

Within and between stock re-identifications of bowhead whales in Eastern Canada and West Greenland

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ABSTRACT

Skin samples from 717 bowhead whales (*Balaena mysticetus*) collected between 1995 and 2009 at four localities in Eastern Canada, (Foxye Basin, Pelly Bay, Repulse Bay and Cumberland Sound) and at one locality in West Greenland (Disko Bay) were used for determination of individual ID, sex, and re-identifications within and between localities. A total of 647 individuals were identified of which 91 were re-identifications within the same year collected from Foxye Basin, Disko Bay and Cumberland Sound. The total number of different individuals identified was 208 males and 348 females. The total of 556 individuals yielded 16 re-identifications of which 13 were re-identifications between years (one to eight years between re-identifications) at the same locality and three were re-identifications between localities. The low number of re-identifications between years indicates that the samples were taken from a relatively large population. The three re-identifications between localities crosses the putative stock boundary between the Hudson Bay-Foxye Basin stock and the Baffin Bay-Davis Strait stock, providing evidence that this is not a valid stock delineation.

INTRODUCTION

Bowhead whales (*Balaena mysticetus*) congregate predictably at several coastal locations in the Canadian eastern Arctic and in West Greenland at different seasons. In 1977, a two-stock hypothesis for bowhead whales occupying eastern Canadian and western Greenlandic waters was adopted as the working model of the IWC (1978). The stocks came to be identified as the Baffin Bay-Davis Strait (BB-DS) or “Baffin Bay stock” and the Hudson Bay-Foxye Basin (HB-FB) or “Hudson Bay stock” and have been treated as separate populations since (see Mitchell and Reeves 1981; Cosens and Innes 2000; Finley 1990, 2001). Satellite tracking studies have demonstrated that bowhead whales wintering off the west coast of Greenland can 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 Foxye 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 the Hudson Strait, at the mouth of Cumberland Sound, along West Greenland and in the North Water.

Given that bowhead whales are subject to a limited hunt in Nunavut, Northern Canada, and that a quota was recently given by IWC to the West Greenland wintering aggregation (IWC 2009), it is timely to re-assess the population structure of these whales in light of new information that has been collected. Heide-Jørgensen *et al.* (2006) suggested that the bowhead whales summering in eastern Canada and wintering in West Greenland might consist of a single population. Based on satellite tracking studies of bowhead whales tagged in West Greenland, they argued that bowhead whales are capable of travelling long distances in relatively short periods of time and suggested that there was no reason why whales should be restricted to relative small portions of the total potential range in eastern Canada and Greenland waters. They also noted that there was little geographical separation between individuals belonging to the two putative stocks. Heide-Jørgensen *et al.* (2010) argued that based on patterns of sexual aggregations, bowhead whales summering in the eastern Canadian Arctic and wintering off the west coast of Greenland must belong to one population. In the present paper we discuss the pattern of re-identifications of bowhead whales sampled in Eastern Canada and Western Greenland in the period 1995 – 2009 in relation to the putative stock structure in this area.

METHODS

In this study we collected 710 skin biopsies from bowhead whales by use of crossbows with biopsy darts at several localities in the Eastern Canadian Arctic and in the Disko Bay, West Greenland, between 1995 and 2009 (Fig. 1). An additional seven samples were collected from the subsistence hunt in Canada and West Greenland. The majority of samples were collected during field operations where bowhead whales were instrumented with satellite transmitters, but in some communities (Pelly Bay, Repulse Bay, Disko Bay) biopsies were collected by local hunters. The majority of samples in Disko Bay were collected between April and May, and the samples from Nunavut, Canada, were collected between July and September. All samples were stored in salt saturated, 20% DMSO and kept frozen at 20 degrees Celsius until analysis in the laboratories.

Total DNA was extracted from the skin biopsy samples using commercially available DNA extraction kits (DNeasy®, Qiagen, E.Z.N.A. Tissue DNA kit (Omega Bio-tek), or GenElute™, Sigma-Aldrich). Molecular sex determination of all whales used a PCR-based approach as described by Berubé and Palsbøll (1996).

Part of the mitochondrial control region was amplified and sequenced as described by Rooney *et al.* (2001). The obtained nucleotide sequences were aligned and edited with the computer program Sequencher 4.1 (GeneCodes). All samples with identical mitochondrial control region sequence and sex were analyzed at four to eight highly variable microsatellite loci (as described in Huebinger *et al.* 2006) to identify samples collected from the same individual (see Bachmann *et al.* 2010 for further information).

RESULTS

Individual genetic identity and sex was determined for 647 samples in a total of 717 biopsies collected bowhead whales in Canada and Greenland from 1995 through 2009 (Table 1). A total of 91 re-identifications within the same year collected from Foxe Basin, Disko Bay and Cumberland Sound. The total number of individuals identified was 208 males (M) and 348 females (F). Both the number of samples and the proportion of replicates increased after 2006.

A total of 16 between year re-identifications of whales after one to eight years were recorded of which 13 were from the same locality (Fig. 2) and three were from different localities. Eight of the re-identifications from the same locality (three males and five females) were from Disko Bay ($n = 359$). The period between first identification and re-identification varied between one and eight years. One male out of seven individuals (five males and two females) identified in 2000 was re-identified out of 97 individuals (18 males and 79 females) sampled seven years later (in 2007). One female out of 12 individuals (five males and seven females) identified in 2001 was re-identified out of 54 individuals (19 males and 35 females) identified eight years later (in 2009). Another female first sampled in 2001 was re-identified four years later among 24 individuals (six males and 18 females) identified in 2005. Four of the re-identifications were between the years 2007, 2008 and 2009 when the sampling was most intensive, and involved one male and three females.

In Foxe Basin ($n = 192$) one male and one female first identified among 11 individuals (three males and eight females) in 1995 were re-identified among 63 individuals (32 males and 29 females) in 2002, while one male and one female first identified among 38 individuals (21 males and 17 females) in 2001 were re-identified among 61 individuals (32 males and 29 females) in 2002.

In Repulse Bay ($n = 18$) one female out of three individuals (one male and two females) sampled in 1997 was re-identified among one male and two females identified in 2000, and one male identified among four individuals (three males and one females) in 1998 was re-identified in 2000.

There were three re-identifications (one male and two females) between localities; all three were re-identified in Cumberland Sound in 2006 among 22 individuals (12 males and 10 females) (Fig. 1). One of the females was first identified in Foxe Basin in 2003 among 30 individuals (nine males and 21 females). The other female was first identified in Repulse Bay in 1998 among four individuals (three males and one female). The male had been identified in Repulse Bay both in 1998 and 2000. So two out of four individuals identified in Repulse Bay in 1998 were re-identified in Cumberland Sound eight years later.

DISCUSSION

In 1977, a two-stock hypothesis for bowhead whales occupying eastern Canadian and western Greenlandic waters was adopted as the working model of the IWC (1978). According to the two stock model, the sample localities of Disko Bay, Pelly Bay and Cumberland Sound are within the BB-DS stock distribution area while the localities of Foxe Basin and Repulse Bay are within the HB-FB stock distribution area.

The low number of re-identifications between years (16) in the 556 individuals spanning 12 years suggests that the population is large, perhaps with cyclic movement patterns with long cycles between returns to the sampling localities. Bowhead whales are well known to conduct large scale movements and exhibit considerable plasticity in their movement patterns (Heide-Jørgensen *et al.* 2006). However, bowhead whales have for centuries arrived in a highly predictable manner with a similar annual timing at these aggregation sites. It is therefore surprising that relatively low individual site fidelity to these aggregation sites between years (13) could be detected.

It is likely that the occurrence of whales in Disko Bay is part of a multi-year reproductive cycle for females where years with calving and nursing are spent in the Central Canadian Arctic Archipelago and where pregnant or post-lactating females feed intensively in Disko Bay (Laidre *et al.* 2007, Heide-Jørgensen *et al.* 2010). If the whales appear in Disko Bay as part of a multi-year reproductive cycle, then it would be expected that some re-identifications would occur after 3-4 years based on the assumed reproductive cycle of a bowhead whale. In this study, the re-identification period in Disko Bay varied between one and eight years. In the first years relatively few individuals were identified. However, after the sampling effort increased in 2007 the number of re-identifications increased both for the individuals sampled from the first years and for those new individuals identified in later years. The identifications from 2010 (under process) and the coming years will clarify if this trend continues.

The re-identification rate in Foxe Basin is similar to that from Disko Bay. The re-identification period varied between one and seven years and it is worth noting that all re-identifications were done the same year (2002). In Repulse Bay the re-identification rate was apparently higher than in the other two areas, but the sample size was small.

Among the 16 re-identifications there was a large fraction ($n=3$) of re-identifications between areas – with all three crossing the presumed stock boundaries. The three whales were first identified within the HB-FB stock and were re-identified in Cumberland Sound within the BB-DS stock area three years and eight years later, respectively. Accordingly, bowhead whales appear to move between the two presumed stock areas clearly calling into question if these presumed stocks are real biological entities. It must be noted that the sampling effort was rather low before 2007 in most areas. After 2006, the sampling effort increased substantially in the two areas within the putative BB-DS stock (2007-2009 = 171 individuals), while sampling effort was relatively low in the HB-FB putative stock area (2007 = 35). The large number of identified individuals from the BB-DS stock after 2007 has consequently not been available for re-identification in the HB-FB stock area.

It should also be noted that several important aggregations of bowhead whales have not been sampled at all, including Prince Regent Inlet (estimated at 6,344 bowhead whales in 2002 95% CI 3,119-12,906, Report of Scientific Committee 2009, Annex F, p. 179) and Isabella Bay on the east coast of Baffin Island (estimated at 1,105 in 2009 95% CI: 532-2,294, Hansen *et al.* IWC 2010). The limited number of re-identifications in West Greenland also suggests that the Disko Bay aggregation is not a closed population and instead is being supplied from a presumably very large population of whales coming from other areas. This needs to be further evaluated.

Bowhead whales have a life expectancy of more than 200 years (George *et al.* 1999) and it is possible that the aggregation in Disko Bay is being visited by whales at longer intervals than the nine year period covered by the sampling at this locality, or possibly some reproductive stages of whales visited and left West Greenland before the samples were collected. 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 (Larsen and Hammond 2004, Smith *et al.* 1999) based on a population of about 1000 humpback whales summering off West Greenland (Heide-Jørgensen *et al.* in review). This high rate of re-identifications occurred despite the fact that the humpback whales were spread out over a much larger area of the West Greenland coast (62°-66° N) than the bowhead whales sampled in this study.

The picture of widespread and long-term redistribution of whales in both putative stocks which emerges from this limited sample of genetic re-identifications is also confirmed by studies using satellite tracking to document movements of individuals from different focal areas across the range. In 2009, 27 bowhead whales were tagged in Disko Bay. Four of these whales crossed the borders for the spatial delineation of the HB-FB stock and the BB-DS stock (GINR unpublished data, Fig. 3). The two stocks are supposed to be separated by Fury and Hecla Strait in northern Foxe Basin and the Hudson Strait. In reality, this strait formed no barrier to whales and their movements were not restricted. Similar movements of the whales were also recorded in earlier satellite tracking studies in the area (cf. Heide-Jørgensen *et al.* 2008).

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Table 1. Sampling periods, number of individuals identified, number of re-identifications within area/year, number of individual males and females sampled each year, number of re-identifications between years, and number of re-identifications between areas of bowhead whales sampled in Eastern Canada and West Greenland 1995 - 2009.

Area/Year	Range of dates	Individuals identified	Re-identifications within area and year	Individual males	Individual females	Re-identifications within areas in later years	Re-identifications between areas				
							Disko Bay	Pelly Bay	Foxe Basin	Repulse Bay	Cumberland Sound
Disko Bay											
2000	22-28/4	7	0	5	2	1M (2007)					
2001	28/4-8/5	15	3	5	7	1F (2007) 1M (2009)					
2002	4/5-13/5	10	0	4	6						
2003	4/5-18/5	11	1	0	10						
2004	6/5	1	0	0	1						
2005	11/3-3/5	24	0	6	18						
2006	15/4-6/5	24	4	0	20						
2007	10/3-17/5	139	42	18	79	F (2008) 2F (2009)					
2008	20/4-3/6	59	14	10	35	M (2009) F (2009)					
2009	16/2-4/6	69	15	19	35						
Sum		359	79	67	213	8					
Pelly Bay											
2000	September	1	0	1	0						
2001	September	1	0	0	1						
2002	September	5	0	4	1						
Sum		7	0	5	2						
Foxe Basin											
1995	August	11	0	3	8	1F (2002)					
1996	4-6/7	13	0	7	6						
1997	August	2	0	0	2						
2001	30 /6-6/7	39	1	21	17	1F (2002) 1M (2002)					
2002	1-15/7	63	2	32	29						
2003	August	30	0	9	21						1F (2006)
2007	July	34	2	17	15						
Sum		192	5	89	98	3					
Repulse Bay											
1995	September	1	0	1	0						
1997	Aug.-Sept.	6	3	1	2	1F (2000)					
1998	September	4	0	3	1	1M (2000)					1F (2006)
2000	September	4	0	1	3						1M (2006)
2001	September	3	0	3	0						
Sum		18	3	9	6	2					
Cumberland Sound											
1997	June to August	21	2	13	6						
2002	June to August	7	1	2	4						
2004	June to August	7	0	3	4						
2005	June to August	14	1	8	5						
2006	June to August	22	0	12	10						
Sum	June to August	71	4	38	29	0					

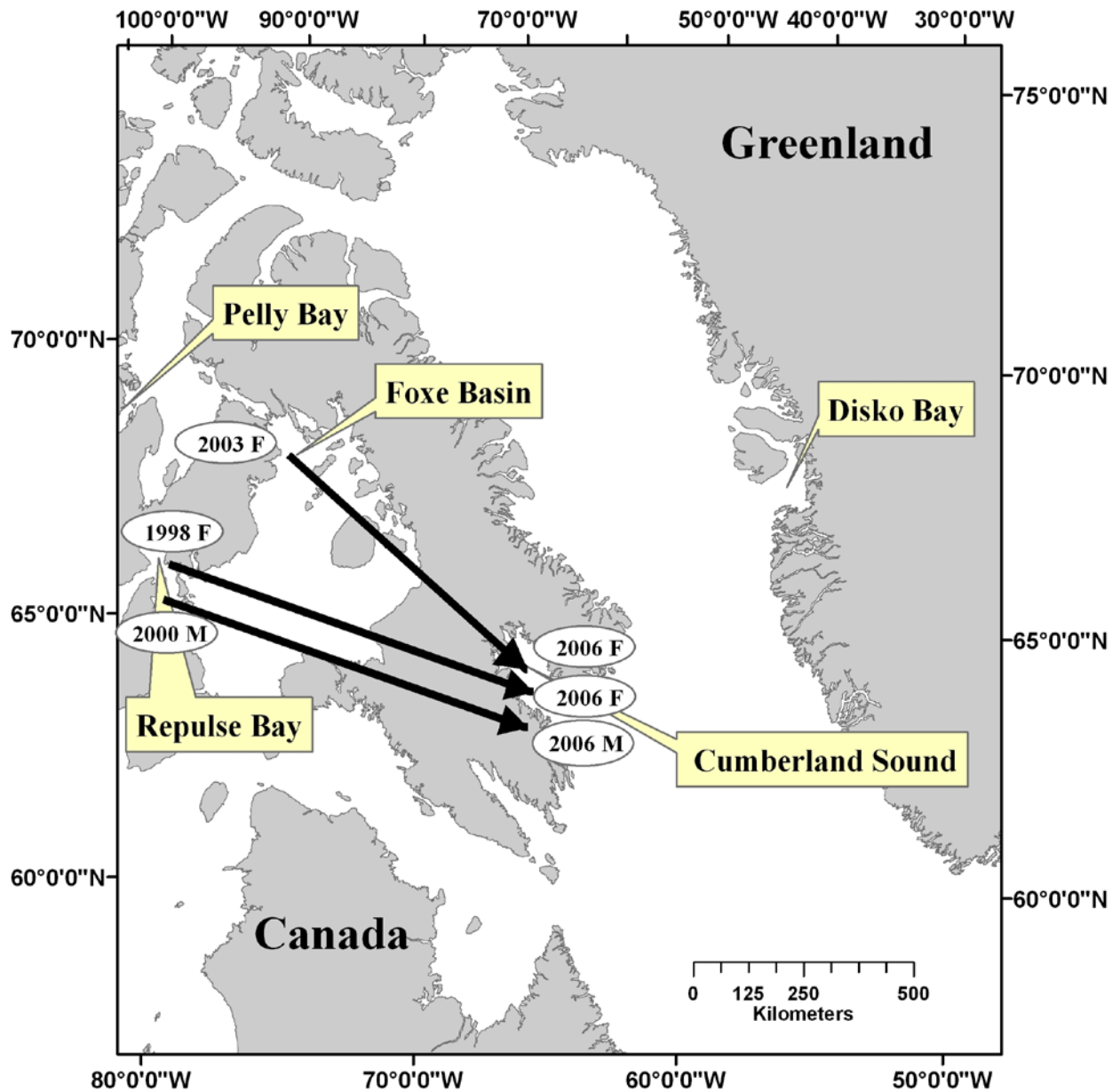


Fig. 1. Map of the localities where the bowhead whales were sampled and the three re-identifications females at each of these localities.

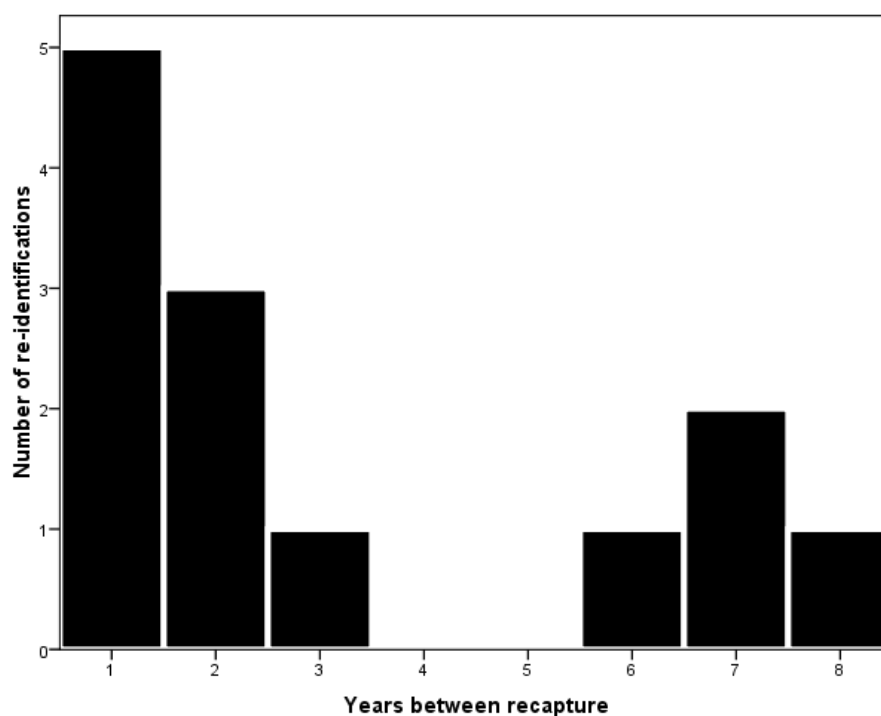


Fig. 2. Re-identifications between years at same localities (Disko Bay, Foxe Basin and Repulse Bay) of bowhead whales sampled in Eastern Canada and West Greenland 1995 – 2009.

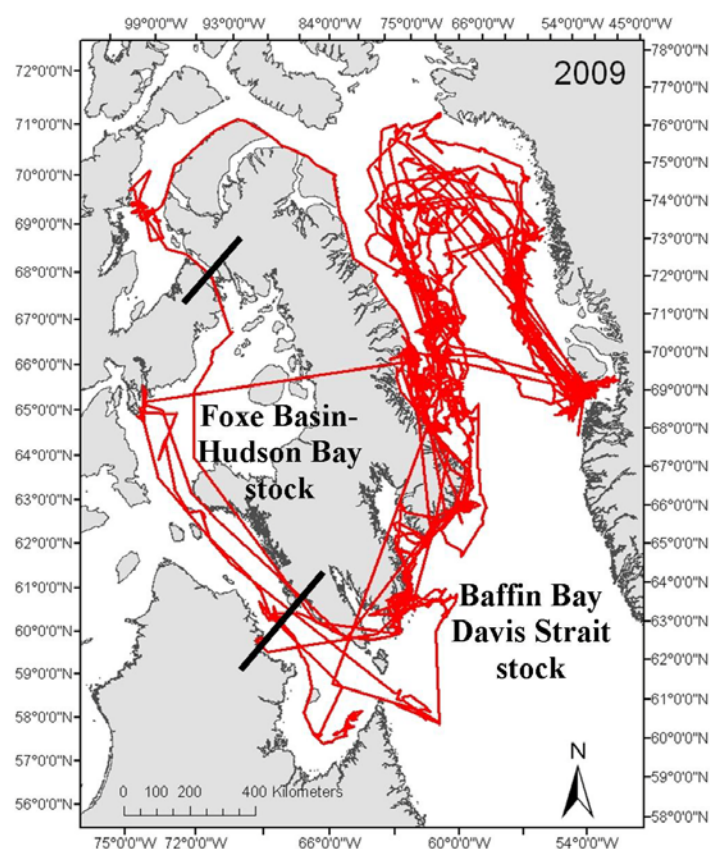


Fig. 3. Satellite tracking of 20 bowhead whales instrumented in Disko Bay in April-May 2009 (GINR unpublished data). The presumed delineation between the Hudson Bay-Foxe Basin stock and the Baffin Bay-Davis Strait stock is indicated by the two bold lines.