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Distribution and Numbers of Bowhead Whales (*Balaena mysticetus*) in Northwestern Hudson Bay in August 1995

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ABSTRACT. There is interest among the Inuit of Nunavut in renewing subsistence hunting of bowhead whales. Managing a limited harvest while allowing for stock recovery from commercial whaling requires some estimate of stock numbers. The large geographic range of bowhead whales in the eastern Canadian Arctic precludes cost-effective estimation of total stock size; however, estimates of summer aggregation sizes can be derived from sampling of summering areas. Although these numbers do not represent total stock size, they do provide indicators of the minimum number of bowheads known to be present and may be useful as indices for monitoring stock recovery. A visual aerial survey conducted in northwestern Hudson Bay resulted in an estimate of 75 ± 27.5 (95% Confidence Interval = 17–133) bowhead whales. This estimate is conservative because it was not corrected for submerged whales or for whales that were at the surface but not seen by observers. Most sightings of whales were made in Repulse Bay and Frozen Strait.

Key words: aerial survey, bowhead whale, distribution, northwestern Hudson Bay, stock size

RÉSUMÉ. Parmi les Inuit du Nunavut, on s'intéresse à reprendre la chasse de subsistance à la baleine boréale. La gestion d'une récolte limitée, qui permettrait au stock de baleine boréale de se rétablir des effets de la pêche commerciale, demande qu'on ait une idée du nombre d'individus qui composent cette population. L'ampleur du territoire géographique de la baleine boréale dans l'Arctique canadien oriental écarte la possibilité de réaliser une estimation du nombre total d'individus, qui soit efficace en terme de coûts; il est cependant possible de dériver des estimations de la taille des concentrations estivales à partir d'échantillonnages de zones d'estivage. Bien que ces nombres ne représentent pas la taille totale du stock, ils fournissent des indications sur le nombre minimum de baleines boréales dont on a attesté la présence et ils peuvent servir d'indicateurs pour la gestion du rétablissement du stock. Un relevé visuel aérien mené dans le nord-ouest de la baie d'Hudson a donné une estimation de 75 ± 27,5 (intervalle de confiance de 95 p. cent = 17-133) baleines boréales. Cette estimation est prudente car elle n'a pas été corrigée pour tenir compte des baleines submergées ou de celles qui étaient en surface mais qui n'auraient pas été aperçues par les observateurs. La plupart des observations de baleines ont été faites à Repulse Bay et Frozen Strait.

Mots clés: relevé aérien, baleine boréale, distribution, nord-ouest de la baie d'Hudson, taille du stock

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INTRODUCTION

Summer distribution of bowhead whales (*Balaena mysticetus*) in the eastern Canadian Arctic suggests that at least two stocks are present. One summers in northern Hudson Bay and Foxe Basin and the other in Baffin Bay, Davis Strait, and the waters of the Canadian High Arctic (Reeves et al., 1983; Moore and Reeves, 1993; Cosens et al., 1998). Both stocks were commercially hunted until about 1915 (Ross, 1993; Reeves and Heide-Jorgensen, 1996), by which time their numbers were severely reduced (Mitchell and Reeves, 1982; Reeves et al., 1983; Reeves and Mitchell, 1990; Woodby and Botkin, 1993). Between 1915 and 1951, bowheads were occasionally hunted for both subsistence and commercial use by Canadian and Greenlandic Inuit (Mitchell and Reeves, 1982; Reeves et al., 1983). Commercial hunting in Canada was banned in 1951 (Mitchell and Reeves, 1982). Subsistence hunting continued until 1979, when it was restricted under the Cetacean Protection Regulations of the *Fisheries Act* (Cosens, 1997). In 1996, a limited licensed subsistence hunt was renewed in Nunavut.

Inuit of Nunavut have reported that there are now many more bowhead whales throughout the eastern Canadian Arctic than there were in the 1960s and 1970s (Hay, 1995, 1997). Consequently, they wish to resume their subsistence and cultural use of bowhead whales as specified in their land-claim settlement with the government of Canada (Anonymous, 1993). To support management of a hunt and to ensure that removals do not threaten stock recovery, estimates of population size upon which to base a total allowable removal are needed.

The large geographic range of bowhead whales in the eastern Canadian Arctic precludes both cost-effective

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sampling of all potential habitats and estimating of total stock size for either the Hudson Bay/Foxe Basin or the Baffin Bay/Davis Strait stock. However, bowheads aggregate in relatively well-defined areas to feed during the summer, and several summering areas are typically used by each stock (see Reeves et al., 1983). Estimates of summer aggregation size can be derived from sampling of these summering areas. Although these numbers do not represent total stock size, they do provide indicators of the minimum number of bowheads present and may be useful as indices for monitoring stock recovery.

We used this sampling approach to estimate the size of summering aggregations of the Hudson Bay/Foxe Basin bowhead stock. Two aerial surveys of bowhead whales summering in northern Foxe Basin in August 1994 resulted in estimates of 256 (S.E. = 31.3) and 284 (S.E. = 48.6) whales (Cosens et al., 1997). Even though these surveys did not include northern Hudson Bay, the results suggested the presence of significantly more than the few tens of bowhead whales previously assumed to comprise the northern Hudson Bay/Foxe Basin stock (Reeves et al., 1983; Reeves and Mitchell, 1990; Zeh et al., 1993).

In August 1995, aerial surveys in northwestern Hudson Bay estimated the numbers of bowhead whales summering in the waters near Southampton Island, one of the two main summering areas used by the Hudson Bay/Foxe Basin stock (see Reeves et al., 1983; Reeves and Mitchell, 1990). This paper outlines the methods used and the estimates obtained from these surveys.

METHODS

Aerial surveys conducted from 12 to 17 August 1995 sampled a total area of 70 950 km^2 from Whale Cove to north of Lyon Inlet, Nunavut, Canada (Fig. 1). The survey area covered the expected summer distribution of bowhead whales determined from the historical distribution of commercial catches and sightings (Fig. 2, based on Reeves et al., 1983; see also Reeves and Mitchell, 1990; Moore and Reeves, 1993; Ross, 1993) and the present distribution of sightings, as reported by hunters at consultation meetings in Rankin Inlet and Repulse Bay. The near-shore area between Whale Cove and Southampton Island (Block A) was surveyed using systematic transects spaced 11 km apart, while the offshore area of Block A and the rest of the survey area were surveyed using a 22 km spacing (Fig. 1). The near-shore area of Block A, extending about 70 km out from the coastline, was covered with increased effort because it was a region where large commercial catches of bowhead whales had been made. Systematic transects were oriented perpendicular to the coast to minimize the expected variance by having each transect cover similar types of habitat.

Line-transect survey methods with paired observers were used to estimate the number of whales visible at the surface (Buckland et al., 1993) and the proportion of surfaced whales not seen by the observers (Buckland and Turnock, 1992; Harwood et al., 1996). The survey crew consisted of four observers and a survey coordinator. Before surveying began, each crew member was trained in the goals of the survey, the use of the survey equipment, and the information required about each marine mammal observation. Each observer was supplied with a cassette tape recorder with a time-date stamp feature (Sony TCM-38V or Sony NT-1) for recording observations, a clinometer (Suunto PM/360S) for measuring the declination angle to whales, and a field book for making notes.

One observer and the survey coordinator were from the Department of Fisheries and Oceans, and two consecutive teams of three observers each were recruited from Rankin Inlet and Repulse Bay. Neither of the locally recruited survey teams had previous survey experience. The crew from Rankin Inlet surveyed from Whale Cove to Southampton Island (Fig. 1, Block A), and the crew from Repulse Bay surveyed the rest of the area in Roes Welcome Sound and Frozen Strait (Fig. 1, Blocks B and C). Additional transects, based on community consultations, were flown in Wager Bay, in Duke of York Bay, and along the northeastern coast of Southampton Island (Fig. 1, Block D). The crew from Repulse Bay worked on these additional transects.

The survey was flown in a de Havilland Twin Otter with a four-hour flight range and flat windows. The onboard Global Positioning System (GPS) was used for navigation. Observations were made from an altitude of 462 m (1500 feet) and at a flight speed of 222–259 km/hr (120–140 knots). The survey coordinator sat in the co-pilot's seat and recorded data on aircraft position, time of day, Beaufort sea state, cloud cover, and ice conditions, estimated as percent ice cover (Table 1). Four observers sat in the first and third seats on each side of the plane. The coordinator indicated when transects started and ended and communicated with the observers through headsets connected to the aircraft communication system. To reduce fatigue, observers moved at the end of each transect, in clockwise rotation, to the next seating position. When bowhead whales were sighted, observers were to record the number, declination angle, behaviour, and orientation of the whales relative to the aircraft. Sightings of other marine mammals were also noted.

Too few bowheads were seen to determine the density of bowhead whales using line-transect methods. In addition, over half the observations were recorded without the clinometer reading. Strip-transect methods were therefore applied to estimate the total number of bowheads in the survey area. To account for the area under and near the aircraft obscured by the flat windows, the strip was assumed to start at 0.2 km from the trackline of the aircraft. The outer boundary of the strip was set at 2.4 km, the distance to the furthest whale seen at 11° from the horizontal on transect 38. Thus, the strip was 2.2 km wide on each side of the aircraft for a total strip width (W) of 4.4 km. The seven observations made without clinometer readings were assumed to be within this strip.

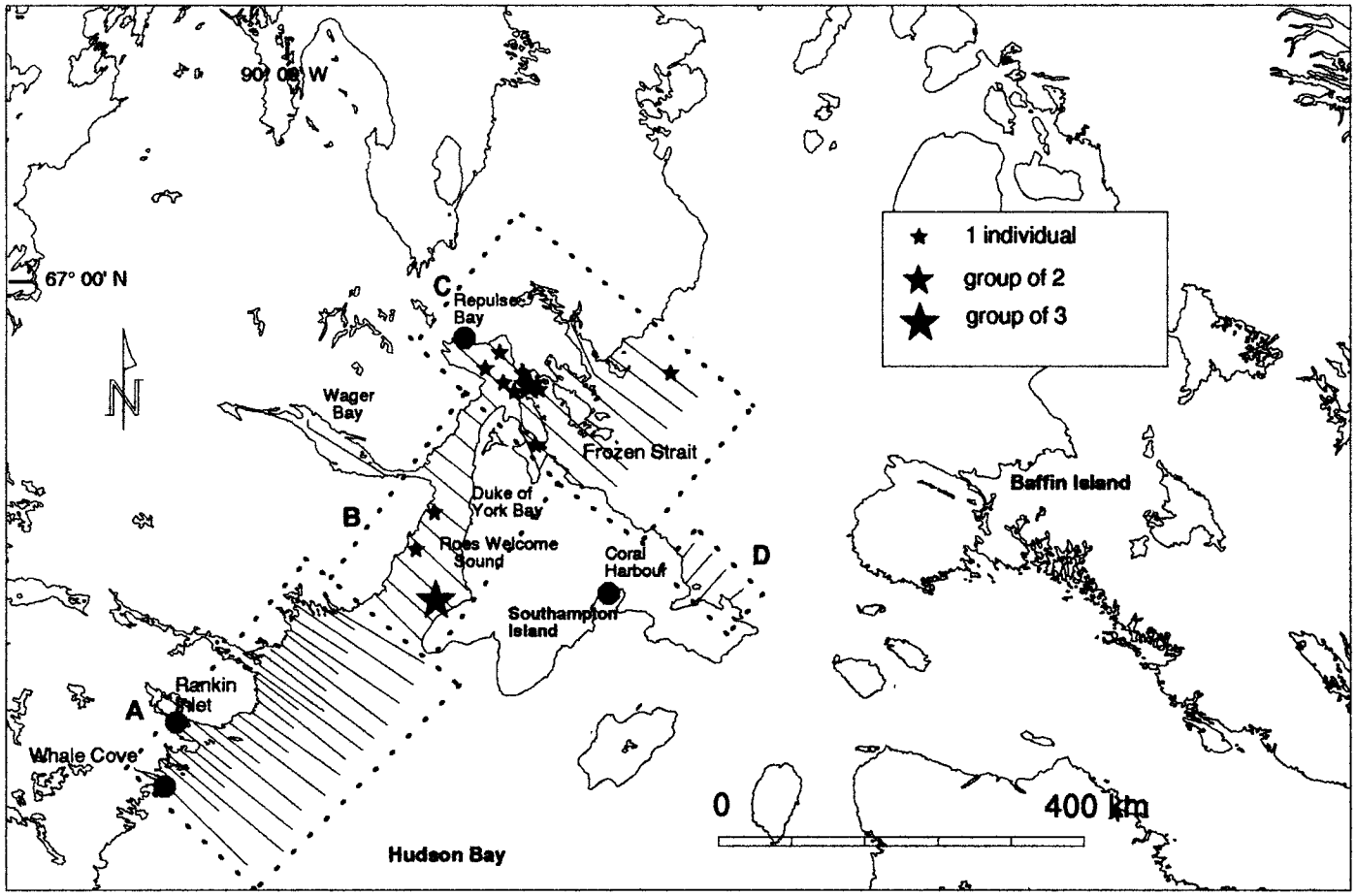

FIG. 1. Survey transects flown and bowheads seen in northwestern Hudson Bay. Block A = Transects 1–25 (12–14 August); Block B = Transects 26–35 (15–16 August); Block C = Transects 36–43 (16–17 August); Block D = Transects 44–47 (17 August). Transects in Wager Bay, in Duke of York Bay, and along the northeastern coast of Southampton Island (Block D) were included after discussions with local communities. Some sightings were close together, so points on the map may overlap.

Sightings were considered to be duplicates if they were made less than one minute apart by observers on the same side of the aircraft and had similar recorded sighting angles. Two such sightings were eliminated from the analysis (see Table 2).

The estimated number of bowheads at the surface in the total survey area was determined by multiplying the total number of whales sighted, summed over all transects, by the increasing factor:

$$k = S/W \qquad (1)$$

where S = transect spacing (i.e., 22 km), and W is the strip width (4.4 km). The estimated number of bowhead whales for the area sampled is thus:

$$\hat{N} = k\sum_{j=1}^{J} x_j \qquad (2)$$

where $\hat{N}$ is the estimated number, J is the number of transects flown in Blocks B and C, and x_j is the number of bowhead whales seen on transect j. The estimates for Blocks A and D were zero, because no bowhead whales were seen in these blocks. The variance of $\hat{N}$ was determined by the serial difference method (Yates, 1960; see Kingsley and Smith, 1981; Stenson et al., 1993; Kingsley, 1996) for systematic surveys adjusted with a finite population correction factor. This estimate is:

$$V_N = k(k-1)\frac{J}{2(J-1)}\sum_{j=1}^{J-1}(x_j - x_{j+1})^2 \qquad (3)$$

Symmetrical confidence intervals were calculated on the basis of Student's t-distribution for J-1 degrees of freedom.

The locations of the bowhead sightings along transect lines were calculated by using the difference between the time when flight along a transect began and the time when bowhead whales were sighted, multiplied by the average flight speed. Transect locations and positions of bowhead sightings were mapped using MapInfo version 3.0 (MapInfo Corp., Troy, New York).

RESULTS AND DISCUSSION

Bowhead whales were seen in Roes Welcome Sound, Repulse Bay, Frozen Strait, and Duke of York Bay (Fig. 1). A total of 17 bowhead whales were seen on transect; however,

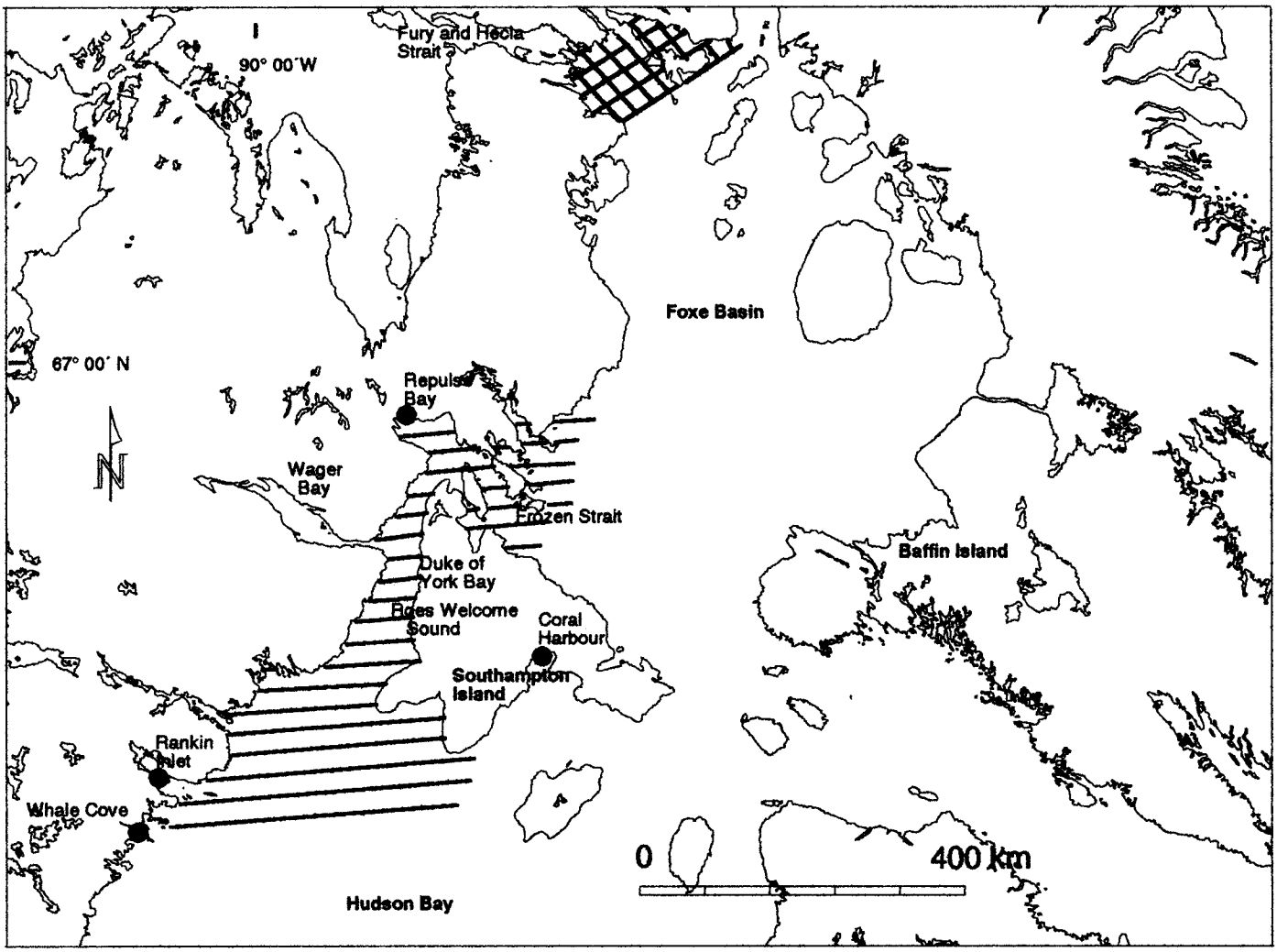

FIG. 2. Main historical distribution of commercial catches of bowhead whales in northwestern Hudson Bay, 1859–1913 (striped area) and second summering area in northern Foxe Basin (cross-hatched), where commercial hunting did not occur (after Reeves et al., 1983).

two sightings were eliminated from the analysis because they appeared to be duplicates (Table 2). One bowhead was seen off transect in Duke of York Bay. The estimated number of bowhead whales in Blocks B and C of the survey area was 75 (S.E. = 27.5) with a 95% Confidence Interval of 17–133 bowhead whales. This estimate is negatively biased. Some whales present at the surface of the water might not have been seen by the survey crew, and some unknown proportion of bowheads would have been underwater.

There were shortcomings in the way survey data were collected. Although the survey was designed to estimate the number of surfaced whales not seen by observers, observers were overheard discussing some of the sightings, so matched observer counts could not be used to correct for surfaced animals not seen. Also, most sightings (7 of 12) were made without recording clinometer angles, suggesting that more training is necessary for survey crews.

Ideally, there would have been enough observations to estimate the density of bowheads by line-transect methods. However, the low number of recorded declination angles made this impossible, so the population size was estimated using strip-transect methods. We assumed that bowhead whales were uniformly sightable up to 2.4 km from the aircraft and that all whales seen were within this outer boundary. Three of the six observations with information about perpendicular distance were made between 11 and 15 degrees from the horizontal (i.e., near the outer strip boundary). Although the sample was small, this fact suggests that bowheads at 2.4 km from the plane's trackline were as visible as bowheads nearer the trackline. It was not possible to be certain that the seven sightings without clinometer readings were within the strip. If one of the sighted whales had been outside the strip, the estimate of numbers would be slightly lower, at 70 whales.

The observed distribution of bowhead whales in Roes Welcome Sound and Frozen Strait during the survey matched only part of the historical distribution of commercial whale kills. During the survey, bowheads were not seen either near Marble Island or between Rankin Inlet and Whale Cove, areas that accounted for several kills during the commercial whaling era. However, lack of sightings in

TABLE 1. Weather and ice conditions during the aerial survey of northwestern Hudson Bay, Nunavut, Canada in 1995.

Date	Time	Survey Block: Transect	Beaufort Sea State	Glare	Low Cloud	% Ice Cover
12 August	14:42–18:20	A: 1 to 6	1–3	yes	offshore, reduced visibility	0
13 August	08:55–18:12	A: 7 to 20	1–3	yes	some near-shore	0
14 August	10:03–12:49	A: 21 to 24	1–3	yes	nil	0
15 August	14:42–18:30	B: 25 to 31	2–3	yes	nil	0
16 August	10:17–18:28	B: 31 to 35	1–3	yes	nil	up to 90
		C: 36 to 39	0–1	yes	nil	up to 90
17 August	09:38–16:00	C: 40 to 43	0–2	yes	nil	up to 90
		D: 44 to 47	0–1	yes	nil	up to 90

an area does not necessarily mean that whales were not present. For example, one bowhead was reported near Whale Cove at the time of our survey (R. Luke, pers. comm. 1995), but this whale was not seen from the aircraft.

It is also possible that, in August, bowheads are more likely to be in Frozen Strait and Repulse Bay than in Roes Welcome Sound or farther south. Most commercial kills in the southern portion of the survey area were made in June and July, while those in Frozen Strait and Repulse Bay were made in August and September (see Ross, 1974; Reeves et al., 1983). This pattern suggests that there is seasonal movement of bowheads into Frozen Strait from the Hudson Bay coast. The distribution of sightings made during the survey is consistent with the distribution of whale kills made during the month of August between 1860 and 1915 (Ross, 1974). Given the likelihood that seasonal variation in bowhead distribution occurs along the Hudson Bay coast, the area between Whale Cove and Roes Welcome Sound (Block A) was probably oversampled, and future summer surveys could reduce effort in this block.

The sightability of whales might also have been lower in the southern part of the survey area than in the northern part because sea states were higher when Blocks A and B were surveyed than when Blocks C and D were done. Sea state 3 was reported on 15 of 24 transects in Block A and on the first four transects of Block B. Sea states of 1 and 2 were reported on the other transects in these blocks. Lighter winds on the days when Blocks C and D were surveyed resulted in sea states of 0 and 1. The sighting of three whales on transect 28 in Block B was made at a sea state of 3. The remaining 12 whales were seen at sea states of 0 or 1. Ongoing survey work in northern Foxe Basin (Cosens et al., 1997; Cosens, unpubl. data) has indicated that a sea state of 2 or higher can significantly reduce the sightability of bowheads from a survey aircraft.

Northwestern Hudson Bay appears to be one of two main summering areas used by the Hudson Bay/Foxe Basin stock (Reeves and Mitchell, 1990). Ongoing research (Cosens and Blouw, unpubl. data) indicates that whales summering in northern Foxe Basin are juveniles and cow-calf pairs. These observations suggest that segregation of bowheads by age and female reproductive status occurs in this stock and that the two summering areas are not used interchangeably. Additional work, however, is required to determine whether the sum of the 1995 estimate of numbers in northwestern Hudson Bay and the 1994 estimate of numbers in northern Foxe Basin can be used to estimate total stock size. Future surveys should sample both areas at the same time to ensure that no movement of animals from one summering area to the other has occurred between surveys.

TABLE 2. Distribution of sightings among transects where bowheads were seen. (One bowhead seen off transect in Duke of York Bay is not included in the analysis.) Sightings 38** and 39** were also eliminated from the analysis because they were considered to be duplicates of 38* and 39*, that is, resightings of whales seen by another observer on the same side of the aircraft. Thus the remaining total of 12 sightings included 15 whales (nd = no data).

Transect #	Ice Conditions	Number Seen	Angle Below Horizontal
28	open	3	15
29	open	1	nd
31	open	1	nd
37	< 5%–80%	1	nd
37	< 5%–80%	1	nd
37	< 5%–80%	1	45
38*	<1%–50%	1	11
38**	<1%–50%	1	12
39*	< 1%	2	nd
39	< 1%	1	39
39	< 1%	1	nd
39**	< 1%	1	nd
39	< 1%	1	nd
43	0–50%	1	42

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