

Segregation of sexes and plasticity in site selection of bowhead whales

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Abstract

Skin biopsy samples from 333 bowhead whales (*Balaena mysticetus*) collected between 1995 and 2007 at four localities in the Eastern Canadian Arctic (Igloolik, Pelly Bay, Repulse Bay and Pangnirtung) and at one locality in West Greenland (Disko Bay) were used for determinations of sex and individual site fidelity of bowhead whales from the Baffin Bay stock. There was a pronounced dominance of females (81% female) in Disko Bay whereas a more balanced sex ratio (~50% female) was detected at localities in the Eastern Canadian Arctic. Observations on the length of whales suggest that it is primarily large mature whales without calves that are seen in Disko Bay and mother-calf pairs at Igloolik. Despite the large sample size, only three between year re-identifications of bowhead whales were detected, all from Igloolik. The results suggest that the population size is large and that there is limited annual individual site fidelity to specific localities. The reliable presence and high population site fidelity at specific localities throughout the range could be part of a larger cycle of movements that extends beyond the 12 yr extension of this study.

Introduction

Bowhead whales (*Balaena mysticetus*) congregate predictably at a number of coastal locations in the Canadian eastern Arctic and in West Greenland at different seasons. One of these sites is Disko Bay, West Greenland (Fig. 1), where bowhead whales are present between February and May following patterns observed since the 1700s (Eschricht and Reinhardt, 1861). Satellite tracking studies have demonstrated that bowhead whales that winter in Disko Bay spend the summer in the eastern Canadian Arctic and move to Hudson Strait for the subsequent winter (Heide-Jørgensen et al. 2003, 2006).

Similarly, bowhead whales are found in large concentrations at specific locations in Foxe Basin, Northern Hudson Bay, in fjords along the east coast of Baffin Island and in the Canadian high Arctic during summer. In winter they tend to congregate in Hudson Strait, at the mouth of Cumberland Sound, along West Greenland and in the North Water (cf. Heide-Jørgensen et al. SC/60/BRG20).

Based on observations from whalers, it was first noted by Southwell (1898) that bowhead whales in Baffin Bay-Hudson Bay exhibit considerable sex and age-class segregation across this geographic range. However quantitative evidence of this segregation was not available and the observations by Southwell

(1898) were largely ignored. With the recent increase in bowhead whale abundance and with the development of genetic methods it became feasible to examine the sex structure as well as individual site fidelity in this population.

Methods

Skin biopsies from bowhead whales were obtained by crossbow with biopsy darts at localities in the Eastern Canadian Arctic and in the Disko Bay between 1995 and 2007 (Table 1). Additionally four samples were collected from the subsistence hunt in Canada. The majority of samples were collected during tagging programs, but in some communities (Pelly Bay, Repulse Bay and Disko Bay) local hunters biopsy-sampled bowhead whales opportunistically. The majority of samples in Disko Bay were collected between the months of April and May and the samples from Canada were collected between July and September. All samples were stored in salt saturated, 20% DMSO and kept frozen until analysis.

Total DNA was extracted from the samples using a commercial tissue extraction kit (DNeasy®, Qiagen or GenElute™, Sigma-Aldrich). Sex of all whales was determined using a PCR-based method for the identification of sex in cetaceans (Berubé and Palsbøll 1996; Shaw *et al.* 2003). This method amplifies ZFX- and ZFY-specific regions of nuclear DNA that results in a product that corresponds to a portion of the X chromosome and a product specific to the Y chromosome (if present). Separation and visualization of these products on a 1% agarose gel allows for the reliable assignment of sex.

Samples from Canada were analyzed with >19 microsatellite loci (Heubinger *et al.* 2006) and alleles at all loci were compared for to identify identical genotypes. For the samples from West Greenland, part of the mitochondrial control region was amplified as described by Rooney *et al.* (2001). The obtained nucleotide sequences were aligned and edited with the computer program sequencer 4.1 (GeneCodes) and haplotypes were subsequently assigned to each individual. The obtained information on mitochondrial haplotype and sex allow for a first prescreening of the sampled individuals. Re-identifications were confirmed using a comparison of alleles at three highly variable microsatellite loci.

Results

Sex was determined for 380 biopsy samples from bowhead whales in Canada and Greenland from 1995 through 2007 (Table 1). A total of 47 re-identifications within the same year collected from Igloodik, West Greenland and Pangnirtung were removed.

Females made up 81% of the overall proportion in Disko Bay when all years were combined. This was slightly lower than the estimate of 84% females for 2007 alone, the year with the largest sample size. The most extreme case was 2006 when no males were detected in 20 samples.

Igloodik provided the second largest sample size with a sex ratio for all six years of 56% females. Smaller samples from Repulse Bay and Pangnirtung had sex ratios of 50 and 47% females, respectively, and an even smaller sample from Pelly Bay (n=8) had a female proportion of 38% (Fig. 1).

Of the 333 whales that were identified, only three re-identifications between years were found all from Igloodik; one female between 1995 and 2002, one male and one female both between 2001 and 2002.

Discussion

Observations made during field operations from 2000 to 2007 suggest that it is essentially adult whales (>14 m, with some whales >12 m) that is found in Disko Bay in spring (Heide-Jørgensen *et al.* 2002, 2006). Newborns have not been recorded for the past >150 yrs and calves are rarely, if ever, seen and have not been detected in recent aerial surveys in West Greenland (Heide-Jørgensen *et al.* 2007). Considering the large number of whales that were taken along West Greenland in the 18th and 19th century the relatively few accounts of calves indicate that this is not a major calving ground or a site that young whales frequently visit (Eschricht and Reinhardt 1866).

Few calves have been seen in other parts of Baffin Bay: Davis and Koski (1980) reported less than 3% (n=46) calves during aerial surveys of Lancaster Sound. In Isabella Bay (Fig. 1) Finley (1990) measured 83 bowhead whales (mean length=14.4 m) on aerial photographs and found only one cow calf (6 m) pair, and one sub-adult whale (<10 m). The absence of mother-calf pairs and sub-adults in Isabella Bay was confirmed by land based observations during 1984-88. Results from these studies strongly suggest that the bowhead whales occupying Baffin Bay and Davis Strait during summer and fall are mainly adults.

However, the calf-producing segment of the population can be found in the Canadian high Arctic where whaling records indicate that cows, calves, and sub-adult whales were taken in northwestern Hudson Bay from June through September (Reeves and Cosens 2003). Recent aerial photogrammetric and visual studies have shown that bowhead whales in Foxe Basin mainly consist of young-of-the-year calves and sub-adults, and that the adult component was believed to be cows with young-of-the-year calves (Cosens and Innes 2000, Cosens and Blouw 2003). Apparently the population segment that is found in Foxe Basin and northwestern Hudson Bay is lacking adult males and resting females, and no location within Hudson Bay and Foxe Basin has shown significant concentrations of adult whales.

Disko Bay is an important feeding ground for bowhead whales (Laidre *et al.* 2007) but there are also indications from acoustic studies that Disko Bay is at the same time a mating ground. Intensive singing activity of bowhead whales with up to three unique songs have been recorded in April 2007 (Stafford *et al.* submitted). Singing is an activity that usually is attributed to male display in baleen whales and the fact that most singing was recorded during spring makes it plausible that mating between the relatively few males and the large fraction of females indeed occur in Disko Bay.

Disko Bay had a disproportionate number of females that suggests that this area does not have a fully functional population. These whales are more likely a fraction of a larger population that exists in population segregations throughout the eastern Canadian high Arctic. This is also supported by the observation that mainly large adult whales are seen in Disko Bay and no newborns or calves have been seen today (or during the whaling period). With the observed increase in abundance of bowhead whales in West Greenland (Heide-Jørgensen *et al.* 2007) it is also evident that these whales must be recruited from other areas.

Foxe Basin had as the only locality three between year re-identifications and the general lack of re-identifications between years in the 333 samples spanning 12 years is remarkable. It suggests that the population is large and highly segregated, perhaps with cyclic movement patterns with long cycles between returns to the sampling localities. The lack of recaptures also confirms that the Disko Bay aggregation is not a closed population and that it is being supplied from a presumably very large population. Given the consistent fraction of mature females that show up in the sample, and which are

either pregnant, in estrous, resting, or perhaps reproductively senescent, and given the lack of re-identifications over 8 years, the results suggest that there is a large supply of mature females.

In comparison, a study of humpback whales (*Megaptera novaeangliae*) in West Greenland had on average 24% re-identifications annually based on ~100 identified whales photographed each year between 1988 and 1993, from a population of >10,000 humpback whales (Larsen and Hammond 2004, Smith et al. 1999). This high rate of re-identifications occurred despite the fact that the humpback whales were spread out over a much larger area of West Greenland (62°-66°N) than the bowhead whales sampled in this study.

If the whales appear in Disko Bay as part of a reproductive cycle, then it would be expected that some re-identifications would occur after 3-4 years which is believed to be the reproductive cycle of a bowhead whale. If it is the reproductive cycle that drives the presence of females in Disko Bay it was expected that the large sample size in 2007 would re-identify some of the females sampled in the earlier years. However, bowhead whales have longevity of more than 200 yrs (George *et al.* 1999) and it is possible that Disko Bay is being visited at longer intervals than the 8 yrs extension of the sampling at this locality or that some reproductive stages visit and leave West Greenland before the samples were collected.

Bowhead whales have for centuries arrived in a highly predictable manner with a similar annual timing at the aggregation sites sampled in this study and there is no doubt that at a population level bowhead whales show clear site fidelity to these as well as other un-sampled locations. It is therefore surprising that no individual site fidelity to these aggregation sites could be detected. Bowhead whales conduct large scale movements and exhibit considerable plasticity in their movement patterns (Heide-Jørgensen *et al.* 2006) and this together with the lack of between-year site tenacity observed all contribute to the high genetic diversity detected in bowhead whales (Borge et al. 2007, Rooney *et al.* 2001). The effects on bowhead whales of variations in Arctic productivity and sea ice changes may be alleviated through the lack of individual short-term site fidelity. The plastic dispersal pattern will ensure that the population is spread out over large areas which reduces competition for patchy resources as well as increases the possible mating combinations.

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Table 1. Sampling periods, number biopsies and fraction females in the samples without within-year re-identifications.

Area/Year	Range of dates	Biopsies analyzed	Number with sex determinations	Re-identifications within year	Fraction females (re-identifications removed)
Disko Bay					
2000	22-28/4	7	7	0	0.29
2001	28/4-8/5	13	13	1	0.58
2002	4/5-13/5	10	10	0	0.60
2003	4/5-18/5	11	11	1	1.00
2004	6/5	1	0	0	
2005	11/3-3/5	25	25	0	0.74
2006	15/4-6/5	24	24	4	1.00
2007	10/3-17/5	157	155	19	0.84
Sum				25	0.81
Pelly Bay					
2000		1	1	0	1.00
2001		2	2	0	0.50
2002	September	5	5	0	0.20
Sum			8	0	0.38
Igloodik					
1995		13	9	0	0.78
1996	4-6/7	20	17	1	0.41
1997		1	1	0	1.00
2001	30 /6-6/7	42	34	3	0.50
2002	1-15/7	65	52	7	0.50
2003		31	27	3	0.74
2007	July	45	29	2	0.50
Sum			169	16	0.56
Repulse Bay					
1997	Aug.-Sept.	5	5	0	0.80
1998	September	4	3	0	0.33
2000	September	4	4	0	0.75
2001	September	4	4	0	0.00
Sum			16	0	0.50
Pangnirtung					
1997		25	19	1	0.37
2002		10	8	0	0.75
2004		9	6	0	0.67
2005		18	16	-	0.44
2006		32	32	-	0.42
Sum			81		0.47

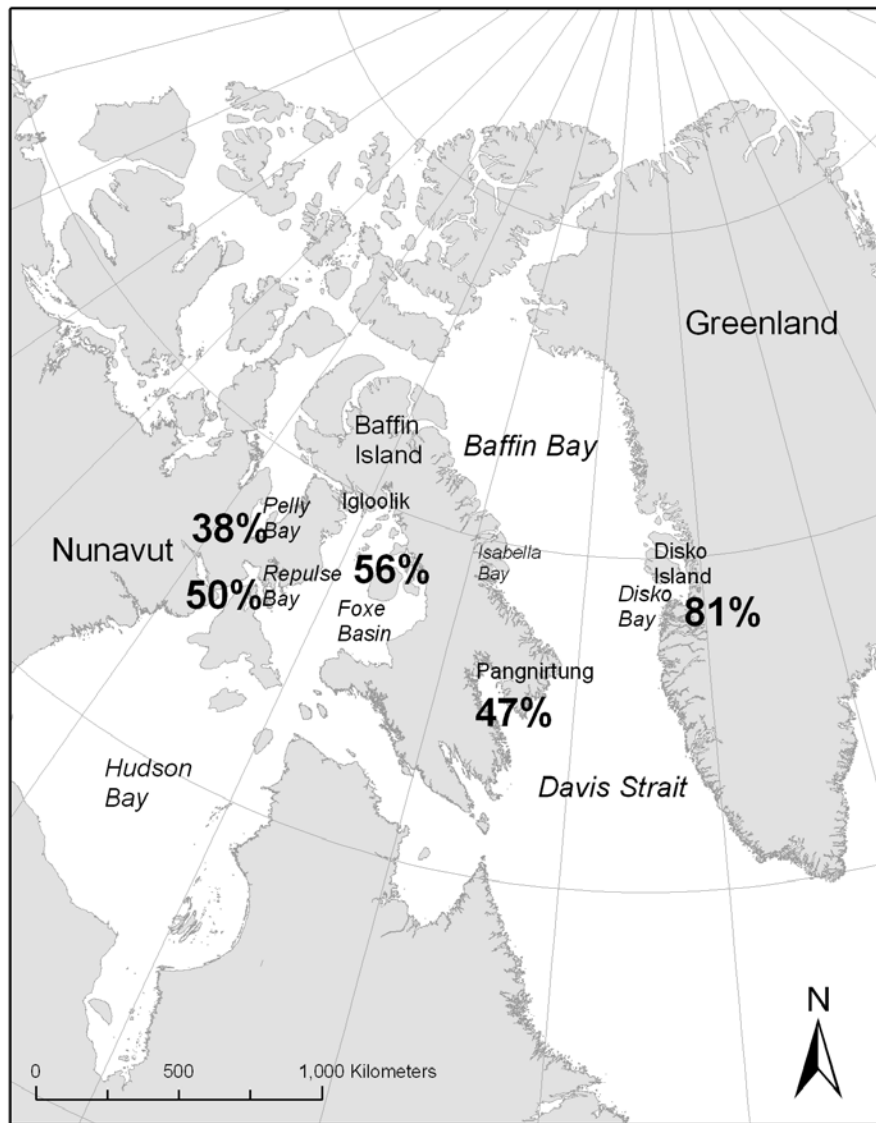


Fig. 1. Map of the localities where the bowhead whales were sampled and the percentage of females at each of these localities.