Abundance of Atlantic walrus in Western Nares Strait, Baffin Bay Stock, during summer

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ABSTRACT

Atlantic walruses (*Odobenus rosmarus rosmarus*) belonging to the Baffin Bay subpopulation occur year round in the North Water polynya (NOW) between Northwest Greenland and eastern Ellesmere Island (Canada). They are hunted for subsistence purposes by residents of the Qaanaaq area (Northwest Greenland) bordering the NOW to the east and by Canadian Inuit at the entrance to Jones Sound in Nunavut. During the open-water period Northwest Greenland is virtually devoid of walruses which concentrate along eastern and southern Ellesmere Island at this time of the year. To determine the abundance of walruses in the NOW area, aerial surveys were conducted in August of 1999, 2008, and 2009. In July 2009, nine satellite-linked transmitters were deployed in nearby Kane Basin. Surveys on 9 and 20 August 2009 along eastern Ellesmere Island were the most extensive and were augmented with concomitant data on haul-out and at water surface activity from three (1 F, 2 M) of the nine tags that were still functioning. We therefore focus on the 2009 surveys. Walruses were observed on the ice and in water primarily in Buchanan Bay and Princess Marie Bay where the remaining functional tags were located. The Minimum Counted population (MCP) was 571 on 20 August. Adjusting the MCP of walruses on ice for those not hauled out, the estimate of abundance of walruses in the Baffin Bay stock was 1,251 (CV=1.00, 95% CI=1,226) when adjusted by the proportion of tags 'dry' at the time of the survey and 1,249 (CV=1.12, 95% CI=1,370) when adjusted by the average time tags were dry. The surveys did not cover all potential walrus summering habitat along eastern Ellesmere Island and are negatively biased to an unknown degree.

INTRODUCTION

Atlantic walruses (*Odobenus rosmarus rosmarus*) occur year-round in the area of the North Water polynya (NOW) in northern Baffin Bay, Smith Sound, and Kane Basin between Northwest Greenland and Ellesmere Island in Canada (Born et al. 1995). During April the NOW extends from ca. 76° 30′ N (eastern Devon Island, Canada) to ~79° N and may cover 70,000–80,000 km^2 (Stirling and Cleator 1981). Walruses winter in several places in the NOW area but can more predictably be found at Coburg Island at the entrance to Jones Sound and the Qaanaaq area in Northwest Greenland (Born et al. 1995, Stewart 2008). However, during the summer open water season the distribution of walruses in the NOW area is more restricted and basically confined to the eastern coast of Ellesmere Island (Canada). Walruses that have wintered in the eastern parts of the NOW (i.e. in the Qaanaaq area of Northwest Greenland) migrate west in late spring to summer along the coasts and in the fjords of Ellesmere Island, only ~40 km across the Smith Sound from Greenland (Born 1987). Apparently this movement from the Qaanaaq area has happened earlier (May) in recent years (Born et al. 2011). Hence, walruses are absent during the open water season in Greenland waters, except for a few stragglers. Sometime in the fall they reappear in the Qaanaaq area (Born 1987, Born et al. 1995 and references therein).

A review of available information on distribution, movement studied by satellite telemetry, genetics, and Pb-isotope signatures led the North Atlantic Marine Mammal Commission (NAMMCO 2006) and Stewart (2008) to the tentative conclusion that walruses in the North Water area constitute a demographically distinct population which has only limited connection with neighbouring groups of walruses in the Canadian Arctic Archipelago and western Greenland. Previously, walruses in the NOW were regarded as being a part of a population with a larger range covering also the Canadian Arctic archipelago (Born et al. 1995 and references therein). This larger population was referred to as "the North Water" or "Baffin Bay–Eastern Canadian Arctic population" (Born et al. 1995, NAMMCO 1995, 2006). However, in the review by NAMMCO (2006, 2011) the North Water population was subdivided into three stocks: (1) Baffin Bay (BB), (2) West Jones Sound (WJS), and (3) Penny Strait–Lancaster Sound (PS-LS) (see also Stewart 2008; Fig. 1). Results of a recent genetic study provide some evidence for one population of walrus encompassing the BB, WJS, and PS-LS stocks (Shafer et al. 2014) although the relationship among walrus stocks in these areas remains uncertain. Here we use the terminology suggested by NAMMCO (2006, 2011) and refer to walruses that occur in the North Water area in northern Baffin Bay, Smith Sound, and Kane Basin as "the Baffin Bay (BB) stock".

Walruses are hunted for subsistence purposes in the Qaanaaq area where they have always been important in the subsistence economy of the hunting culture (Born 1987, Born et al. 2011). During the 1990s the catch of walruses reported in the Qaanaaq area averaged 136/year (Witting and Born 2005). In Greenland quotas for the catch of walruses from the Baffin Bay subpopulation were introduced in the fall 2006. These annual quotas have gradually been reduced from 90 in 2007 to 64 in 2012 (Anon. 2006, 2010, 2011). However, walruses are also hunted by Inuit in Nunavut (Born et al. 1995; Priest and Usher 2004). During 1977–2002 the reported catch of walruses in Jones Sound averaged ~10/year (COSEWIC 2006) and during 2002–2009 ~4/year (A. Currie, DFO, pers. comm.). An unknown fraction of the walruses taken in Jones Sound are from the BB stock.

Since 1976 several attempts have been made to estimate the number of walruses in the Baffin Bay population. However, information on numbers of walruses in the North Water and adjacent areas has been collected in different seasons, in different years and using different methods. Both aerial surveys and ship-borne surveys have been used and the entire range has rarely been covered by any one survey.

An aerial survey conducted in August 1999 corrected for walruses not available to the observers (i.e. at sea and/or submerged) resulted in an estimate of ~1,000 walruses for "the North Water" or "Baffin Bay–Eastern Canadian Arctic population" (Witting and Born 2005). However, to account for walruses potentially present in un-surveyed areas, another 500 animals were added resulting in a total estimate of 1,500 walruses. The authors suggested this estimate of 1,500 was probably negatively biased. This abundance estimate was, however, found by NAMMCO (2006) to be problematic given the new putative stock areas, since most of the abundance estimate in the North Water area was a "guesstimate" due to incomplete survey coverage.

To provide an estimate of the Baffin Bay walrus population in the North Water area during the open water season aerial surveys were conducted over the walrus summering areas along eastern Ellesmere Island in 1999, 2008 and 2009. We use data on haul-out activity collected simultaneously with the 2009 survey to adjust the abundance estimate for the fraction of the population not detected because the walruses were not hauled-out. In this paper we present an estimate of abundance for 2009.

Fig. 1. Map of the study area with survey routes flown during surveys for walruses. The 1999 route includes both helicopter and Twin Otter coverage. All other years are Twin Otter routes only.

MATERIALS AND METHODS

Instrumentation and data collection from walruses

Not all walrus in the area at the time of a survey will be hauled out, and of those at sea, not all will be at the surface where they can be seen. To obtain estimates of the total abundance of walruses, we estimated the number of walruses that were not available to be detected by the observers because they were not hauled out. We made no adjustment to the number recorded, opportunistically, 'at sea' because we had neither estimates of the depth to which walruses were seen nor the time they were in view. The latter is required to apply instantaneous estimates of submerged time. Information on time hauled out and time at surface were was obtained from activity measurements from the saltwater switch (SWS) of satellite-linked transmitters (SLT) deployed in July 2009 on walruses found either swimming or resting on ice floes in southern Kane Basin at ~79° N (Fig. 1). The field team cooperated with experienced walrus hunters from Qaanaaq using small skiffs powered by outboard engines for transportation and tag deployment (Fig. 2a).

Nine ~60 g SPOT-5 "match box" SLTs (Fig. 2b, Wildlife Computers, Redmond, Washington, USA) were deployed on the walruses using a CO_2-powered rifle (Dan-Inject, www.dan-inject.com) or with adaptations of traditional harpoons used by the Greenlandic Inuit when hunting walruses. All SLTs were attached to the tough skin of the walruses using a ~6.5 cm long harpoon head-

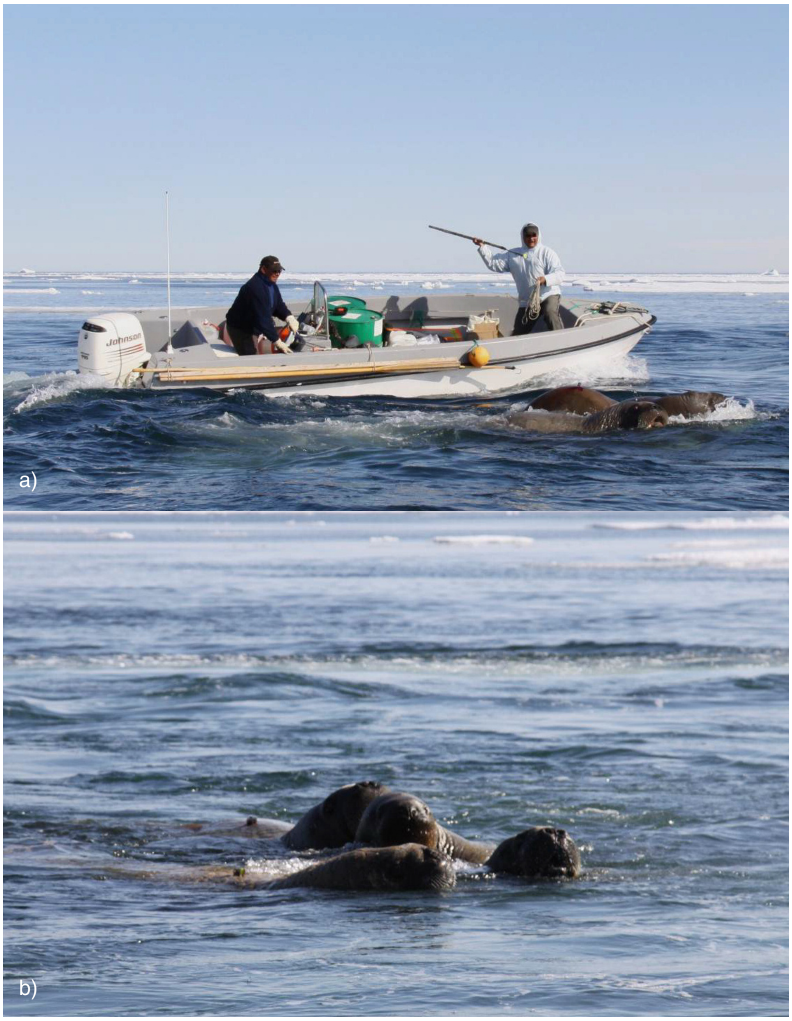

Fig. 2.
a) A satellite transmitter is being deployed on a walrus in southern Kane Basin in July 2009. Note: one animal in the herd already has a transmitter on its back;
b) A group of adult female walruses and young (same as in 1a) in southern Kane Basin in July 2009. Two of the adults have a SPOT-5 satellite transmitter attached to the back. Photos: M. Villum

like stainless steel anchor developed by Mikkels Værksted ("Mikkel's Workshop"; www.mikkelvillum.com). The main target site was the medial dorsal thorax region that comes above the water's surface when a walrus is ventilating, but positioning was sometimes difficult and in some cases the tags were placed in other parts.

Eight different walruses (3 F, 4 M, 1 unidentified), all judged to be 5+ years old, were instrumented in three events on 12 (n=3), 13 (n=1) and 14 (n=4) July 2009. We refer to these animals by their SLT number. By accident two tags (SLTs 2919 and 3758) were placed on the same female swimming in a small herd. SLT 3758 transmitted longer and therefore only data from this unit are included in analyses of haul-out behaviour of this walrus. Female walrus 3758 which was judged to be 5 years old based on tusk size and body dimensions was together with another female and two young when instrumented. Walrus 4188 (~12 years) and walrus 8375 (~15 years) were both in mixed groups. During 9 and 20 August 2009, when aerial surveys were flown along eastern Ellesmere Island, only transmitters 3758, 4188, and 8375 were still functional and collected behavioural data which is included in the analyses. Transmitter 3758 was placed a little to the right of the medial axis relative high on the mid back. The two other tags were placed on the medial axis in the lower thorax region. Hence, these three tags were all positioned so that they came out of the water each time the walruses surfaced and became available for detection.

The SLTs had a transmission rate of 45 s in water and 90 s when the walrus was hauled out. They were programmed to transmit continuously between 7 and 22 GMT when the SWS was dry, with a maximum allowance of 150 transmissions per day. Duty cycle was every day in June–December. During the aerial surveys in 2009 the instrumented walruses were along eastern Ellesmere Island (Fig. 1), in time zone -5 h GMT, (http://www.worldtimezone.com). Accordingly, the behavioural data recorded by the SLTs were subsequently adjusted to local time. The internal system of the SLTs continuously checked the status of the SWS ("dry" vs. "wet") every 0.25 sec and recorded SWS activity in 60 min intervals. This information was stored in "timelines" (TIM) that show the percentage of each 60 min interval when the SLT was dry. Percentage of "dry" time/h was given in a total of thirteen increments ranging from "0%" (every measurement was wet) to "100%" (every measurement was dry). Two increments were 5% (i.e. >0 – <5% and ≥95 – <100%) and nine increments between >5% and <95% SWS dry spanned 10%. TIMs with information on haul-out activity during 24 h were transmitted along with the "time-at-temperature" histograms (Wildlife Computers 2006).

Aerial surveys

On 9 and 20 August 2009, aerial surveys were conducted along a section of the coast of eastern Ellesmere Island. Based on scientific and Inuit (Grise Fiord) information about walrus distribution, the 9 August survey focused on the coast and fjords between Cape Wilkes, at the NE mouth of John Richardson Bay, and Cape Herschel, south of Pim Island, covering approximately 1,170 km of survey effort. On 20 August, only the coast between Cape Herschel and Cape Prescott, approximately 800 km, was surveyed (Figs. 3 and 4); the area north of Cape Prescott was not surveyed due to flight restrictions.

A DeHavilland DH6 Twin Otter was used for the surveys that were flown between 1146 and 1820 h local time. Target altitude and speed were 200 to 250 m ASL (650–800 feet) and 210 kph (110 knots), but the aircraft would slow down to facilitate counting when groups of walruses were sighted. All surveys were flown about 400 m from the shoreline. Two primary observers sat on opposite sides of the aircraft in the rear-most seats. Secondary observers sat on opposite sides forward in the cabin. The pilot and co-pilot also relayed sightings.

When walruses were seen on ice or in the water, the numbers were estimated independently by each observer and oblique aerial photographs were taken whenever possible. Digital photographs were taken of major concentrations using a Canon EOS 30D or 40D and an EFS 17–85 mm or

70–300 mm zoom lens, with image stabilizer, for later counting. When a large concentration of walruses was sighted and if time allowed, an observer would change sides of the aircraft to maximize the number of digital photos available.

Aerial surveys to estimate the number of walruses were also conducted jointly by the Department of Fisheries and Oceans and the Greenland Institute of Natural Resources in August 1999 and August 2008 in the NOW region. In 1999, a Bell 206 helicopter was used and in 2008 a DeHavilland Twin Otter. Surveys were conducted in a similar manner to the 2009 survey, although the area covered varied. Ice coverage was much greater than in 2009. These surveys recorded few walruses along eastern Ellesmere Island (4 in 1999, all in Princess Marie Bay; 74 in 2008, all in Princess Marie Bay and smaller adjacent waters; Fig 4a and b) and are not discussed further. No walrus were observed in the flights along SE Ellesmere south of Buchanan Bay.

During all surveys it was noted whether the walruses were hauled out on ice or were in the water. No walrus were seen on land.

Analysis of data

Haul-out

For each animal we determined the percentage of time per day: (1) hauled out, (2) at sea, and (3) at the water's surface when at sea during August and during the survey "window" between 12 and 19 h local time. "Extended" haul-out period was defined as a haul-out period ≥2 hours. Following identification of extended haul-out periods the locations received during each individual haul-out period were identified by comparing time of the haul-out period with time of reception of high quality re-locations (LC:2 and 3, cf. www.argos-system.org). The percentage of time hauled out per day was calculated based on the binary record (hauled out/not hauled out) as a proportion of dry hours/24 h. Time in water was simply the residual from hauled-out. All other 'time dry' as reported by the SWS was considered to be at the surface at sea; hence 'surface time' indicates the back of the walrus was above the sea surface.

For analysis of haul-out time we defined a walrus to be hauled out if the SWS showed ≥ 70% "dry" during a 60 min interval. Overall, intervals recording 70 to <100% dry constituted about 7.0% of all 60 min intervals (n=1,848). They usually occurred at the ends of a continuous series of "100% dry" intervals, that is at the beginning or end of a haul-out period (during the survey window, 12–19 h local, ≥70 – <100% recordings constituted 5.0% of all 60 min intervals, n=616).

Analyses of haul-out patterns

Haul-out percentages were first square root and then arcsine transformed prior to statistical analyses to approach the assumptions of normal errors and constant variance as recommended in e.g. Zar (1999). To test for differences in haul-out in relation to time of day, the mean haul-out percentage per hour was calculated and the 24 hours were subsequently divided into four 6 h intervals beginning at 24 h local time. To describe the diurnal pattern, polynomial regression analyses were employed. The software Microsoft Excel 2007 and software "R" version 2.12.1 (R Development Core Team 2008) were used for the calculations.

Estimating the number of walruses not available for detection

Total counts from 20 August (hauled out and at sea) allowed a Minimum Counted Population (MCP, for a definition and description see Stewart et al. 2014a). Based on information from the three tagged animals we established adjustment factors to account for the proportion of animals that were not hauled out. We explored several approaches to adjust the counts of walruses for animals unavailable for counting.

We used the maximum count of walruses hauled out (MCP^{HO}) divided by (a) the proportion of concurrent tags that were hauled out in the area during the survey period and (b) the average proportion of time 'dry' recorded for the three tags during survey hours through August. We also used the Bounded Count method (see Stewart et al. 2014a,b) with 9 and 20 August 2009 as replicates to estimate the number of walruses hauled out. Coverage was less extensive on 20 August and counts from 9 August were reduced (118 hauled out, 66 at sea) to represent only the area replicated on 20 August. In view of the small number of concurrent tags, we examined the feasibility of adjusting the counts by assuming the maximum proportion of walruses were hauled out (0.74; Stewart et al. 2014a,b) at the time of the survey. However, the assumption was contra-indicated because on both days, less than 74% of observed walruses were hauled out: 65% on 9 August and 73% on 20 August and the 0.74 adjustment was not used.

Counting walruses

Data included visual estimates from airborne observers as well as aerial photographs. Regression analysis (SigmaStat® v 3.11) was used to assess between-observer counts of photos taken from aircrafts and boats in the Canadian High Arctic during 1998–2008 and along Baffin Island during 2007–2008. These analyses indicated there was little inter-observer variation (Stewart et al. 2014a) thus numbers of walruses in photographs from the survey in eastern Ellesmere Island in 2009 were counted by one observer (REAS). When there were data of more than one type available for a site, aerial photo-count was preferred over a visual estimate. On each photo individual walruses were identified, marked digitally and tallied. Counts on a series representing a group photographed from several angles were then evaluated to obtain a maximum count of animals at that location. All images were examined in Adobe Photoshop®, cropped and adjusted for contrast and brightness to facilitate counting. The number of walruses observed during was summed for each survey day.

The variance of the proportion of tags dry was binomial p(1-p)/(n-1) for small samples (Zar 1999). Most final estimates were derived from the counts of walruses hauled out adjusted by a proportion and the variance on the final estimate was calculated following Thompson and Seber (1994):

$$\mathrm{var}(\tilde{N}) = \frac{\mathrm{var}(\hat{N}\ )}{p^2} + \hat{N}\frac{1-p}{p} + \frac{\tilde{N}^2}{p^2}\mathrm{var}(p) \qquad \text{[Eq. 1]}$$

where p is the measured proportion of walrus hauled out, $\hat{N}$ is the number of counted walruses (MCP) and $\tilde{N}$ is the corrected estimate of abundance. The number of animals at sea was then estimated by subtraction and presented without an error term. When two means were added, their variances were summed.

RESULTS

Movement and general distribution

In 2009 five walruses gave signals after deployment of the satellite tags. One stopped the day after deployment and another moved into Buchanan Bay where it stopped on 4 August. The three instrumented walruses which transmitted during August were located close to the coast in Buchanan Bay and along Bache Peninsula in areas where waters presumably are shallow. A female walrus instrumented in northern Smith Sound on 19 June 2008 also moved directly from the Kap Inglefield area in Northwest Greenland to Buchanan Bay where it stayed until transmission stopped 10 days later (Born unpublished data).

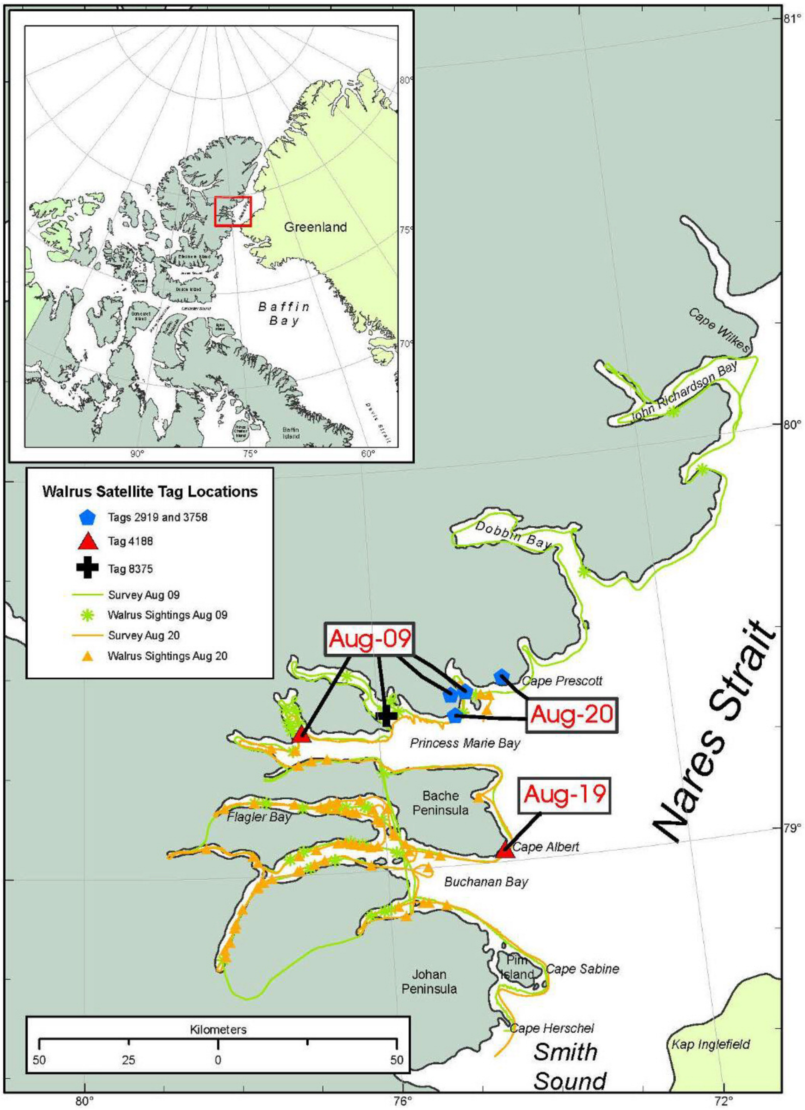

Fig. 3. *Tag locations on 9 and 20 August, 2009, with respect to the survey route and walrus observations. Tags 2919 and 3758 were on the same animal and provided slightly different locations on both 9 and 20 August. Tag 8375 did not provide a location on 20 August 2009.*

The high quality locations (LC2 and 3; cf. Harris et al. 1990) were located sufficiently far from shore to indicate that the walruses did not use terrestrial haulouts in these areas during July and August 2009 and apparently only used ice for hauling out. When the aerial survey was conducted in 2009, all three walruses with tags still transmitting were in northern Princess Marie Bay and along eastern Bache Peninsula (Fig. 3) and from the aerial observations walruses were primarily observed in Buchanan Bay and tributary fjords (Fig. 4c and d). As during the two previous survey years (1999, 2008) no walruses were observed on land.

Diurnal haul-out patterns

There was no difference in haul-out pattern between July and August (ANOVA, haul-out time interval and month interaction, p=0.15). During August, the mean haul-out percentage of the 18–24 h block was significantly higher than the other three (Tukey *post hoc* test, p adjusted for multiple comparisons = 0.05). The walruses preferred to haul out during the evening and curve fitting by polynomial regression to the diurnal pattern of haul-out resulted in a quartic (fourth-order) regression (Fig. 5).

In August the duration of haul-out sessions averaged 12.8 to 17.2 h (Table 1a) and extended (>2 h) haul-out sessions ranged between 16.1 (SD=7.2, n=7 periods) and 21.2 h (SD=36.7, n=11) for the three walruses. The overall mean of duration of on ice haul-out periods was 18.3 h (SD=21.7, range: 2-130 h, n=32; Table 1a). When in the water during August the three walruses spent an average, overall, of 17.9% (SD=9.2, n=1,114 h) of the time at the surface and 19.3% of the time (SD=11.1, n=368 h) between 12 and 19 h local time.

Adjustment Factors

During August 2009, dry SWS readings from ≥70 – 100% constituted ~32% of all 1 h readings (n_{total}=1,848 h). Of these, dry readings from ≥70 – 85% constituted 2.1% (or 6.3% of all ≥70 - 100% readings, Fig. 6). The three instrumented walruses hauled out for between 21.6 and 42.7% of each day with an overall average of 32.6% per day (SD=29.0, n=77 days; Table 1b).

Table 1. Behaviour of three walruses monitored with satellite transmitters in the study area during August 2009. (a) Duration of unaborted haul-out periods on ice and of extended haul-out periods (i.e. ≥2 h). Unaborted haul-outs were periods that were not terminated due to a break in the data-string (i.e. due to missing timelines for some days). (b) Daily mean haul-out, in water, and at surface (tag at sea reported 'dry'). (c) Daily mean haul-out, in water, and at surface time during 12-19 h local time (i.e. eastern Ellesmere Island, -5 h GMT).

a)

Animal ID	Sex	Duration (h) of unaborted haulout periods				Duration of extended haulout periods			
		Mean	SD	Range	N	Mean	SD	Range	N
3758	F	17.2	7.4	3-29	14	17.2	7.4	3-29	14
4188	M	12.8	9.1	1-24	9	16.1	7.2	2-24	7
8375	M	15.8	32.3	1-130	15	21.2	36.7	4-130	11
Overall		15.6	20.9		38	18.3	21.7		32

b)

Animal ID	Sex	Total days with records: N (d)	% Time hauled out per 24 h	SD	% Time in water per 24 h	SD	Total hours: N (h)
3758	F	29	32.0	26.8	15.2	7.6	472
4188	M	23	21.6	21.3	21.8	7.4	299
8675	M	25	42.7	34.5	18.0	11.2	342
Overall		77	32.6	29.0	17.9	9.2	1114

c)

Animal ID	Sex	Days with records during surveys (n)	Mean time hauled out during 12-1900 h local	SD	N (d)	%Time in water, 12-1900 h local	Mean Time at surface, 12-1900 h local	SD	N(h)
3758	F	29	37.1	40.8	29	62.9	15.4	9.7	147
4188	M	23	17.9	25.8	23	82.1	24.0	9.0	109
8375	M	25	44.0	39.2	25	56.0	19.7	12.8	112
Overall			33.4	37.4	77	66.6	19.3	11.1	368

To establish adjustment factors for walruses on ice we used the haul-out time between 12 and 19 h local time during August when the aerial surveys were conducted. During this survey window, the three walruses hauled out for an average of 33.4% (SD=37.4, range: 13.0–41.6, n=77 of the time; Table 1c). We would therefore expect, on average, that about 33% of the walruses in the survey area were on ice at the time of the survey and the number observed on ice was multiplied by 1/0.33 or 3.0 to account for walruses not hauled out during the aerial survey.

Only walrus 3758 was hauled out when the surveys were conducted between 12 and 19 h local time on 9 and 20 August. This (1 of 3) is the same correction factor derived above from measures of haul-out time.

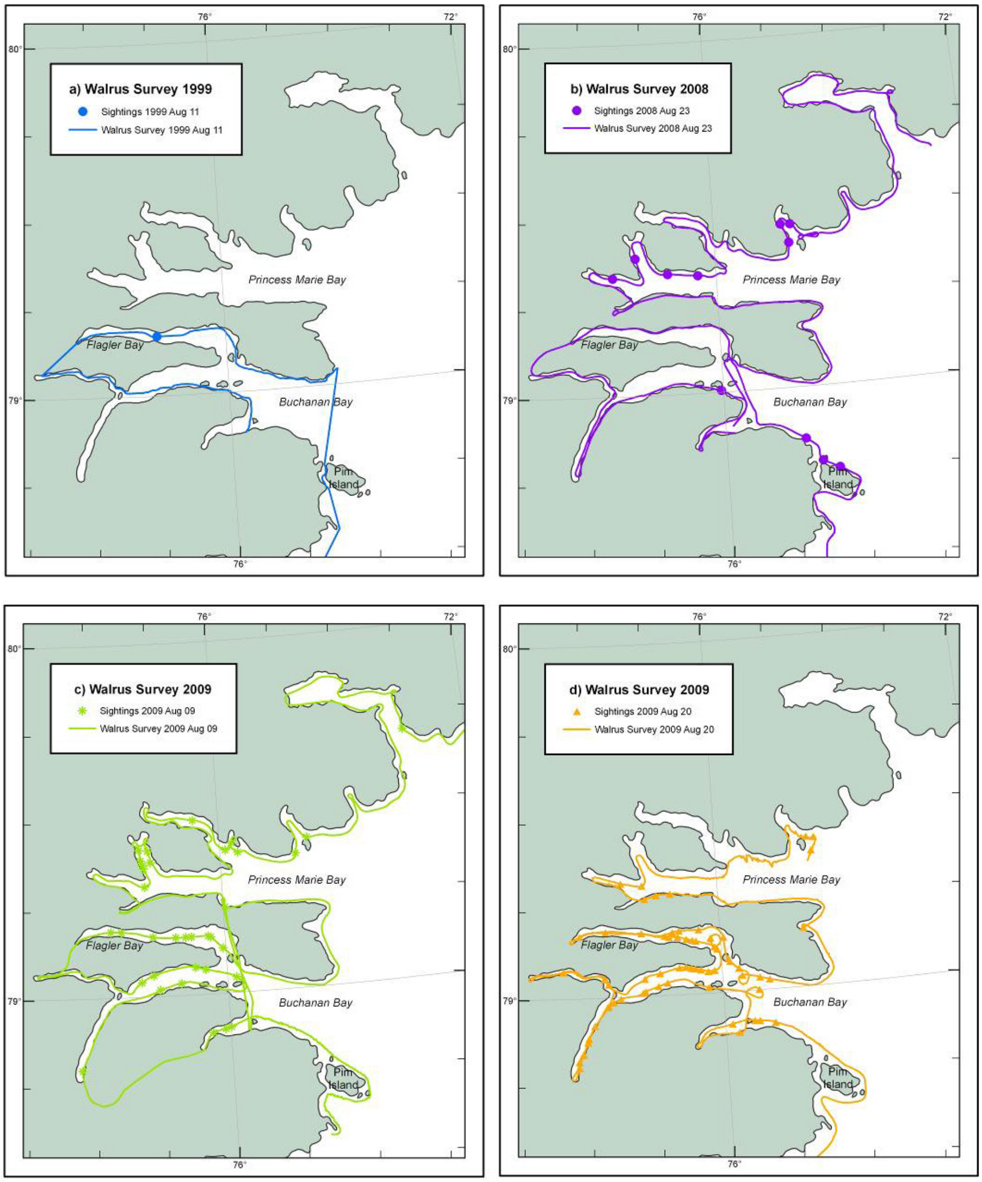

Fig 4. *Survey routes flown in the Bache Peninsula area of eastern Ellesmere Island, with locations of observations of walruses: (a) 11 August 1999 (helicopter route only); (b) 23 August 2008; (c) 9 August 2009; and (d) 20 August 2009.*

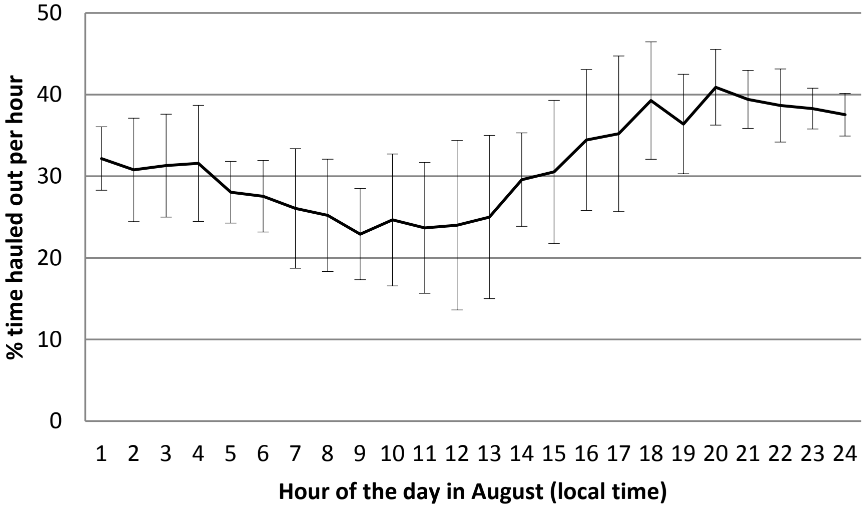

Fig. 5. *Diurnal haul-out pattern on ice in August 2009 of three walruses (2 M, 1 F) that were monitored using satellite transmitters in the Bache Peninsula area. Error bars are 1 SE. There is 24-hour daylight in the area in August.*

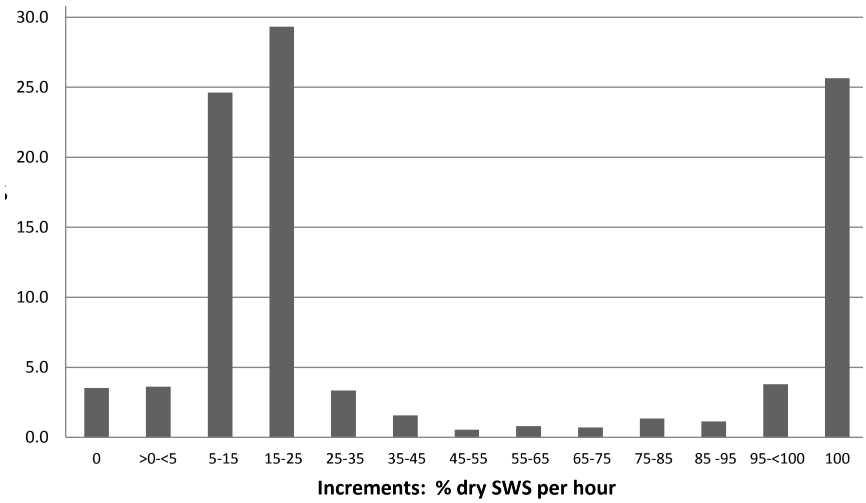

Fig. 6. *August 2009 recordings of the activity of the saltwater switch in 1 h intervals as "% dry per hour categories". Data are from the satellite transmitters on three walruses in the study area (n^{total}= 1,848 hours).*

Aerial surveys and estimate of abundance

When the coast of eastern Ellesmere Island between Pim Island and Cape Wilkes was surveyed on 9 August 2009, 208 walruses were seen; 135 on ice, 72 at sea and 1 unspecified. The majority was in Buchanan, Flagler, and Princess Marie Bays (Fig. 4c). During a survey of most of the same coastline on 20 August, 571 were observed. Most of the walruses were in Buchanan Bay and tributary fjords (Fig. 4d). Of these walruses, 417 (73%) were hauled out on ice and 154 (27%) were in the water (walruses that obviously were scared into the water by the noise of the aircraft are included in the "on ice" count). Judging from the photos the groups consisted of adults of both sexes and young.

The Minimum Counted Population was 571. Using the MCP for 20 August 2009 and concurrent tag data on the proportion of tags hauled out (1 of 3) during the survey period and percentage of time dry (33.4% Table 1c) both produced abundance estimates of about 1,250 (1,251, CV=1.00, 95% CL=571(MCP)–2,477 and 1,249, CV=1.12, 95% CL=571–2,619 respectively). The Bounded Count estimate from both surveys (9 and 20 August) for walrus hauled out was 699 (CV=3.71). Because it was based on reduced coverage and could not be adjusted for animals at sea, it is not discussed further.

DISCUSSION

The survey design used in this work is basically a 'colony' count survey wherein walruses hauled out on ice constitute the colony. Especially on 20 August 2009 there was only light scattered ice in the bays and fjords. Visibility was unlimited, the sea calm, and the widest fjords are about 20 km across. Any dark mark on the ice was closely investigated and, although these were single platform surveys, we consider it unlikely that large numbers of hauled out walruses escaped detection. However, in oblique photographs, especially of larger groups, it is possible that smaller animals were obscured by others and were thus not counted. Both of these factors negatively bias the counts although it is impossible to assess the magnitude of this bias.

Movement and distribution

During summer or the open water season walruses in the North Water area are primarily found along the coast of Ellesmere Island. According to the people of the Qaanaaq area in Northwest Greenland some walruses, predominantly males, may migrate along the coast of Inglefield Land (Greenland) to summer off the Humboldt Glacier in eastern Kane Basin. However, there is no recent information that larger numbers summer there (Born et al. 1995). We therefore chose to estimate the abundance of walruses during the open water season by conducting an aerial survey over their summer concentration area along eastern Ellesmere Island in August when walruses are virtually absent from Greenland. Albeit few in number, the walruses that were tracked by use of satellite telemetry moved from Kane Basin into the Buchanan Bay–Princess Marie Bay region in the survey period, consistent with local knowledge. Neither satellite tag data nor observations indicated the presence of terrestrial haulout sites on the east coast of Ellesmere Island or in north Greenland.

The occurrence of walruses in Buchanan Bay and its tributary fjords, and in Princess Marie Bay from spring until formation of new shore-fast ice appears to be fairly regular (Born et al. 1995). Historically, in some years walruses have been observed along the coast of Ellesmere Island between Buchanan Bay and the entrance to Jones Sound. Greely (1888) considered Baird Inlet an important feeding area (season unstated) and Ohlin (1895) reported 'great numbers' in August of 1894 in Talbot Inlet. More recently, 'considerable numbers' were seen in Goding Bay in July 1987 (J. Schneller pers. comm. to Born et al. 1995). At the east end of Jones Sound, the Glacier Strait/Coburg Island area appears important in winter (Riewe 1992). East Lancaster Sound summering sites have been identified at Cape Sherard, Croker Bay and Dundas Harbour on Devon Island, and Wollaston Islands near Bylot Island (Born et al. 1995).

When the bays and inlets of east Ellesmere, south of Pim Island, were inspected from a distance in 2008 and 2009 walruses were not observed. The bays were full of drift ice and we likely would have seen large walrus groups had they been present, but it is less likely that we would have spotted only a few individuals. The walruses tracked in 2008 (n=1, Born, unpublished data) and 2009 (n=3) indicate that during those years the main summering areas were Buchanan Bay and Princess Marie Bay, and tributary fjords and we therefore believe the 2009 aerial survey covered the main summering areas for walrus in the Smith Sound–Kane Basin region. However, it cannot be excluded that some groups of walruses were missed because the survey area did not cover their entire distribution. Walrus are not uncommon in northeast Jones Sound in summer and Inuit from Grise Fiord specifically reported groups of walrus estimated to be 50+ on the ice east of Starnes Fiord (roughly 76° 20′ N, 81° 30′ W) in the first week of August 2008 (E. Noah, Grise Fiord Hunters and Trappers Association (HTA), pers. comm.) and late July 2009 (L. Noah, Grise Fiord HTA, pers. comm.). These animals were not found during our aerial surveys of the area in either year. In 2009 there was no ice at these locations at the time of the survey. The nearest over-wintering population is at Coburg Island but the relationship of these summering walrus to those in west Jones Sound and on east Ellesmere Island remains unclear. In east Lancaster Sound, the haulout at Wollaston Island was abandoned several decades ago and recent surveys have found no concentrations at these sites in August (Stewart et al. 2014a), although a sizeable group was seen on Cape Sherard in early August 2008 (M. Kuluguktuq, Grise Fiord HTA, pers. comm.).

Until the relationship of these groups to the overall Baffin Bay population can be established, our estimate of abundance in 2009 may be negatively biased. The foregoing also highlights some challenges in estimating walrus abundance. Walrus groups are transient and even when survey coverage is good, if a group moves into or out of the survey area, estimates can change greatly. For example, had the group of 50+ animals been near Starnes Fiord during the survey rather than 2–3 weeks earlier, the 2008 count would have been almost doubled. The number of walruses using individual haulouts within a summering area also varies among years (Stewart et al. 2014a) while the overall summering range itself may change, especially due to changes in ice distribution. And within a summering area, some haulouts are abandoned, such as Wollaston Island, and new ones appear over the course of decades (e.g. Cape Hornby; Stewart et al. 2014a). It will take several more years of investigation to determine if our lack of walrus sightings on southeastern Ellesmere in August represents an overall reduction of summer range, a shift in summer range, or a temporary redistribution within a consistent summer range.

Haul-out and dive behaviour

We found diurnal variation in haul-out patterns with a tendency to haul out during afternoon and evening. A similar pattern was observed from the instrumented walruses in July (Born, unpublished data). The locations indicated that the three monitored walruses were only hauled out on ice. To our knowledge only a few studies have provided information about haul-out behaviour of walruses when using only ice as a resting platform. A study of 43 walruses monitored with satellite transmitters in the Bering Sea region during April also showed a diurnal cycle with highest "on ice" haul-out values in the evening (Udevitz et al. 2009).

Generally the tendency to haul out is influenced by weather conditions and, in particular, is negatively affected by low temperature and high wind speeds (i.e. wind chill) and precipitation (Salter 1979, Hills 1992, Born and Knutsen 1997, Udevitz et al. 2009). We have not been able to obtain weather data from any weather station in the Kane Basin region. This prevents us from pursuing in detail how, or to what extent, weather factors influenced the haul-out behaviour of the instrumented walruses in this study. Weather data from the settlements of Grise Fiord in Jones Sound and Qaanaaq in Northwest Greenland were considered not useful for our study because these sites are too far away to be representative of the situation in the Buchanan Bay and Princess Marie Bay areas. However, judging from data from Qaanaaq it appears that during August 2009 generally the entire Smith Sound–Kane Basin region had stable high pressure conditions with <5 m/sec wind, a mean temperature around 7 °C, and >1010 hPa (http://www.dmi.dk/dmi/en/vejrarkiv-gl?region=1&year=2009&month=8). Moreover, the decision to commit to survey east Ellesmere from Resolute (~690 km away) was based on real-time satellite imagery showing clear skies in the survey area. During the 9 and 20 August surveys, skies were clear or had only high clouds, winds were calm, and temperatures in the +5/+10 °C range, conditions apparently favourable to hauling out.

We found instrumented walruses hauled out for 32–33% of the time during August. Jay et al. (2006) and Udevitz et al. (2009), who used basically the same type of transmitters as those used in the present study, considered a walrus to be hauled out if the percentage of dry time for a given interval was ≥85%. In our study we defined a walrus as being hauled out if a 1 h interval showed ≥70% dry. Intervals with dry SWS readings from ≥70 – <85% constituted 2.1% of all 1 h intervals (6.3% of all ≥70–100% increments). If we had used the same haul-out threshold as Jay et al. (2006) and Udevitz et al. (2009) our estimate of mean haul-out time in August would have been ~6.1% lower, or 30.6%. The comparable values for the survey window (12–19 local) were:

≥70 – <85% intervals=2.4% of all 1 h intervals (7.3% of all ≥70–100% increments). Consequently, if using the Jay et al. (2006) and Udevitz et al. (2009) threshold criterion the estimate of mean haul-out time in August in our study would have been 31.0% and not 33.4%. One may even argue that intervals with even lower percent dry than 70% may represent a walrus being hauled out and not at the water surface. In the present study intervals with ≥50 – <85% dry readings constituted 3.4% of all 1 h intervals (10.0% of all ≥50–100% increments) and if we had included ≥50 – <70% dry intervals, our estimate of mean haul-out time in August would have been 34.0%. This suggests that analyses of haul-out percentage (and consequently adjustment factor) are relatively insensitive to which haul-out threshold value is chosen.

Studies of the haul-out activity of free-ranging walruses have mainly been conducted during summer. They have shown a remarkable consistency in mean fraction of time spent out of the water between 23–25% (Jay et al. 2001, Lydersen et al. 2008) and 30–35% (Hills 1992, Born and Knutsen 1997, Acquarone et al. 2006, Born and Acquarone 2007, Born et al. 2014). For the estimate of the number of walruses in the Baffin Bay population, we used 33.4% of the time on ice to adjust for those not hauling out. Apparently, a fair proportion of the walruses summering in the Buchanan Bay–Princess Marie Bay comprises females and young. A haul-out percentage of ~33% falls well within the range found by Hills and Gilbert (1994) for 15 female Pacific walruses monitored with SLTs in the Bering Sea–Chuckchi Sea area. These researchers reported that female walruses spent 56–89% of the time in water (i.e. hauled out for 11–44% of the time).

We used the behavioural data from three tagged walruses to convert our counts into population estimates. Despite our small sample size our findings agree with other studies in the average per cent time hauled out, but this may be a poor indicator of the proportion of the population hauled out as reflected in the large associated variance. The average includes days when walruses may not haul out at all, due to weather, disturbance, feeding, or other factors. The data are bi-modally distributed (Fig. 4) which probably factors into the apparent contradiction that, on average, a walrus is hauled out 1/3 of each day but each haul out is an average of ~2/3 (15.6 h) of a day (Table 1a). Conversely, the simple proportion of the tagged walruses hauled out at the time of the survey was similar.

Estimates of abundance and comparison with other surveys

Our surveys in 1999, 2008 and 2009 show that numbers can be highly variable even in the same sector of Ellesmere Island. Similarly, between year and within year variability was also noted in the surveys of the Canadian Arctic archipelago surveys (Stewart et al. 2014a). Previous observations in Princess Marie Bay and tributary fjords have been made over decades. Royal Canadian Mounted Police (RCMP) game reports from Alexandra Fjord refer to a herd of 500–800 in Flagler Bay in summer 1956 and a group of 400, mainly females with calves, near Cape Sabine on eastern Pim Island in early September 1962 (unpublished RCMP game reports cited in Born et al. 1995). Schledermann (1978, 1980) reported about 300 walruses in Flagler Bay in 1978, which may have been a subset of the 700+ reported by Born and Kristensen (1981) in Smith Sound the same season (Born et al. 1995). In August 1985, Born (unpublished) estimated at least 300 walruses in Buchanan Bay. Born and Knutsen (1988) estimated a minimum of 171 in the same area, not corrected for walruses at sea and submerged. While our counts in 2009 were of a similar order to previous counts, there are no methods of calibrating any of these previous visual estimates with our own or with our photographic counts.

Line-transect surveys for marine mammals including walrus were conducted in the North Water in May 2009 and 2010. The purpose was to determine the abundance of marine mammals in NOW during late winter/early spring. Most of the walruses were distributed on a belt across from Greenland to Ellesmere Island in the southern part of the North Water at a latitude of ca.76°30′N over both shallow and deep (>500m) water. Only three sightings were made north of 77° N.

Observations were post hoc treated as strip-census data. The probability of detection of walruses in the water appeared to be constant to a distance of 300m and walruses on ice are thought to be at least as detectable as walruses in the water. The surveys resulted in a corrected estimate of abundance of walrus in the NOW area in 2009 as 1,238 (CV=0.19) in 2009 and 1,759 (CV=0.29) in 2010 (Heide-Jørgensen et al. 2013). These two estimates did not differ significantly and bracket our 2009 summer estimates of 1,249 (CV=1.12) and 1,251 (CV=1.00). Additional walruses may have occurred in areas of the Kane Basin–Smith Sound region that were not covered during the summer aerial survey. Furthermore, it is not known whether—or to what extent—walruses from the Baffin Bay stock migrate into Jones Sound and Lancaster Sound.

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