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Population ecology

# Increasing abundance of bowhead whales in West Greenland

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**In April 2006, a dedicated survey of bowhead whales (*Balaena mysticetus*) was conducted on the former whaling ground in West Greenland to determine the current wintering population abundance. 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. Bowhead whales were estimated to spend an average of 24% (cv = 0.03) of the time at or above 2 m depth, the maximum depth at which they can be seen on the trackline. This resulted in a fully corrected abundance estimate of 1229 (95% CI: 495–2939) bowhead whales when the availability factor was applied and sightings missed by observers were corrected. This surprisingly large population estimate is puzzling given that the change in abundance cannot be explained by a recent or rapid growth in population size. One possible explanation is that the population, which demonstrates high age and sex segregation, has recently attained a certain threshold size elsewhere, and a higher abundance of mature females appears on the winter and spring feeding ground in West Greenland. This in combination with the latest severe reduction in sea ice facilitating access to coastal areas might explain the surprising increase in bowhead whale abundance in West Greenland.**

**Keywords:** bowhead whale; *Balaena mysticetus*; West Greenland; satellite tracking; aerial survey; sea ice

## 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 Nations in 1931 to agree on a worldwide protection of the species to ensure its survival. 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 approximately 1900 (Ross 1993). The population size in 1825 was estimated to be 11 000 and by the end of the nineteenth century the stock was so reduced that commercial whaling was no longer viable (Woodby & Botkin 1993). Despite protection for more than 100 years, no signs of recovery have been documented for bowhead whales in Baffin Bay. Bowhead whales in this area are widely dispersed throughout the year and no surveys have so far covered the full range of the population (Zeh *et al.* 1993; Reeves & Heide-Jørgensen 1996).

A dedicated aerial survey effort was conducted in April 2006 in order to assess the current status of bowhead whales on the former whaling ground in West Greenland. The estimate of population size included satellite tracking of the movements of individual whales and estimation of surface time from archival tagging.

## 2. MATERIAL AND METHODS

Nine satellite transmitters were applied to bowhead whales in Disko Bay, West Greenland, in April 2006 following methods described by Heide-Jørgensen *et al.* (2006). Locations of whales were collected via the ARGOS system, and area use patterns were estimated as fixed-kernel range estimates using the Animal Movement and Spatial Analyst extensions in ArcView. Average daily positions calculated from all locations were used to create home range estimates.

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 was systematically covered (figure 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 during Beaufort sea states less than 3 and visibility greater than 10 km. Bubble windows allowed for surveillance of the trackline straight below the plane and distance to sightings was calculated from the angle abeam measured with inclinometers. The independent observer configuration provided data to estimate the perception bias (due to observers missing whales that were available to be detected) where the perpendicular distance to each sighting was used to estimate a detection function using the point independence model (Borchers *et al.* 2006). Based on the lowest AIC value, a logit model with no covariates 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 sightings with distances (figure 2, cf. Buckland *et al.* 2001). Inclusion of observers gave a higher AIC. 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

Approximately 10 500 linear kilometres were flown in March and April 2006 over bowhead whale habitat in West Greenland to provide a systematic sample of an area approximately 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 approximately 25 000 km$^2$ southwest of Disko Island (figure 1). The survey was designed to cover the area used by the whales as well as adjacent potential habitat, and 89% of the sightings were made inside the area used by satellite-tracked whales and the remaining 11% of the sightings were detected in adjacent areas. Only a small area (2975 km$^2$ or 12%) in the southwest corner of the home range area was not covered by the survey due to sea states greater than 2.

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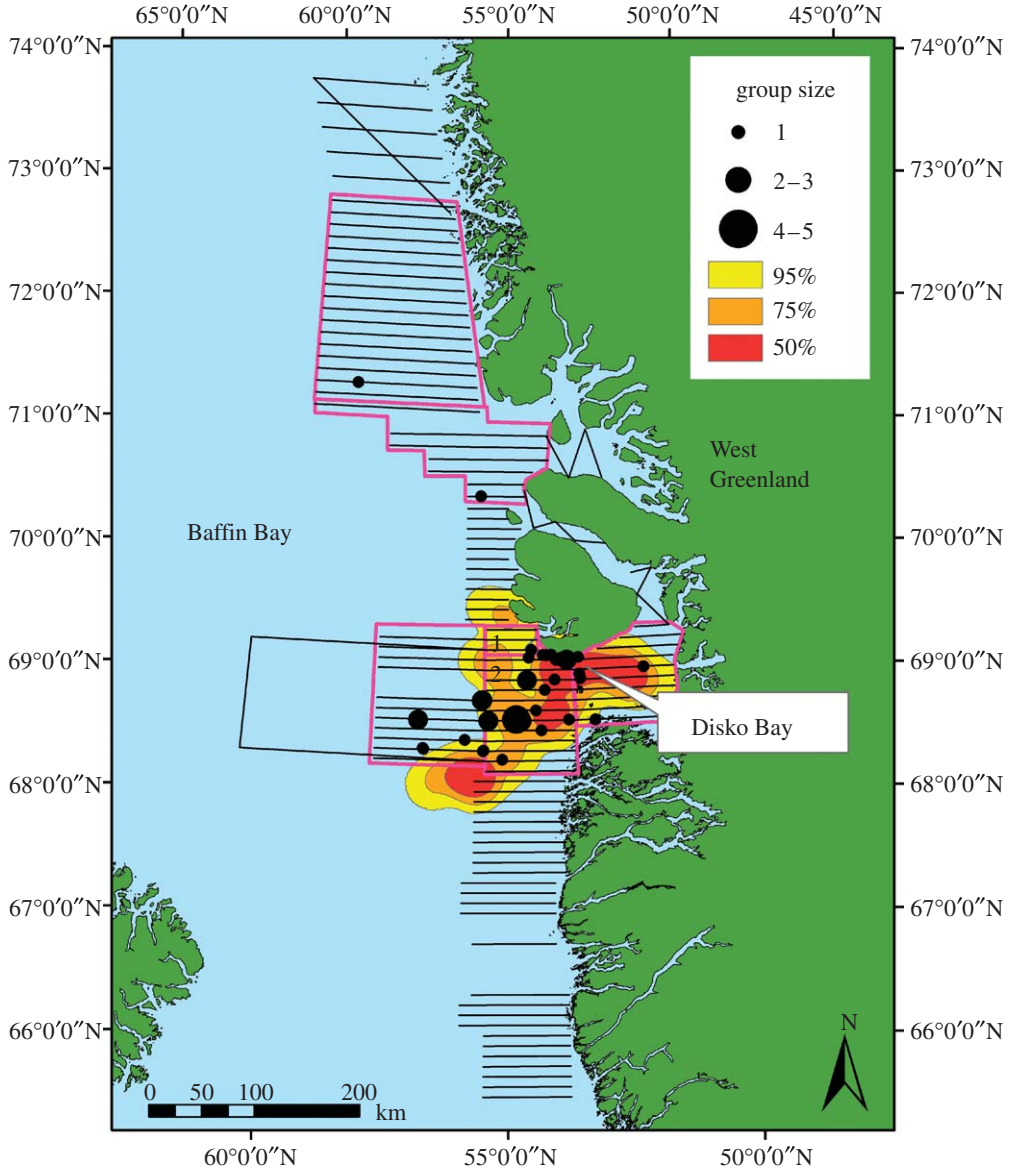


Figure 1. Survey effort, delineation of six strata (strata 1 and 2 labelled), sightings of bowhead whales and home range of nine bowhead whales shown as the 95, 75 and 50% kernel home ranges of 24 692, 13 657 and 5335 km$^2$, respectively.

A total of 33 sightings with distance estimates less than 1500 m were included in the abundance estimation calculated for six strata. There were 6 duplicate detections and 13 detections only by the front platform and 14 only by the rear platform. The detection of a single platform was $p(0)=0.28$ (cv$=0.34$) and the detection for both platforms combined was $p(0)=(2\times0.28)-(0.28\times0.28)=0.48$ (cv$=0.29$). Expected group size corrected for size-bias was 1.1 (cv$=0.05$), and the estimated total abundance of bowhead whales corrected for perception bias was 295 (cv$=0.47$; 95% CI: 129–708).

Availability bias was corrected for by assuming that bowhead whales could be sighted to a maximum depth of 2 m on the trackline during visual aerial surveys. This was based on experiments with the detection of narwhal (*Monodon monoceros*) silhouettes, another dark whale found in clear Arctic waters (Heide-Jørgensen 2004). Data from whales instrumented with time–depth recorders showed that they spent an average of 24% (cv$=0.03$) of their time at or above 2 m depth. The estimated total abundance of bowhead groups corrected for both perception and availability bias was 1229 whales (cv$=0.47$, 95% CI: 495–2939). If two sightings without distance measurements are included the abundance increases to 1303 (cv$=0.47$).

The rate of increase in sighting rates of bowhead whales in West Greenland over the last 25 years was estimated for nine aerial surveys using similar methods in a comparable survey area (figure 1, strata 1 and 2). The exponential growth of the sighting rates between 1981 and 2006 excluding three surveys (where no sightings were made of bowhead whales, table 1) and adjusted for double observers in 2006 was 0.11.

## 4. DISCUSSION

Bowhead whales are long-lived (more than 200 years, George *et al.* 1999) and are currently assumed to be sexually mature at approximately 25 years of age (Zeh *et al.* 1993). They have been observed to increase at 3.4% per year in Alaska (George *et al.* 2004).

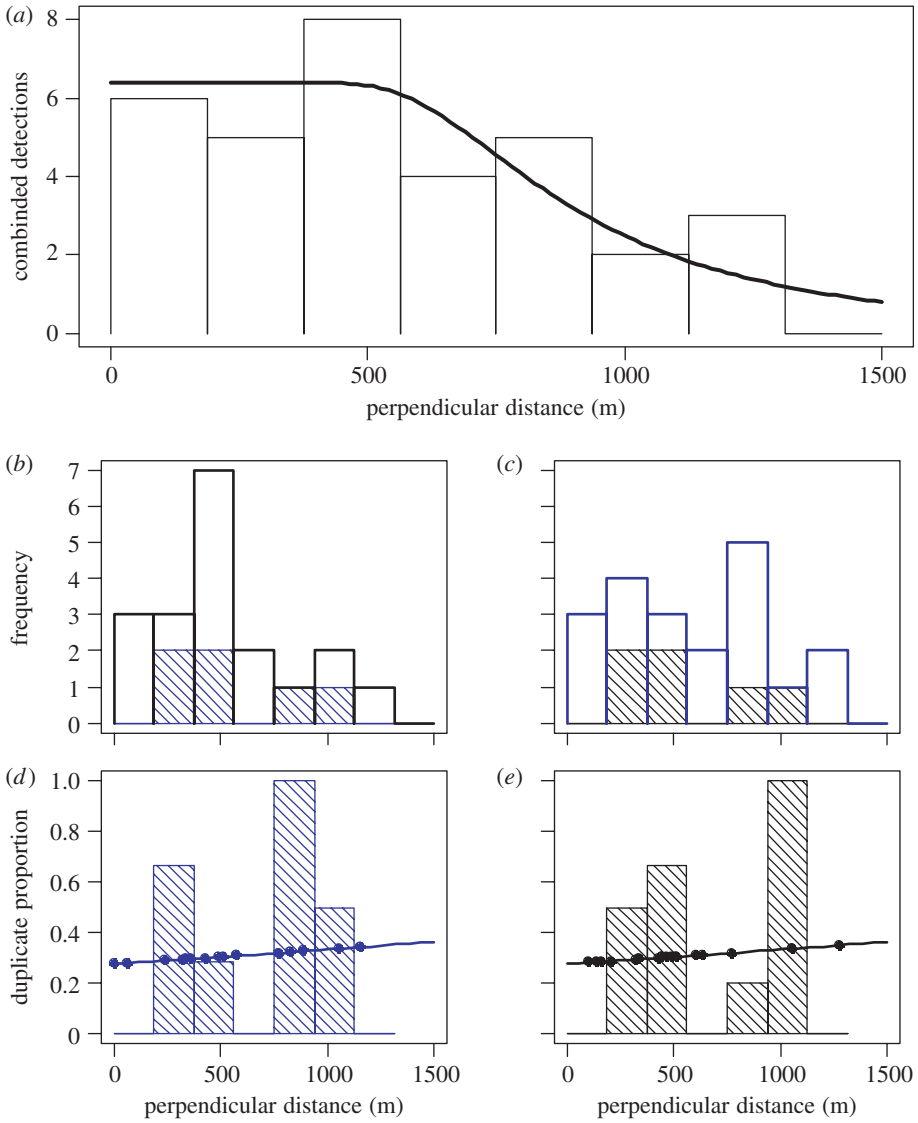


Figure 2. (*a*) Combined detection functions with observations and fitted detection function curve (scaled to histogram area). The final estimated detection function is the black curve with intercept (average combined $p(0)$) equal to the combined detections $p(0)=0.48$ (cv$=0.29$). Conditional detection functions for the independent observers. (*b*,*c*) Number of detections by each observer (blue is second observer), with duplicate detections shaded. (*d*,*e*) Duplicate proportions (shaded histograms) with fitted conditional detection function overlaid (dark curve) and the estimated detection probability of the individual detections (dots). (*b*) No. 1 observer detections, (*c*) no. 2 observer detections, (*d*) proportion of no. 1 detections seen by no. 2 and (*e*) proportion of no. 2 detections seen by no. 1.

Bowhead whales have been surveyed intensively in West Greenland with comparable methods since 1981 but all previous surveys resulted in too few sightings to allow for construction of reliable abundance estimates (table 1). The low sighting rates in previous surveys for bowhead whales confirm the scarcity of local observations, despite the fact that a correction was applied for double observers in 2006. This supports the conclusion that very few bowhead whales were present in West Greenland throughout the twentieth century (e.g. Born & 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 (less than 14 m) have been observed in the area over the past decade, a pattern which is in agreement with observations during the whaling period (Eschricht & Reinhardt 1866). Despite this, a large proportion of the whales in

Table 1. Sighting rates of bowhead whales in strata 1 and 2 (Reeves & Heide-Jørgensen 1996; Heide-Jørgensen & Acquarone 2002). (The sighting rate for a single observation platform is shown in parenthesis for 2006. Sea ice coverage for West Greenland is shown based on data from Stern & Heide-Jørgensen (2003) and updated through 2006.)

| year | sightings, $n$ | effort, $L$ (km) | sighting rate, $n/L$ | sea ice coverage (km$^2$) |
|---|---|---|---|---|
| 1981 | 1 | 951 | 0.0011 | 94 656 |
| 1982 | 1 | 2273 | 0.0004 | 106 071 |
| 1990 | 1 | 591 | 0.0017 | 96 626 |
| 1991 | 3 | 1088 | 0.0028 | 100 410 |
| 1993 | 0 | 577 | 0.0000 | 103 990 |
| 1994 | 0 | 1092 | 0.0000 | 97 765 |
| 1998 | 5 | 1184 | 0.0042 | 91 717 |
| 1999 | 0 | 1104 | 0.0000 | 89 540 |
| 2006 | 18 | 791 | 0.0228 (0.0109) | 46 560 |

Disko Bay in spring are females (85%) and greater than 14 m (Laidre *et al.* in press, GINR 2000–2006, unpublished data). Given these whales are unaccompanied by calves they must be either pregnant, resting or reproductively senescent. Bowhead whales in West Greenland are part of a population that ranges into the Canadian high Arctic, Foxe Basin and Hudson Bay (Heide-Jørgensen *et al.* 2006). Information from satellite tracking, photographic observations of age and sex segregation, genetic studies and ability to travel extreme distances in a short amount of time all support the idea that Foxe Basin and Baffin Bay bowhead whales are connected and are one segregated population. The Foxe Basin is a major calf-rearing area for females, presumably those from West Greenland, and mating probably occurs in winter in Hudson Strait (Heide-Jørgensen *et al.* 2006).

The trend in sighting rates from low numbers in the 1980s and 1990s to an abundance of over 1200 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 in bowhead whale populations, other scenarios are needed to explain the sudden increase in abundance observed in West Greenland. One scenario is that bowhead whales arriving in West Greenland are migrants that 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 in West Greenland. Another explanatory factor might be changes in sea ice conditions and primary production.

The area of mid-winter sea ice in West Greenland has declined rapidly since 2002 in the region extending from 65° N to 70° N and 51° W to 58° W (figure 1; table 1). The mean March sea ice area in that region for 1979–2002 was 92 000 km$^2$ with a standard deviation of 10 000 km$^2$. The March sea ice area for the years 2003 to 2006 was 64 000, 69 000, 30 000 and 47 000 km$^2$. Reduced sea ice would allow bowhead whales access to coastal feeding grounds in Disko Bay both earlier in the season and for a longer period of time. Although the observed increase in abundance may be a combination of several factors, this survey documents the largest number of bowhead whales recorded in the past 100 years on the former whaling ground in West Greenland, the first clear indication that this population is increasing.

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