed near Barrow in spring 2003 were similar for spring photographs from the Bering Sea in 2005 and from near Barrow in 2004. Insufficient numbers of recaptures were obtained for a statistical comparison of recapture rates between the Bering Sea and Barrow in 2003-2005, and so matching of all images prior to 2001 with 2003 and 2004 Barrow photographs and with the 2005 spring Bering Sea photographs will likely be required. A current funding short-fall for 2007-2008 will not permit all earlier-planned analyses to be completed for the 2008 IWC meeting, and will require decisions on priorities for analyses to be conducted during 2007.

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Table 1

Status of analyses of bowhead whale photographs obtained during 2003–2005 studies near Barrow, Alaska, and the 2005 study in the Bering Sea. A total of 173 images were obtained during fall 2006 and no analyses have been started on them.

Priority	Task	2003	2004	2005 Bering	2005 Fall
	Number of images	1606	1975	967	114
	Number of images printed	1602	1973	962	114
	Number of different whales[1]	1233	1228	917	77
	Number of marked whale images[2]	356	731	90	25
	Number of marked different whales	179	275	71	13
1	Images scanned and cropped	100%	100%	100%	100%
1	Images printed	100%	100%	100%	100%
1	Images filed	100%	100%	100%	100%
1	Images scored for quality and identifiability	100%	100%	100%	100%
1	Images compared within-year	100%	100%	100%	100%
1	Whales scored for composite qual & ident	100%	100%	100%	100%
1	Images compared between 2003 and 2004	100%	100%	NA	NA
1	Images compared between 2003 and 2005spring	100%	NA	100%	NA
1	Images comp'd bet'n 2005fall and 2003-05 spring	100%	100%	50%	NA
2	Between-year matching checks 2003-2005	100%	50%	50%	50%
2	Images compared between 1981-2000	1%	1%	0%	0%
3	Images measured and calibrated	100%	95%	100%	100%
3	Best lengths for each whale	100%	0%	100%	100%
4	Within-year matching checks	0%	100%	0%	0%
1	Data entered into database	90%	80%	90%	90%

[1] This is an overestimate of different whales because some duplicate images were not recognized.

[2] Whales with at least one zone with adequate or better quality (2+) and markings (M-) (see Zeh *et al*., 2002).