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ABUNDANCE OF ATLANTIC WALRUS (*ODOBENUS ROSMARUS ROSMARUS*) IN EAST GREENLAND

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Abstract

A geographically and genetically distinct population of Atlantic walrus (*Odobenus rosmarus rosmarus*) is found in East Greenland. This population has its main distribution north of 73° 30´ N but is hunted for subsistence purpose further south in East Greenland. To determine the abundance of walruses in East Greenland, visual aerial surveys were conducted between 74º N and 81º 45´ N during 12-19 August 2009. The surveys were designed as a combination of total counts of walruses at terrestrial haul-outs and a systematical line-transect survey between 80º 21´ and 81º 24´ N in the Northeast Water (NEW) area. During the surveys the walruses were observed on land in five places on the coast between 74º 39´ N and 80º 01´ N but were absent from three traditionally used haul-outs (Sandøen in Young Sund, Port Arthur and Lille Snenæs in Dove Bugt). Females and young walruses were found in the NEW area whereas males were distributed between 75º 00´ N and 76º 36´ N confirming previous information that walruses are sexually segregated during this time of the year. Data on "haul-out" and "at surface" activity obtained from eight adult male walruses that were monitored with satellite-linked radio transmitters in the area simultaneous with the aerial surveys were used to correct estimates of abundance for walruses that were not hauled out during the surveys. The corrected estimate of walruses in their prime distribution area in East Greenland in 2009 was 1429 (90% CI: 705-2896). The survey indicates that the East Greenland population probably numbers at least 1500 walruses.

Introduction

A small group of Atlantic walruses (*Odobenus rosmarus rosmarus*), genetically distinct from walruses in neighboring Svalbard and West Greenland (Andersen et al. 1998, Born et al. 2001), lives year-round in eastern Greenland where they are distributed mainly north of 73° 30´ N (Born et al. 1997a). Walruses in East Greenland are segregated by age and sex class for most of the year. Most adult females with young stay year-round in the Northeast Water (NEW) area north of approx. 79° N whereas adult males during spring make southward migration along the coast from NEW to their terrestrial haul-outs between 74° and 77° N. Some walruses winter in small polynya areas and in the shear zone between fast ice and pack ice south of NEW (Born et al. 1997a).

The walrus population in eastern Greenland was probably reduced to very low numbers around the middle of the 20th century due to over-exploitation by European whalers and sealers. However, since its protection in 1956 the population has shown signs of a slow increase (Born et al. 1997a, Witting & Born 2005).

In East Greenland an estimated about 10 walruses are taken annually by Inuit hunters primarily at the entrance to Scoresby Sound (Witting & Born 2005).

The walrus population in East Greenland has not been systematically censused before and the current and pre-exploitation abundance is not known (NAMMCO 2006). However, based on various observations made between the mid-1980s and the first years of the 21st century, a rough estimate of 500 to 1,000 animals in the eastern Greenland subpopulation was tentatively suggested by Born et al. (1995, 1997a), who believed that the estimate of 1,000 was closer to the real order of magnitude than the estimate of 500.

Clearly, there was a need for a systematic survey specifically dedicated to estimation of abundance of this relatively small and geographically isolated group of walruses. Hence, to estimate their number visual aerial surveys were flown during 12-19 August 2009 over the main distribution area of walruses in East Greenland. During 12-18 August the shores between 74° N and 81° 45´ N were searched for walruses that were hauled out on land. In addition to this, a systematic line-transect survey was conducted between 80° 21´ and 81° 24´ N in the NEW area on 19 August to estimate the density on this important walrus feeding ground. Prior to the surveys (26 July – 1 August) satellite-linked radio transmitters were deployed to walruses in the survey area. Thereby information on distribution and behavior (haul-out and at surface time) was collected simultaneous with the aerial surveys allowing for correction of counts to include walruses that were not hauled out during the surveys.

In this paper we present an estimate of abundance of walruses in East Greenland based on the 2009-aerial survey. We use data collected by the satellite transmitters to correct the estimate of abundance so that it includes walruses that were not hauled out and therefore missed during the surveys.

Material and methods

Field work

Instrumentation and data collection from walruses

In order to obtain estimates of the total abundance of walruses, correction factors were developed to account for walruses that were not available to be detected by the observers either because they were not hauled out on sea ice or land or were submerged.

Information on "haul-out" and "at surface time" was obtained from activity measurements from the saltwater switch (SWS) of satellite-linked transmitters (SLT) that were deployed during 26 July-1 August 2009 on walruses that were resting on the Sandøen ("Sand Island") haulout (74º 15' N - 20º 18' W) in Young Sund near Daneborg (East Greenland; Fig. 1). Each year this haulout is used by a group of 40-80 primarily male walruses from break-up of the fast ice sometime in July until formation of new fast-ice in October (Born & Acquarone 2007).

Twelve 60 g SPOT-5 "match box" SLTs (Wildlife Computers, Redmond, Washington, USA) were deployed on the walruses using a CO_2-powered rifle (DanInject www.dan-inject.com). All SLTs were attached to the tough skin of the walruses using a 6.5 cm long harpoon head-like stain-less steel anchor developed by Mikkels Vaerksted ("Mikkel´s Workshop"; www.mikkelvillum.com). Main target site was the medial back thorax region (i.e. where the walrus´ back gets out of the water when surfacing to breathe). In 10 cases the tag was placed there, whereas in two cases it was placed a little more caudally.

During August 2009, when the aerial surveys were flown, eight of the transmitters functioned and collected behavioral data. Haul-out and movement data from August 2008 of two adult male walruses that were furnished with similar transmitters on the Sandøen on 18 July 2008 are included for comparison.

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.

The internal system of the SLTs continuously checked the status of the SWS ("dry" vs. "wet") every 0.25 sec and recorded the activity of the SWS in 60-min intervals. This information was stored in "timelines" (TIM) that show what percentage of each 60-min interval 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 ranged 5% (i.e. 0-5%; 95-100%) and nine increments between 5% and 95% SWS dry ranged 10%. TIMs with information on haul-out activity during 24 h were transmitted along with the "time-at-temperature" histograms (Wildlife Computers 2006).

Temperature information was summed in four 6-h blocks (histograms) per 24 h (beginning at 3, 9, 15 and 21 h GMT). Each temperature histogram consisted of 12 user defined temperature intervals ranging from -40 °C to 60 °C. To obtain highest resolution for the range of ambient temperatures that walruses were likely to experience when hauling out during the survey period, 10 (out of 12) 2°C – intervals ranged between -9.9 and 10.0 °C.

Aerial surveys, 2009

Visual aerial surveys specifically dedicated to observation of walruses were conducted in Northeast Greenland between 12 and 19 August 2009. The survey covered the coastal areas from 74º N (Clavering Ø) north to 81º 45' N (i.e. the northern parts of NEW) where walruses are known to occur regularly (Figs. 1 and 2; Table 1). Walruses that are observed or caught south of Clavering Ø are considered to be mainly male stragglers, and no haul-outs south of 74º N are known today (Born et al. 1997a).

A DeHavilland DH6 Twin Otter equipped with four bubble windows (two in the front and two in the rear of the passengers´ cabin) was used for the surveys.

Coastal surveys flown between 12 and 14 August primarily aimed at detecting walruses at terrestrial haul-outs in the area between Clavering Ø and Germania Land (ca. 77 º N). A coastal survey was flown on 15 August between ca. 77 º N and Station Nord (ca. 82º N). During these surveys the aircraft flew at a distance of ca. 100 m parallel to the coastline with a altitude of ca. 213 m (700 feet) and a speed of 167 km $* h^{-1}$ (90 knots).

To get information on general distribution of walruses and the ice situation a reconnaissance was flown on 17 August at ca. 600 m (2000 feet) altitude with three survey tracks placed parallel to the coast of the NEW. To determine the number of females and young in the NEW area 17 systematically placed and ca. 50 km long transects were flown offshore perpendicular to the coast on 19 August (Fig. 2). These lines were flown at an altitude of ca. 213 m (700 feet) and a speed of 167 km $* h^{-1}$ (90 knots). During this survey distance sampling methods were used (Buckland et al. 1993). The aerial surveys were flown between ca. 9 and ca. 17 h local time with main effort between ca. 1030 and 16 h local.

A GPS (Trimple GeoXT) recorded the track lines flown

The study was designed as a sight-resight experiment with two independent observation platforms on the land-ward side of the aircraft and a third observer on the sea-ward side. The three observers all had experience from previous aerial surveys of marine mammals and one (DMB) had conducted aerial surveys along the coasts of NE Greenland on previous occasions. Two observers were always at the rear windows, while the third observed changed side in order to have a double observer team on the land-ward side. During the transect flights the third observer changed side so there were two observers to the side with the best observation conditions.

In each case of an observation of a walrus or a group of walruses on land or ice or in water the declination angle was measured to the observation using a Silva Clino Master CM-P inclinometer. Each observer recorded his or her observations independently by speaking to a microphone noting the exact time of the observation. After the first passage of a group of walruses the aircraft made a turn and the group was photographed using a Canon EOS 30 D camera with 70 – 300 mm zoom lense for later counting and determination of sex and approximate age.

During the surveys it was noted whether the walruses were hauled out on land or on ice or were in the water. Approximate age class (adult, or calf and adult female) was also noted.

A multi-species aerial survey was conducted by the National Environmental Research Institute (Roskilde) in July 2009 in NE Greenland (Boertmann unpublished data). Although relatively few walruses were observed during this survey, some information relevant to the present study is presented

Analysis of data

Haul-out and diving activity

Data on haul-out activity and temperature were extracted from the Argos dispose files by use of the Wildlife Computers Argos Message Decoder software version 1.0.55.

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. On average intervals with "≥70%-95% dry" constituted <5% of all 70-100% 60-min intervals and usually occurred at the beginning or end of a continuous series of "100% dry" intervals (i.e. at the beginning or end of a haul-out period). The duration of a single haul-out period was defined as the time elapsed between the beginning and the end of a continuous series of "≥70% dry" intervals. "Extended" haul-out period was defined as a haul-out period ≥ 2 hours.

To determine % of time in water all ≥70% dry intervals were subtracted from the total sum of 60-min intervals during August. Subsequently, % of time at water´s surface (i.e. % of time when SWS was dry <70%) was calculated for this "in water" time.

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 (LC:2 and 3, cf. www.argos-system.org) re-locations. In this manner the exact location (and substrate: ice vs. land) of haul-outs was determined.

Hence, for each animal we determined % of time per hour and day (1) on land, (2) on ice, (3) at water´s surface and (4) submerged during (1) August, (2) the survey period (12-19 August), and (3) the survey "window" between 10 and 17 h local time during 12-19 August.

Correction factors for walruses not available for detection

Based on information from the eight tagged male walruses we established a correction factor to account for the proportion of animals at sea and not available to be counted on the terrestrial haul-outs. The proportion of time spent on land was calculated as the mean of individual haul-out times with it´s estimate of variance.

For the systematic transects flown offshore in the NEW area we applied a correction factor to account for animals that were not hauled on ice. One may argue (cf. Lydersen et al. 2008) that the general haul-out patterns of adult male walruses differ from that of females with young. Furthermore, our study showed that the diurnal haul-out pattern differed when walruses were using ice as resting platform in contrast to land. Therefore correction factors obtained from studies of adult males using terrestrial haul-outs are probably not applicable to surveys of females and young resting on ice which was the case when the NEW was surveyed systematically in 2009. Hence, to establish a correction factor for the survey on 19 August we use data obtained from three walruses (1 F, 2 M, all judged to be 5+ years old) that were monitored in August 2009 with SPOT-5 satellite transmitters at ca. 79° N in the Kane Basin region (NW Greenland), i.e. at latitudes and time comparable to the walruses in the NEW area. These three individuals which only hauled out on ice were monitored during a period when generally stable high pressure and fair weather conditions reigned in the Kane Basin region similar to the situation in NE Greenland.

Analyses of haul-out patterns

For all individuals, we tested the relationship between the haul-out pattern and (1) the time of the day, and (2) the wind chill situation. The wind chill index (W) was calculated from:

$$W = 13.12 + 0.6215T - 11.37(V^{0.16}) + 0.3965T(V^{0.16}),$$

where T is the temperature in °C and V is the wind speed in $km * h^{1}$ at 02:00 and 14:00 h local time at (Danish Meteorological Institute; unpublished data). The wind chill index is only defined for wind speeds above 4.8 $km * h^{1}$ (www.nws.noaa.gov).

Haul-out percentages were square root and arcsine transformed prior to statistical analyses to approach the assumptions of normal errors and constant variance as recommended in e.g. Zar (1996).

To test for effects of weather on the tendency to haul out, a linear mixed effect model was applied with transformed haul-out percentages as dependent variable, individual walrus as a random, or grouping, factor and the fixed factors as time of day (2 and 14 h local time) and the continuous variables wind-chill and barometric pressure. These times of day were chosen because the tendency to haul-out on land was low after midnight where after it increased reaching a peak haul-out “plateau” around 14 h local (Fig. 6, later).

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. A two-way analyse of variance (ANOVA) including the interaction term was applied to test for differences in mean haul-out percentage among these time intervals for land and ice, respectively.

To describe the diurnal pattern of haul-out on land and ice, polynomial regression analyses were employed. The first order hour term in the regression model is equivalent to a linear relationship, the second order to a quadratic (second-power) and the third to a cubic (third-power) relationship etc. Terms were added to the polynomial regression models until no longer significant at the 5% level.

The software Microsoft Excell-2007 and free software “R” (R Development Core Team 2008) were used for the calculations.

Counting of number of walruses

During the survey digital photos (1-2 Mb) were taken of each site with walruses. Photos that were considered of sufficient quality were studied by one of the authors (EWB). Often 100-300 x digital magnification was used. In some cases the contrast and brightness of the photos were enhanced using Adobe Photoshop software.

On each photo individual walruses were identified, marked digitally and tallied. Counts on a series of photos representing a group or an entire haul-out photographed from several angles were then evaluated for a finale estimate of number of animals on that particular location.

Age and sex distribution

From selected photos of sufficient quality we attempted to estimate the age and sex composition of the walrus herds. One of the authors (EWB) categorised the walruses´ sex and approximate age based on physical appearance. If an animal had (1) slender and usually parallel or converging tusks with a length ≥15 cm, (2) a small head and slender neck relative to body size, and (3) was lacking skin lumps (“bosses”) on neck and thorax, it was regarded as being an adult female. Atlantic walrus females become sexually mature (1st ovulation) at ca. 6 years of age (Born 2001) at which age tusk length usually is ca. 15 cm (Fay 1982, Born unpublished data). Individuals with (1) stout and >15 cm long and diverging tusks, (2) relatively massive head and neck, and (3) “bosses” on shoulder and thorax were categorised as adult males. Tusk lengths used for categorisation of age were: (1) no tusks (and dark and small body size) = calf of the year, (2) visible part of the tusks <15 cm = subadult of both sexes, (3) tusks ≥15-30 cm long = adult female or male and (4) tusks >30 cm long and slender = old female. Estimation of the external length of tusks was made semi-quantitatively based on their relative size compared to head size and muzzle width.

Movement

Data on movements and transmitter status were collected via the Argos Location Service Plus system (Toulouse, France). All location classes were used in the present study after being filtered by a SAS-routine, Argos_Filter V7.02 (Douglas 2006). Filter settings were: Maximum swim speed: 10 km/h (minrate = 10), which means that locations leading to swim speed > 10 km h-1 were excluded. If however the distance between locations were less than 5 km (maxredun = 5), they were both retained, because the swim speed calculations may be unrealistic due to the respective inaccuracies of the close positions. Finally positions were deleted if the angle between consecutive vector lines between previous and following location were less than 10 degrees (ratecoef = 10). All other settings were set as default. However, for identification of haul-out sites we only used quality 3 locations (and in a few cases LC2).

ArcGis V9.2 and MapInfo 8.5 were used to present the maps using GEBCO bathymetry.

Aerial surveys

The number of walruses observed during the 2009-survey along shores was summed for each survey day. In cases where a coastal stretch was covered more than once on different days (Table 1) the highest count obtained on any of these surveys was used for the estimation of numbers. A correction factor obtained from the instrumented walruses in 2009 was applied to the total count to account for walruses not present at the haul-outs during the surveys.

For the systematical line transect survey of the NEW area angles to sightings were converted to perpendicular distances based on the formula: Distance to sighting = 213 * (tan(90 – angle to sighting)).

Distributions of perpendicular distances were fitted by conventional distance sampling methods (Distance ver. 5.1) to a suite of models in order to estimate detection functions.

The abundance of walruses offshore in the NEW was estimated as the product of the density, the mean group size and the size of the stratum area. The stratum area was defined as the area delineated by the outer perimeter of the 17 transect lines (=5225 km^2).

A simple estimate of perception bias can be derived by the *mark-recapture* method from Magnusson et al. (1978) assuming that all walruses have the same probability of being detected or not detected, i.e. the probability that a walrus is being seen by one observer is the same as it being seen by the other observer. Variance of the perception bias in 2009 was estimated by a Jackknife procedure.

Confidence limits of the abundance estimates were calculated based on the assumption of log-normal distribution with lower limit=N/V and upper limit=N*V where V=exp(*z* * sqrt(ln(1+varN/N^2))); where N is the abundance of walruses and the factor *z* varied with the desired range of the confidence limits (90%) and the degrees of freedom.

Results

Weather conditions

During August 2009 the weather in the survey area was very favorable for walruses hauling out on land or ice (cf. e.g. Born & Knutsen 1997 and references therein) with calm and stable high pressure conditions. The weather conditions during 12-19 August when the surveys were conducted were mainly sky clear with fair positive air temperatures and light winds mainly blowing from N and E (Table 2). On some days local fog patches prevented observations in some parts of the survey area. This was particularly the case on 15 August between Danmarkshavn and Hovgaard Ø (Figs. 1 and 2) on a stretch of the coast where walruses are known not to be frequent (Born et al. 1997a).

Instrumentation with satellite transmitters and movement

Of the two walruses that were instrumented with SLTs on Sandøen in July 2008 one continued to use the haul-out on this island whereas the other moved offshore to the northeast and hauled out on ice during August (not shown).

During the tagging operation in 2009 harsh weather conditions prevailed in the Young Sund area with strong winds and rain. The number of walruses hauling out on the island dropped dramatically and by 7th August the Sandøen was no longer used for hauling out and was deserted for the remainder of the study period. After having left the Young Sund area the walruses moved north where they used several terrestrial haul-outs between Lille Pendulum island (74º 39´ N) and southern Dove Bugt (76º 15´ N). Two individuals (60272, 67997) made long excursions offshore to the edge of the continental shelf (Fig. 3).

Terrestrial haul-outs

During the aerial surveys in August 2009 four terrestrial male haul-outs were detected between southern Clavering Ø (74° 05´ N – 21° 16´ W) and northern Dove Bugt (76° 55´ N – 20° 06´ W). Furthermore, drag marks from walruses were seen on the southern tip of Slædeøen in Dove Bugt. North of Dove Bugt a terrestrial haul-out used by females and young was found on Lynn Ø in Dijmphna Sund (Figs. 4 and 5, Table 3).

Judging from high-accuracy re-locations and timelines indicating extended haul-out periods seven other terrestrial sites were used for hauling out between Clavering Ø and northern Dove Bugt for a variable length of time during August (Table 3).

On 20 July 2009, 30 walruses were observed on the Sandøen haul-out during the aerial surveys and during the tagging operation up to ca. 25 walruses hauled out on the island.

Walruses were not seen when the traditionally used haul-outs at Lille Snenæs, Hvalrosodden (Born et al. 1997a, Born & Acquarone 2001) and Port Arthur (Gilg et al. 2003) in Dove Bugt were checked during the aerial surveys on 12 August. During 12-13 August Lille Snenæs, and Hvalrosodden were inspected from the ground but no walruses or drag marks were seen.

Age and sex distribution

On the photographs of 12 different sites where walruses hauled out on land or ice a total of 172 different individuals were counted of which 79.7% were categorized to age class and 27.9% to sex (Table 4). Overall, adults comprised 58.4%, subadults 37.2% and 0-year-olds 4.4%. Hundred percent of adults identified as males occurred south of 77°N whereas all adults identified to sex north of there were females (Table 4). Judging from the photos the ratio of 0 year old calves to adult females was 1:0.3 indicating a triennial reproductive cycle.

Haul-out behavior

When using terrestrial haul-outs the eight walruses that were monitored during August preferred to haul out between ca.14 and ca. 20 h local time (Fig. 6). Three of these walruses also hauled out on ice between using terrestrial haul-outs. When resting on ice the diurnal haul-out curve peaked between 11 and 15 h (Fig. 6). The diurnal haul-out patterns differed significantly between land and ice (ANOVA, haul-out time interval and location interaction, $p<0.001$). The curve fitting of the diurnal pattern of haul-out by polynomial regression resulted in a cubic regression for land whereas a quartic (i.e. fourth-order) regression described diurnal haul-out pattern on ice.

Time of day (i.e. 2 and 14 h local) and wind chill had no significant effect on the tendency to haul out during August (linear mixed effect model, p=0.94 and p=0.51, respectively), whereas haul-out percentage increased significantly with increasing barometric pressure (p=0.01). However, this significance was driven by haul-out data from only one day (22 August) with a pressure below 1000 hPa and a low haul-out percentage. When re-running the linear mixed effect model without these data the effect of barometric pressure was no longer significant (p=0.16).

Individual haul-out periods (i.e. unaborted series of ≥70% dry SWS messages) lasted between 1 and 68 h. Duration of extended (>2 h) haul-out sessions on land ranged between 11.0 (sd=1.4, n= 2 periods, animal 67997) and 43.3 h (sd=30.7, n=3 periods, 60273). For three individuals that also hauled out on ice “on ice” haul-out sessions ranged between an average of 11.3 h (sd=5.8, n=3, 83308) and 25.2 h (sd=4.6, n=5, 67997) (Table 5).

On average, haul out time totaled 33.3% per day (sd=6.6, range: 23.1-41.8%, n=8) during August 2009 (Table 6). The walruses spent an average of 27.7% (sd=14.6, range 3.6-41.8%, n=8) of the time on land in August. Average haul-out time on ice of three individuals was 15.0% (sd=8.9, range: 4.7-20.7, n=3) (Table 6).

Two walruses that were monitored during August 2008 were included for comparison (Table 6). The duration of individual haul-outs in 2008 and 2009 did not differ (linear mixed effect model, p=0.83); neither did duration of single haul-outs differ between ice contra land in any year (linear mixed effect model, p=0.80) nor the interaction term between the two factors (p=0.38).

Correction factors for walruses on the terrestrial haul-outs

For establishing correction factors for walruses on land the haul-out time between 10 and 17 h local time during 12-19 August, when the aerial surveys were conducted, was used. During this survey window, seven walruses hauled out on either ice or land for 42.8% (sd=15.7, range: 14.3-62.4, n=7) of the time. The proportion of time hauled out on land was 39.5% (sd=17.6, range: 14.3-62.4%, n=7) (Table 7).

Hence, theoretically the number of walruses observed on land can be multiplied by 1/0.395 or 2.53 (cv=0.17) to account for walruses that were not present at the terrestrial haul-outs during the aerial surveys.

However, alternatively the fraction of instrumented walruses that actually hauled out on the specific survey days may be considered. Of particular interest is the fraction on land during surveys of the areas where the walruses were using the terrestrial haul-outs. Instrumented walruses that were hauling out offshore on ice during the survey were not available for detection and were deleted from the proportions of animals available at the terrestrial haul-outs. On 12, 13 and 14 August when the shores between Clavering Ø and Dove Bugt were surveyed 25% to 38% of the instrumented walruses hauled out on land. This indicates that a correction factor ranging 2.7-4.0 can be applied to the counts of animals on land to account for animals not present at the haul-outs.

Between 10 and 17 h (i.e. when the survey was conducted of the NEW), the three walruses that were monitored in Kane Basin in August 2009 hauled out on ice for an average of 28.2% (sd=14.2, range: 14.2-42.5, n=3), Table 8. Hence, the number of walruses observed on ice must be multiplied by 3.55 (cv=0.29) to account for the proportion not hauling out.

Correction factors for walruses in water

When at sea during August eight walruses spent an average of 14.5% (sd=4.8, range: 7.1-20.9, n=8) of the time at the surface (Table 6). Between 10 and 17 h during the survey period the walruses spent an average of 17.6% of the time (sd=4.5, range: 12.3-24.5%, n=7) at the water´s surface (Table 7) resulting in a surface:subsurface ratio of 1:5.7 walruses (i.e. for one walrus at the surface 5-6 were submerged).

Three walruses that were monitored in Kane Basin in August 2009 spent on average 18.0% (sd=2.6, range: 16.4-21.0) of the time at the water´s surface during 10-17 h local time (Table 8).

Aerial surveys

Estimates of abundance obtained from the coastal surveys

The distribution of observations of walruses made during the aerial survey in August 2009 is shown in Figs. 5 and 6. On 12, 13 and 14 August a total of 60 different walruses were observed on hauled out on land between northern Dove Bugt (76° 55´ N) and southern Clavering Ø (74° 05´ N; Table 1). When correcting for the proportion of animals that were not hauled out on land during the surveys an estimated 152 (cv=0.17) walruses were present south of NEW (Table 9). If alternatively applying a correction obtained from the proportion of the eight instrumented walruses that actually were on land during these days 156 to 240 walruses were present in the area.

A group of 17 female walruses and young was observed on 15 August on Lynn Ø in Dijmphna Sund about 50 km from the NEW *sensu strictu*. This observation was not treated separately and a correction factor was not applied to the count. The reason is that we believe that these walruses were encompassed by the correction we applied to the survey on 19 August to include walruses that were not hauled out on the ice (i.e. walruses were able to move between land and the NEW area during the survey).

Estimates of abundance in the NEW area

When the NEW was surveyed using the line transect methodology on 19 August, a total of 27 sightings (19 on ice, 7 in water, 1 undetermined) were made on 17 transect lines totaling 854 linear km applicable to a total survey stratum of 5225 km^2.

The double platform experiment could be performed on “on ice” observations only because all “in water” observations were made by the front observer. The experiment resulted in 14 detections “on ice” with: 4 animals seen by both platforms, 5 seen by the front platform only and 5 seen by the rear platform only. The low number of duplicate detections does not allow for mark-recapture distance sampling methods that include estimation of the heterogeneity in the detection process and instead a simple mark-recapture estimate was applied to a strip census density estimate with fixed strip width of 800 m.

Since the survey had one single observer platform and one double observer platform two different estimates for the NEW are developed (see Table 9). The density for the single observer platform was 0.010 walrus groups per km^{-2} with a mean group size of 2.4 (cv=0.17) or a total of 54 walruses (cv=0.74). The estimate of perception bias for the single observer platform was 0.47

(cv=0.20) and the availability correction for walruses hauled-out on ice in August 2009 was 0.28 (cv=0.29). Correcting for these two biases results in an estimate of 404 (0.73) walruses hauled out on ice. The density for the double observer platform was 0.034 walrus groups per km^{-2} with a mean group size of 1.8 (cv=0.21) or a total of 176 walruses (cv=0.55). The estimate of perception bias for the double observer platform was 0.74 (cv=0.20) and correcting for this and the availability bias gives 873 (0.66) walruses hauled out on ice in the NEW.

The the coastal survey and the survey of the NEW area combined results in a fully corrected abundance estimate for walruses in East Greenland in August 2009 of 1429 (90% CI: 705-2896).

Discussion

General distribution, movement and terrestrial haul-outs

The surveys 2009 confirmed earlier information (Born et al 1997a) that walruses are patchily distributed in the shallow water areas along the coast of NE Greenland north of ca. 74° N and that the two gender are geographically separated during summer with females occurring further north than males. This is accordance with observations during aerial surveys conducted over the same areas in 2008 (Boertmann et al. 2009).

The movement of the tagged walruses indicated that some animals may occur far offshore during August. In 2009 two individuals spent quite some time offshore at the edge of the continental shelf while sometimes also visiting terrestrial haul-outs. One out of two walruses that were tracked in 2008 also moved offshore. Sporadic observations of walruses offshore in the Greenland Sea during 1863 and 1992 were summarized in Born et al. (1997). About 56% had been made during July and August. Previous studies involving satellite telemetry also revealed that some walruses make excursions offshore more than 100+ km from the terrestrial haul-outs (Born & Acquarone 2007). However, we assume that male walruses that occur offshore use terrestrial haul-outs and therefore were included by the correction factor we applied to walruses that were counted on land. If, however, for some reason some walruses south of 77° N never haul-out on land and only rest on ice our estimate of the male portion of the population is negatively biased.

During August 2009 the walruses used several haul-outs between Young Sund and Dove Bugt. Judging from the satellite telemetry data the haul-outs at SW Shannon, Kap Carl Ritter and Kap Peschel were used regularly. However, from early August the traditionally used haul-out on Sandøen was no longer used and apparently had the haul-outs at Lille Snenæs, Hvalrosodden and Port Arthur in Dove Bugt not been used when they were inspected in August.

Hence, in August 2009 the distribution and use of haul-outs differed markedly from what was previously known (Born et al. 1997a). Ice conditions in August 2009 in Young Sund and Dove Bugt seemed not to differ markedly from several earlier years when walruses did haul-out on Sandøen (Born & Berg 1999, Born, personal observation) and in Dove Bugt (e.g. in 1989, Born & Knutsen 1997), respectively.

During late July 2009 the number using Sandøen dropped dramatically. A similar though less dramatic decrease in the number hauling-out on Sandøen was observed in early August 1998 (Born & Berg 1999) and 2008 (Born et al. 2009). In 2008 daily counts of walruses were conducted at the beach of Sandøen between 17 July and 24 August. The number of walruses hauled out varied from 0 to 37 animals with a declining trend over time ($Y=0.014x^2 – 0.96x + 20.5$, $r^2=0.23$) (Born et al. 2009).

Born & Berg (1999) and Born et al. (2009) suggested that the drop in numbers seen on Sandøen in 1998 and 2009 was associated with man-made disturbance including aircraft traffic in close proximity of the haul-out and sometimes over it, and photographers and tourists disturbing the walruses by getting too close (Ibid.). In late July and August 2009 there was intense helicopter (at one stage 3 different types) and fixed-wing aircraft traffic to and from Daneborg in close proximity of Sandøen. This in combination with prevailing strong winds and the tagging operation may have motivated the walruses to leave the Sandøen haul-out during August 2009.

To our knowledge there had been no disturbance of at the haul-outs in the Dove Bay prior to the surveys. The absence of drag marks and fresh feces on the beach of Lille Snenæs and Hvalrosodden indicates that walruses had not used these haul-outs prior to 12 August. Walruses that otherwise would have used these haul-outs likely chose to rest on the coast further south.

Earlier information suggests that walruses in some years haul-out on land between Young Sund and Dove Bugt (e.g. Påskenæsset and eastern Shannon, Born & Knutsen 1992, Born et al. 1997, Sabine Ø, Born & Acquarone 2007).

However, the radical shift in choice of terrestrial haul-outs experienced in 2009 and in particular their absence from the formerly used haul-outs in Dove Bugt is difficult to explain. We suggest that it may represent (1) either a reaction to the overall decrease in sea ice in East Greenland (UNEP 2007) and/or (2) a long term behavioral adaptation and shift in distribution in order to reduce the predation pressure on their localized foraging banks. It cannot be excluded that these factors also made the walruses leave the Sandøen haul-out in early August. In light of the current changes in sea ice in East Greenland this development warrants further investigation in the future.

None of the instrumented walruses moved between alternative haul-outs during the brief survey period.

A haul-out used by females and young was discovered in 2009 on Lynn Ø in Dijmphna Sund. Walruses have been observed on land during summer in Dijmphna Sund earlier and also in Hanseraq Fjord on the outer coast bordering the NEW (Born et al. 1997a). The sex of the walruses in the earlier observation was not determined but given the general distribution of the two gender in East Greenland during this period of the year they were likely females. In the NEW area the female walruses and young mainly hauled out on the sea ice. However, they also choose to haul-out on land in this part of East Greenland despite the fact that this is good polar bear habitat where polar bears occur year-round (Born et al. 1997b).

Hence, except for a change in the haul-out sites occupied the overall distribution of walruses found during 2009 was similar to that described earlier (Born et al. 1997a, Born 2009, Boertman et al. 2009).

Diurnal haul-out rhythm

We found a diurnal variation in haul-out rhythm. When hauling out on land the greatest proportion of time was spent out of the water during afternoon and early evening – whereas the tendency to haul out on ice peaked around noon. These patterns are in general accordance with studies of haul-out behavior of walruses during summer in Alaska (Hills 1992), the Canadian High Arctic (Salter 1979) indicating that walruses prefer to haul out during day time hours. A previous study in NE Greenland indicated that the walruses especially preferred to haul-out during afternoon and early evening (Born & Knutsen

1997). A study of 43 walruses that were monitored with SLTs in the Bering Sea region during April also showed a diurnal cycle with highest haul-out values in the evening (Udevitz et al. 2009).

Generally the tendency to haul out is influenced by weather conditions - and is in particular negatively affected by low temperature and high wind speeds (i.e. wind chill) and precipitation (Salter 1979, Hills 1992, Born & Knutsen 1997, Udevitz et al. 2009).

In contrast, Lydersen et al. (2008) did not find any relationship during summer at Svalbard between haul-out activity of walruses instrumented with transmitters and wind chill. Similar to what was found in the study at Svalbard we were not able to detect any relationship between wind chill (and barometric pressure) and walrus haul out patterns in NE Greenland. However, similar to the situation described by Lydersen et al. (2008) this was likely caused by the fact that when the walruses were monitored the weather conditions were fine in NE Greenland with little variation in wind and temperature and with no precipitation.

Haul-out and at surface time

We found that the instrumented walruses generally hauled out for ca. 33% of the day during August. 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 & Knutsen 1997, Acquarone et al. 2006, Born & Acquarone 2007). Percentage of time hauling out may, however, differ per month. In a study of Pacific walruses Hills (1992) found the highest haul-out percentage in May. Overall, tagged walruses averaged only about 17% of their time (range: 7-30%) hauled out on sea ice in April in the Bering Sea region (Udevitz et al. 2009).

For estimation of the number of female walruses and young in the NEW area we applied a correction obtained for walruses that only hauled out on ice in Kane Basin in 2009. This correction factor (ca. 28% of the time hauled out) falls well within the range found by Hills & Gilbert (1994) for 15 female Pacific walruses that were 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).

In August the walruses in NE Greenland spent an average of ca. 15% of the time at the surface. Direct observations indicate that during travelling and feeding walruses are at the water surface for 11 to 24% of the time (Fay 1982, Born & Knutsen 1997 and references therein). Fay et al. (1997) summarized information on at surface time and found that walruses on average spend ca. 16% of the time at the surface during various behaviours. However, at surface times may vary substantially among studies. At Svalbard during summer, Wiig et al. (1993 found that about 24% of the time was spent between 0 and 2 m. In contrast, Jay et al. (2001) found that four Pacific walruses equipped with time-depth-recorders (TDR) when at sea spent ca. 40% of the time between 0 and 2 m during summer. Using TDRs and SLDRs to study walrus activity during late July-August at Svalbard, Gjertz et al. (2001) found that nine walruses spent ca. 83% of their time in water of which 39% was spent between 0 and 2 m depth, and 44% of the time below 2 m (Ibid.).

Estimates of abundance and comparison with previous surveys

Walruses are among the most difficult marine mammals to census because of their extremely clumped distribution that leads to large variability of the abundance estimates. Further complicating factors are there simultaneous occurrence on and in three different substrates: land, ice and water. This behavior requires correction factors to be developed for each type of habitat while avoiding double correction for animals that are not in one habitat but included in surveys of the other. To this should be added that walruses are segregated by sex for a major part of the year which makes representative sampling of the population difficult. Finally, walruses occur in remote and inaccessible areas that in places like East Greenland makes it difficult to conduct an otherwise well designed survey effort (Estes and Gilbert 1978, Gilbert 1989, 1999, Hill & Gilbert 1994, Fay et al. 1997, Udevitz et al. 2001).

In this study we tried to enumerate walruses on their terrestrial haul-outs and combine this estimate with a density estimation of the fraction of the population that chose to use the sea ice located over the banks in NE Greenland. To correct for animals that for whatever reasons are away from the haul-out sites satellite transmitters were providing data on the fraction that is not hauled-out. The animals that were instrumented with satellite transmitters were mature males. However, adult male walruses are presumably not well represented during summer in the ice habitat in NEW where density of walruses on ice was estimated. Sightings of walruses in the water in this area were not used for abundance estimation and instead a correction factor for time hauled-out on sea ice in Kane Basin in Northwest Greenland during the same period was used.

The pitfalls of double counting of walruses should with this design have been carefully avoided but there are still possibilities for the abundance estimates to be negatively biased:

South of the main distribution area shallow water banks with suitable food for walruses are few and of very restricted distribution. Furthermore, in these areas walruses are subject to hunting which in fact in 1925 resulted in that they permanently abandoned a traditionally used haul-out at the entrance to Scoresby Sund (Born et al. 1997a). Due to a combination of these factors walruses are mainly distributed north of 73°30´ N. Hence, there are no reasons to believe that the 2009 surveys missed a noticeable number of walruses because they were south of the survey area.

The surveys concentrated on areas of the coast where walruses have been observed earlier (i.e. in areas with shallow water banks along the outer coast, Born et al. 1997a). Therefore, fjords with deep waters were not surveyed. However, due to their preference for food that lives in shallow water areas (Fay 1982) we find it unlikely that walruses occurred in these areas. However, small groups or single walruses on land may have been missed during the surveys of the outer coast and the many islands in Dove Bugt. Although the double-observer platform experiment did not indicate a perception bias during the coastal surveys some walruses may have hauled out on coasts that were not surveyed. However the intense expedition activity every summer in NE Greenland would have reported if any larger haul-out concentrations were discovered.

Boertmann et al. (2009) presented an estimate of abundance of walruses based on a systematical aerial survey conducted on 4 June 2008 in the NEW area. The density in the stratum in NEW, defined by the transects, was 0.075 walruses/km^2 (95 % c.i. 0.016-0.035) giving a population (not corrected for individuals that were not hauled out) of 470 (95 % CI: 100-2207) walruses in NEW (Ibid.). Although this estimate is higher than the estimate obtained during the present study it has a wide confidence interval and is not statistically significantly different from the 2009-estimate. However, direct comparison between Boertmann et al.´s estimate and that obtained by us in 2009 is not feasible. The survey in 2008 that involved a different aircraft and altitude and survey procedures was conducted at a different time of the year. Furthermore, the 2008-survey did not involve double-observer platform or collection of area or time specific correction factor data. Hence correction factors applied in our survey are not applicable to the 2008-survey. Nevertheless, a higher encounter rate experienced in 2008 compared to 2009 may indicate that (1) a larger fraction of the East Greenland population of walruses was present in the NEW that year or/and (2) the fraction hauling out on the ice was higher during the June 2008-survey than during the August 2009-survey. A third possibility of a seasonal immigration to NEW of walruses from the Svalbard region seems less plausible.

Satellite telemetry has shown that during fall adult male walruses move north to winter in the NEW area (Born & Knutsen 1992, Born et al. 2005). The mating season in Atlantic walrus is January-June with a peak in April (Born 2001). Hence, the early June survey in 2008 may in contrast to the 2009-survey also have included a certain proportion of adult males that had not yet begun their migration south after the mating season to their summer feeding areas.

However, it cannot be precluded that a higher encounter rate experienced in 2008 was due to the fact that a higher proportion of walruses hauled out during early June 2008. We are not aware of the existence of information on haul-out time for Atlantic walrus in late May-early June. Haul-out time (or SWS dry time) monitored by Hills (1982) in nine male Pacific walruses (*O. r. divergens*) in the Bristol Bay area differed significantly among months being highest in May (45%) whereas during June-September the haul-out time range between 27% (June) and 35% (August).

The season of birth in walruses is extended over several months (Fay 1982, Born 2001) but in Atlantic walrus the peak birth period is in May-June (Born 2001 and references therein). The NEW-survey in 2008 that was conducted in June likely found a larger proportion of the population hauling out on ice because females were given birth or had newborn.

The distribution of walruses in NE Greenland and at Svalbard is about 400 km apart. Sporadic observations of walruses in the Fram Strait may indicate that a connection exists between walruses in these two areas. A single instance of a walrus that moved from East Greenland to NW Spitsbergen in Svalbard was documented in 1992 (Born & Gjertz 1993). However, satellite telemetry in East Greenland (Born & Knutsen 1992, Born et al. 2005, Born & Acquarone 2007) and in the Svalbard-Franz Joseph Land region (Wiig et al. 1996, Freitas et al. 2009) and genetic studies (Andersen et al. 1998, Born et al. 2001) indicate only very limited exchange between the East Greenland and the Svalbard-Franz Joseph Land populations of walruses. Furthermore, during winter the females and young of the latter population congregates east of Svalbard and in the Franz Joseph Land area far from NEW (Wiig et al. 1996, Freitas et al. 2009). We therefore find it very unlikely that an apparent higher concentration of walruses in NEW in 2008 should represent any significant immigration that winter and spring of walruses from neighboring Svalbard.

Hence we suggest that the apparent higher sighting rate of walruses in NEW in 2008 compared to 2009 was due to the combined effect of a higher number actually being present in combination with a larger fraction of the population being hauled out.

The corrected estimate for the traditionally used haul-out on Sandøen was 87 in July (2009). By using genetic markers on skin samples from walruses that were sampled on Sandøen it was determined that a total of 81 different individuals used this haul-out during August 2003 (Born & Acquarone 2007). In 2003, 34 walruses were observed at three haul-outs in the Dove Bugt area (i.e. Lille Snenæs, 8; and two other haul-outs that were discovered that year: Port Arthur, 18, and at 76°45´ -21°13´ W, 8 animals; Gilg et al. 2003). Without giving details, Gilg et al. write that at least 50 walruses were present in Dove Bugt during their survey in 2003. Hence, a minimum estimate of the number of male walruses between 74° and 77°N in 2003 was 115 to ca. 130. It indicates that our estimate of the number present in these areas in 2009 was in the similar order of magnitude.

Hunter-returned tags have provided information on gross movements in East Greenland: An adult male that was tagged in Dove Bugt in August 2000 was shot at the entrance of Scoresby Sund on 15 June 2003. Another adult male tagged in Young Sund in late July 2001 was shot at Scoresby Sund in May 2002 (Born unpublished data). In addition an animal with drill holes in the tusks from the attachment of a transmitter was shot at Scoresby Sund on 14 December 2007 (Born, unpublished data). This information on gross movements is in accordance with Andersen et al. (1998), who found that samples from Dove Bugt, Young Sund and the entrance of Scoresby Sund did not differ genetically, and information in Born et al. (1997) in which photo-identification of individuals was used to demonstrate a connection between the haul-outs in Dove Bugt and Young Sund. Hence, this evidence supports the notion that walruses in East Greenland belong to one coherent sub-population and that the catches are taken from the population enumerated during our study.

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References

Acquarone, M., E.W. Born & J. Speakman 2006. Walrus (*Odobenus rosmarus*) field metabolic rate measured by the doubly labeled water method Aquatic Mammals 32(3): 363-369.

Andersen, L.W., E.W. Born, I. Gjertz, Ø. Wiig, L.E. Holm & C. Bendixen 1998. Population structure and gene flow of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in the eastern Atlantic Arctic based on mitochondrial DNA and microsatellite variation. Molecular Ecology 7: 1323-1336.

Boertmann, D., K. Olsen, K. & R.D. Nielsen 2009. Seabirds and marine mammals in Northeast Greenland. Aerial surveys in spring and summer 2008. National Environmental Research Institute, Aarhus University, Denmark. 50 pp. NERI Technical Report no. 721. http://www.dmu.dk/ Pub/FR721.pdf

Born, E.W. 2001 Reproduction in female Atlantic walruses (*Odobenus rosmarus rosmarus*) from northwestern Greenland. Journal of Zoology (London) 255: 165-174.

Born, E.W. 2009. Walruses (*Odobenus rosmarus*), 100-107. In: Boertmann, D., Mosbech, A., Schiedek, D. & Johansen, K. (eds.) 2009. The western Greenland Sea. A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area. National Environmental Research Institute, Aarhus University, Denmark. 246 pp. – NERI Technical report no. 719. http://www.dmu.dk/Pub/FR719.pdf

Born, E.W. & I. Gjertz 1993. A link between walruses (*Odobenus rosmarus*) in northeast Greenland and Svalbard. Polar Record 29:329.

Born, E.W. & L. Ø. Knutsen 1997. Haul-out activity of male Atlantic walruses (*Odobenus rosmarus rosmarus*) in northeastern Greenland. Journal of Zoology (London) 243:381-396.

Born, E.W. & T.B. Berg 1999. A photographic survey of walruses (*Odobenus rosmarus*) at the

Sandøen haul-out (Young Sund, eastern Greenland) in 1998. Greenland Institute of Natural Resources - Technical Report No. 26: 1-19.

Born, E.W. & M. Acquarone 2001. Tilbage til Hvalrosodden (Return to the Walrus Spit). Tidsskriftet Grønland 2: 51-61. In Danish.

Born E. W. & M. Acquarone 2007. An estimation of walrus predation on bivalves in the Young Sound area (NE Greenland), 176-191. In: S. Rysgaard & Glud, R.N. (eds.) Carbon cycling in Arctic marine ecosystems: Case study Young Sound. Meddelelser om Grønland - Bioscience 58.

Born, E.W., I. Gjertz & R.R. Reeves 1995. Population Assessment of Atlantic Walrus. Norsk Polarinstitutts Meddelelser 138: 1-100.

Born, E.W., R. Dietz, R., M.P. Heide-Jørgensen & L.Ø. Knutsen 1997a. Historical and present status of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in eastern Greenland. Meddelelser om Grønland, Bioscience 46:1-73.

Born, E.W., Ø. Wiig & J. Thomassen 1997b. Seasonal and annual movements of radiocollared polar bears (*Ursus maritimus*) in NE Greenland. Journal of Marine Systems 10: 67-77.

Born, E.W., L.W. Andersen, I. Gjertz & Ø. Wiig 2001. A review of genetic relationships of Atlantic walruses (*Odobenus rosmarus rosmarus*) east and west of Greenland. Polar Biology 24: 713-718.

Born, E.W. M. Acquarone, L. Ø. Knutsen, & L. Toudal 2005. Homing behaviour in an Atlantic walrus (*Odobenus rosmarus rosmarus*). Aquatic Mammals 31: 23-33.

Born, E.W., C. Egevang, F. Ugarte, L. Maltha Rasmussen & M. Willemoes Kristensen 2009 *In Press*. Walrus studies on Sand Island 2008. ZERO – 14th Annual Report

Douglas D. 2006. The Douglas Argos-Filter Algorithm, Version 7.03. U.S. Geological Survey, Anchorage, Alaska.

Estes, J.A. & J.R. Gilbert 1978: Evaluation of an aerial survey of Pacific walruses (*Odobenus rosmarus divergens*). Journal of Fisheries Research Board of Canada 35: 1130-1140.

Fay, F.H. 1982. Ecology and Biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. North American Fauna No. 74. U.S. Department of the Interior Fish and Wildlife Service: 279 pp.

Fay, F.H., L.L. Eberhardt, B.P. Kelly, J.J. Burns & L.T. Quakenbush 1997. Status of the Pacific walrus population, 1950-1989. Marine Mammal Science 13: 537-565.

Freitas, C., K.M. Kovacs, R.A. Ims, A. Fedak & C. Lydersen. 2009. Deep into the ice: over-wintering and habitat selection in Atlantic walruses. Marine Ecology Progress Series 375: 247-261.

Gilbert, J.R. 1989. Aerial census of Pacific walruses in the Chukchi Sea. Marine Mammal Science 5:17-28.

Gilbert, J.R. 1999: Review of previous Pacific walrus surveys to develop improved survey design, pp. 75-84. *In:* G.W. Garner, S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald & D.G. Roberton (Eds.). Marine mammal survey and assessment methods. A.A. Balkema, Rotterdam, Brookfield, the Netherlands: 287 pp.

Gilg, O., B. Sabard, B. Sittler, F. Mariaux, P. Legesdron & V. Gilg 2003. ECOPOLARIS 2003 Ecological Expedition to Northeast Greenland and Dove Bugt: North-East Greenland National Park. Field Report: 12 pp + 8 appendices.

Gjertz, I., D. Griffiths, B.A. Krafft, C. Lydersen & Ø. Wiig 2001. Diving and haul-out patterns of walruses *Odobenus rosmarus* on Svalbard. Polar Biology 24: 314-319.

Hills, S. 1992. The effect of spatial and temporal variability on population assessment of Pacific walruses. PhD-thesis, University of Maine, Orono, December 1992: 120 pp.

Hills, S. & J.R. Gilbert 1994. Detecting Pacific walrus population trends with aerial surveys: A review. Transactions of the 59th North American Wildlife and Natural Resources Conference. Wildlife Management Institute: 201-210.

Jay, C.V., S.D. Farley & G.W. Garner 2001. Summer diving behavior of male walruses in Bristol Bay, Alaska. Marine Mammal Science 17: 617-631.

Lydersen, C., J. Aars & K.M. Kovacs 2008. Estimating the number of walruses in Svalbard from aerial surveys and behavioural data from satellite telemetry. Arctic 2: 119-128.

Magnusson, W.E. and G.J.Caughley & G.C. Grigg. 1978. A double-survey estimate of population size from incomplete counts. The Journal of Wildlife Management 42 (1): 174-176.

NAMMCO. 2006. NAMMCO Annual Report 2005, North Atlantic Marine Mammal Commission, Tromsø, Norway: 381 pp.

R Development Core Team 2008. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Salter, R. 1979. Site utilization, activity budgets and disturbance responses of Atlantic walruses during terrestrial haul-out. Canadian Journal of Zoology 57: 1169-1180.

Udevitz, M.S., J.M. Gilbert & G.A. Fedoseev 2001. Comparison of methods used to estimate numbers of walruses on sea ice. Marine Mammal Science 17: 601-616.

Udevitz, M.S, C. V. Jay, A. S. Fischbach & J. L. Garlich-Miller 2009. Modeling haul-out behavior of walruses in Bering Sea ice. Canadian Journal of Zoology (In press).

UNEP 2007. Global Outlook for Ice & Snow. United Nations Environment Programme ISBN: 978-92-807-2799-9

Wiig, Ø., I. Gjertz, D. Griffiths & C. Lydersen 1993. Diving patterns of an Atlantic walrus *Odobenus rosmarus rosmarus* near Svalbard. Polar Biology 13: 71-72.

Wiig, Ø., I. Gjertz & D.Griffiths 1996. Migration of walruses (*Odobenus rosmarus*) in the Svalbard and Franz Josef Land area. Journal of Zoology (London) 238:769-784.

Wildlife Computers 2006. SPOT 5 User Guide, 22 November 2006. Wildlife Computers, Redmond, Washington, USA: 25 pp.

Witting, L. & E.W. Born 2005. An assessment of Greenland walrus populations ICES Journal of Marine Science 62: 266-284.

Zar, J.H. 1996. Biostatistical Analysis. 3rd Edition. Englewood Cliffs, N.J: Prentice Hall.

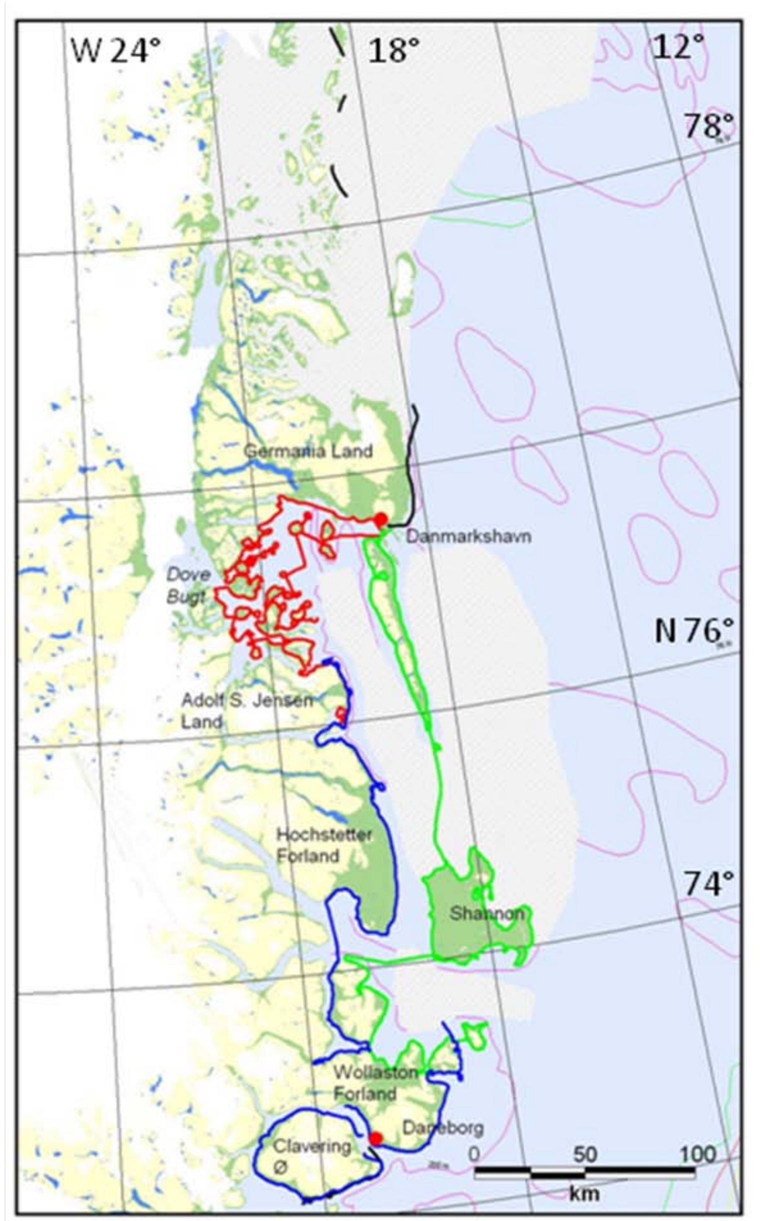

Fig. 1: Survey routes flown during 12-15 August 2009 in the southern part of the walruses´ summering range in East Greenland. Red line: 12 Aug., green: 13 Aug., blue: 14 Aug., and black lines: 15 Aug. Consolidated fast ice and fjord ice (more or less disintegrated) are indicated with a dotted white signature. The 200 m bathymetric curve is shown.

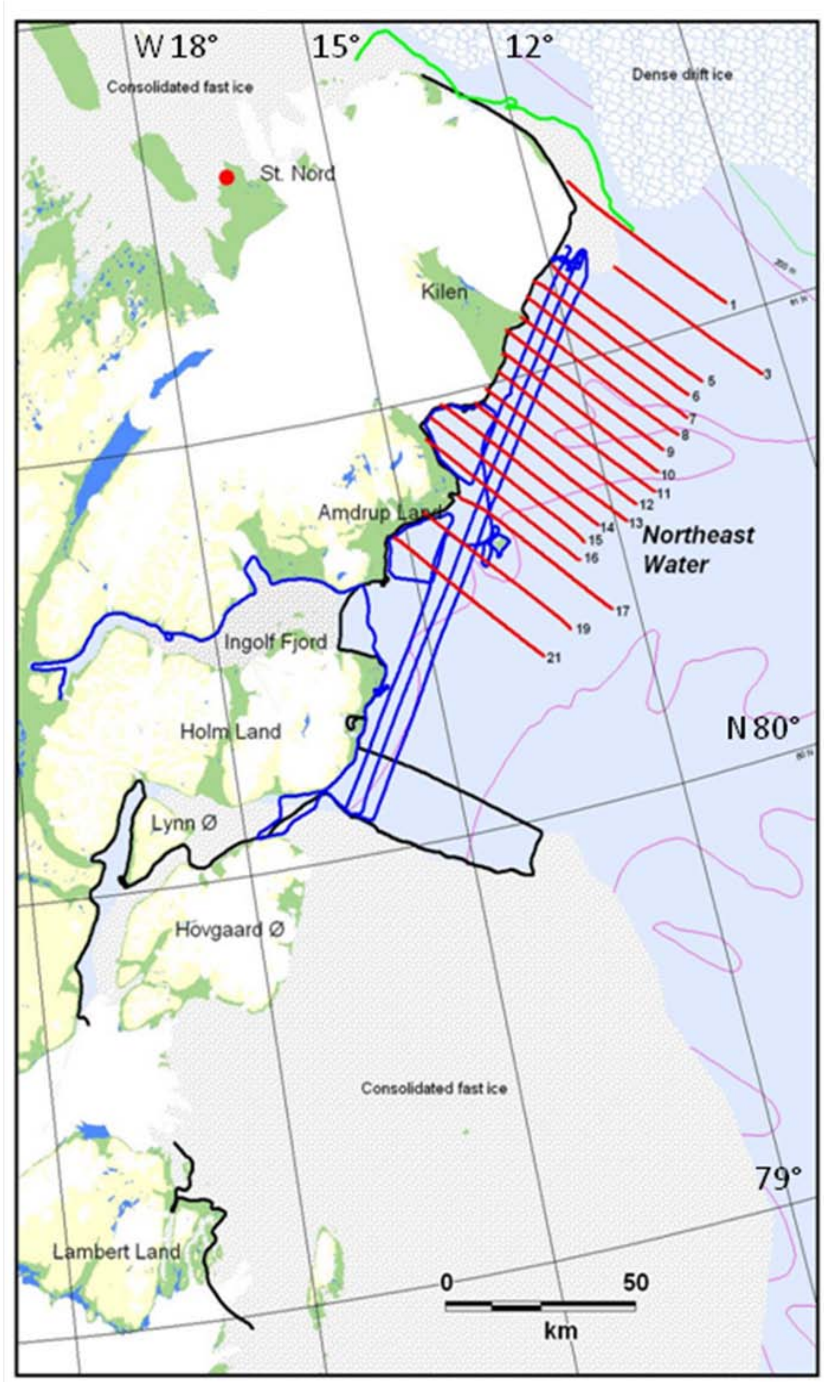

Fig. 2: Survey routes flown during 15-19 August 2009 in the northern parts of the walruses summering range in East Greenland. Black line: 15 Aug., blue: 17 Aug., green: 18 Aug and red lines: 19 Aug. Transect numbers are indicated for the systematic survey of the Northeast Water (NEW). Consolidated fast ice and fjord ice (more or less disintegrated) are indicated with a dotted white signature. The 200 m bathymetric curve is shown.

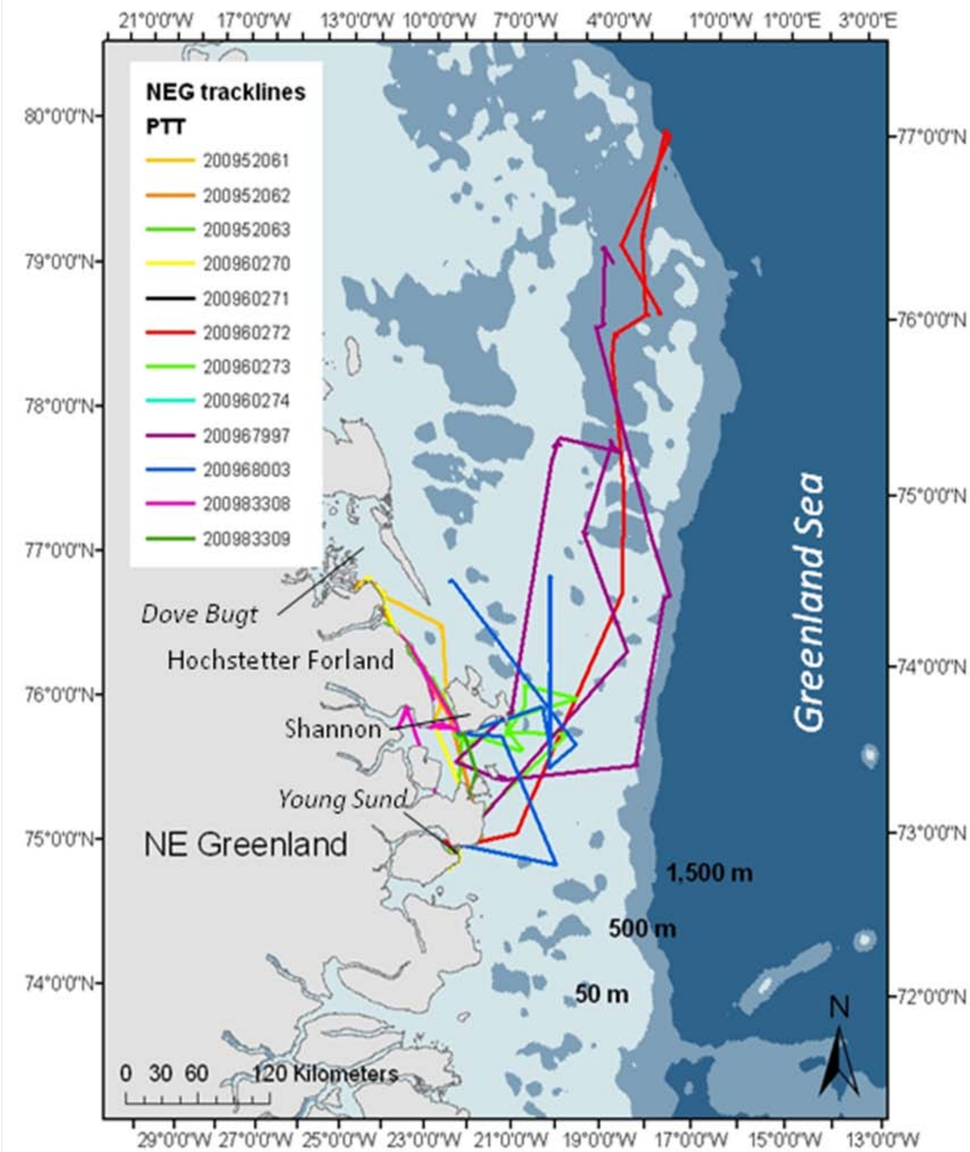

Fig. 3: Movement of 10 adult male walruses in August 2009. Eight of the 2009-animals provided information on haul-out activity that was used for correcting aerial surveys counts during August 2009.

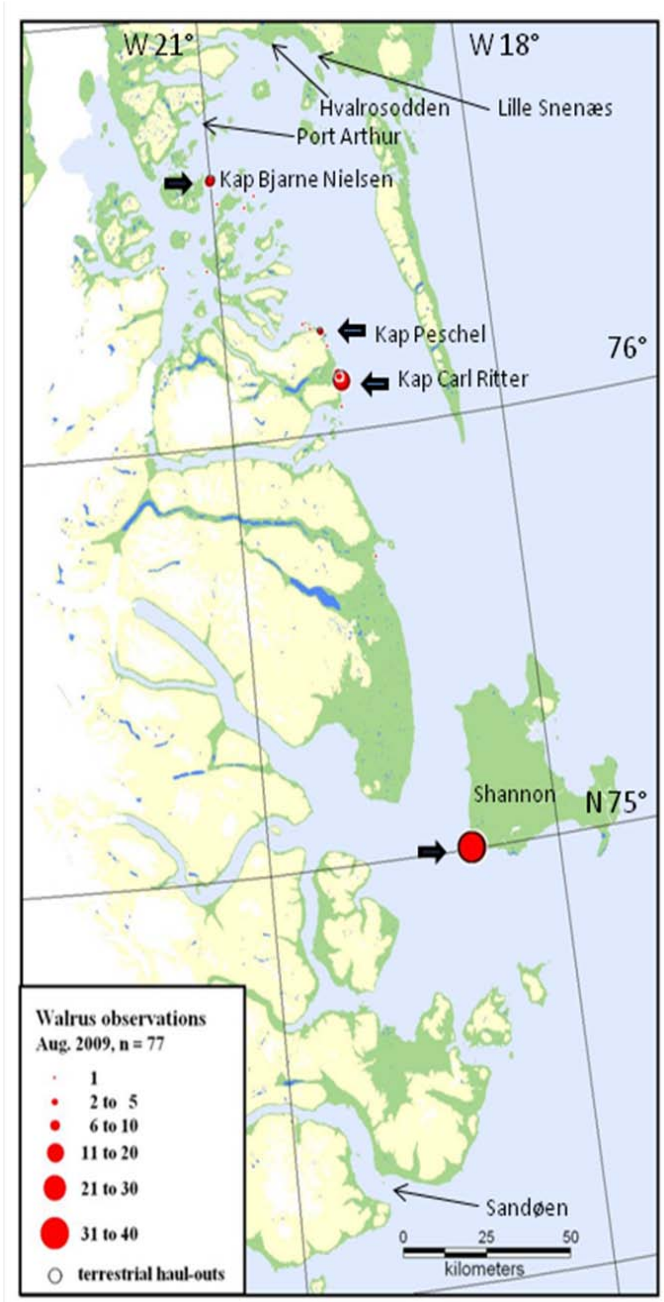

Fig. 4: Distribution of walrus observations between Clavering Ø (74° N) and northern Dove Bugt (77° N) during 12-15 August 2009. Terrestrial haul-outs found in 2009 are indicated by fat arrows. The location of traditionally used haul-outs are indicated with thin arrows.

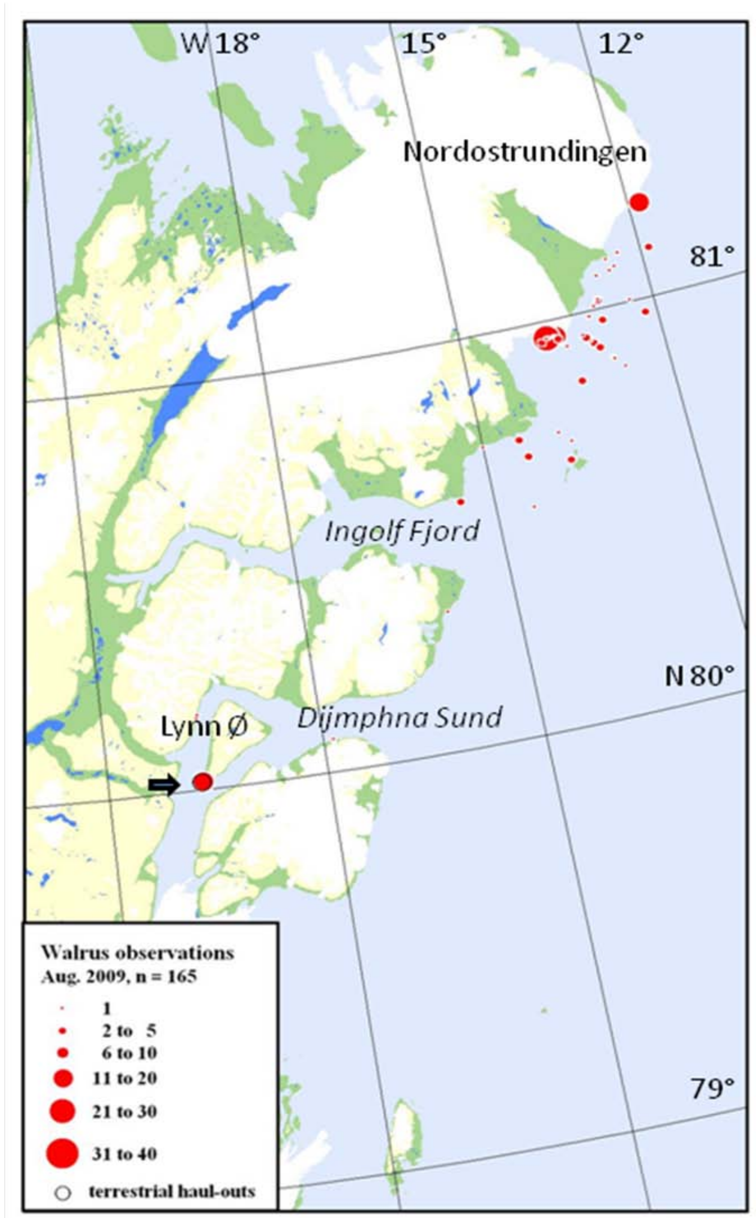

Fig. 5: Distribution of walrus observations made during aerial surveys conducted 15-19 August 2009 north of 77° N in East Greenland. A terrestrial haul-out is indicated by an arrow.

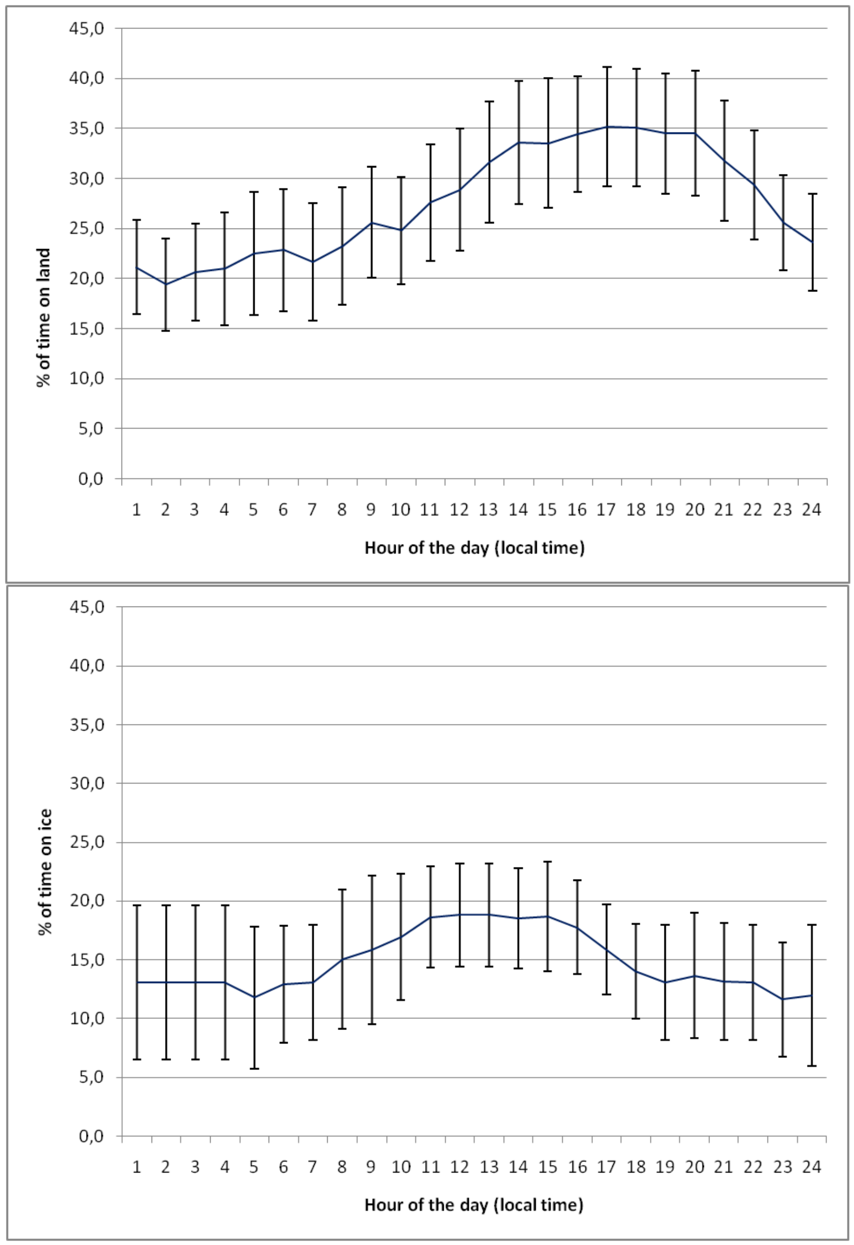

Fig. 6: Diurnal haul out pattern on land (upper panel; n=8 individuals) and ice (lower panel; n=3) of adult male walruses that were monitored by use of satellite transmitters in NE Greenland during August 2009. Three of the eight walruses used ice for hauling out in between resting on land. Error bars are ± SE.

Day in August	Area searched	Numbers observed Land	Ice	Water
12	Dove Bugt, northern coast of Ad. S. Jensen Land	20	2	10
13	S. of Dove Bugt incl. Store Koldewey and Shannon	37	0	0
14	S. of Dove Bugt to southern coast of Clavering Ø	17(14*)	1	8
15	N. of Danmarkshavn to ca. 81° 45´ N	17	63	5
17	Ingolf Fj. and 3 transects parallel to coast in NEW	0	41	2
19	17 transects flown over the Northeast Water (NEW)	0	40	10

*: 14 of the 17 were also seen on land at same site on 12 August

Table 1: Summary of areas surveyed and number of walruses (by substrate) observed during aerial surveys conducted 12-19 August 2009 between Clavering Ø (ca. 74° N) and Nordostrundingen (ca. 81° 45´ N) including the Northeast Water (NEW) area in East Greenland.

Day in August	Area	Temperature Mean (SD) (°C)	Temperature Range	Wind Speed Mean (SD) (km/h)	Wind Speed Range	Wind Direction Range true angle	Barometric pressure (hPa)	Recording site
12	Dove Bay	3.3 (1.7)	1.6-6.5	8.3 (3.1)	3.6-11.2	170-250	1015	Danmarkshavn
13	S. of Dove Bay	1.7 (0.5)	1.2-2.0	9.1 (1.6)	9.4-11.2	100-120	1013	Danmarkshavn
14	S. of Dove Bay	6.8 (1.0)	4.9-7.8	9.8 (3.0)	3.6-13.0	150-170	1012	Daneborg
15	N. of Dove Bay	-1.1 (0.1)	-0.8 to -1.1	11.5 (3.5)	7.6-16.6	80-100	1013	Danmarkshavn
17	Northeast Water	8.1 (0.3)	7.5-8.4	9.9 (3.0)	3.6-13.0	60-90	1014	Station Nord
18	Northeast Water	6.6 (0.6)	5.7-7.6	7.2 (0.9)	5.4-7.6	40-90	1011	Station Nord
19	Northeast Water	6.7 (1.2)	4.4-8.3	8.9 (3.5)	1.8-13.0	90-320	1009	Station Nord

Table 2: Weather conditions during between 10 and 17 h local during 12-19 August 2009 when aerial surveys were flown to count walruses in Northeast Greenland. Data from Danish Meteorological Institute (Denmark).

Site	Position		Located via
	N lat.	W long.	
Lille Pendulum	74° 39´	18° 32´	Telemetry
Southwestern point of Shannon	75° 00´	18° 52´	Observation
Eastern point of Shannon	75° 01´	17° 21´	Telemetry
Kap Rink	75° 19´	20° 05´	Telemetry
North of the Ailsa Hut on Hochstetter Forland	75° 26´	19° 08´	Telemetry
Central on Hochstetter Land	75° 34´	19° 21´	Telemetry
South of the entrance to Bessel Fjord	75° 45´	19° 28´	Telemetry
South of the entrance to Bessel Fjord	75° 56´	19° 55´	Telemetry
Kap Carl Ritter (east coast of Adolf S. Jensen Land)	76° 15´	19° 45´	Observation
Southern tip of Slædeøen	76° 14´	19° 52´	Observation
Kap Peschel (NE-corner of Adolf S. Jensen Land)	76° 07´	19° 54´	Observation
Kap Bjarne Nielsen (Edward Ø, Dove Bugt)	76° 38´	20° 60´	Observation
Lynn Ø in Dijmphna Sund	80° 01´	19° 46´	Observation

Table 3: Terrestrial haulouts in Northeast Greenland used by walruses during aerial surveys, 12-19 August 2009.

Day in Aug 2009	Site	Substrate	Total on the site	No. identified to sex	% identified fied to sex	No. identified to age	% identified fied to age	Unid.	Ad. unid	Ad. M	Ad. F tusks: >30 cm	Ad. F tusks: 15-30 cm	Ad F. Total	Sub-adults	Calves 0-yrs	% M of ID.	% F of ID.	% Ad.	% Sub-adults	% 0-yr calves	Ratio calves/ ad. F	% 0-yr calves of all
12	C. Carl Ritter	Land	14	3	21.4	11	78.6	3	4	3	0	0	0	4	0	100	0	63.6	36.4	0.0		
12	C. Bjarne Nielsen	Land	6	5	83.3	6	100.0	0	1	5	0	0	0	0	0	100	0	100.0	0.0	0.0		
13	SW Shannon	Land	37	13	35.1	32	86.5	5	3	13	0	0	0	16	0	100	0	50.0	50.0	0.0		
14	C. Carl Ritter	Land	14	3	21.4	13	92.9	1	7	3	0	0	0	3	0	100	0	76.9	23.1	0.0		
14	C. Peschel	Land	3	0	0.0	2	66.7	1	2	0	0	0	0	0	0	0	0	100.0	0.0	0.0		
	Total south of 77° N	Land	74	24	32.4	64	86.5	10	17	24	0	0	0	23	0	100	0	64.1	35.9	0.0	0.0	0.00
15	Lynn Island	Land	17	2	11.8	12	70.6	5	4	0	1	1	2	5	1	0	100	50.0	41.7	8.3	0.5	0.06
15	Antarctic Bay group 1	Ice	19	4	21.1	17	89.5	2	5	0	3	1	4	8	0	0	100	52.9	47.1	0.0		
15	Antarctic Bay group 2	Ice/water	30	12	40.0	27	90.0	3	2	0	2	10	12	10	3	0	100	51.9	37.0	11.1	25.0	10.00
15	Antarctic Bay group 3	Ice	7	0	0.0	3	42.9	4	3	0	0	0	0	0	0	0	0	100.0	0.0	0.0		
15	Antarctic Bay group 4	Ice	2	0	0.0	1	50.0	1	1	0	0	0	0	0	0	0	0	100.0	0.0	0.0		
17	Henrik Krøyer Holme	Ice	4	0	0.0	2	50.0	2	0	0	0	0	0	2	0	0	0	0.0	100.0	0.0		
17	Kilen	Ice	19	6	31.6	11	57.9	8	0	0	1	5	6	3	2	0	100	54.5	27.3	18.2	33.3	10.53
	Total north of 77° N	Ice	98	24	24.5	73	74.5	25	15	0	7	17	24	28	6	0	100	53.4	38.4	8.2	0.3	6.12
	Overall total		172	48	27.9	137	79.7	35	32	24	7	17	24	51	6	50	50	58.4	37.2	4.4	0.3	3.49

Table 4: Age and sex category of walruses determined from photographs that were taken in Northeast Greenland during aerial surveys, 12-19 August 2009. The number in each category represents a summary of the categorization/count of several photos of that particular site.

Year	Animal ID	Sub-strate	Duration of full haulout periods				Duration of extended haulout periods			
			Mean (h)	SD (h)	Min-max (h)	N	Mean (h)	SD (h)	Min-max (h)	N
2008	74778	Ice	28.0	20.8	16-52	3	28.0	20.8	16-52	3
	74781	Land	26.7	8.6	14-36	6	26.7	8.6	14-36	6
2009	52061	Land	18.8	13.3	2-40	11	22.6	11.5	3-40	9
	52062	Land	23.3	15.5	1-41	12	25.5	14.2	4-41	11
	52063	Land	20.8	15.9	6-47	6	20.8	15.9	6-47	6
	60270	Land	12.3	10.1	1-31	16	13.7	9.8	4-31	14
	60272	Land	15.5	11.1	9-38	6	16.8	11.9	10-38	5
		Ice	23.3	12.9	18-38	3	23.3	12.9	14-38	3
	60273	Land	26.4	31.7	1-68	5	43.3	30.7	9-68	3
	67997	Land	6.5	5.3	1-12	4	11.0	1.4	10-12	2
		Ice	25.2	4.6	22-33	5	25.2	4.6	22-33	5
	83308	Land	12.7	8.3	1-30	12	14.9	7.1	10-30	10
		Ice	11.3	5.8	8-18	3	11.3	5.8	8-18	3

Table 5: Average duration of haulout periods of 10 adult male walruses that were monitored with satellite radios during August 2008 and 2009. Extended haulout periods are haulouts that were above 2 h duration. The term "full haulout periods" means that only haulout periods are included that were not aborted due to timelines missing for some days.

Year	Days with records in August	Animal ID		Time hauled out per day (%)	SD	Time in water per day (%)	% Time at sea surface (%)	SD	Total time exposed per day (%)	Total time hauled out in Aug. (h)	Total time monitored in Aug. (h)
2008	11	74778	Total[1]	14.8	22.6	85.2	15.6	4.3	30.4	39	264
	28	74781	Total	23.8	32.3	76.2	9.9	2.7	33.7	160	672
2009	29	52061	Total	38.5	36.0	61.5	20.0	7.2	58.5	268	696
	20	52062	Total	41.8	38.1	58.2	15.9	10.6	57.7	301	720
	22	52063	Total	37.9	32.1	62.1	7.1	5.6	45.0	200	528
	28	60270	Total	32.6	31.6	67.4	13.9	3.7	46.5	219	672
	26	60272	Total	30.0	33.5	70.0	9.3	7.9	39.3	187	624
			Land	9.3	17.1						
			Ice	20.7	35.1						
	15	60273	Total	36.9	44.5	63.1	20.9	15.1	57.8	133	360
	30	67997	Total	23.1	31.3	76.9	16.7	6.4	39.8	167	720
			Land	3.6	11.8						
			Ice	19.5	30.5						
	30	83308	Total	25.8	25.7	74.2	15.7	6.9	41.5	186	720
			Land	21.1	24.3						
			Ice	4.7	15.7						
	2009	Mean	Total	33.3	6.6	66.7	14.5	4.8	45.0		
		Mean	Land	27.7	14.6						
		Mean	Ice	15.0	8.9						

Table 6: Percent time hauled out, in water and at the water surface of 10 adult male walruses that were monitored with satellite transmitters during August 2008 (2) and 2009 (8).

For three animals that hauled out on land and ice in 2009, % of time on the two substrates are also shown.

1: 74778 ocurred offshore in August 2008 where he hauled out on ice.

			Survey period (12-19 Aug.)						Between 10 and 17 h in survey period					
Animal ID	Days with records during the survey		Mean time hauled out per day (%)	SD	Mean time in water per day (%)	Mean time at surface per day (%)	SD	Total time exposed per day (%)	Mean time hauled out 10-17 local time (%)	SD	Mean time in water 10-17 local time (%)	Mean time at surface 10-17 local time (%)	SD	Total time exposed per h (%)
52061	8	Total	45.3	38.4	54.7	22.7	5.1	68.0	50.0	53.5	50.0	22.5	6.0	72.5
52062	8	Total	44.3	41.1	55.7	17.2	7.9	61.5	62.4	51.7	37.6	15.6	7.8	78.0
52063	8	Total	28.1	27.5	71.9	12.3	3.8	40.4	46.4	50.5	53.6	13.2	7.1	59.6
60270	8	Total	46.4	34.7	53.6	15.6	3.3	62.0	50.0	45.2	50.0	17.1	7.8	67.1
60272	8	Total	13.5	17.4	86.5	9.4	2.2	22.9	14.3	30.5	85.7	12.3	11.6	26.6
60273	4*	Total	21.1	42.3	78.9	20.3	13.6	41.4	3.6	7.1	96.4	18.6	14.4	22.2
67997	8	Total	20.8	26.8	79.2	15.8	4.8	36.6	30.3	36.2	69.7	24.5	15.3	54.8
		Land	12.5	20.0					19.6	29.5				
		Ice	8.3	23.6					10.7	30.3				
83308	8	Total	26.0	30.0	74.0	14.8	3.0	40.8	46.4	50.5	53.6	17.7	12.6	64.1
		Land	21.9	31.2					33.9	47.6				
		Ice	4.1	11.8					12.5	35.6				
	Mean	Total	32.1	13.3	67.9	15.4	4.1	47.5	42.8	15.7	57.2	17.6	4.5	60.4
	Mean	Land	30.3	15.0					39.5	17.6				
	Mean	Ice	6.2	3.0					11.6	1.3				

Table 7: Daily time hauled out, in water and at the water surface during the survey period 12-19 August and during 10-17 local time of eight adult ma walruses that were monitored with satellite radios in August 2009.
For 2 animals that hauled out on land and ice % of time on the two substrates during these particular survey windows are also shown.
*: Animal 60273 not included in the summary statistics because the recording af timelines malfunctioned after four days of the survey period

Animal ID	Age/sex	Days with records during survey	Mean time hauled out per day 10-17 local time (%)	SD	% Time in water	Mean time at sea surface per day 10-17 local time (%)	SD	Total time exposed per day (%)
3758	Ad. F	29	28.0	37.7	72.0	16.4	6.6	44.4
4188	Ad. M	23	14.1	27.0	85.9	16.6	9.5	30.7
8375	Ad. M	25	42.5	43.6	57.5	21.0	1.9	63.5
		Mean	28.2		Mean	18.0	Mean	46.2
		SD	14.2		SD	2.6	SD	16.5

Table 8: Percentage of time spent on ice and at the water´s surface during 10-17 local h of three walruses that were monitored by use of SPOT5 satellite transmitters in the Kane Basin region (NW Greenland) during August 2009.

Month	Day	Method[1] Coastal Line-transect	Total obser-ved	Primary[2] obser-vations	Substrate L/I/W[3]	Mean group size (cv)	Density (ind./km^2)	Estimate hauled out	Per-ception bias	Availability factor (cv)	Corrected total (cv)	90% CI
July	20	Coastal	34	n.a.	34/-/-	n.a.	n.a.	30	n.a.	0.39 (0.17)	87 (0.17)	
July	20	Coastal	15	n.a.	-/10/5	1.5 (0.19)	n.a.	15	n.a.	0.28 (0.29)[4]	36 (0.29)	
		Total									123 (0.16)	Not included
Aug.	12-14	Coastal	60	-	60/-/-	n.a.	n.a.	60	n.a.	0.39 (0.17)	152 (0.17)	
Aug.	19	Line-transect	44	27	-/20/7							
		Single observer				2.4 (0.17)	0.010 (0.64)	54 (0.74)	0.47 (0.20)	0.28 (0.29)	404 (0.73)	
		Double observer				1.8 (0.21)	0.034 (0.55)	176 (0.55)	0.74 (0.20)	0.28 (0.29)	873 (0.66)	
		Total									1429 (0.45)	705-2896

1: Survey method: Coast = coastal survey; Line-transect = line transect estimation.
2: Number of primary observations (groups) that formed the basis for the line-transect estimation of numbers.
3: Substrate: Land, Ice, Water,
4: Availability factor (% on ice) obtained from three walruses that were monitored in August 2009 in NW Greenland (see text).

Table 9: Summary of observations of walruses made during aerial surveys in NE Greenland during August 2009 with corrected estimates of abundance.

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