Surprising recovery of bowhead whales

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The bowhead whale was severely depleted for several decades of commercial whaling when the species was offered worldwide protection in 1931. No signs of population recovery in West Greenland were observed over the course of the 100-year post-whaling period. In April 2006, a dedicated survey for bowhead whales was conducted on the former whaling grounds in efforts to determine the current population status. This effort included a double platform aerial survey design, satellite tracking of the movements of nine whales, and estimation of high resolution surface time from 14 whales instrumented with time-depth recorders. The whales utilized an area of ~25.000 km^2 and 32 out of 36 bowhead whale sightings during the survey were within this area. Only 12% of the area used by the tracked whales was not covered by the survey. The aerial survey sampled 125.634 km^2 of bowhead whale habitat with 10.500 km flown. After accounting for perception bias, there were estimated to be 295 animals in the survey area (cv=47%). Using data from the instrumented whales, animals were estimated to spend an average of 24% (cv=0.03) of the time at or above 2 m depth,, the maximum depth to which bowhead whales can be seen on the trackline. Applying this availability factor and correcting for sightings missed by observers resulted in a fully corrected abundance estimate of 1229 (95% CI: 495-2939) bowhead whales in West Greenland in April 2006. This surprisingly large population estimate, much larger than any previous estimates for the area, is puzzling given that the change in abundance cannot be explained by a recent or rapid growth in population size given current assumptions about population dynamics and stock identity. One possible explanation is that the population recently has attained a certain threshold size where mature females start to appear abundantly on the feeding ground in West Greenland. This in combination with the latest severe reduction in sea ice might explain why this survey documents the largest number of bowhead whales recorded in the past 100 yrs on the former whaling ground in West Greenland.

Keywords: Bowhead whale, *Balaena mysticetus*, West Greenland, satellite tracking, aerial survey, sea ice recession

1. INTRODUCTION

Sequential depletion of bowhead whales, *Balaena mysticetus*, in East Greenland, West Greenland, the Canadian high Arctic, and Alaska due to commercial whaling caused the International League of Nation in 1931 to agree on a worldwide protection to ensure the survival of the species. This was the first international effort ever undertaken to protect a species of wildlife.

Commercial harvest of bowhead whales in Baffin Bay and adjacent waters removed a minimum of 28,700 whales between 1719 and ~1900 (Ross 1993). The population size in 1825 was estimated at 11,000 and by the end of the 19th century the stock was so reduced that commercial whaling was no longer viable (Woodby & Botkin 1993). Despite protection for more than 100 yrs no signs of recovery have been documented for bowhead whales in Baffin Bay. Previous population estimates underestimated abundance using surveys that did not represent the population (Zeh *et al.* 1993, Reeves & Heide-Jørgensen 1996).

In order to assess the current status of bowhead whales on the former whaling ground in West Greenland a dedicated aerial survey effort was conducted in April 2006, including satellite tracking of individual whales and estimation of surface time from a sample of whales. New methods were developed for correcting for availability bias caused by whales that are diving during the passage of the survey platform.

2. MATERIAL AND METHODS

A total of nine satellite linked radio transmitters were applied to bowhead whales in Disko Bay, West Greenland, following methods previously described for satellite monitoring movements (Heide-Jørgensen *et al.* 2006). Locations of the transmitters were collected via the ARGOS system (Service Argos 1989, Harris *et al.* 1990) and area usage patterns was estimated as the 95, 75, and 50% fixed-kernel range estimates using the Animal Movement and Spatial Analyst extensions in ArcView (Hoodge & Eichenlaub 1997). An average daily position calculated from all locations from a given day was used to create range estimates. Overlapping land area was removed from the home range estimates and least squares cross validation (h=17 km) was used.

A visual aerial line-transect survey was conducted in West Greenland between 21 March and 19 April 2006. The area where bowhead whales were intensively hunted up to 300 years ago was systematically covered (Fig. 1). The survey platform was a De-Havilland Twin Otter with target altitude and speed of 213 m and 90 knots. Sightings were recorded from two independent platforms on each side of the plane. Bubble windows allowed for surveillance of the trackline straight below the plane. Estimation of abundance was conducted with sight-resight line transect methods where the distance to each sighting was used to estimate a detection function. The independent observer configuration provided data to estimate the perception bias (due to observers missing whales that were available to be detected) using the methods of Borchers *et al.* (2006). Perpendicular distances to a total of 34 groups were obtained. Based on lowest AIC value a logistic model with group size and Beaufort sea state was selected to estimate detection probability at distance zero (i.e. the detection function intercept) and a hazard rate model with no covariates was used to model the shape of the detection function for the 34 sightings with perpendicular distances (Fig. 2, cf. Buckland *et al.* 2001). Correction for whales submerged during the survey (availability bias) was conducted using data from 14 deployments of time-depth-recorders in the survey area during April-May of 2002-2006 (see Laidre *et al.* in press). Correction for availability bias was incorporated in the abundance estimate using the method of Pollock *et al.* (2006).

3. RESULTS

Approximately10.500 linear kilometers were flown in March-April 2006 over bowhead whale habitat in West Greenland to provide a systematic sample of an area of 125.000 km^2. Satellite tracking studies, concurrent to the aerial survey, showed that instrumented bowhead whales were focused on a relatively coastal home range area of ~25.000 km^2 southwest of Disko Island (Fig. 1). Observations of whales during the survey revealed that 32 out of 36 of the sightings were made inside this area. The survey was designed to cover the area used by the whales as well as adjacent potential habitats. Only a small area

(2975km^2 or 12%) in the southwest corner of the home range area was not covered by the survey due to sea states >2.

Fourteen bowhead whales were instrumented with time-depth-recorders in April of 2002 to 2006 and the whales spent an average of 24% (cv=0.03) of their time at or above 2 m (see Laidre *et al.* in press). This is considered the maximum depth to which bowhead whales can be seen on the trackline during visual aerial surveys.

Detections beyond 1,500m were discarded in analysis. A total of 34 sightings with distance estimate less than 1,500m were included in the abundance estimation calculated for 6 strata. The estimated abundance of bowhead groups corrected for perception bias but not availability bias was 267 (cv = 0.47; 95% CI: 111-641) and the corresponding total abundance of individuals was estimated to be 295 (cv = 0.47; 95% CI: 129-708).

Availability bias was corrected for using the method described in Pollock et al (2006). This involves estimating the probability of an animal being available using the mean proportion of time instrumented animals were recorded to be within 2m of the surface. The estimated abundance of bowhead groups corrected for both perception and availability bais was 1113 (cv=0.47; 95% CI: 458-2668) and the corresponding estimate of the total abundance of whales was 1229 whales (cv=0.47, 95% CI: 495-2939). If two sightings without distance measurements are included the abundance increases to 1303 (cv=0.47).

4. DISCUSSION

Bowhead whales are long-lived (>200 yrs, George *et al.* 1999) and they are currently assumed to be sexually mature at about 25 years of age, an estimate nearly twice that of all other cetaceans (Zeh *et al.* 1993). In Alaska, where surveys for bowhead whales have been conducted for 25 years they have been observed to increase at 3.4% per year (George *et al.* 2003). In West Greenland the bowhead whales wintering ground has been surveyed intensively with comparable methods since 1981. All previous surveys gave substantially lower sighting rates than that reported in this study (Table 1). The low sighting rates follow well with the scarcity of local observations, supporting the idea that few bowhead whales were present in West Greenland throughout the 20th century (e.g. Born and Heide-Jørgensen 1983).

The Disko Bay is an important feeding ground for adult bowhead whales (Laidre *et al.* in press). Few calves or juvenile whales <14m have been observed over the past decade, a pattern which follows well with that observed during commercial whaling (Eschricht & Reinhardt 1866). Despite this, a large proportion of the whales in Disko Bay in spring are females (85%) and >14m (Laidre *et al.* in press, GINR unpubl data). Given these whales are unaccompanied by calves they must be either pregnant, resting, or reproductively senescent. The bowhead whales in West Greenland are part of a population that ranges into the Canadian high Arctic, Foxe Basin and Baffin Bay (Heide-Jørgensen *et al.* 2006). Information from satellite tracking, age and sex segregation across their geographic range, genetic studies, and ability to travel extreme distances in a short amount of time clearly demonstrates that Foxe Basin and Baffin Bay bowhead whales are connected into one segregated population. The Foxe Basin is a major calf rearing area for females, presumably those from West Greenland, and mating likely occur in winter in Hudson Strait (Heide-Jørgensen *et al.* 2006).

The trend from very low numbers in the 1980s and 1990s to an abundance of over 1,200 animals in 2006 cannot be explained using the observed population growth rate from Alaska nor by a predicted growth rate based on currently accepted life history parameters (*e.g.* Zeh *et al.* 1993). Even though both approaches might severely underestimate potential maximum growth rates, other scenarios are needed to explain the sudden recovery observed in West Greenland. One scenario is that bowhead whales in West Greenland are part of a behavioural cycle where mature females visit West Greenland to feed during the interbreeding period. A sudden large number of mature females in West Greenland requires that the entire population (including the Canadian high Arctic), has recently reached a certain threshold level, where cohorts of mature females appear abundantly on the feeding ground in West Greenland. Another contributing factor might be changes in sea ice conditions and production. Extent of mid winter sea ice in West Greenland has declined rapidly since 2002 with the lowest values reached in 2006 (Table 1; Stern & Heide-Jørgensen 2003, GINR unpublished data). It is not known if bowhead whales are reacting to the reduced sea ice coverage in West Greenland.

Regardless of the explanatory factors, this survey documents the largest number of bowhead whales recorded in the past 100 yrs on the former whaling ground in West Greenland, the first clear indication that this population is recovering

REFERENCES

Borchers, D.L., Laake, J.L., Southwell, C. & Paxton, C.G.M. 2006. Accommodating unmodelled heterogeneity in double-observer distance sampling surveys. *Biometrics* 62: 372-378.

Born, E.W. & Heide-Jørgensen, M.-P. 1983. Observations of the bowhead whale (*Balaena mysticetus*) in central west Greenland in March-May 1982. *Rep. Int. Whal. Commn*. 33: 545-547.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L. & Thomas, L. (2001). *Introduction to Distance Sampling: estimating abundance of biological populations*. Oxford University Press, pp: 256-8.

Eschricht, F. & Reinhardt, J. 1866. The Greenland right-whale with especial reference to its geographical distribution and migrations in times past and present, and to its external and internal characteristics. *The Ray Society*, Lond. 192: 1-49.

George, J. C., J. Bada, J. Zeh, L. Scott, S. E. Brown, T. O'Hara & Suydam, R. 1999. Age and growth estimates of bowhead whales (*Balaena mysticetus*) via aspartic acid racemization. *Can. J. Zool.*77:571–580.

George, J.C., Zeh, J., Suydam, R. & Clark, C. 2004. Abundance and population trend (1978-2001) of western Arctic bowhead whales surveyed near Barrow, Alaska. *Mar. Mammal Sci.* 20(4): 755-73.

Harris, R.B., Fancy, S.G., Douglas, D.C., Garner, G.W., Amstrup, S.C., McCabe, T.R. & Pank, L.F. 1990. Tracking wildlife by satellite: Current systems and performance. United States Department of the Interior, Fish and Wildlife Service, *Fish and Wildlife Technical Report* 30: 52 pp

Heide-Jørgensen, M.P. & Acquarone, M.. 2002. Size and trends of the bowhead, beluga and narwhal stocks wintering off West Greenland. *Scientific Publications of the North Atlantic Marine Mammal Commission* Vol. 4: 191-210.

Heide-Jørgensen, M.P., Laidre, K. L., Jensen, M.V., Dueck, L. & Postma, L. D.. 2006. Dissolving stock discreteness with satellite tracking: Bowhead whales in Baffin Bay. *Mar. Mammal Sci.* 22(1): 34-45.

Hoodge, P.N. & Eichenlaub. B. 1997. Animal movement extension to Arcview. ver. 1.1. Alaska Biological Science Center, U.S. Geological Survey, Anchorage, AK, USA.

Laidre, K. L., M. P. Heide-Jørgensen, & Nielsen, T. G.. In press. The role of the bowhead whale as a predator in West Greenland. *Marine Ecology Progress Series*.

Pollock, K.H., Marsh, H.D., Lawler, I.R. & Alldredge, M.W. 2006. *J. Wildl. Manage.* 70: 255-262.

Reeves, R.R. & Heide-Jørgensen, M.P. 1996. Recent status of bowhead whales, *Balaena mysticetus*, in the wintering grounds off West Greenland. Polar Research 15 (2): 115-125.

Ross, W.G. 1993. Commercial whaling in the North Atlantic Sector. Pages 511–577 i*n* J. J. Burns, J. J. Montague and C. J. Cowles, eds. The bowhead whale. Special Publication No. 2, Society for Marine Mammalogy, Lawrence, KS.

Service Argos 1989. Service Argos Inc. Guide to ARGOS system, September 1989. *CLS ARGOS, Toulouse, France*.

Stern, H.L. & Heide-Jørgensen, M.P.. 2003. Variability of sea ice in Baffin Bay and Davis Strait. Polar Research 22(1): 11-18.

Woodby, D.A. & Botkin, D.A.. 1993. Stock sizes prior to commercial whaling. Pages 387–407 *in* J. J. Burns, J. J. Montague and C. J. Cowles, eds. The bowhead whale. Special Publication No. 2, Society for Marine Mammalogy, Lawrence, KS.

Zeh, J. E., Clark, C. W., George, J. C., Withrow, D., Carroll, G. M. & Koski, W. R.. 1993. Current population size and dynamics. Pages 409–489 *in* J. J. Burns, J. J. Montague and C. J. Cowles, eds. The bowhead whale. Special Publication No. 2, Society for Marine Mammalogy, Lawrence, KS.

Table 1. Sightings of bowhead whales and survey effort during aerial surveys covering the wintering ground in West Greenland shown together with sea ice coverage . Data from Heide-Jørgensen *et al.* (1993), Reeves & Heide-Jørgensen (1996), Heide-Jørgensen & Acquarone (2003), Stern & Heide-Jørgensen (2003) and the present study.

Year	Sightings *n*	Effort *Km*	Sea ice Km^2
1981	4	11.630	94,656
1982	7	9.877	106,071
1990	1	1.360	96,626
1991	7	3.479	100,410
1993	1	3.222	103,990
1994	5	4.554	97,765
1998	8	4.753	91,717
1999	1	4.948	89,540
2006	36	10.500	68,783

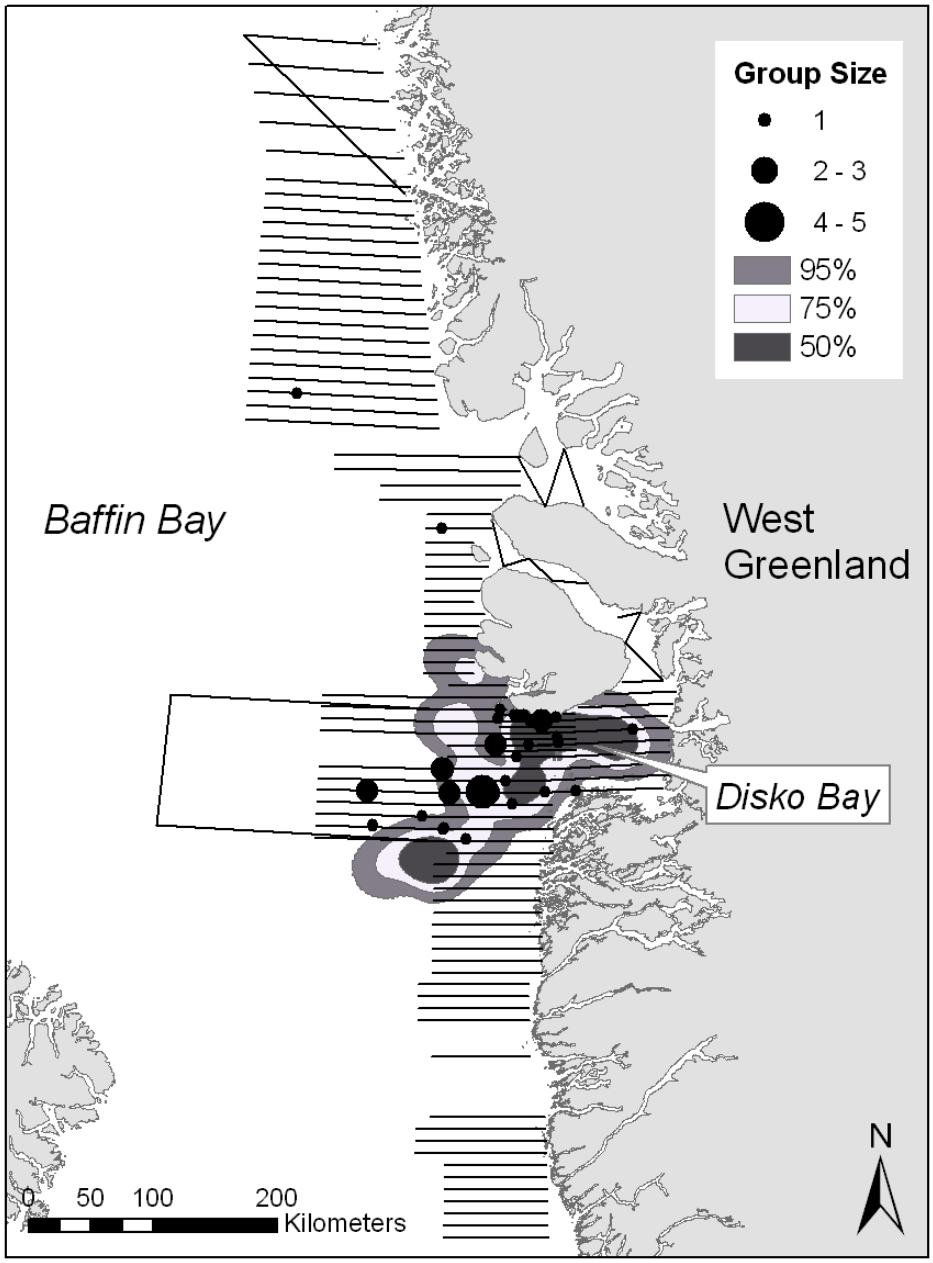

Fig. 1. Survey effort, sightings of bowhead whales and the home range of 9 bowhead whales tracked by satellite during April 2006 are shown as the 95%, 75% and 50% kernel home ranges of 24692, 13657, and 5335 km^2, respectively.

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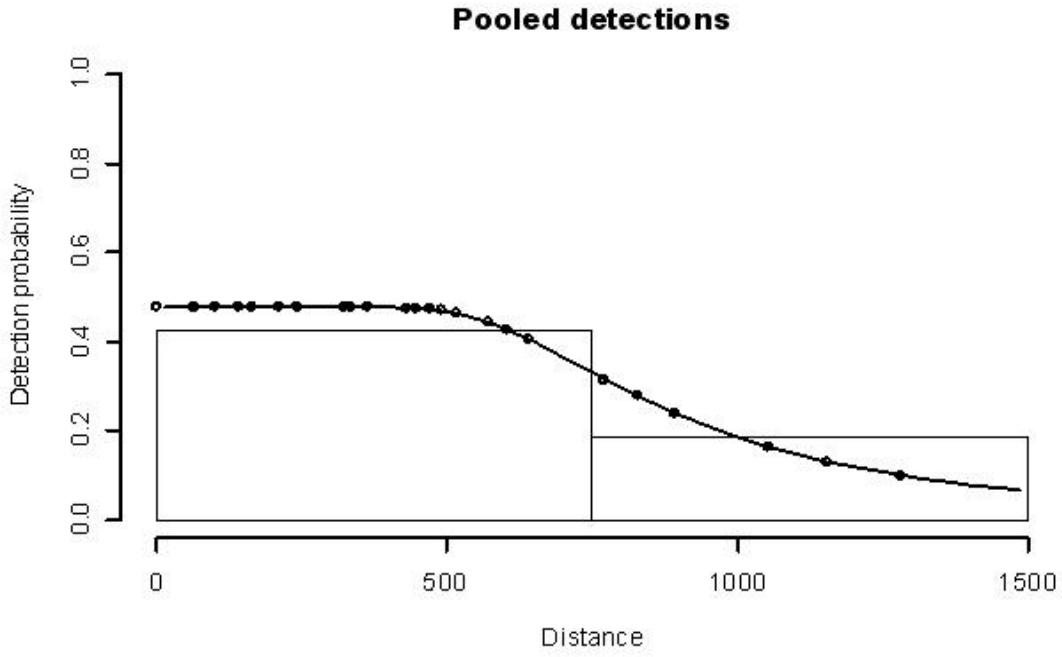

Fig. 2. Hazard rate detection function for bowhead whale sightings from both platforms. Tthe detection probability on the trackline is about 0.5. Two out of 36 sightings were omitted because of lack of distance estimates and one was outside the right truncation at 1.500m.