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Results of narwhal (*Monodon monoceros*) aerial surveys in Admiralty Inlet, August 2010

Résultats des relevés aériens du narval (*Monodon monoceros*) dans l'inlet de l'Amirauté en août 2010

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ABSTRACT

Two aerial surveys were completed in August 2010 to assess the summering stock of narwhals in Admiralty Inlet. The surveys used an adaptive sampling plan which combined visual line-transect sampling of the entire inlet and aerial photography of aggregations of more than 50 animals. The two surveys yielded estimates of 24,398 (CV=0.25) and 13,729 (CV=0.40) narwhals. The differences between the two survey estimates are likely due to sampling variation related to survey coverage, sea state and animal movement. Combining the estimates from the two surveys using an effort weighted mean yielded a final Admiralty Inlet narwhal estimate of 18,049 (CV=0.23, 95% C.I.=11,613-28,053). This estimate was used to calculate a new recommended Total Allowable Landed Catch (TALC) for the Admiralty Inlet narwhal stock of 233 animals.

RÉSUMÉ

On a effectué deux relevés aériens en août 2010 pour évaluer la population estivante de narvals dans l'inlet de l'Amirauté. On a suivi un plan adaptatif qui combinait un échantillonnage en bande et en ligne visuel de tout l'inlet et des photographies aériennes de groupes de plus 50 individus. Les deux relevés ont donné des estimations de 24 398 (CV=0,25) et de 13 729 (CV=0,40) narvals. Les différences entre les deux estimations sont probablement dues à des variations d'échantillonnage liées au champ d'observation du relevé, à l'état de la mer et aux mouvements des animaux. La combinaison des estimations des deux relevés au moyen d'une moyenne pondérée en fonction de l'effort a permis d'estimer la population totale de narvals dans l'inlet de l'Amirauté à 18 049 (CV=0,23, 95 % IC=11 613-28 053). On s'est servi de cette estimation pour calculer une nouvelle recommandation pour le total autorisé des captures débarquées de narvals dans l'inlet de l'Amirauté à 233 animaux.

INTRODUCTION

Narwhals (*Monodon monoceros*) in the Canadian Arctic are known to consistently aggregate in certain areas during the summer (Richard 2010). Admiralty Inlet is home to one of these aggregations and, for management purposes, these animals are considered a separate stock (Richard 2010). Previous surveys of the summering stock of narwhals in Admiralty Inlet were conducted in 1974 (Hay and McClung 1976 and Fallis et al. 1983), 1975, 1976 (Fallis et al. 1983), 1984 (Richard et al. 1994), 2003 and 2004 (Richard et al. 2010). As this stock is the target of a subsistence hunt by local Inuit, and at risk of impact from killer whale (*Orcinus orca*) predation (Laidre et al. 2006) and climate-induced habitat changes (Laidre et al. 2008), an accurate stock estimate is needed to ensure responsible wildlife management. Richard et al. (2010) provide a stock estimate of 5,362 (95% C.I. 1,920-12,199) in 2003. However, due to high levels of clumping of narwhals at the time of the surveys, this estimate had both large confidence intervals and was thought to be biased (Richard et al. 2010). A new survey was undertaken in August 2010, both to continue with long-term monitoring of the stock, and to obtain a more accurate abundance estimate of narwhals summering in Admiralty Inlet. A further objective was to update the recommended Total Allowable Landed Catch (TALC) (DFO 2008) for the Admiralty Inlet narwhal stock using the new abundance estimate.

MATERIALS AND METHODS

STUDY AREA

The study area is Admiralty Inlet, northwest Baffin Island, Nunavut (Fig. 1). The staging area was the community of Arctic Bay situated on the eastern side of the inlet, along the northern shore of Adams Sound. Water depths in excess of 700 m are found in Admiralty Inlet (Jakobsson et al. 2008) and sea ice breaks-up in mid to late July while freeze-up begins in late September – early October (Canadian Ice Service 2002).

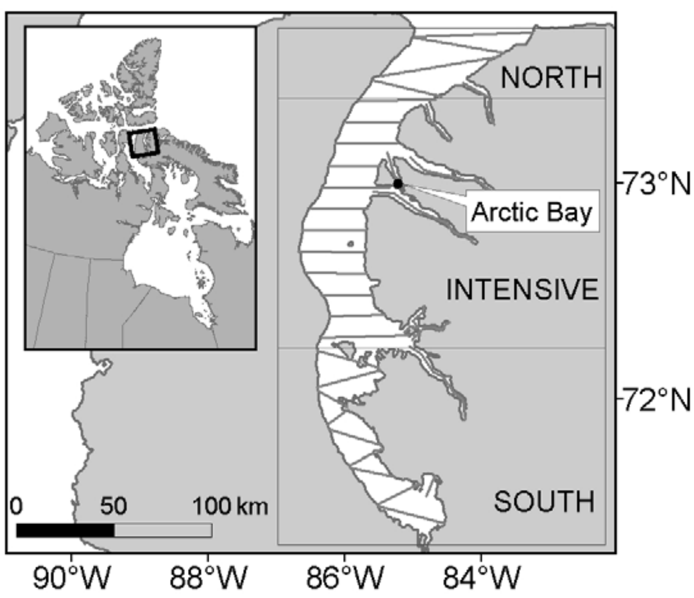

Figure 1. Study area, stratum boundaries and visual survey plan. Note: the boundaries of the Fjord stratum are not outlined but these extended to the mouths of the fjords.

SURVEY DESIGN

As large narwhal aggregations were encountered during previous surveys and resulted in imprecise stock estimates (Richard et al. 2010), we chose to use an adaptive survey plan consisting of line-transect visual surveys over the entire inlet and photographic surveys of large aggregations (>50 animals) encountered during the visual surveys.

In order to minimize the variance of estimates, we also divided the inlet into four strata: North, Intensive, South and Fjords (Fig. 1). The boundaries of the North, Intensive and South strata were determined using densities observed during past surveys (Richard et al. 2010) and data from satellite-linked transmitters deployed on narwhals in Admiralty Inlet (Dietz et al. 2008; Richard, unpubl. data). Systematic random visual line-transect surveys were planned for these strata with the location of the first line chosen at random. As previous surveys and local knowledge indicated the bays and inlets of Admiralty Inlet are used infrequently by narwhals, and these bays are relatively narrow, reconnaissance surveys, up the middle of each bay and inlet, were planned for the Fjords stratum. In this way we would ensure no aggregations in the bays and inlets were missed while minimizing our survey effort in this less used portion of the study area. In the Intensive stratum, an east-west parallel line design, with transects 11.1 km (6 nmi) apart, was used to provide uniform coverage probability (Buckland et al. 2001) (Fig. 1). In the North and South strata, we used a zigzag design to maximize coverage and reduce between transect travel time (Buckland et al. 2001) (Fig. 1). Two complete surveys were planned in order to maximize the number of observations and thus the accuracy of the analysis.

In addition to the visual surveys, we planned to conduct photographic surveys of any large aggregations (>50 narwhals) identified during the visual surveys to allow for complete counts of animals. To identify these aggregations, all personnel on board the aircraft (pilots, observers and crew chief) were instructed to look out for herds of narwhals and alert everyone when one was sighted. The most experienced observer on board (NA) made the final decision as to what constituted an aggregation of >50 narwhals. When such an aggregation was located, we planned to fly two lines, in a cross pattern over the group, to determine its spatial extent. We would then photograph the herd using a systematic grid with complete coverage.

Visual Survey Equipment, Crew, Observation Procedure

Surveys were flown in a DeHavilland Twin Otter (DH-6) equipped with bubble windows and an optical glass covered camera hatch at the rear. A Global Positioning System (GPS) unit logged the position, altitude, speed and heading of the aircraft every second. Visual surveys were conducted at an altitude of 305 m (1000 ft) and a ground speed of 185 km/hr (100 kn) with four observers, two on each side. Using black curtains, observers were visually isolated from each other to ensure that each observation was independent (i.e., that observers were not cueing each other to sightings). The aircraft noise combined with aviation headsets provided the auditory isolation.

One of the observers had extensive previous experience conducting aerial surveys while the other three were novice aerial surveyors but had previous experience observing narwhals. Observer training was provided prior to the start of the visual surveys in the form of on-the-ground instructions followed by a practice flight on August 7 and recap discussions. Observers were instructed to focus their attention on the area closest to the track line and to use their peripheral vision for sightings farther afield. Speaking into a handheld Sony PCM-D50 digital recorder, observers counted all sightings of narwhals. When a group of animals was first spotted, observers called ‘whale’. Using a Suunto clinometer, the perpendicular declination angle to the center of each group was measured once it was abeam of the observer. A ‘group’ was defined as animals within one body length of each other. Observers also noted the species and number of individuals in the group. When time permitted, observers were instructed to give additional details on the sightings, such as the presence of calves, tusked narwhals, behaviour and direction of travel. The two observers with the most scientific research experience were designated as ‘Primary’ (seated at the rear) and the other two as ‘Secondary’ (seated at the front). Primary observers, in addition to counting animals, were charged with describing the following environmental conditions throughout the surveys: ice concentrations (in tenths), sea state (Beaufort scale), fog (% of field of view) and glare (% of forward field of view). These environmental conditions were stated at the start of each transect and re-stated at any time a change was detected throughout the survey.

The survey crew was based in Arctic Bay for the duration of the field work. Beginning with Survey 1 on 7 August 2010, the entire Intensive stratum was surveyed as well as transects 17 to 20 of the South stratum, working from north to south (Fig. 2, Table 1). On 8 August 2010, surveying continued in the South stratum starting at transect 21 and working south to transect 24 (Fig. 2, Table 1) when an aircraft malfunction forced a return to Arctic Bay prematurely. Low clouds precluded surveying on 9 August 2010 and until late afternoon on 10 August 2010. Due to the delay in surveying, we abandoned the remaining lines of Survey 1 as animals would have had time to redistribute within the inlet, thus biasing survey results. Consequently, we surveyed the Intensive stratum of Survey 2 the evening of 10 August 2010, working from north to south, as well as three of the fjords (numbered 28 to 30) (Fig. 2, Table 1). We were able to complete all of the lines of the North (working from south to north) and South strata (working from north to south) of Survey 2, as well as the remaining fjords (numbered 26, 27 and 31-34) on 11 August 2010 (Fig. 2, Table 1).

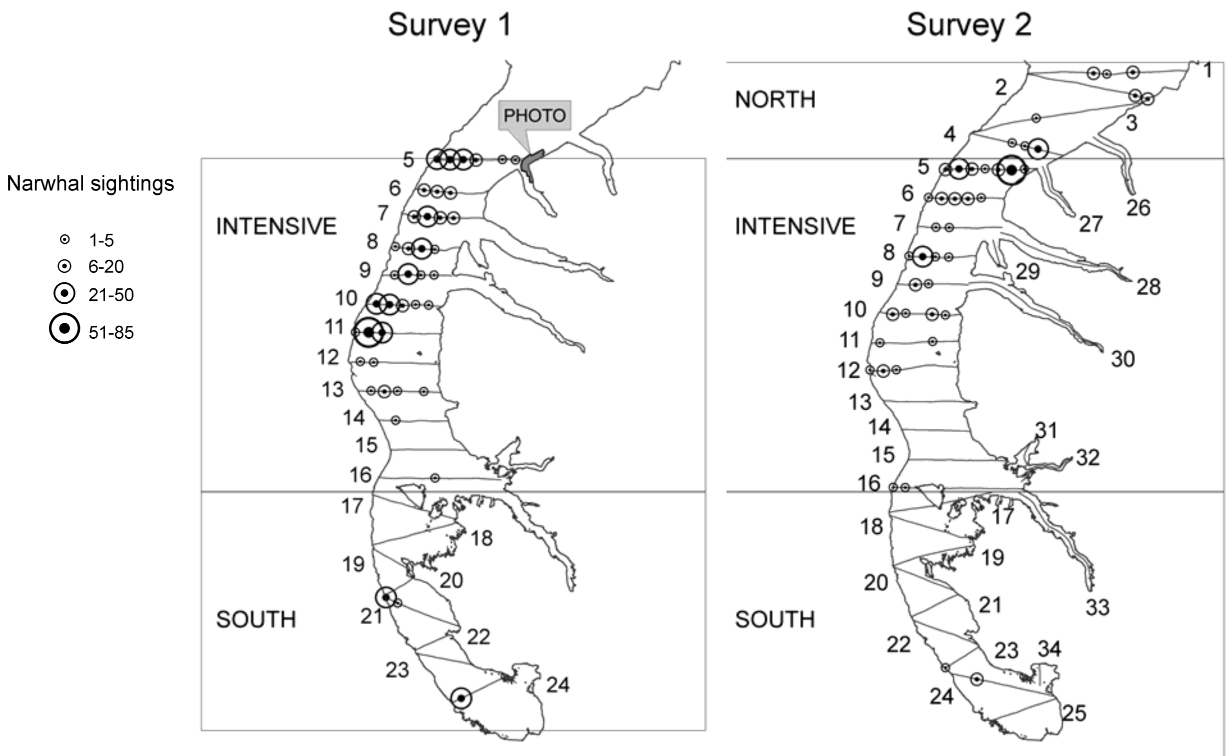

Figure 2. Survey lines, stratums and narwhal sightings. Note: narwhal sightings were grouped at 5 km intervals for map clarity. The boundaries of the Fjord stratum are not outlined but these extended up to the mouths of the fjords.

Table 1. Field work summary.

Date	Time (EDT)	Survey	Stratum	Transects	Total Transect Distance (km)
2010-08-07	11:39-15:19	1	Intensive	5-16	375
2010-08-07	15:21-16:06	1	South	17-20	92
2010-08-08	11:10-12:01	1	South	21-24	92
2010-08-10	19:22-19:54	2	Intensive	5-6	64
2010-08-10	20:00-21:04	2	Fjord	28, 30, 29	122
2010-08-10	21:13-23:45	2	Intensive	7-16	319
2010-08-11	10:49-10:57	2	Fjord	27	21
2010-08-11	11:25-12:52	2	North	4-1	209
2010-08-11	13:03-13:17	2	Fjord	26	29
2010-08-11	14:48-14:57	2	Fjord	31	12
2010-08-11	15:01-17:05	2	South	17-25	254
2010-08-11	17:09-17:47	2	Fjord	34-32	77

Photographic Survey Procedure

In the Twin Otter, we installed two identical camera systems. Each consisted of a Canon EOS 5D Mark II camera, a 35.00 mm lens, a WFT-E4A Wireless File Transmitters (WFT), a Garmin GPSmap76CSx GPS unit and a laptop computer. We installed the cameras within the optical glass covered camera hatch on a custom-made mount. Using the WFT, we connected a GPS unit to each camera which was in turn connected to a laptop. Geo-referenced images were thus saved on the laptop in real time. The cameras were oriented widthwise (long side perpendicular to the track line) and angled obliquely: one to the port side and the other to the starboard side.

As we wanted each camera to provide an oblique image starting at the track line, the viewing angle of each camera (α) was simply equal to half its field of view (shown as β in Fig. 3), calculated using (Covington 1985: 59) (eq. 1):

(1) $$\alpha = \beta = \arctan\left(\frac{SensorWidth}{FocalLength \times 2}\right)$$

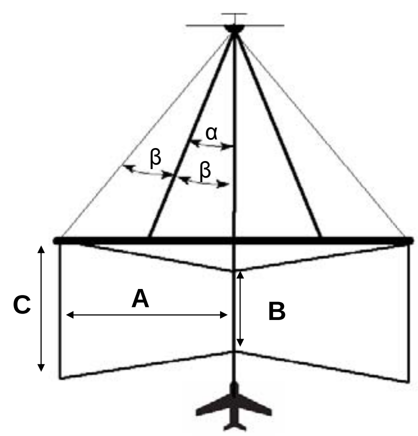

Figure 3. Geometry of oblique aerial photos (modified from Grendzdörffer et al. 2008.

As the sensor on the Canon EOS 5D Mark II is 24.00 mm by 36.00 mm and the focal length of the lens used is 35.0 mm, the viewing angle of the cameras (α) was 27°.

We planned to conduct photographic surveys at one of three altitudes, 305 m (1000 ft), 457 m (1500 ft) and 610 m (2000 ft), dependent on the height of the cloud base when an aggregation of narwhals was identified. Using the methods described in Grendzdörffer et al. (2008), we calculated the swath width for our two camera system (eq. 2) (Fig. 3) and the necessary photographic interval to allow for 15% endlap of the photos while flying at 100 knots (Table 2):

(2)

$$A = Altitude \times \tan\left[radians(\alpha + \beta)\right]$$

$$B = \left\{ \frac{Altitude \times \cos\left[radians(\beta)\right]}{FocalLength \times \cos\left[radians(\alpha - \beta)\right]} \right\} \times sensorwidth$$

$$C = \left\{ \frac{Altitude \times \cos\left[radians(\beta)\right]}{FocalLength \times \cos\left[radians(\alpha + \beta)\right]} \right\} \times sensorwidth$$

Where: $\alpha =$ angle of camera
$\beta =$ half the field of view of the lens

Table 2. Dimensions of images at three possible survey altitudes and image interval needed for 15% endlap.

	Altitude (m)		
	305	**457**	**610**
A (m)	420	629	839
B (m)	186	279	372
C (m)	317	475	634
Interval (sec)	3	5	6

Three sets of grid lines, corresponding to the three possible survey altitudes, were prepared prior to field work so that a photographic survey could be coordinated within minutes of spotting an aggregation.

One narwhal aggregation was identified during Survey 1 on 7 August 2010 at the end of transect 5 along the east shore of Admiralty Inlet (Fig. 2). Due to cloud cover, the highest altitude at which we could conduct the photographic survey was 457 m (1500 ft). High cliffs along the shore precluded the use of the grid lines as we couldn't fly perpendicular to shore. As an alternative, the pilots were instructed to fly four parallel lines, 1.1 km (0.6 nmi) apart, along shore, which enabled us to capture the entire aggregation photographically (Fig. 4). Photos were taken at 5 second intervals resulting in approximately 15% endlap.

A second aggregation, of approximately 40 to 60 narwhals, was identified during Survey 1 in the South stratum on 8 August 2010 at the end of transect 24, along the west shore of Admiralty Inlet. Unfortunately, as we were preparing to photograph this aggregation, an aircraft malfunction forced us to return to Arctic Bay. No aggregations of narwhals (>50 animals) were identified during Survey 2.

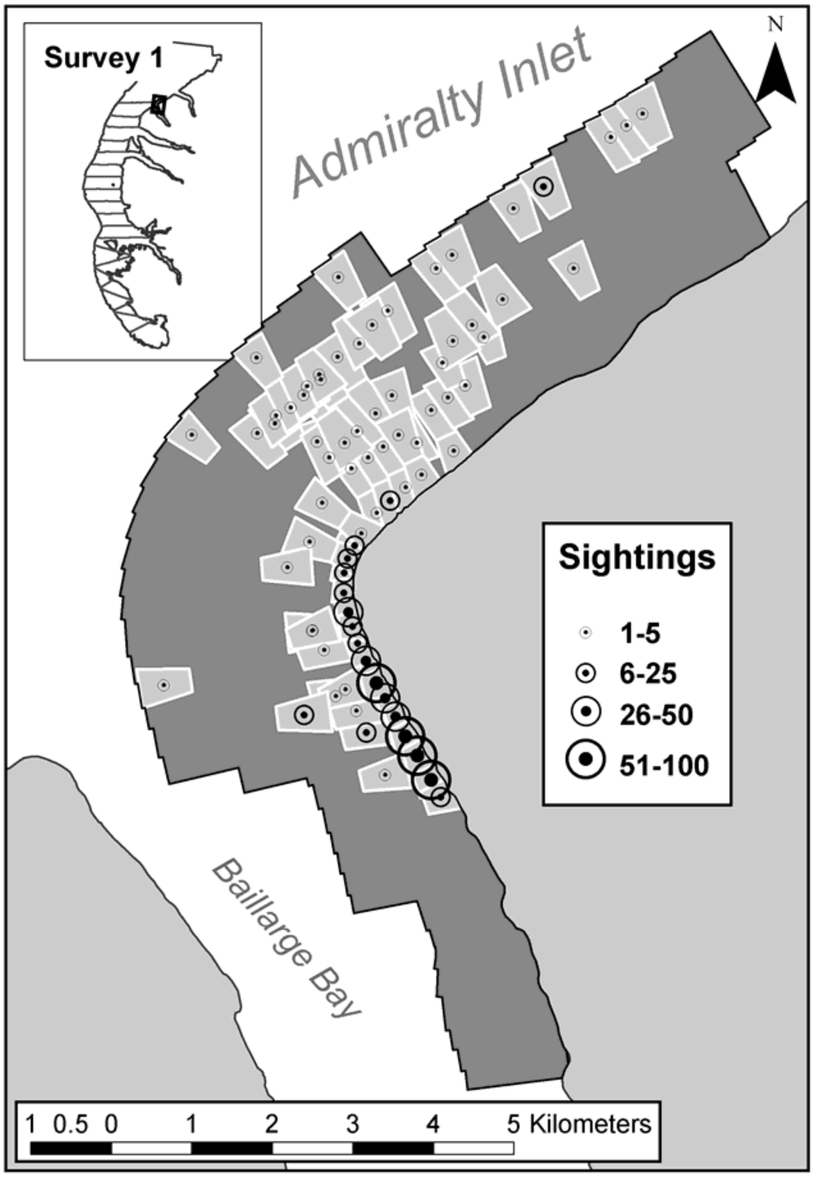

Figure 4. Map of photo coverage from Survey 1 showing the entire area photographed (in dark grey), the images with narwhal sightings (outlined in white) and narwhal sightings per photo.

ANALYTICAL METHODS

Observations were geo-referenced using the GPS track. To estimate the flight altitude, we used an 11 second rolling average of the GPS altitude output. Aircraft headings were also extracted from the GPS stream and matched to the photographic database.

Direction of Movement Analysis

In order to analyze the direction of movement of narwhals, sightings from the visual surveys for which a direction was given were graphed in Oriana 3 software (Kovach Computing Services). Due to the precision of the measurements given (e.g., 'north', 'south-east', 'south-south-east'), directions were binned at intervals of 22.5°. To test for uniformity in distribution of directions, a chi-squared test was run using these same 22.5° bins (Batschelet 1981).

Visual Survey Estimation Methods

Audio recordings of visual observers were transcribed and each whale sighting was geo-referenced by matching the observed time with the GPS time. Narwhal sightings and aircraft flight tracks were mapped using ArcGIS 9.2 (ESRI Inc.) (Fig. 2). Transect lengths and stratum areas were determined in ArcGIS.

Adjustment for Perception Bias

Aerial survey observers miss some of the narwhals visible at the surface (Innes et al. 2002 and Richard et al. 2010) ('perception bias' *sensu* Marsh and Sinclair 1989). Observations from two observers on each side of the plane can be used to correct for perception bias by combining line-transect sampling with mark-recapture methods (Borchers and Burnham 2004; Laake and Borchers 2004). We thus planned to conduct a Mark-Recapture Distance Sampling (MRDS) analysis with the point independence fitting method in Distance 6.0 (Thomas et al. 2010). MRDS combines Conventional Distance Sampling with mark-recapture analysis to estimate abundance when the probability of detection at distance zero is less than one (Laake and Borchers 2004). To conduct MRDS analysis in Distance, duplicate sightings (those seen by both the primary and secondary observer) must be identified. The following criteria were used to identify duplicate sightings:

1) Timing of sightings within 5 seconds
2) Perpendicular declination angle within 10°

As MRDS analysis in Distance requires that duplicate sightings be identical, when this was not the case, we made the following adjustments to the data:

1) Used perpendicular declination angle as measured by the primary observer
2) Used group size as the average of group size from the two observers
3) Used highest level of group differentiation of the two observers (e.g., if one observer said one group of three narwhals and the other said three singles in succession, sighting was analyzed as three singles)

Distance Analysis

As Distance Analysis assumes that all animals on the track line are seen (g(0)=1), we needed to offset the measured distances to compensate for the reduced visibility close to the flight line. A histogram of distances for each sighting indicated that many observations were missed within 150 m of the track line (Fig. 5). We consequently left truncated the data prior to analysis in Distance 6.0. We also right truncated the data at 1,500 m to eliminate three distant sightings. We tested various models and covariates to determine the best detection function based on the shape of the curve and the lowest value for Akaike's Information Criterion (AIC) (Buckland et al. 2001; Burnham and Anderson 2002). For each survey, a detection function was modeled and then used to calculate surface estimates by stratum. These stratum surface estimates were then summed to determine the total survey surface estimate for each survey.

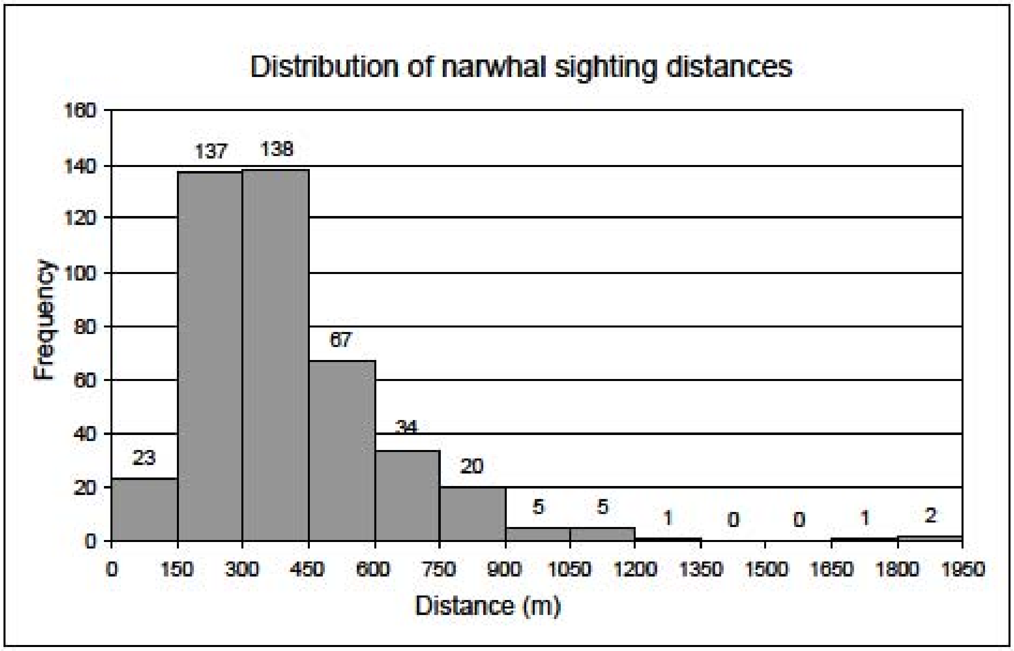

Figure 5. Distribution of narwhal sighting distances for both surveys combined.

Adjustment for Availability Bias in the Visual Surveys

In order to estimate species abundance, visual and photographic aerial surveys of aquatic marine mammals should be corrected for availability bias (Marsh and Sinclair 1989): animals in the study area but not visible to observers (i.e., under water). Experiments with narwhal-shaped models showed that narwhals could be seen and identified by observers (i.e., are available) at depths of about 2 m but not deeper (Richard et al. 1994). This depth threshold for visibility has been used to correct for availability bias in narwhals surveys (Richard et al. 2010). To calculate the proportion of time narwhals spend within 2 m of the surface, August data from four archival time-depth recorders (ATDR) were combined with August data from five satellite-linked time-depth recorders (STDR) deployed on a total of nine narwhals in Tremblay Sound (n=1), Creswell Bay (n=3) and Lyon's Inlet (n=5) (Laidre et al. 2002; Richard et al. 2010). The average proportion of time narwhals spent within 2 m of the surface was estimated at 0.319 (SE=0.0143). This is the proportion of whales available to be seen when sightings are instantaneous (p_{aI}) (e.g., on an aerial photo). The correction factor for availability bias when sightings are instantaneous (C_I) is given by (eq. 3):

(3) $$C_I = \frac{1}{p_{aI}}$$

Where: p_{aI} = proportion of whales available to be seen instantaneously

We used the delta method to calculate the variance (Buckland et al. 2001: 52) (eq. 4).

(4) $$\text{var}(C_I) = C_I^{\,2} \times \left(\frac{\text{var}(p_{aI})}{P_{aI}^{\,2}} \right)$$

To correct for availability bias, C_I is used as a correction factor when sightings are instantaneous (e.g., for photographic surveys). If sightings aren't instantaneous, this correction factor positively biases the estimate. McLaren (1961) developed a correction factor (C_M) that incorporates the dive cycle of the animal and the search time of the observer (eq. 5).

(5) $$C_M = \frac{t_d}{t_o + t_s}$$

Where: t_d = average time for a complete dive cycle

t_o = time available for an observer to see a group ('Time in View')

t_s = average time at the surface per dive cycle

Using data from three ATDRs deployed on narwhals in Tremblay Sound in August 1999 (n=1) and in Creswell Bay in August 2000 (n=2) (Laidre et al. 2002), Richard et al. (2010) calculated the average time for a complete dive cycle (t_d) (depths>2 m) and the average time at the surface per dive cycle (t_s) (depths 0-2 m) (Table 3). For 'Time in View' (t_o), we examined the length of time from the initial recording of a detection to the recording of the abeam declination angle measurement (Fig. 6). We used all observations with an abeam-declination angle (n=489) which resulted in an average 'Time in View' of 3.13 seconds (SE=0.10).

Table 3. Average duration of the surface (≤2 m) interval per dive cycle ($\bar{t}_s$) and complete dive cycle ($\bar{t}_d$) from three archival time-depth recorders (ATDRs) deployed on narwhals (data from Laidre et al. 2002; Richard et al. 2010).

ATDR	**Year**	**Location**	$\bar{t}_s$ **(sec)**	$\bar{t}_d$ **(sec)**
Cres1	2000	Creswell Bay	42	110
Cres 2	2000	Creswell Bay	40	145
Trem3	1999	Tremblay Sound	46	134
		Mean	**43**	**130**
		SE	1.764	10.333
		CV	0.041	0.080

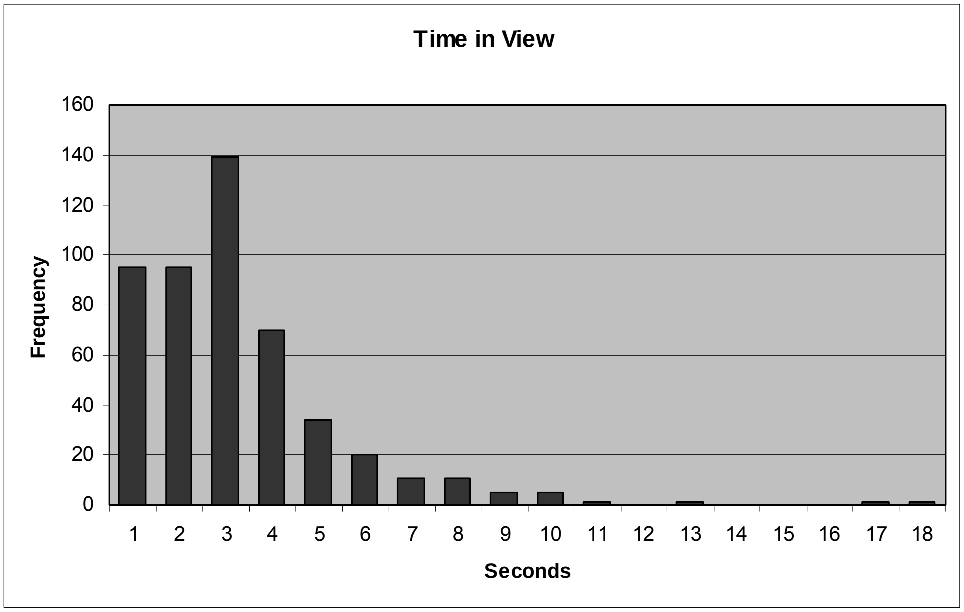

Figure 6. Histogram of Time in View for narwhal groups.

Following the technique proposed by Richard et al. (2010) we used a weighted availability bias correction factor (C_a) which combines the data from the ATDRs, the five STDRs and the 'Time in View' from our survey (eq. 6) (Table 4).

(6)
$$C_a = C_I \times \frac{\sum_{i=1}^{n} f_i (1 - b_i)}{\sum_{i=1}^{n} f_i}$$

Where: f_i = frequency of times in view of duration i sec

$$b_i = \frac{C_{M(0\,\text{sec})} - C_{M(i\,\text{sec})}}{C_{M(0\,\text{sec})}} \times 100$$ =percent bias of an instantaneous correction C_I

The variance of C_a was calculated using the delta method (Buckland et al. 2001: 52) with only C_I contributing to its variance (eq. 7):

(7)
$$\text{var}(C_a) = {C_a}^2 \times \left(\frac{\text{var}(C_I)}{{C_I}^2} \right)$$

Table 4. Correction factor for time in view (t_o) from McLaren (1961) (C_M), instantaneous correction from McLaren (1961) ($C_{M(0\sec)}$), percent bias of an instantaneous correction (b_i), frequency of times in view (f_i), instantaneous correction (C_I) and the resulting weighted availability correction factor (C_a).

t_o (sec)	C_M	$C_{M(0\sec)}$	b_i	f_i
1	2.969	3.039	2.29%	95
2	2.903	3.039	4.48%	95
3	2.839	3.039	6.57%	139
4	2.779	3.039	8.57%	70
5	2.720	3.039	10.49%	34
6	2.664	3.039	12.33%	20
7	2.611	3.039	14.09%	11
8	2.559	3.039	15.79%	11
9	2.510	3.039	17.42%	5
10	2.462	3.039	18.99%	5
11	2.416	3.039	20.50%	1
12	2.372	3.039	21.95%	0
13	2.329	3.039	23.35%	1
14	2.288	3.039	24.71%	0
15	2.249	3.039	26.01%	0
16	2.210	3.039	27.27%	0
17	2.173	3.039	28.49%	1
18	2.137	3.039	29.67%	1
			n	489
			C_I	3.135
			C_a	**2.919**
			SE	0.131
			CV	0.045

Following Richard et al. (2010) the surface abundance estimate ($\hat{N}_s$) calculated in Distance 6.0 was corrected for availability bias to give a total abundance estimate per visual survey ($\hat{N}_V$) (eq. 8).

(8) $$\hat{N}_V = \hat{N}_S \times C_a$$

With variance calculated using the delta method (Buckland et al. 2001: 52) (eq. 9):

(9) $$\mathrm{var}(\hat{N}_V) = \hat{N}_V{}^2 \times \left\{ \frac{\mathrm{var}(\hat{N}_S)}{\hat{N}_S{}^2} + \frac{\mathrm{var}(C_a)}{C_a{}^2} \right\}$$

Photographic coverage from Survey 1

Aerial photos were viewed in Adobe Photoshop 7.0 and all narwhals were counted. After calculating the dimensions of each photo using the formula from Grendzdörffer et al. (2008) (above), we used the 'Create Sample Plots' tools from Hawth's Analysis Tools Version 3.27 (Beyer, available from http://www.spatialecology.com/htools/download.php) in ArcMap 9.2 (Esri Inc.) to draw two rectangles per photo: one corresponding to the wide edge of the oblique photos (A X C) and one corresponding to its narrow edge (A X B) (Fig. 3). In ArcMap 9.2, we used the Field Calculator and the polygon_rotate_byFieldValues.cal add-in from Easy Calculate 5.0 (available from http://www.ian-ko.com/) to align each rectangle with the heading from the aircraft. The overall area covered by the photos was mapped using the boundaries of the rectangles representing the widest dimension of the photos and correcting the polygon along the edges to account for their oblique shape. The individual photos with sightings were drawn by hand in ArcMap 9.2 by snapping to the appropriate points on the wide and narrow rectangles drawn to represent the photo dimensions. Photos with redundant coverage (i.e., no new water) were removed from the analysis. The overland portion of photos was also removed from the herd coverage area calculation. Due to photograph sidelap and endlap, some narwhals were photographed more than once. In order to estimate the number of narwhals at the surface in the photos ($\hat{N}_{PS}$) (i.e., exclude the positive bias of double-counts), we calculated the within-photo animal density and multiplied it by the total area covered by photos with sightings (eq. 10).

(10) $$\hat{N}_{PS} = \frac{\sum_{i=1}^{n} n_i}{\sum_{i=1}^{n} a_i} \times A_P$$

Where: n_i =number of narwhals in photo i
a_i =area of photo i
A_P =total area covered by photos with sightings

Adjustment for Availability Bias in the Photographed Area

As with the visual surveys, we corrected the surface estimate of narwhals ($\hat{N}_{PS}$) in the photographed area for availability bias to determine the total abundance estimate of narwhals in the photographed area ($\hat{N}_P$). As sightings are instantaneous in photographs, C_I was used as a correction factor (eq. 11).

(11) $$\hat{N}_P = \hat{N}_{PS} \times C_I$$

The variance of the total count of narwhals in the photographed area ($\hat{N}_P$) was calculated using the delta method (Buckland et al. 2001: 52) (eq. 12):

(12) $$\mathrm{var}(\hat{N}_P) = \hat{N}_P{}^2 \times \left(\frac{\mathrm{var}(C_I)}{C_I{}^2} \right)$$

Combining Visual Estimate and Photo Count

The total estimate for Survey 1 ($\hat{N}_1$) was calculated by summing the estimate from the visual survey, corrected for availability bias ($\hat{N}_{1V}$), with the estimate from the photographed area, also corrected for availability bias ($\hat{N}_{1P}$) (eq. 13).

(13) $$\hat{N}_1 = \hat{N}_{1V} + \hat{N}_{1P}$$

With variance (eq. 14):

(14) $$\mathrm{var}(\hat{N}_1) = \mathrm{var}(\hat{N}_{1V}) + \mathrm{var}(\hat{N}_{1P})$$

We used a t-test to determine if the estimates from the two surveys were significantly different ($p<0.05$) (Gasaway et al. 1986: 62). The final abundance estimate ($\hat{N}*$) was calculated by combining the estimates from Survey 1 (Visual and Photo) and Survey 2 (Visual only) using a mean weighted by effort (eq. 15):

(15) $$\hat{N}* = \frac{E_1\hat{N}_1 + E_2\hat{N}_2}{E_1 + E_2}$$

Where E_i is the effort calculated as the area covered by the survey *i*.

The variance of the mean estimate is calculated as follows (eq. 16):

(16) $$\mathrm{var}(\hat{N}*) = \frac{E_1^2 \ \mathrm{var}(\hat{N}_1) + E_2^2 \ \mathrm{var}(\hat{N}_2)}{\left(E_1 + E_1\right)^2}$$

Confidence intervals (95%) were calculated using the lognormal method of Buckland et al. (2001: 77) (eq. 17).

(17) $$(\hat{N}*/C, \hat{N}* \times C)$$

Where: $C = \exp\left[z_\alpha \times \sqrt{\mathrm{var}(\log_e \hat{N}*)} \right]$

and: $\mathrm{var}(\log_e \hat{N}*) = \log_e\left[1 + \frac{\mathrm{var}(\hat{N}*)}{\hat{N}*^2} \right]$

Recommended Total Allowable Landed Catch (TALC)

As in Richard (2008), the Potential Biological Removal (PBR) method (Wade 1998), corrected to include hunting losses (i.e., animals that are struck and lost), was used to calculate the recommended Total Allowable Landed Catch (TALC) (eq. 18).

(18) $$TALC = \frac{PBR}{LRC}$$

Where: $PBR = 0.5 \times R_{Max} \times \hat{N}_{Min} \times F_r$

$LRC =$ Hunting loss rate correction

$R_{Max} =$ Maximum rate of increase for the stock

$\hat{N}_{Min} = 20^{th}$ percentile of the log-normal distribution of $\hat{N}*$

$F_r =$ Recovery factor

We used the Hunting Loss rate correction of 1.28 (SD=0.15) (Richard 2008). As the maximum rate of increase for the stock (R_{Max}) is unknown, we used the default for cetaceans of 0.04 (Wade 1998). The recovery factor (F_r) can be set to 0.1 for a critically low stock status, 0.5 for a depleted status and 1.0 for a healthy status (Wade and Angliss 1997).

RESULTS

OVERALL SURVEY CONDITIONS

Overall, throughout the two surveys, visibility was excellent (Appendix 1). By the start of our surveys, on August 7, little ice remained in Admiralty Inlet and observers mainly recorded ice concentrations of 0/10 to 2/10 throughout both surveys. Some small regions with ice floes were encountered throughout the Intensive stratum with ice concentrations ranging from 5/10 to 9/10. Ice was also encountered in concentrations ranging from 2/10 to 8/10 in Elwin Inlet (transect 26) and 1/10 to 8.5/10 in Baillargé Bay (transect 27) during Survey 2. During Survey 1, on August 7 and August 8, sea state, as measured by the Beaufort Scale, ranged from Beaufort 0 to 3 but was largely in the Beaufort 0 to 1 range. During Survey 2, on August 10, sea state ranged mainly from Beaufort 0 to 3 with a very small area of Beaufort 5 within 0.5 km of the coast at the eastern end of transect 6 and some scattered Beaufort 4 in the middle of Admiralty Inlet. For the second part of Survey 2, on August 11, sea state was mainly in the Beaufort 0 to 1 range with a small area of Beaufort 3 and 4 at the western ends of transects 1 and 2 within 10 km of shore. We encountered minor fog on August 7 over 2.5 km of the western end of Transect 5 during Survey 1. On August 10, fog was present on transects 5, 14 and 15 extending out along each transect from the eastern coast of Admiralty Inlet for 1 km, 4 km and 8 km, respectively. On August 8 and August 11, no fog was encountered. Due to the presence of high clouds throughout most of the surveys, we did not encounter much glare on the water. Observers largely reported less than 50% glare in the forward field of view with large areas of no glare. Some regions with 80% glare were also reported.

NARWHAL DIRECTION OF MOVEMENT

During the visual surveys, direction of movement was recorded for 130 of the 407 narwhal groups sighted. While surveys were mainly worked from north to south for both surveys, with the exception of the North stratum during Survey 2, the average direction of movement of the animals shifted from mainly south on August 7 to mainly north on August 8 and 9 and back to mainly south on August 11. Specifically, the mean recorded orientations of narwhals were 220° (SE=22°, n=41), 0° (SE=0°, n=3), 8° (SE=11°, n=62) and 213° (SE=10°, n=24) for August 7, August 8, August 10 and August 11, respectively (Fig. 7). Chi-square analysis indicated that for both surveys, narwhals were not oriented randomly in terms of direction (Survey 1: x^2=127.636, p<0.001, Survey 2: x^2=214, p<0.001). Furthermore, on August 7 and August 10, if we looked only at the Intensive stratum, for both surveys, chi-squared analysis also indicated narwhals were not distributed randomly in terms of direction (Survey 1: x^2=116.268, p<0.001, Survey 2: x^2=228.065, p<0.001). As Distance Sampling assumes animals are either stationary or moving randomly (Buckland et al. 2001) this non-random movement may have introduced bias into our analysis. Correcting for bias caused by movement would require an estimate of the average speed of animals relative to the speed and direction of the survey. As these data were not collected during our survey, we cannot quantify the impact of movement but the abundance estimate for Survey 1 may have been positively biased as most animals were moving in the same direction as the plane while the opposite situation may have occurred during Survey 2, possibly causing a negative bias.

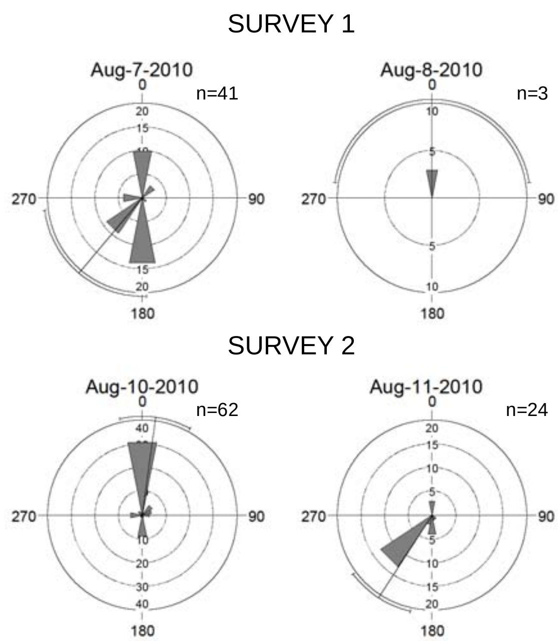

Figure 7. Histograms of frequencies of narwhal direction of movement. For each plot, the radius of the circles indicates the number of groups travelling in that direction, the mean direction is indicated by the black line extending from the center of the plot, the 95% C.I. of the mean is indicated by the brackets extending from the mean on the outside of the circle.

VISUAL SURVEYS

Two visual surveys were completed between August 7 and August 11, 2010. A total of 407 groups of narwhals were observed during the visual surveys: 241 in Survey 1 and 166 in Survey 2 (Fig. 2, Table 5). As expected, most observations were made in the Intensive stratum: 223 during Survey 1 and 130 during Survey 2. Of the total 407 groups, 352, 207 and 152 were seen by the primary observer, the secondary observer and both observers, respectively. Both the primary and secondary observers missed observations at the track line [g(0)]. The primary observers had probabilities of detection [p(0)] of 0.81 (CV=0.05) and 0.63 (CV=0.10), respectively, for surveys 1 and 2, while the secondary observers had p(0) of 0.48 (CV=0.10) and 0.41 (CV=0.14). The estimated p(0) of the two observers combined were 0.90 (CV= 0.03) and 0.77 (CV= 0.07). While a few groups of narwhals were seen at distances in excess of 1,000 m from the track line, examination of the detection curves (Figs 8-9) indicates that animals were increasingly missed beyond 300-400 m.

Table 5. Survey coverage, sightings and surface estimates by stratum for the visual surveys using the survey-specific detection functions (CVs are shown in parentheses).

	Area (km^2)	Total Transect Distance (km)	Surveyed Area (km^2)[1]	Sightings with Distance	Average Group Size	Average Probable Detection over Distance *g(x)*	Estimated Coverage (km^2)[2]	Average Probable Detection at Track Line *p(0)*	Surface Estimate
Survey 1									
Intensive	3,953	375	799	223	2.14 (0.12)	0.39 (0.06)	324	0.90 (0.03)	6,645 (0.29)
South	2,279	183	391	18	3.92 (0.26)	0.39 (0.06)	159	0.90 (0.03)	1,154 (0.65)
Total	**6,232**	**558**	**1,191**	**241**	**2.30 (0.11)**	**0.39 (0.06)**	**483**	**0.90 (0.03)**	**7,799 (0.27)**
Survey 2									
North	1,851	209	437	22	3.35 (0.32)	0.43 (0.08)	188	0.77 (0.07)	907 (0.43)
Intensive	3,964	383	800	130	1.81 (0.19)	0.43 (0.08)	343	0.77 (0.07)	3,618 (0.50)
South	2,344	254	530	14	1.17 (0.64)	0.43 (0.08)	228	0.77 (0.07)	179 (0.89)
Total	**8,159**	**846**	**1,766**	**166**	**1.95 (0.15)**	**0.43 (0.08)**	**758**	**0.77 (0.07)**	**4,704 (0.40)**

[1] total transect distance multiplied by double the largest perpendicular distance measurement (1,067 m [Survey 1]; 1,044 m [Survey 2])
[2] surveyed area multiplied by *g*(x)

In Distance, we tested multiple combinations of covariates and found that using observer (primary or secondary) and side of aircraft (left or right) as covariates of the Mark-Recapture model resulted in the lowest AIC. Observer and side of aircraft plus all of their interactions were included as covariates. The MRDS analysis in Distance resulted in surface estimates of 7,799 (CV=0.27) and 4,704 (CV=0.40) for visual surveys 1 and 2, respectively (Table 5). Multiplying the surface estimates with the calculated correction factor for availability bias (C_a =2.919, CV=0.045, Table 4) resulted in total estimates of 22,763 (CV=0.27) and 13,729 (CV=0.40) for visual surveys 1 and 2, respectively.

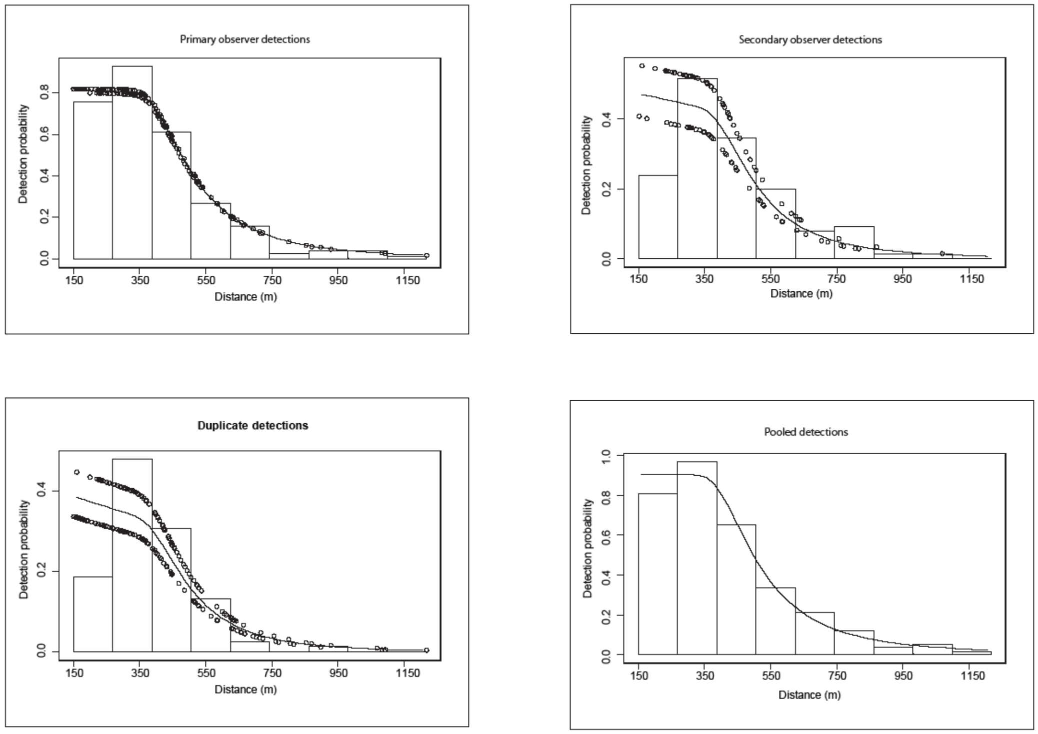

Figure 8. Probability of detection of each narwhal sighting, histograms of frequency of sightings and fitted detection functions for single observers (top), both observers (bottom left) and pooled detections (bottom right) for Survey 1.

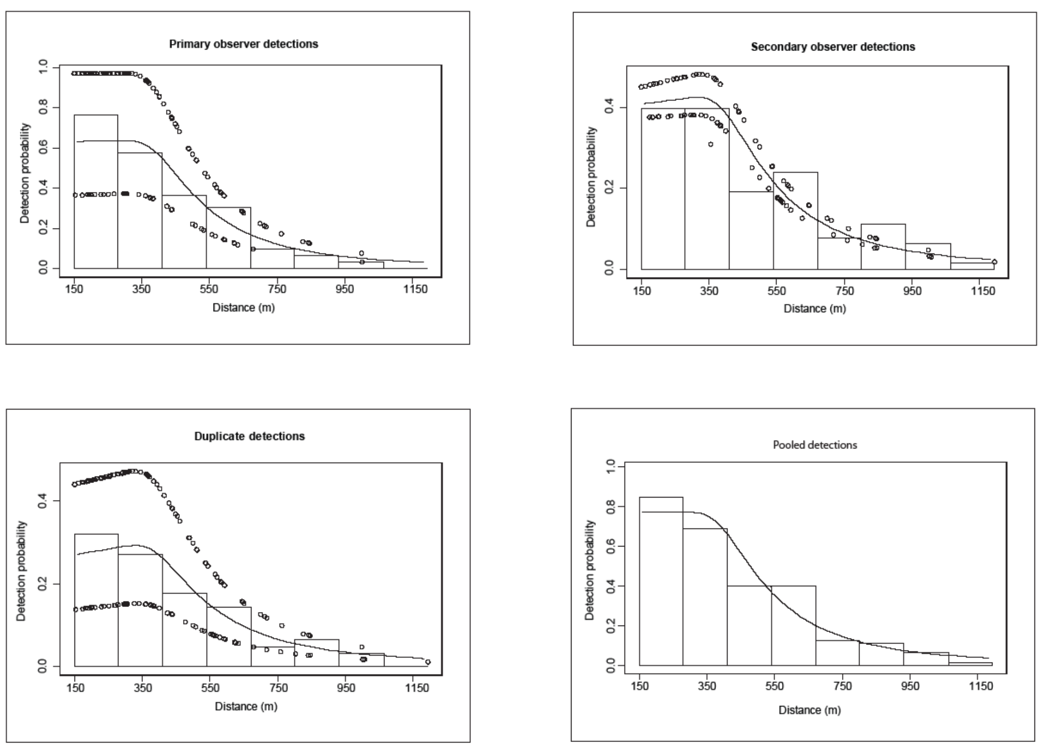

Figure 9. Probability of detection of each narwhal sighting, histograms of frequency of sightings and fitted detection functions for single observers (top), both observers (bottom left) and pooled detections (bottom right) for Survey 2.

PHOTOGRAPHIC COVERAGE DURING SURVEY 1

In all, 326 photographs were taken to capture the narwhal aggregation identified during Survey 1 on August 7, with a total area photographed of 35.4 km^2 (Fig. 4, Table 6). Narwhals were visible on 79 of the images for a total area with sightings of 11.3 km^2 (Fig. 4, Table 6). Mapping in ArcGIS 9.2 revealed that the area of three photos was completely covered by other images and so these, and their sightings, were removed from the analysis. Thus 718 narwhals in 76 photos were used in the analysis. The sum of the area of the individual photographs with sightings totaled 15.6 km^2 resulting in an average density of 46 narwhals/km^2 within these images. Multiplying the average density (46 narwhals/km^2) by the total area of images with sightings (11.3 km^2) resulted in a surface estimate of 522 narwhals. The surface estimate was then corrected for availability bias using C_I =3.135, resulting in a total narwhal estimate for the photographed area of Survey 1 of 1,635 (CV=0.04) (Table 6).

Table 6. Calculation of photo coverage in Survey 1

Number of Photos	326
Total area photographed (km^2)	35.4
Average photo area (km^2)	0.24 (SE=0.002)
Photos with sightings	79
Photos with 100% overlap removed from analysis	3
Sightings (*n*)	718
Sum of area (km^2) of photos with sightings	15.6
Density (n/km^2)	46
Covered area of photos with sightings (A_P) (km^2)	11.3
Surface photo coverage estimate ($\hat{N}_{PS}$)	**522**
Correction factor (C_I)	3.135
Photo coverage estimate ($\hat{N}_P$)	**1,635**
CV	0.04
C.L. 2.5%	1,498
C.L. 97.5%	1,785

NARWHAL ABUNDANCE ESTIMATE

Summing the totals of visual Survey 1 and photographed area resulted in a total estimate for Survey 1 of 24,398 (CV=0.25) (Table 7). As no aggregations of narwhals were identified during Visual Survey 2, the visual survey estimate is the total estimate in this case (13,729, CV=0.40).

Comparing the two survey estimates using a t-test indicated that they were not significantly different (t=1.294, df=30.0, p=0.21). Furthermore, Surveys 1 and 2 were completed within a total of five days, and narwhals are not believed to move in and out of Admiralty Inlet in summer (Dietz et al. 2008). However, within the study area, we did observe non-random movement which may have positively biased Survey 1 and negatively biased Survey 2. The difference in abundance estimates from the two surveys was therefore deemed to be due to sampling variation, as opposed to real changes in stock size. Consequently, we averaged the two abundance estimates using an effort-weighted mean, where effort was measured by the area covered over the total area of the survey. This resulted in a final stock estimate of 18,049 (95% C.I. 11,613-28,053) (Table 7).

Table 7. Narwhal abundance estimates for the two surveys and the weighted mean abundance estimate for Admiralty Inlet.

	C.L. 2.5%	Mean	C.L. 97.5%	CV
Survey 1				
Visual	13,551	22,763	38,236	0.27
Photo	1,498	1,635	1,785	0.04
Total	*15,022*	*24,398*	*39,626*	*0.25*
Survey 2				
Visual (Total)	*6,437*	*13,729*	*29,284*	*0.40*
Average	**11,613**	**18,049**	**28,053**	**0.23**

RECOMMENDED TOTAL ALLOWABLE LANDED CATCH (TALC)

The 20th percentile of the log-normal distribution of the stock estimate ($\hat{N}_{Min}$) is 14,936. We used a Recovery factor (F_r) of 1 for this calculation as this new abundance estimate indicates the stock is healthy. The PBR is the product of 0.5, 0.04 (R_{Max}), 14,936 ($\hat{N}_{Min}$) and 1 (F_r) and equals 299 (Table 8). The TALC is the PBR divided by 1.28 (LRC) and equals 233.

Table 8. PBR and TALC calculations for Admiralty Inlet narwhals based on the 2010 survey.

Mean Abundance Estimate	$\hat{N}_{Min}$	R_{Max}	F_r	PBR	LRC	TALC
18,049	14,936	0.04	1	299	1.28	233

DISCUSSION

Prior to this study, attempts to survey the narwhal stock of Admiralty Inlet (in 2002, 2003 and 2004) had been somewhat thwarted by a combination of inclement weather and dense aggregations of animals (Richard et al. 2010). While one cannot control Arctic weather or animal behaviour, our adaptive sampling approach, combining stratified visual surveys with photographic coverage of aggregations, allowed us to survey all of Admiralty Inlet, capturing areas with both high and low narwhal densities. While the combination of aerial photography and visual surveys has been used previously to assess Arctic stocks of belugas (Innes et al. 2002), the use of photography has been largely restricted to areas where high animal densities were already known to occur (e.g., estuaries). Our use of adaptive sampling compensated for the lack of predictability in the location of narwhal aggregations in Admiralty Inlet. For example, while Richard et al. (2010) had previously identified large aggregations of narwhals on the western side of Admiralty Inlet, approximately adjacent to our transects 12-17, we found two aggregations: one on the eastern side at the mouth of Baillargé Bay (which was photographed) and a second one on the western side of the inlet but further south than previously identified aggregations (not photographed due to an aircraft malfunction).

While many Arctic marine mammal abundance estimates rely on data from a single survey (e.g., Richard et al. 1994, Harwood et al. 1996, Innes et al. 2002, Richard et al. 2010), favourable weather conditions enabled us to survey Admiralty Inlet twice within a five day period. Notably, the two surveys produced two mean abundance estimates, one of which (Survey 1) is nearly double that of the other (Survey 2), although their error distributions do overlap (Table 7). Sampling variation of the clustered distribution of narwhals likely explains this difference in mean abundance.

During Survey 1, we did not survey transect 25, in the South stratum, or the entire North and Fjord strata. However, as Survey 1 produced the higher of the two stock estimates, we hypothesize that most narwhals within Admiralty Inlet were within the boundaries of the Intensive and South strata surveyed during the first survey flight on August 7. Thus, we believe the reduced coverage of Survey 1 did not result in a large negative bias in its stock estimate. Secondly, slightly higher sea states were encountered during Survey 2. As sea states above 1 have been found to reduce the detection of belugas during aerial surveys (DeMaster et al. 2001), it is likely that more narwhals were missed during Survey 2, negatively biasing that estimate. However, because adding sea state as a covariate in our Distance model did not improve the fit of the detection function, we hypothesize that this bias was not severe.

While we flew the Intensive stratum from north to south for both surveys, the direction of travel of animals in this stratum was not random and mainly southerly during Survey 1 (August 7), and mainly northerly during Survey 2 (August 10). We did not find any published research analyzing the impact of animal movement on abundance estimates in line-transect sampling, nor is there data available on the speed of narwhal movement during our surveys. Distance sampling assumes animals are either stationary or moving randomly (Buckland et al. 2001). Non-random movement has been found to introduce bias in underwater visual transect surveys for fish (Watson et al. 1995; Ward-Paige et al. 2010). We consequently hypothesize that the abundance estimate for Survey 1 may have been positively biased by animal movement in the same general direction (north to south) as the survey plane progressed through the Intensive stratum survey. Similarly, we hypothesize that the abundance estimate for Survey 2 may have been negatively biased by animal movement in the opposite direction (south to north) of the survey plane in the Intensive stratum. These uncontrollable differences in our two surveys highlight the benefits of averaging multiple surveys to correct for potential sampling variation due to animal clustering and movement, and improve the precision and accuracy of stock estimates.

Increased precision is particularly important in analyzing stock trends for long-term monitoring and hunt management. As mentioned above, the previous Admiralty Inlet narwhal estimate of 5,362 (CV=0.50, 95% C.I. 1,920-12,199) dates back to 2003 and was thought to be biased by weather conditions and severe aggregation of narwhals (Richard et al. 2010). Prior to 2003, a photographic survey completed in 1984 calculated a surface estimate of 5,556 (CV=0.22, 95% C.I. 3,759-8,213) narwhals in Admiralty Inlet (Richard et al. 1994). If we correct this estimate for availability bias (Marsh and Sinclair 1989) using the same techniques we used for our photographic coverage (i.e., multiplying by C_I =3.135), we arrive at a total Admiralty Inlet narwhal estimate of 17,418 (CV=0.22, 95% C.I. 11,277-26,899) in 1984, which is very similar to the 2010 estimate (Table 6). Comparing the 1984 corrected estimate to our 2010 estimate using a two-tailed t-test indicates the two estimates are not significantly different (t=0.96, df=41.06, p=0.34). This may indicate a stable narwhal stock over 25 years, but, due to the large variance associated with each estimate, and possibly some further sampling error not accounted for by the variance estimates, our ability to detect small changes in stock size, such as 10%, is rather limited. For a stock that may not increase by more than three to four percent per year (Kingsley 1989), a 10% decline represents a large loss. Furthermore, two estimates over a 25 year period are not enough on which to base a trend analysis. Repeated surveys and ongoing monitoring are needed to support management to ensure the long-term viability of this stock.

While these results are a significant improvement on prior attempts to estimate the abundance of Admiralty Inlet narwhals, there are still a number of sources of uncertainty with the estimation of the stock size. The correction factor in particular has a large effect on the estimated size of the stock but has a small variance. It is possible that the mean of the proportion of time narwhal instrumented with time-depth recorders spend at the surface does not fully account for the variation in behaviour of Admiralty Inlet narwhals during the surveys. The impact of movement of narwhals during surveys on the estimate is also uncertain, although averaging the two estimates may have reduced bias. Combining a photographic survey of off-transect aggregations with a systematic line transect survey could positively bias the abundance estimate. All these sources of uncertainty require further research to determine if they are a source of bias or cause an underestimation in the error variance of the estimated number of Admiralty Inlet narwhals. A source of uncertainty in the calculation of the TALC comes from the use of a fixed loss rate (1.28) derived from hunts throughout Nunavut (Richard 2008) rather than one derived from observations of Arctic Bay narwhal hunts only. Such data are as yet not available but a correction factor derived from them should be applied to TALC calculations when obtained. We recommend the collection of independent hunt loss rate data for Admiralty Inlet to compare current losses to the fixed loss rate used here.

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Appendix 1: Range of survey conditions encountered on each transect.

Survey	Transect	Date	Ice (tenths)[1]	Beaufort Sea State[2]	Fog (%)[3]	Glare (%) Left[4]	Glare (%) Right
1	5	7-Aug	0 - 3.5	1 - 2	0 - 100	0 - 40	0
1	6	7-Aug	0 - 5	0 - 3	0	50 - 65	0
1	7	7-Aug	1 - 5	0 - 2	0	0	0 - 80
1	8	7-Aug	1 - 9	0 - 1	0	30 - 50	0 - 10
1	9	7-Aug	0 - 9	1 - 2	0	0 - 40	0 - 70
1	10	7-Aug	0.5 - 1	1 - 3	0	50 - 65	0
1	11	7-Aug	0 - 2	0 - 2	0	40	0 - 40
1	12	7-Aug	0 - 2.5	1 - 3	0	80	0
1	13	7-Aug	0 - 4	1 - 3	0	0	0 - 50
1	14	7-Aug	0 - 2	0 - 2	0	0 - 35	0
1	15	7-Aug	0 - 4	0 - 1	0	0	0 - 20
1	16	7-Aug	0 - 7.5	0	0	0	0
1	17	7-Aug	0 - 3	0 - 1	0 - 5	0	0
1	18	7-Aug	0 - 2	0 - 1	0	0	0
1	19	7-Aug	0 - 0.5	0 - 1	0	0	0 - 20
1	20	7-Aug	0 - 1.5	0 - 1	0	0	0
1	21	8-Aug	0 - 1	1 - 3	0	0	0
1	22	8-Aug	0 - 3	0 - 3	0	0	0
1	23	8-Aug	0	1 - 2	0	0	0
1	24	8-Aug	0	0 - 1	0	0	0
2	5	10-Aug	0 - 1	2 - 3	0 - 100	0	0
2	6	10-Aug	0.5 - 2	1 - 5	0	0	0
2	7	10-Aug	0 - 2	1 - 4	0	0	0 - 20
2	8	10-Aug	0 - 3	1 - 3	0	0	0
2	9	10-Aug	0 - 5	1 - 4	0	0	10 - 50
2	10	10-Aug	0.5 - 8	0 - 4	0	0	0
2	11	10-Aug	0 - 3	0 - 3	0	0	30 - 50
2	12	10-Aug	0.5 - 9	0 - 3	0	0	0
2	13	10-Aug	0 - 9	0 - 2	0	0	0 - 20
2	14	10-Aug	0 - 5	0 - 2	0 - 100	0	0
2	15	10-Aug	0 - 3	0 - 2	0 - 90	0	0 - 20
2	16	10-Aug	0 - 0.5	0 - 2	0	0	0
2	28	10-Aug	0 - 1	0 - 4	0	0	0
2	29	10-Aug	0.5 - 6	0 - 3	0	80	0
2	30	10-Aug	0 - 1	0 - 3	0 - 10	0	0 - 20
2	1	11-Aug	0 - 2	0 - 3	0	0	0 - 80
2	2	11-Aug	0 - 1	1 - 4	0	0	0
2	3	11-Aug	0 - 2	0 - 2	0	0	0 - 90
2	4	11-Aug	0 - 3	0 - 2	0	0	0

[1] Ice concentration in tenths of surface area covered by ice in the Field of View
[2] Sea state as described by the Beaufort Wind Force Scale
[3] Percentage of Field of View obstructed by fog or low clouds
[4] Percentage of Forward Field of View obstructed by glare or by the sun reflecting on the surface of the water. Given for each side of the aircraft (Left and Right)

Survey	Transect	Date	Ice (tenths)	Beaufort Sea State	Fog (%)	Glare (%) Left	Glare (%) Right
2	17	11-Aug	0 - 1	0 - 1	0	0 - 10	0
2	18	11-Aug	0 - 0.5	0	0	0	0
2	19	11-Aug	0 - 1	0 - 1	0	0	0
2	20	11-Aug	0	0	0	0	0
2	21	11-Aug	0	0 - 1	0	0	0
2	22	11-Aug	0	0 - 2	0	0	0
2	23	11-Aug	0	1 - 2	0	20	0
2	24	11-Aug	0	0 - 2	0	0	0
2	25	11-Aug	0	0	0	0	0
2	26	11-Aug	2 - 8	0	0	0	0 - 20
2	27	11-Aug	1 - 8.5	0 - 2	0	0	0
2	31	11-Aug	0 - 3	0 - 1	0	0	0 - 10
2	32	11-Aug	0	0	0	0	0
2	33	11-Aug	0	0	0	0	0
2	34	11-Aug	0	0 - 1	0	0	0