

Re-analysis of the availability correction factor used in the aerial survey of bowhead whales in the Eastern Canadian Arctic 2002-2004.

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Abstract

Abundance estimates obtained during an aerial survey of bowhead whales (*Balaena mysticetus*) in the Canadian eastern Arctic (Dueck et al. 2008) were re-analysed to include availability bias data using a larger sample of diving whales, and hence a better estimate of the fraction of whales submerged during the passage of the plane (availability bias). The larger sample size of dive data from bowhead whales was collected in Disko Bay, West Greenland, in April and May between 2002 and 2006. Correction for the non-instantaneous sighting process in aerial surveys was included and fully corrected alternate estimates were developed. The estimates for the BBDS and FBHB stocks using the revised method presented here were 14196 (0.49) and 2125 (0.73), respectively. These are similar to those presented by Dueck et al. (2008) but are slightly more precise and include all variance components.

Introduction

Dueck et al. (2008) presented an analysis of an aerial survey of bowhead whales (*Balaena mysticetus*) in the Canadian eastern Arctic. The survey was conducted as a double platform line transect survey with corrections for whales that were submerged during the passage of the plane as well as an adjustment for correcting for non-instantaneous availability of whales at the surface. In the analysis, the abundance of bowhead whales at surface was corrected for the average percentage of time bowhead whales spend at or above 4 m, the depth which was considered the maximum depth for detecting a bowhead whale from an aircraft. The data for this correction factor were collected from 4 individuals instrumented with satellite linked time depth recorders in Foxe Basin (Dueck et al. 2005). Data were collected in 6-hr periods and a total of 50 6-hr periods from three of the whales that transmitted during the first week of August were used for developing an availability correction factor of 0.26 (cv=0.39, n=3).

However, this estimate of the proportion of whales available at the surface to be seen by the observers has an unrealistic large variance with confidence limits that

range between 12 and 54% of the time spent at or above 4 m depth. Considering all other information on the time spent at surface by whales (cf. Heide-Jørgensen et al. 2001, 2007, Laidre et al. 2002, 2007) the lower range of this estimate is unrealistic and is probably below the minimum time cetaceans need to spend at surface (~20%). The large variance on the estimate of time spent at surface also results in wide confidence intervals around the abundance estimate. Here we use a larger data set on the proportion of time spent at surface (PTS) and propose how this estimate should be corrected for non-instantaneous sighting process in aerial surveys in order to develop more precise estimates of the abundance of bowhead whales in the eastern Canadian Arctic .

Methods

Data from time-depth-recorders deployed on 15 bowhead whales in the Disko Bay, West Greenland, between 2002 and 2006 were used to estimate the average PTS and its associated variance (Table 1). Descriptions of the tags and deployment methods are described in Laidre et al. (2007).

In order to account for availability bias, corrected abundance (denoted by the subscript 'c') was estimated by:

$$(1) \quad \hat{N}'_c = \frac{\hat{N}}{\hat{a}'}$$

where the parameter \hat{a}' is the estimated proportion of time animals are available at the surface (PTS) for detection. This was estimated from the time-depth-recorders that were deployed on bowhead whales in West Greenland and it was assumed that the whales are available for detection when at or above 2 m (Table 1). \hat{N} is number of whales estimated at surface corrected for perception bias in Dueck et al. (2008).

Correction with the availability correction factor \hat{a}' leads to a positive bias in the abundance estimate, because sightings of bowhead whales from aerial surveys are not an instantaneous process as some whales may be seen ahead of the plane. The average observation time (i.e. the difference between first observation and time when the whales are passing abeam) for 29 sightings was estimated. McLaren (1961) and Barlow et al. (1988) provided a formula for estimating the average probability of detecting a whale at the surface:

$$(2) \quad \text{Pr (being visible)} = (s+t)/(s+d)$$

where s is the average time the whale is at the surface between two dives, d is the average time it is below the surface and t is the window of time the whale is within visual range of the observers. The probability of detecting a whale at the surface

during a visual survey is used to correct the bias from an instantaneous sighting process:

$$(3) \quad \text{Bias-correction of availability } (\hat{b}') = \frac{s}{d} - \frac{1}{(t/d) + (s/d)}$$

Using the delta method the coefficient of variation of \hat{N}''_c was estimated by:

$$(4) \quad cv(\hat{N}''_c) = \hat{N}'_c \sqrt{cv^2(\hat{N}') + cv^2(\hat{a}') + cv^2(\hat{b}')}$$

where $cv(\hat{b}')$ included the variance of the s , d and t .

Results and discussion

The PTS from the sample of bowhead whales in Disko Bay was 0.24 ($cv=0.03$) for a depth range of 0-2 m and 0.30 ($cv=0.03$) for a depth range of 0-4 m. In a similar survey of bowhead whales in West Greenland it was assumed that the whales were only visible to be seen by the observers down to 2m depths on the trackline (Heide-Jørgensen et al. 2007). The survey by Dueck et al. (2008) used flat windows which results in a 200 offset of the trackline reducing the probability of detecting a whale down to 4 m depth. Consequently, the 0-2 m depth range is most appropriate for the correction of the Dueck et al. (2008) survey. The point value for this PTS is similar to the value of 0.26 used by Dueck et al. (2008) but has a considerably lower cv (0.03 vs. 0.39).

IWC currently recognizes two stocks of bowhead whales in the area surveyed by Dueck et al. 2008. One stock is centered in Foxe Basin and northern Hudson Bay (HBFB) and the other stock is found in West Greenland along the east coast of Baffin Island, in the Lancaster Sound region with tributaries and in Prince Regent Inlet and Gulf of Boothia. This stock is recognized as the Baffin Bay-Davis Strait stock (BBDS). Even though this current stock definition of bowhead whales is under serious question, the abundances are presented following the stock definition currently accepted by IWC.

Dueck et al. (2008) presented results from two years of aerial surveys of which surveys in 2002 covered Eclipse Sound, Prince Regent Inlet and Gulf of Boothia (the main summering area for BBDS stock). The 2003 survey covered Southern Gulf of Boothia, Fury and Hecla Strait, and Foxe Basin, presumably the primary range of the HBFB stock. The survey in 2003 also covered Admiralty Inlet and the east coast of Baffin Island, considered part of the BBDS stock, but since these areas were covered in a

different year than the main survey of the BBDS summering ground (conducted in 2002), estimates from 2003 cannot be merged with the results from 2002 survey.

The abundance of whales at surface in the 2002 survey was 3744 ($cv=0.46$) for BBDS stock and 464 ($cv=0.71$) for HBFB. Correcting these two estimates for the PTS factor gives abundance estimates of 15600 (0.46) and 1933 (0.71). Observations of whales from aerial sighting surveys are not an instantaneous process and some correction is needed to account for the time the whales are available to be seen by the observers. Richard and Dueck (DFO unpubl. data) provided data that demonstrates that the bowhead whales were, on average, visible to the observers for 5.3 seconds before they passed abeam ($cv=0.09$) during the survey presented in Dueck et al. (2008). The average time spent below 2 m and above 2 m was 605s ($cv=0.02$) and 182s ($cv=0.03$), respectively. Following equation 2 the correction for the non-instantaneous sighting process is 0.91 ($cv=0.08$).

The fully corrected estimates for the BBDS and FBHB stocks are 14196 (0.47) and 2125 (0.72). These are similar estimates to those presented by Dueck et al. (2008) but are slightly more precise and include all variance components.

The HB-FB summer abundance of bowhead whales was estimated to be about 345 whales in 1995 based on aerial surveys partially covering the summer range (Cosens et al., 1997; Cosens and Innes, 2000), but no corrections were made for perception and availability bias for that survey.

Koski et al. (2006) used a survey in Hudson Strait and West Greenland in 1981 to estimate the size of the wintering stock of BB-DS and their estimate of 1,549 (95% CI 589-4,072) bowhead whales must be considered an absolute minimum at that time because no corrections were developed for perception bias and some wintering grounds may not have been properly covered. Correction for perception bias could multiply the abundance with as much as a factor 4 (Dueck et al. 2008).

A survey in West Greenland in 2006 only covered the fraction of the BB-DS that winters in West Greenland (Heide-Jørgensen et al. 2007) and is therefore not comparable to the summer survey in the Canadian eastern Arctic presented here.

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Table 1. Data on surface time and average time spent above or below 2 m depth (from Laidre et al. 2007).

Whale ID	Date tagged	Number of seconds	Number of surfacings above 12 m	Average time (sec) of surfacings above 1 m	Average time (sec) of surfacings above 2 m	Average time (sec) below 2 m depths	Average time (sec) below 1 m depths	Cumulated proportion of time spent at different depths					
								0 m	0-1 m	0-2m	0-3m	0-4m	0-5m
a	b	c	d	(c*j)/d	(c*k)/d	(c*(1-k)/d)	(c*(1-j)/d)	i	j	k	l	m	n
02-01	5/5/2002	9584	13	171	184	552.92	566.19		0.232	0.250	0.259	0.269	0.283
02-02	5/8/2002	37560	41	177	340	576.23	739.29		0.193	0.371	0.523	0.653	0.718
02-03	5/12/2002	47192	71	182	247	418.08	482.55		0.274	0.371	0.523	0.653	0.718
03-01	17-5--2003	31786	42	290	356	401.11	466.95		0.383	0.470	0.501	0.520	0.530
03-02	5/18/2003	39988	77	114	122	397.80	405.07		0.220	0.234	0.241	0.243	0.264
04-01	5/6/2004	203364	270	136	157	595.78	616.87	0.046	0.181	0.209	0.228	0.247	0.267
05-01 Anna	4/22/2005	191103	158	140	180	1029.30	1069.21		0.116	0.149	0.187	0.218	0.240
05-02 Naja	4/23/2005	73871	73	210	231	781.21	801.45	0.124	0.208	0.228	0.238	0.243	0.246
05-03 Nuka	4/19/2005	24673	27	81	108	805.98	832.49	0.027	0.089	0.118	0.149	0.165	0.195
05-04F Mette	4/22/2005	18775	23	88	171	645.70	728.14	0.097	0.108	0.209	0.223	0.231	0.247
05-05F Mette	4/26/2005	25436	27	93	168	774.38	848.81	0.064	0.099	0.178	0.210	0.225	0.236
05-06F Mette	4/28/2005	17616	22	59	72	728.66	741.47	0.045	0.074	0.090	0.094	0.099	0.102
05-05F Mette	5/1/2005	49744	78	85	127	510.83	552.29	0.065	0.134	0.199	0.233	0.246	0.254
05-07F Barat	5/4/2005	41662	47	115	208	678.12	771.19	0.100	0.130	0.235	0.262	0.267	0.271
06-01F Mette	1/5/2006	2440	10	49	65	178.85	194.71	0.093	0.202	0.267	0.284	0.290	0.297

Table 2. Estimates and correction factors for the survey of bowhead whales in the Eastern Canadian Arctic (Dueck et al. 2008).

IWC stock area	Year	At surface abundance estimate, corrected for perception bias \hat{N}	$cv(\hat{N})$	Correction factor for availability at 0-2 m depth \hat{a}'	$cv(\hat{a}')$	Abundance corrected for availability \hat{N}'_c	$cv(\hat{N}'_c)$	Correction for non-instantaneous sighting process \hat{b}'	$cv(\hat{b}')$	Fully corrected abundance \hat{N}''_c	$cv(\hat{N}''_c)$	Lower 95% CI	Upper 95% CI
Baffin Bay – Davis Strait	2002	3744	0.46	0.24	0.03	15600	0.46	0.91	0.08	14196	0.47	5935	33956
Foxe Bay – Hudson Bay	2002	464	0.71	0.24	0.03	1933	0.71	0.91	0.08	2125	0.72	603	7488