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Numbers of Bowhead Whales (*Balaena mysticetus*) in the Eastern Canadian Arctic, based on aerial surveys in August 2002, 2003 and 2004

Nombre de baleines boréales (*Balaena mysticetus*) dans l'est de l'Arctique canadien, d'après les relevés aériens d'août 2002, 2003 et 2004

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ABSTRACT

In 2002, a three year program was begun to fly line transect surveys of bowhead whales summering in the Canadian eastern Arctic. The goals of the survey were to estimate numbers in both the putative Davis Strait-Baffin Bay (DS-BB) and Hudson Bay-Foxe Basin (HB-FB) stocks and to develop a better understanding of the summering distribution of these whales. In 2002, bowheads thought to belong to the DS-BB stock, were surveyed in Eclipse Sound, Prince Regent Inlet and Gulf of Boothia. In 2003, surveys were flown in southern Gulf of Boothia, Foxe Basin and northwestern Hudson Bay to estimate numbers in the putative HB-FB stock. A second 2003 survey estimated numbers of DS-BB whales summering along the east coast of Baffin Island. In 2004, Eclipse Sound and Admiralty Inlet were re-surveyed and parts of Barrow Strait were surveyed. Surface counts of bowheads were analyzed in DISTANCE and adjusted for whales not seen because they were diving. Adjustment factors for diving animals were derived using data collected from whales monitored with satellite-linked tags. An estimated 7,309 (95% CI = 3,161-16,900) bowheads occupied Eclipse Sound, Prince Regent Inlet and Gulf of Boothia in 2002. In 2003, 1,828 (95% CI = 940-3,554) bowheads were estimated in Admiralty Inlet and along the east coast of Baffin Island and an estimated 981 (95% CI = 319-3,018) whales occupied the southern Gulf of Boothia, Foxe Basin and northwestern Hudson Bay. Few whales were seen in the areas covered during the 2004 survey; not enough to produce an estimate. Recent results of satellite tracking studies and genetic analyses are consistent with a single population of bowheads in the eastern Canadian Arctic and west Greenland waters. As a result of this and to limit the possibility of counting individuals more than once, surveys results were not combined between years. The best partial estimate from the combined bowhead population is 7,309 (95% CI = 3,161-16,900). This is considered a partial estimate because it covered the Prince Regent Inlet-Gulf of Boothia-Eclipse Sound (PRI-GoB-ES) survey area, which is only part of the known summer range.

RÉSUMÉ

En 2002, un programme triennal de relevés aériens a été amorcé, consistant à survoler des transects afin de dénombrer les baleines boréales qui passent l'été dans l'est de l'Arctique canadien. Les relevés visaient à estimer le nombre, aussi bien du stock présumé du détroit de Davis-baie Baffin (DD-BB) que de celui de la baie d'Hudson et du bassin Foxe (BH-BF), afin de mieux comprendre la répartition de ces cétacés pendant l'été. En 2002, des baleines que l'on croyait appartenir au stock DD-BB ont été observées dans le détroit d'Éclipse, dans l'inlet Prince-Régent et dans le golfe de Boothia. En 2003, les relevés ont été effectués dans le sud du golfe de Boothia, dans le bassin Foxe et dans le nord-ouest de la baie d'Hudson afin d'estimer le nombre d'individus du stock présumé BH-BF. Un deuxième relevé entrepris en 2003 a permis de dénombrer les baleines du stock DD-BB passant l'été le long de la côte est de l'île Baffin. En 2004, on a repris le relevé du détroit d'Éclipse et de l'inlet de l'Amirauté, et entrepris celui de certaines parties du détroit de Barrows. Le nombre des baleines observées en surface a été analysé avec DISTANCE et rajusté pour tenir compte des baleines invisibles, parce qu'elles étaient alors en plongée. Les facteurs de rajustement pour les animaux en plongée ont été établis à partir de données recueillies à l'aide de baleines marquées avec des enregistreurs de plongée à liaison satellite. On a estimé que 7 309 (IC de 95 % = 3 161–16 900) baleines occupaient le détroit d'Éclipse, l'inlet Prince-Régent et le golfe de Boothia en 2002. En 2003, 1 828 (IC de 95% = 940–3 554) baleines auraient occupé l'inlet de l'Amirauté et la côte est de l'île Baffin, tandis que 981 (IC de 95 % = 319–3 018) baleines occupaient le sud du golfe de Boothia, le bassin Foxe et le nord-ouest de la baie d'Hudson. Peu de baleines ont été observées dans les zones ciblées au cours du relevé de 2004, du moins pas suffisamment pour produire une estimation. Les résultats des récentes études à l'aide d'enregistreurs à liaison satellite et d'analyses génétiques correspondent à la théorie d'une seule population de baleines boréales dans les eaux de l'est de l'Arctique canadien et de l'ouest du Groenland. Par suite de cette constatation, et pour limiter le risque de compter plus d'une fois les mêmes individus, les résultats des relevés n'ont pas été combinés d'une année à l'autre. La meilleure estimation partielle de la population combinée de baleines boréales est de 7 309 (IC de 95 % = 3 161–16 900). On qualifie cette donnée d'estimation partielle parce qu'elle englobe la zone de relevé de l'inlet Prince-Régent, du golfe de Boothia et du détroit d'Éclipse, qui ne représente qu'une partie de l'aire d'été connue de ce stock.

INTRODUCTION

After examining available whaling records and data on distribution and migration patterns of bowheads whales in the eastern Canadian Arctic and west Greenland waters, Mitchell and Reeves (1981), Reeves and Mitchell (1990) and Reeves *et al.* (1983) suggested that Davis Strait-Baffin Bay (DS-BB) and Hudson Bay-Foxe Basin (HB-FB) bowheads may consist of two stocks (Figure 1). The designation was provisional because the data were equivocal as to whether these whales belonged to one or two stocks. By back calculating from the numbers of whales removed by commercial whaling, Mitchell and Reeves (1981) estimated the original size of the DS-BB group to have been about 11,000 whales and that of the HB-FB group to be about 700 whales. Mitchell and Reeves (1981) suggested that, at the end of commercial whaling, the BB-DS whales numbered only a few hundred whales and the HB-FB whales numbered perhaps only tens of animals. In view of the low estimates, it was prudent at the time to accept the provisional designation of two stocks for conservation reasons. In 1980, bowhead whales in the eastern Canadian Arctic were listed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) because numbers were deemed to be small and no evidence of population recovery was available.

Based on aerial surveys of HB-FB whales in 1994 and 1995, an estimated 270 whales (95% CI= 210-331) were aggregated in northern Foxe Basin (Cosens *et al.* 1997, DFO 1999) and another 75 (95% CI= 17-133) in Roes Welcome Sound and Repulse Bay (Cosens and Innes 2000). These estimates were only for whales seen at the surface and sighting data were not extrapolated beyond the survey area, thus estimates were considered to be negatively biased and not an estimate of total stock size. The only available estimate for DS-BB whales was derived by Zeh *et al.* (1993) from mark-recapture data from Isabella Bay and partial surveys. Their estimate of 350 whales was also considered to be conservative.

In 2002, a three year program was begun to survey the summering range of bowheads in the Canadian eastern Arctic. The goals of the survey were to estimate numbers in both the DS-BB and HB-FB portions of the population and to develop a better understanding of the summering distribution of these whales. Based on the delineation of stocks by Mitchell and Reeves (1981), it was assumed that any whales surveyed in Eclipse Sound, Prince Regent Inlet and Gulf of Boothia would belong to the DS-BB stock, while those surveyed in Hudson Bay and Foxe Basin would belong to the HB-FB stock. Coverage of the DS-BB whales, surveyed in 2002, 2003 and 2004 was based on whaling records and satellite-linked tracking data from whales tagged off the west coast of Greenland (Heide-Jørgensen *et al.* 2003). Coverage of the HB-FB whales was based on previous surveys (Cosens *et al.* 1997; Cosens and Innes 2000) and satellite-linked tracking data collected in 2002 (Dueck *et al.* 2006).

While the surveys were designed under the presumption of two stocks, recent results of satellite tracking and genetics studies indicate a lack of support for the two-stock hypothesis (Postma *et al.* 2005; Heide-Jørgensen *et al.* 2006; Dueck *et al.* 2006). It appears that a single stock ranges throughout the Canadian Eastern Arctic and West Greenland. The results of the surveys reported here estimate the abundance of bowheads from the single stock.

METHODS

Data collection

Aerial surveys were conducted in 2002-2004 using a de Havilland Twin Otter aircraft, from an altitude of about 1100 feet and an approximate flight speed of 120 knots (215 kph) with two observers on each side of the aircraft. In 2002, surveys were flown in Eclipse Sound, Prince Regent Inlet, Gulf of Boothia and Committee Bay from 5 to 12 August (Figure 2). In 2003, two simultaneous surveys were done (Figure 3). Whales in the southern Gulf of Boothia, the west side of Foxe Basin and northwestern Hudson Bay, were surveyed from 7 to 15 August 2003. A survey conducted from August 7-17 covered Admiralty Inlet and the east coast of Baffin Island. In 2004, surveys were conducted in Eclipse Sound, Admiralty Inlet and Barrow Strait (Figure 4, Table 1).

All surveys were designed as line-transect surveys. Transect spacing varied from 23.5 to 55.3 km, depending on the size of the area to be sampled and available funding in different years (Table 1). Each of the four observers recorded vertical angles to whale sightings using a Suunto clinometer and recorded species, number of animals and, if possible, age class, behavioural and other information. Three age classes were estimated by observers: calf, juvenile and adult. All observations were recorded simultaneously on an eight-track Roland VS-1824 24-bit digital studio workstation. All marine mammal sightings were recorded but only results for bowheads are included in this report. At least two experienced observers recorded ice, wind and sky conditions during the survey as well. A crew chief oversaw aircraft movements, navigational data logging system and operated the recording system to ensure that survey lines were being correctly flown and that all observers were being properly recorded.

A real time navigational data logging system, custom-made by Midwest Avionics, Winnipeg, with Labview software (National Instruments) was used to continuously record aircraft location, altitude and time of day to facilitate determination of sighting locations and times during analysis. Real time measurements of altitude were taken with either a GPS system positioned in the cockpit (2003 HB-FB survey) or a radar altimeter mounted on the outside of the aircraft (2002, 2003 DS-BB surveys). The aircraft pressure altimeter was calibrated with the GPS reading before flight, checked during the flights and adjusted, if necessary. Data from the tracking system were recorded every two seconds and logged into a Dell Latitude Cpi laptop computer. OziExplorer 3.95.3b software (<http://www.ozexplorer.com/>) generated a real time map showing locations and altitudes during the flight.

Data Analysis

Surveys were analyzed as line-transect surveys using the Conventional Distance Sampling engine of Distance 4.1. The parameters estimated by Distance for each survey were: detection probability, effective strip width (ESW) (in m), average cluster size, expected cluster size, estimated density, and whale abundance. The most appropriate model for estimating the ESW was selected by the software by minimizing the Akaike Information Criteria. Since sighting data indicated that few whales were seen within 200 m of the aircraft during any of the three surveys because of the flat windows (Figure 5), all sighting records for 0 to 200 m were omitted from the analysis and the ESW was calculated using only sightings beyond 200 m on either side of the aircraft.

For both the 2002 Prince Regent Inlet-Gulf of Boothia-Eclipse Sound (PRI-GoB-ES) and 2003 Admiralty Inlet-Baffin Island (AI-BI) surveys, individual survey blocks (Eclipse Sound, Prince Regent Inlet, Gulf of Boothia, Admiralty Inlet, Baffin Island) were treated as separate *strata* within the total survey area for the presumed stock. The 2003 GoB-FB-HB survey produced relatively few sightings so all results from individual survey blocks were pooled and estimates were done for the entire survey. With relatively few sightings, the ESW was estimated from sightings from all strata.

Adjustment of estimates for diving whales

Dueck *et al.* (2005) collected dive data from three bowheads summering in Prince Regent Inlet during August 2003. Data were collected on one female (13 m) with a calf, one male (13 m) and one female (12 m) without a calf. Surface times, defined as time spent at or above 4 m, were derived from these data and used to adjust survey estimates for whales that were submerged and not counted by survey observers. On average, tagged whales spent 0.35, 0.22 and 0.20 of their time at or above 4 m, for the female/calf, male and single female, respectively. The pooled average proportion of time at the surface for the week of August 9 was 0.253 (95% CI = 0.17-0.33). Based on these estimates, approximately one quarter of the total whales in the survey area were, on average, at the surface and available to be counted thus surface estimates of abundance were multiplied by 3.95.

RESULTS

2002 – Eclipse Sound, Prince Regent Inlet and Gulf of Boothia

In Eclipse Sound, bowhead whales were seen on only one of seven transects (Figure 2). A total of five groups of bowhead whales were seen at the surface on this survey, along the west side of the sound and in Milne Inlet. All whales sighted on this transect were described as sub-adults. The total estimate for this survey stratum was 465 surface whales (CV=59%).

In Prince Regent Inlet, a total of 12 groups of bowhead whales were sighted on seven of 18 transects (Figure 2). Due to a navigation error, transect 13 was completed out of sequence. Poor weather prevented coverage of lines 12 and 14. An estimated 1382 surface whales (CV=44%) were aggregated in Prince Regent Inlet and Gulf of Boothia at the time of the survey. Of 12 whales that were identified to age class, four were recorded as adults and eight as sub-adults. The pooled estimate for the total survey area was 1847 surface whales (CV=41%; Table 2).

2003 – Southern Gulf of Boothia, Foxe Basin and Northwestern Hudson Bay

Due to relatively few whale sightings in 2003, southern Gulf of Boothia, Foxe Basin and northwestern Hudson Bay were treated as a single *stratum* and the analysis performed for the total survey area (Table 2). Four transects were surveyed in Gulf of Boothia and one in Fury and Hecla Strait (Figure 3). Fifteen transects were flown in Foxe Basin to cover the northern portion where the summering aggregation was surveyed in 1994 (Cosens *et al.* 1997) and the coastal area down to Southampton Island (Figure 3); eleven transects were completed on August 10 and the remaining 5 transects were flown on August 11. In northwestern Hudson Bay (Figure 3), 15 transects were flown in Repulse Bay, Frozen Strait, Roes Welcome Sound and the coastal area as far south as Whale Cove. Transects 1 through 4 were flown twice on two separate days. Wind conditions were at Beaufort 4 to 7 (15 gusting to 30 knots) on August 12 when these transects were first done but had declined below 10 knots (Beaufort 2-3) by August 13 when transects were redone. Transects 5 through 7 were also completed on August 13. Bowheads were not seen on transect either day but one off-transect sub-adult whale was sighted in Repulse Bay during the return flight on August 12. The remaining eight transects were completed on August 15.

One sub-adult bowhead was seen on the northernmost transect in the southern Gulf of Boothia, near Fury and Hecla Strait. An additional sub-adult and two adult whales were seen in Fury and Hecla Strait (Figure 3). In Foxe Basin, a total of six whales were sighted on transects 1, 6, 7, 8 and 14, but no information on age classes for these whales was obtained. There were no whales sighted on transect in northwestern Hudson Bay; a single sub-adult whale was sighted off-transect. Based on these sightings, an estimated 248 surface whales (CV=46%) were present in the southern Gulf of Boothia, Foxe Basin and northwestern Hudson Bay strata (Table 3).

2003 – Admiralty Inlet and East Baffin Island

Admiralty Inlet and the east coast of Baffin Island were treated as a single survey *stratum* (Table 3). Tagging data (Heide-Jørgensen *et al.* 2003) has shown that individual whales may occupy both areas within a single season. The survey of Admiralty Inlet also included Elwin Inlet, Baillarge Bay, Adam's Sound and Moffat Inlet. Along the east coast of Baffin Island (Figure 3), major fiords as well as coastal transects were included in the survey. A total of 18 groups of bowhead whales were sighted on transect. Based on these sightings, an estimated 462

(CV=30%) whales were present in Admiralty Inlet and along the east coast of Baffin Island (Table 3).

2004 – Eclipse Sound, Admiralty Inlet and Barrow Strait

Eclipse Sound and Admiralty Inlet were re-surveyed in 2004 and Barrow Strait was surveyed for the first time. A group of three bowheads were sighted at the south end of Milne Inlet (Figure 4). Not enough whales were seen to produce a reliable estimate.

Abundance Estimates

Estimates of abundance, adjusted for diving animals indicate that in 2002 there were 7,309 (CV= 45%; 95% CI = 3161-16,900) bowheads in the pooled survey regions of Eclipse Sound, Prince Regent Inlet and Gulf of Boothia (Table 3). In 2003, an estimated 1,828 (CV= 35%; 95% CI = 940-3,554) bowheads were in Admiralty Inlet and along the east coast of Baffin Island in 2003 and an estimated 981 (CV= 62%; 95% CI = 319-3,018) whales occupied the southern Gulf of Boothia, Foxe Basin and northwestern Hudson Bay.

DISCUSSION

Abundance

The pooled results of the 2002 surveys represents the best current estimate of the number of bowhead whales in the eastern Arctic to date. The estimate of 7,309 bowhead represents 62% of the pre-whaling estimates of 11,700 for the two stocks (Mitchell and Reeves 1981) suggesting a significant degree of recovery for the population.

Estimating population size for such a wide-ranging species using aerial surveys is extremely difficult, and almost always produces estimates that are conservative. Of most significance are the logistical constraints in surveying such a large area in a short time window under suitable survey conditions. For the analysis reported here, the surveys conducted in each year were incomplete and did not represent the entire range of the stock. The nature of aerial surveys is such that some (or portions of) transects are surveyed under conditions of marginal or less than optimal visibility (surface glare, high seas state, fog, pack ice), therefore an unknown proportion of surface bowhead are not detected by observers. A proportion of animals that are present on transect and are visible may also go undetected, even in optimal conditions, due to observer fatigue.

Distribution

The sighting of only a single (off-transect) whale in northwestern Hudson Bay during the survey in 2003 was unexpected. This area was frequented by whales in the 19th century (Ross 1974) and both Repulse Bay and the coastal area south of Wager Bay appeared to be calf-rearing areas (Reeves and Cosens 2003) at that time. Cosens and Innes (2000) estimated about 75 whales in Repulse Bay, Frozen Strait and Roes Welcome Sound in 1995. Ice conditions, however, were

very light during surveys in 2003. In Frozen Strait, ice conditions were about 1/10, in contrast to the 8/10 ice cover that was observed in 1995. Killer whales had also been reported in the area around the time of the 2003 survey. It is possible that the whales normally found in this region had moved further north where ice cover was heavier. It is not clear whether this absence of observed bowhead whales is linked to limited ice cover in northwestern Hudson Bay. If a link exists, and ice cover is reduced as a result of climate change, then a shift in distribution may persist, especially if killer whales become frequent visitors to Repulse Bay.

An unexpected scarcity of bowhead whales was also recorded during the survey of northern Foxe Basin in 2003. From 1994 to 1998 August pack ice was typically present along the islands that form the south side of the channel leading into Fury and Hecla Strait (Cosens *et al.* 1997, Cosens and Blouw 2003) and whales were reliably present north of Neerlonakto Island (north of Igloodik Island) in a relatively well defined area. In 1999, ice cover was absent from this area as were the whales (Cosens and Blouw 2003). Ice cover was also absent from northern Foxe Basin during the 2003 survey and only two whales were seen on transect in northern Foxe Basin. However, the survey design in 2003 differed from that in 1994 so the distribution and number of whales seen in the two surveys is difficult to compare. Only one transect in the 2003 survey covered the area where bowhead were seen in previous years, and so the scarcity of recorded bowhead whales may be due to less survey coverage relative to previous surveys in 1994 to 1998. The two whales seen on line 1 in 2003 were in the same area as had been sampled in 1994 to 1999. Based on the results of surveys analyzed in this paper, numbers appear to be lower in this area than have been seen in previous years suggesting that distribution may have changed. It is possible that a higher proportion of these whales moved through Fury and Hecla Strait to areas where heavy ice is present. Satellite-linked tracking data from 2002 have shown that whales may also move south out of northern Foxe Basin toward Southampton Island (Dueck *et al.* 2006) during the open water season.

Movements and distribution can be variable from one year to the next. The 2004 survey of Admiralty Inlet produced no sightings of bowheads. This area had been occupied by bowheads in 2003. This result suggests that any surveys done in different areas to monitor recovery of the population should be completed within one season. Differences in animal distribution and survey conditions from one year to the next suggest that surveys of known aggregation areas over several years may be needed to reduce the uncertainty about numbers present.

Movement of whales into Prince Regent Inlet from northern Foxe Basin and Baffin Bay also complicates interpretation of aerial surveys of the population. It may never be possible to obtain accurate estimates of the numbers of bowhead whales in the eastern Arctic, unless the range is covered by many planes simultaneously and in a short period of time. At present, the best coverage we could obtain in a short period of time is the coverage of the PRI-GoB-ES strata in 2002, which resulted in the estimate of 7,309 bowheads.

Aerial surveys done in the 1970s and 1980s (Davis and Koski 1980, Finley and Johnston 1977, McLaren and Davis 1982) of bowheads in the eastern Arctic encountered few whales but likely substantially underestimated the numbers present. These surveys did not focus on key summering areas such as central Prince Regent Inlet, Gulf of Boothia, northern Foxe Basin and the east coast of Baffin Island. Although Isabella Bay has been identified as an aggregation area for bowheads during the fall migration (Finley 1990), there were no dedicated surveys along the Baffin Island coast to search for summering animals. Thus, the substantial increase from a few hundred to over 7000 animals is likely, in part, attributable to underestimates of abundance by earlier work.

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Table 1. Survey coverage in various survey blocks in 2002 and 2003.

Survey Block	Date Surveyed	Area (km²)	Transect Spacing (km)
Eclipse Sound (ES) and ES Bays and Fiords (ESB)	5 Aug 2002	5,915 (ES) + 1,810 (ESB)	28.4 (ES) 1 line per bay (ESB)
Prince Regent Inlet (PRI) and Gulf of Boothia (GoB)	9, 11-12 Aug 2002	87,195 (PRI + GoB)	28.4
Southern Gulf of Boothia (GoB) and Fury and Hecla Strait (FH)	7 Aug 2003	29,763 (GoB) + 295 (FH)	33.0 (GoB) 1 line (FH)
Foxe Basin (FB)	9-11 Aug 2003	38,537	33.0
NW Hudson Bay (HB)	12-15 Aug 2003	33,436	33.0
Admiralty Inlet (AI)	11 Aug 2003	10,527	23.5
East Baffin Island coast and bays (BI)	7-17 Aug 2003	53,779 (coast) 14,831 (bays)	55.3 (coast) 1 line every two bays (bays)

Table 2: Near-surface estimates of bowhead whale numbers from line transect surveys (note: CVs shown in parentheses).

Region	Date	# lines	Effort (km)	Detection function*	ESW (m)*	Sightings	Sighting rate	E(S) **	Estimate (CV)
2002									
Eclipse Sound (ES)	5 Aug -2002	6	195	Hazard rate	259 (77%)	5	0.26 (49%)	1.6 (13%)	465 (59%)
Pond Inlet area bays and fiords	5 Aug 2002	6	342	Hazard rate	259 (77%)	0	0	0	0
Prince Regent Inlet – Gulf of Boothia (PRI-GoB)	9,11-12 Aug 2002	18	2324	Hazard rate	259 (77%)	12	0.52 (29%)	1.6 (13%)	1,382 (44%)
ES-PRI-GoB		-	-		-	-	-	-	1,847 (41%)
2003									
Gulf of Boothia (GoB), Foxe Basin (FB), Hudson Bay (HB) pooled	7-15 Aug 2003	36	3778	Uniform	600	10	0.27 (45%)	1.1 (9.1%)	248 (46%)
Admiralty Inlet (AI) Baffin Island (BI) pooled	11 Aug 2003 (AI) 7-17 Aug 2003 (BI)	42	2570	Uniform	800	18	0.70 (28%)	1.3 (11%)	462 (30%)

* Detection function and effective strip width (ESW) estimated for sightings of all strata because of low sample size.

** E(S): estimated pod size (SE)

Table 3. Abundance estimates of bowhead whales corrected for time spent at the surface.

Area Parameters	PRI-GoB-ES (2002)		GoB-FB-HB (2003)		AI-BI (2003)	
	Estimate	CV	Estimate	CV	Estimate	CV
Surface estimate (N)	1,847	41%	248	60%	462	30%
Proportion available at surface (Pa)	25.3%	18%	25.3%	18%	25.3%	18%
N adjusted for availability bias (Na)	7,309	45%	981	62%	1,828	35%
Confidence limits of Na (alpha = 0.05)	lower	upper	lower	upper	lower	upper
	3,161	16,900	319	3,018	940	3,554

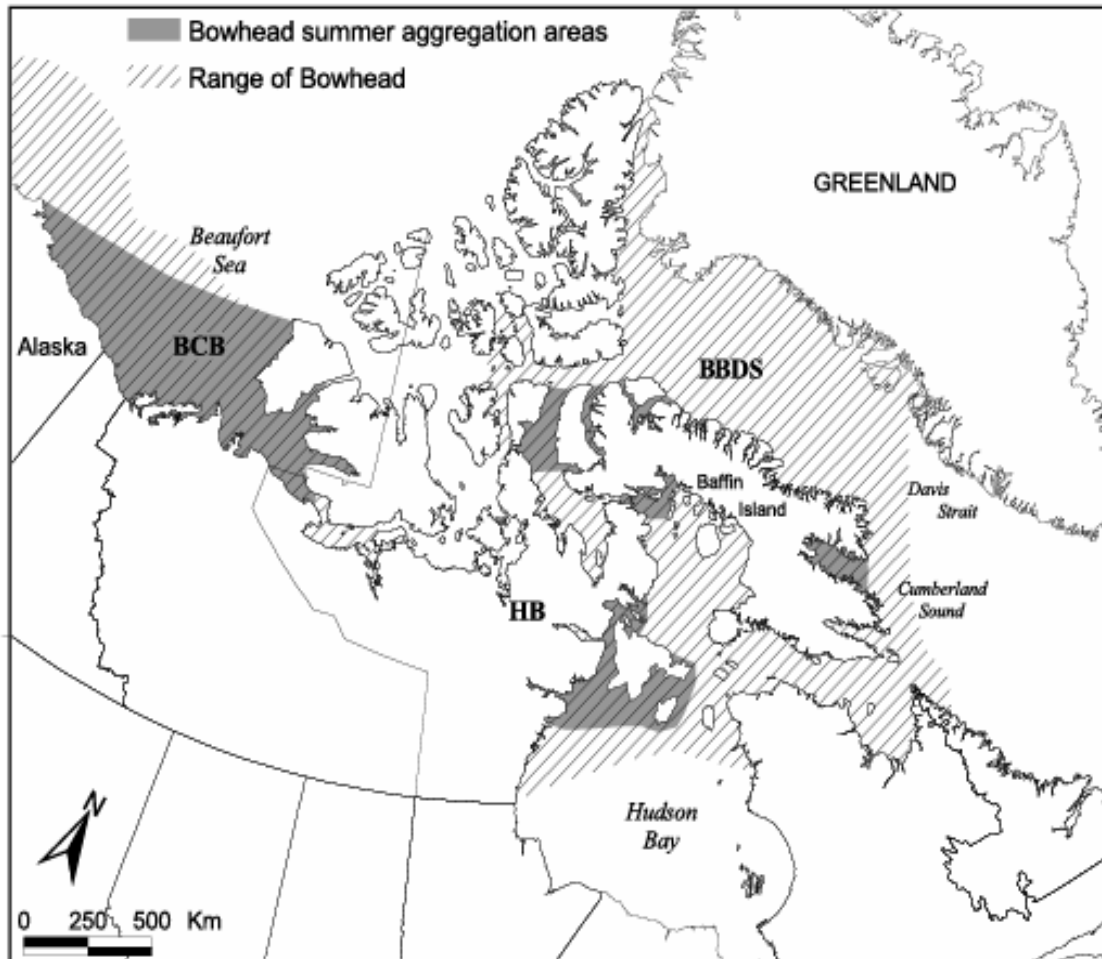


Figure 1. Distribution of bowhead whales in Canada. BCB=Bering-Chukchi-Beaufort, BBDS=Baffin Bay-Davis Strait, HBFB=Hudson Bay-Foxe Basin.



Figure 2. Transect placement and sighting locations of bowhead whales during 2002 survey of Eclipse Sound, Prince Regent Inlet and Gulf of Boothia.

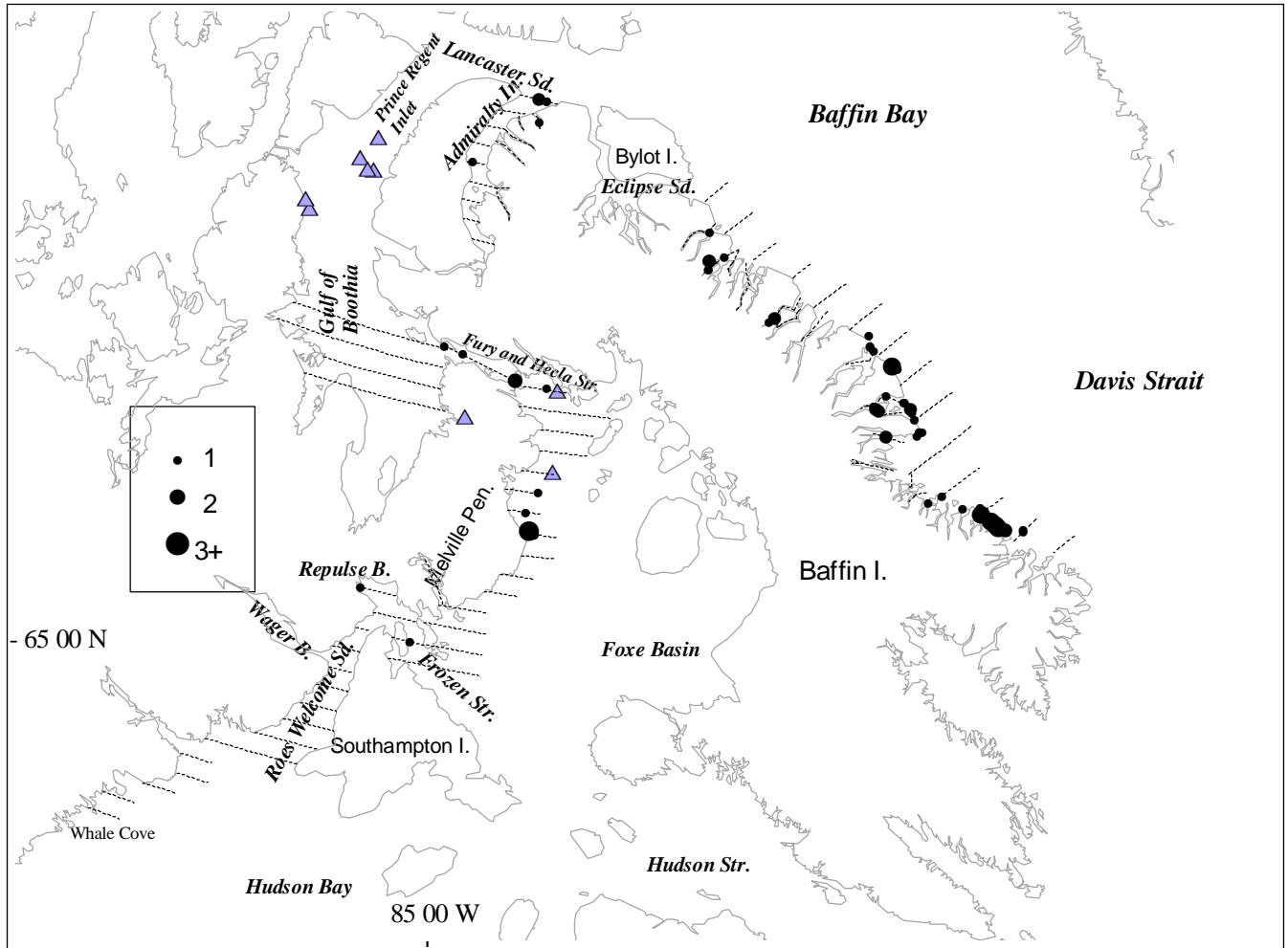


Figure 3. Transect placement and sighting locations of bowhead whales during 2003 surveys of southern Gulf of Boothia, Foxe Basin and northwestern Hudson Bay and Admiralty Inlet and east Baffin Island coast. The sighting locations include sightings of whales that were off-transect. Triangles represent locations of tagged whales in early August (Dueck *et al.* 2006).

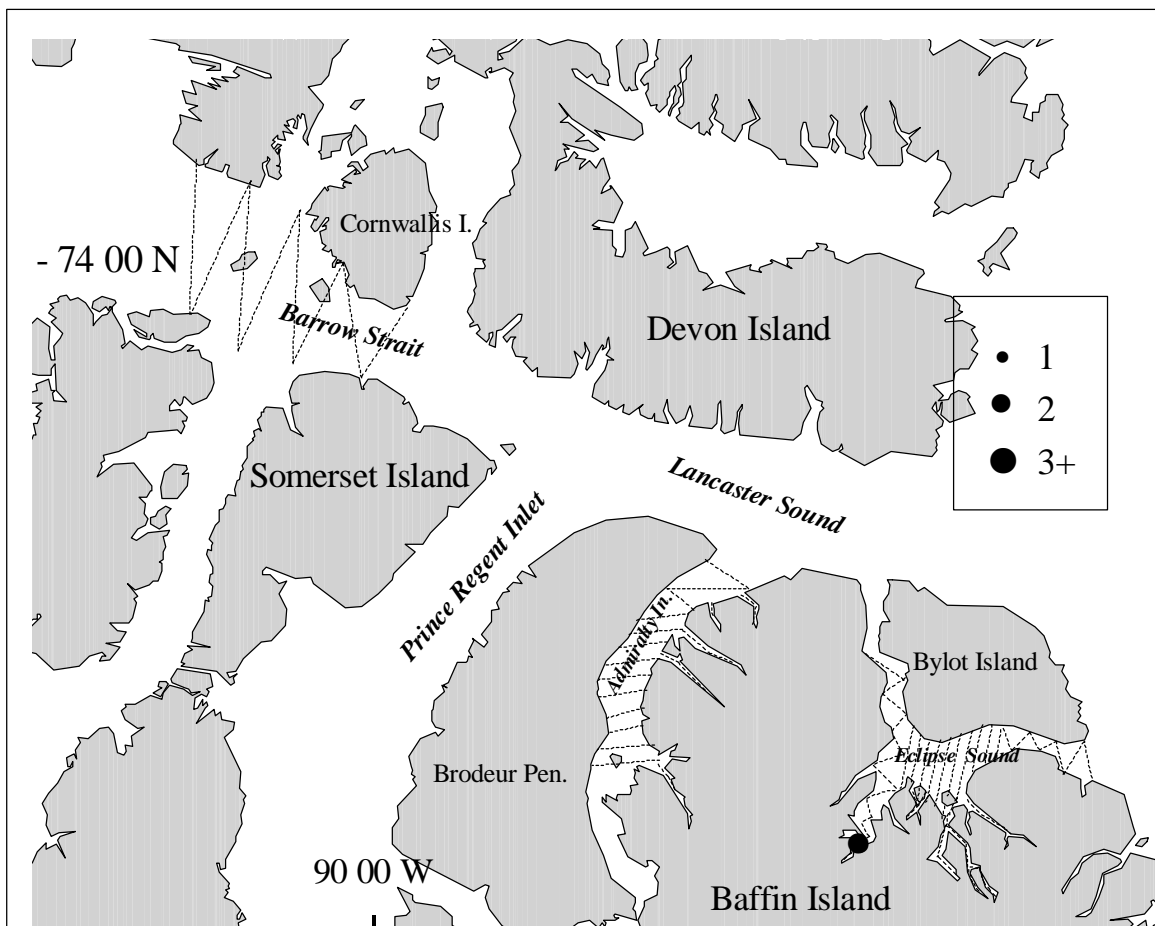


Figure 4. Transect placement and sighting locations of bowhead whales during the 2004 survey of Eclipse Sound, Admiralty Inlet and Barrow Strait.

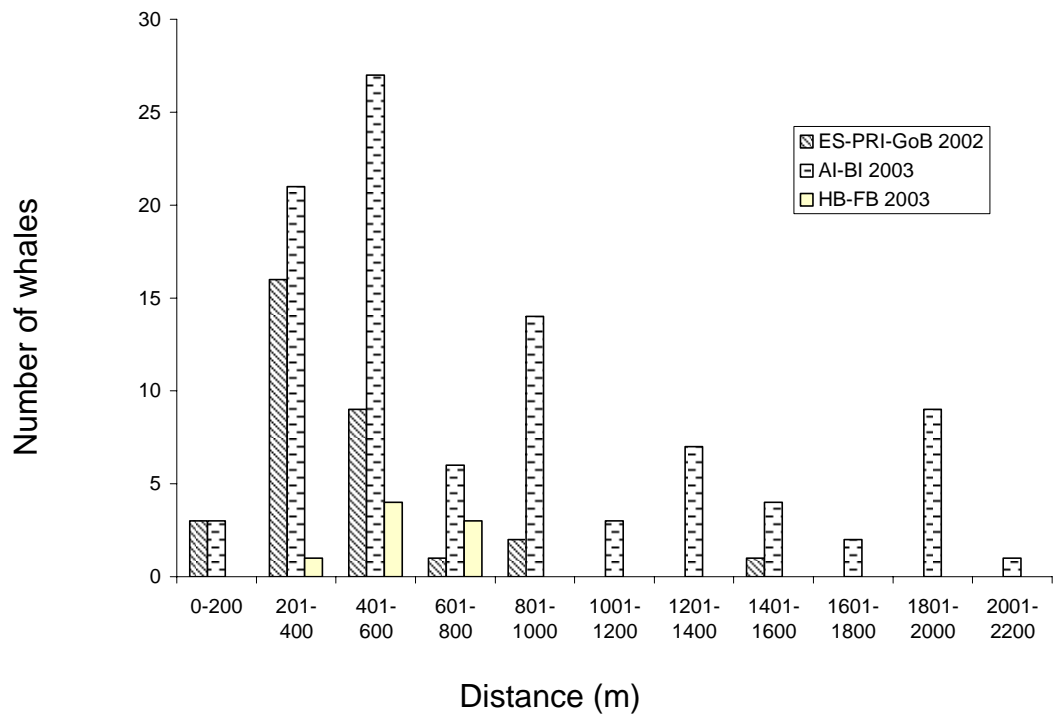


Figure 5. Numbers of whales seen by observers at various distances from the aircraft in each of the three surveys. Solid line diagonal hatching (ES-PRI-GoB in 2002), dotted line horizontal hatching (AI-BI coast in 2003), light shading (GoB-FB-HB in 2003).

Appendix 1. Summary of 2002 Survey Conditions: Eclipse Sound and associated fiords, Prince Regent Inlet and Gulf of Boothia.

Transect No.	Survey Conditions			
	Ice Cover (in tenths)	Sea State	Glare	Sky Conditions
ES 01	0-9	0-1	yes	clear
ES 02	0-10	0-3	yes	scattered
ES 03	0-6	0-2	yes	scattered-overcast
ES 04	0-9	1-3	yes	scattered
ES 05	0	1-2	yes	scattered
ES 06	0-2	0-2	no	overcast
Navy Board Inlet	4-8	0-1	yes	overcast-clear
Tremblay Sound	0-9	0	yes	clear
Eskimo Inlet	0-4	1-3	yes	clear-scattered
White Bay	0-<1	1-3	yes	overcast-scattered
Tay Sound	0-<1	0-1	yes	broken
Paquette Bay	0	0-2	no	overcast
Oliver Sound	0-9	0-1	yes	
PRI 01	0-10	1-3	no	clear-scattered-fog patches
PRI 02	0-3	1-2	yes	broken-scattered-clear
PRI 03	0-4	2-3	no	clear-fog patches
PRI 04	0-9	0-2	yes	overcast-fog patches-clear
PRI 05	0-8	0-2	yes	clear-broken
PRI 06	0-9	0-1	no	overcast-fog patches-scattered
PRI 07	0-9	0-3	yes	scattered-fog patches
PRI 08	0-8	0-3	no	overcast-fog patches-scattered
GoB 09	0-6	0-2	no	broken-scattered-overcast
GoB 10	0-9	0-2	yes	overcast-broken-fog patches
GoB 11	0-7	0-2	no	overcast-fog patches
GoB 13	0-9	0-1	yes	overcast-fog patches
GoB 15	1-8	0-2	no	scattered-overcast-fog patches
GoB 16	2-8	0-1	no	overcast
GoB 17	1-7	0-2	yes	overcast-clear-scattered
GoB 18	0-8	0-1	no	overcast-fog patches
GoB 19	1-8	0	no	overcast-fog patches
GoB 20	0-9	0-1	no	scattered
GoB 21	0	1-3	yes	scattered
GoB 22	0	0-2	yes	clear
GoB 23	0	1-2	yes	clear-scattered

Appendix 2. Summary of 2003 Survey Conditions: Admiralty Inlet and associated fiords, Baffin Island coast and bays.

Transect No.	Survey Conditions			
	Ice Cover (in tenths)	Sea State	Glare	Sky Conditions
AI 01	2-9	0-1	yes	clear-broken-overcast
AI 02	0-<1	1-2	yes	scattered-clear
AI 03	0	1-3	yes	broken-scattered-clear
AI 04	0	1-3	yes	clear/fog patch-scattered
AI 05	0	1-3	yes	scattered-clear
AI 06	0	2-3	yes	clear-scattered-broken
AI 07	0	1-2	yes	scattered
AI 08	0	1	yes	scattered-broken
AI 09	0	1-3	yes	clear-scattered
Elwin Bay	0	1-2	yes	clear
Baillarge Bay	0	1-3	yes	overcast
Strathcona Sound	0	1-3	yes	scattered-clear
Adam's Sound	0	1-2	yes	broken-clear
Moffat Inlet	0	0-3	yes	scattered-overcast-clear
Transect 6 Inlet	0	1-3	yes	scattered-clear
BI 01	0	1-2	yes	broken/fog patch-clear
BI 02	0	0-2	yes	fog-broken
BI 03	0	1-2	yes	scattered/fog
BI 04	0	1-4	yes	overcast
BI 05	0	2-4	yes	scattered
BI 06	0	1-2	yes	scattered-broken
BI 07	0-8	1-4	yes	scattered-broken
BI 08	0	1-2	yes	scattered-clear
BI 09	0	1	yes	clear
BI 10	0	2-5	yes	clear
BI 11	0	4-6	yes	scattered-clear
BI 12	0	4-5	yes	broken-overcast
BI 13	0	2	yes	scattered
BI 14	0	2	yes	clear
BI 15	0	1-2	yes	clear
Coutis Inlet	0-<1	0-1	yes	broken-clear/light fog patch
Buchan Gulf	0-<1	0-2	yes	scattered
Royal Society Fiord	0	0-1	yes	scattered
Scott Inlet	0	0-1	yes	overcast-scattered-broken
Sam Ford Fiord	0	0-1	yes	broken-overcast-scattered
Clyde Inlet 1	0-<1	1-3	yes	scattered-broken
Clyde Inlet 2	0-<1	2-4	yes	scattered-overcast
Clyde Inlet	0	2-5	yes	overcast-broken-fog patch

Summary of 2003 Survey Conditions (continued).

Transect No.	Survey Conditions			
	Ice Cover (in tenths)	Sea State	Glare	Sky Conditions
Isabella Bay	0-<1	1-4	yes	overcast
Home Bay 1	0	1-4	yes	overcast
Home Bay 2	0	2-5	yes	broken
Home Bay 3	0	1-3	yes	scattered-clear
Home Bay 4	0	2-3	yes	broken
Home Bay 5	0	1-3	yes	scattered
Quajon Fiord 1	0	3-4	yes	scattered
Quajon Fiord 2	0	1-2	yes	scattered
Canso Ch 1	0	1-3	yes	clear
Canso Ch 2	0	2-4	yes	clear
Merchants Bay	0	1-2	yes	clear

Appendix 3 . Summary of 2003 Survey Conditions: Gulf of Boothia, Foxe Basin, Hudson Bay.

Transect No.	Survey Conditions			
	Ice Cover (in tenths)	Sea State	Glare	Sky Conditions
GoB 01	7-9	0-1	no	clear-broken-overcast
GoB 02	6-8	0-1	yes	overcast-clear-broken
GoB 03	7-9	0-1	yes	scattered/fog-clear/fog
GoB 04	6-8	0-1	yes	broken-scattered/fog-overcast
FB 01	0	0-1	yes	overcast
FB 02	0-3	0-1	no	overcast/fog
FB 03	0-5	1-3	yes	overcast/fog
FB 04	0-8	1-2	no	overcast/fog
FB 05	0	2-3	yes	scattered-broken
FB 06	0	1-3	yes	clear
FB 07	0-2	0-3	yes	clear-scattered
FB 08	0-2	0-3	yes	clear
FB 09	0	1-3	yes	scattered-clear
FB 10	0	1-3	yes	scattered-broken
FB 11	0	1-3	yes	scattered-broken
FB 12	0	1-2	yes	broken-overcast
FB 13	0-4	1-2	yes	scattered-broken
FB 14	0	1-2	yes	scattered
FB 15	0	1-2	yes	scattered
Lyon Inlet	0	1	yes	broken-overcast
HB 01	0	2-4	yes	scattered-overcast
HB 02	0-4	1-3	yes	overcast-broken
HB 03	0	2	yes	broken-overcast
HB 04	0	2-3	yes	broken
HB 05	0	2-3	yes	overcast-scattered
HB 06	0	2-3	no	overcast/fog
HB 07	0	1-3	no	overcast/fog
HB 08	0	4-5	yes	overcast-scattered
HB 09	0	3-5	yes	clear-scattered
HB 10	0	2-4	yes	clear-scattered
HB 11	0	2-4	yes	clear
HB 12	0	2-4	yes	clear
HB 13	0	2-4	yes	scattered
HB 14	0	2-3	yes	scattered-broken
HB 15	0	1-3	yes	scattered