Walrus *Odobenus rosmarus* research in Svalbard, Norway, 2000-2010

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ABSTRACT

Herein we report results from studies on walruses in Svalbard conducted in 2000–2010. Data from newly developed satellite relay data loggers (SRDLs) revealed seasonal differences in habitat use of adult male walruses. During winter, they moved into areas of >90% ice concentration, traveling as far as 600 km from ice-free water. Breeding areas deep into the pack ice were identified based on timing of the occupancy and diving behaviour. When the breeding season was over, walruses with SRDLs that were still transmitting locations returned to the coast, showing high site fidelity to the previous year's summering area. Haul-out data from the SRDLs provided correction factors for an aerial survey of walruses that covered all known haul-out sites within the Svalbard Archipelago. This survey estimated 2,629 (95 % CI; 2,318–2,998) walruses to be in Svalbard during August 2006. Blubber biopsies from adult male walruses analyzed for fatty acids (FAs) showed vertical stratification similar to that observed in many other marine mammals. However, differences between layers were less pronounced, possibly because the thick dermis of walruses provides an insulating shield, affecting the FA composition of the outer blubber. The FA composition of the inner blubber most closely resembled the lipids in *Mya truncata* and *Buccinum* spp., which are considered the most important walrus prey in Svalbard. A study investigating the use of skin biopsies for assessing levels of organochlorines (OCs) in walruses found a significant relationship between OC levels in skin and blubber. Another contaminant study found a significant decrease in levels of PCBs and DDE in walruses in Svalbard from 1993 to 2002–04. Large inter-individual variation in OC levels was found, although all of the study animals were adult males from roughly the same location. In FA analyses of the inner blubber this variation appeared to be diet-related, with high OC levels having FA compositions in the inner blubber that closely matched seal tissues, while those with low levels matched typical invertebrate prey. Various enzymes, proteins, metabolites, minerals, and hormones were measured in blood samples to serve as baseline data for future health-related studies of both wild and captive walruses. Historical sex-distribution of walruses in southern Svalbard was investigated based on mandible measurements of individuals hunted during the 19th century. The analyses showed that female walruses were once more common in south-eastern Svalbard than they are today.

INTRODUCTION

Walruses became protected in Svalbard in 1952 (Anonymous 1952). The hunt for these animals started in the Archipelago in the early 1600s and the subsequent 350 years of unregulated harvest brought them to the brink of extinction (Norderhaug 1969). A review of observations from Svalbard in the period of 1954-82 concluded that the summering stock in the Archipelago was about 100 animals (Born 1984). Born (1984) also suggested that the walruses in Svalbard were likely part of a larger, common Svalbard–Franz Josef Land population (Fig. 1). This suggestion was subsequently confirmed by both satellite tracking (Wiig et al. 1996) and genetic studies (Andersen et al. 1998). A comprehensive set of studies on this population was conducted in the early 1990s and is reported in a previous review (Born et al. 1995). Herein, we report results from studies on the Svalbard part of this population conducted in the period 2000–2010, in addition to summarizing a few studies that were conducted in the 1990s but not published until into the period 2000–2010.

1. SATELLITE TELEMETRY

A comprehensive study involving satellite tracking of 34 walruses from the Svalbard–Franz Josef Land population was conducted in 1990–1993 (Wiig et al. 1996). This study confirmed the connection between the walruses within the two archipelagos. The tags used in this and other early tracking studies of walruses only transmitted positions when the animals were hauled out on land or ice, and the dive information collected was minimal and fragmented. Thus, the Norwegian Polar Institute and the Sea Mammal Research Unit at the University of St Andrews, Scotland, collaborated to design a new walrus tag prototype that would collect and report these essential data; i.e. positions at-sea and detailed dive information. Six prototypes SRDLs were deployed on walruses in Svalbard in 2002. Initially they worked well, but the antennae broke off after a few months so the tracking records were very short. The tag design was therefore adjusted prior to the 2003 summer season to include a protective ridge in front of the antennae (Fig. 2), which greatly improved the longevity of the tags (Lydersen et al. 2008; Freitas et al. 2009).

1.1 Drugging and intubation

Immobilization of walruses was conducted, in connection with deployment of satellite relay data loggers (SRDLs), in a standard fashion using an intramuscular injection of etorphine HCl, reversed with diprenorphine HCl as described by Griffiths et al. (1993). Drugging of walruses is not a straightforward issue and relatively high mortality has been a common experience for most research groups working with walruses (Jay 2002). The mechanisms leading to death under anaesthesia are unknown, but they are likely related to interference of the regulation of respiratory and circulatory systems (Jay 2002). One general effect of high doses of opiates, such as etorphine HCl, is respiratory failure. During fieldwork with walruses in Svalbard in 2003 and 2004 the drugging and deployment of the SRDLs were conducted as follows: 1) as soon as a drugged animal showed signs of the influence of the etorphine HCl, the reversal agent was injected 2) the tag was then mounted to the tusk as described in Lydersen et al. 2008; a process that took 2-3 min 3) the animal was then rolled onto its belly and a soft silicon endotracheal tube (20 mm

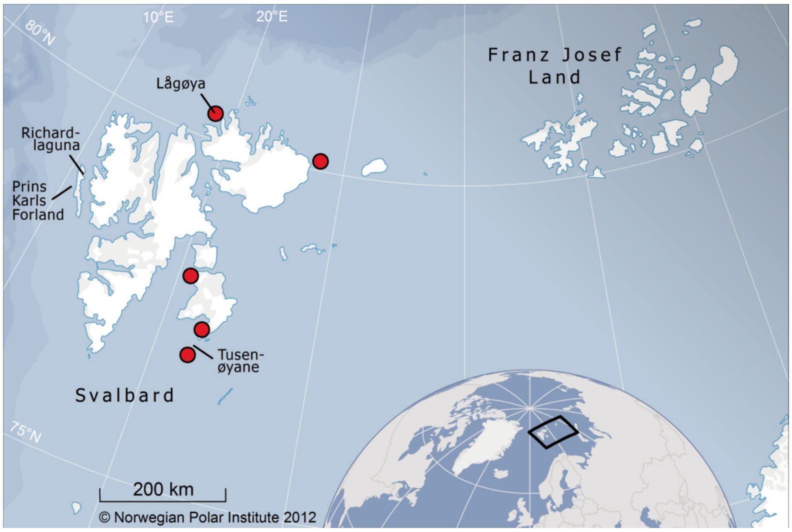

Fig. 1. Map of Svalbard and Franz Josef Land showing place names mentioned in text. Red circles indicate where surveillance cameras are deployed (see section 6).

diameter, 90 cm long, Cook Inc. Bloomington IN, USA) was inserted into the trachea on the assumption that employing mechanical breathing assistance until the antagonist took effect, might reduce the risk death and 4) the endotracheal tube was connected to a Zodiac boat pump via a custom-made transition tube and the walrus was manually kept breathing artificially until the diprenorphine HCl took effect and the animal was breathing unsupported. Nineteen walruses were handled this way with no resulting mortalities.

1.2 Distribution, movements and habitat use

Data from 17 of the newly-developed SRDLs were used to study movement patterns and habitat selection of adult male walruses instrumented in Svalbard in 2003–2004 (Freitas et al. 2009). First-passage time (FPT) analyses were used to study habitat use and habitat selection was quantified using Mixed-effects Cox Proportional Hazards Models. The mean duration of the individual tracking records was 278±32 days (range: 64–550 days); five of the data records were longer than one year. Seven of the tagged walruses spent periods in Russian waters, mainly during the winter months (Fig. 3).

Seasonal differences in habitat use patterns were identified. The walruses actively moved into areas of high ice concentration (>90%) during winter; traveling far into the ice pack, as far as 600 km from ice-free water. During the summer months, when walruses feed intensively, FPTs

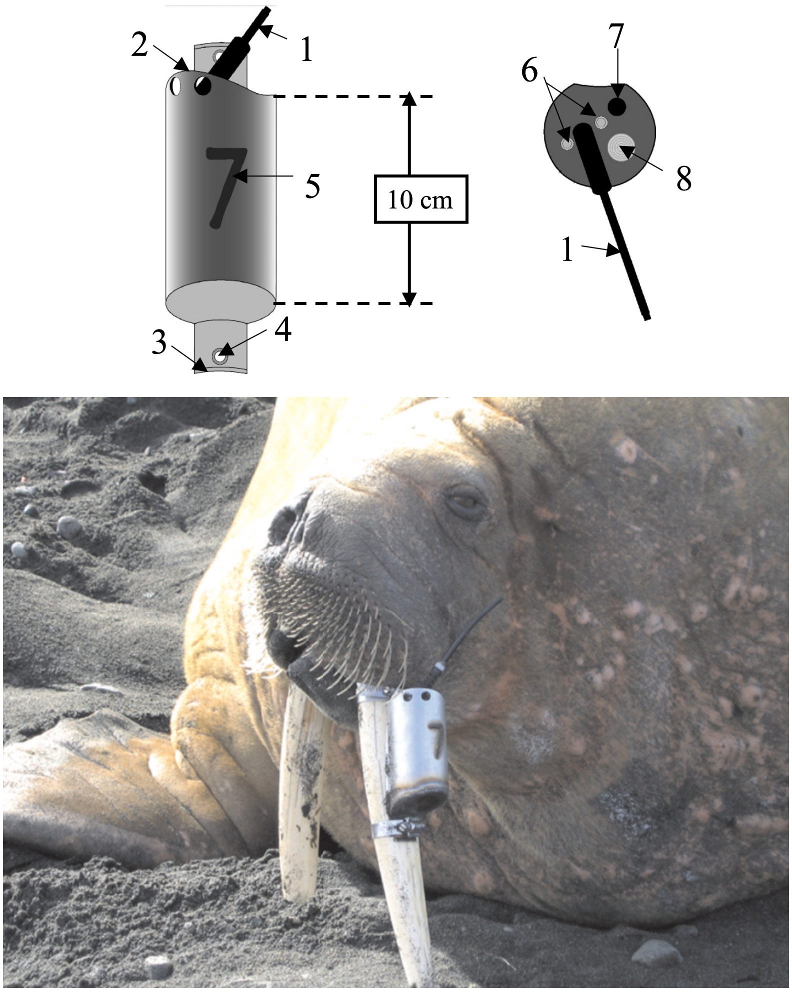

Fig. 2. *Custom-made satellite relayed data loggers (SRDLs) collaboratively developed by the Norwegian Polar Institute and the Sea Mammal Research Unit, University of St Andrews, Scotland, mounted on a walrus tusk. Upper left panel - front view; upper right panel - top view; bottom panel - SRDL mounted on a walrus. Parts of the SRDL 1) antennae; 2) protective ridge; 3) small rim to prevent the hose clamp from sliding off; 4) hole for screw; 5) individual tag ID number; 6) saltwater switch; 7) communication port for PC; 8) pressure transducer. (From Lydersen et al. 2008).*

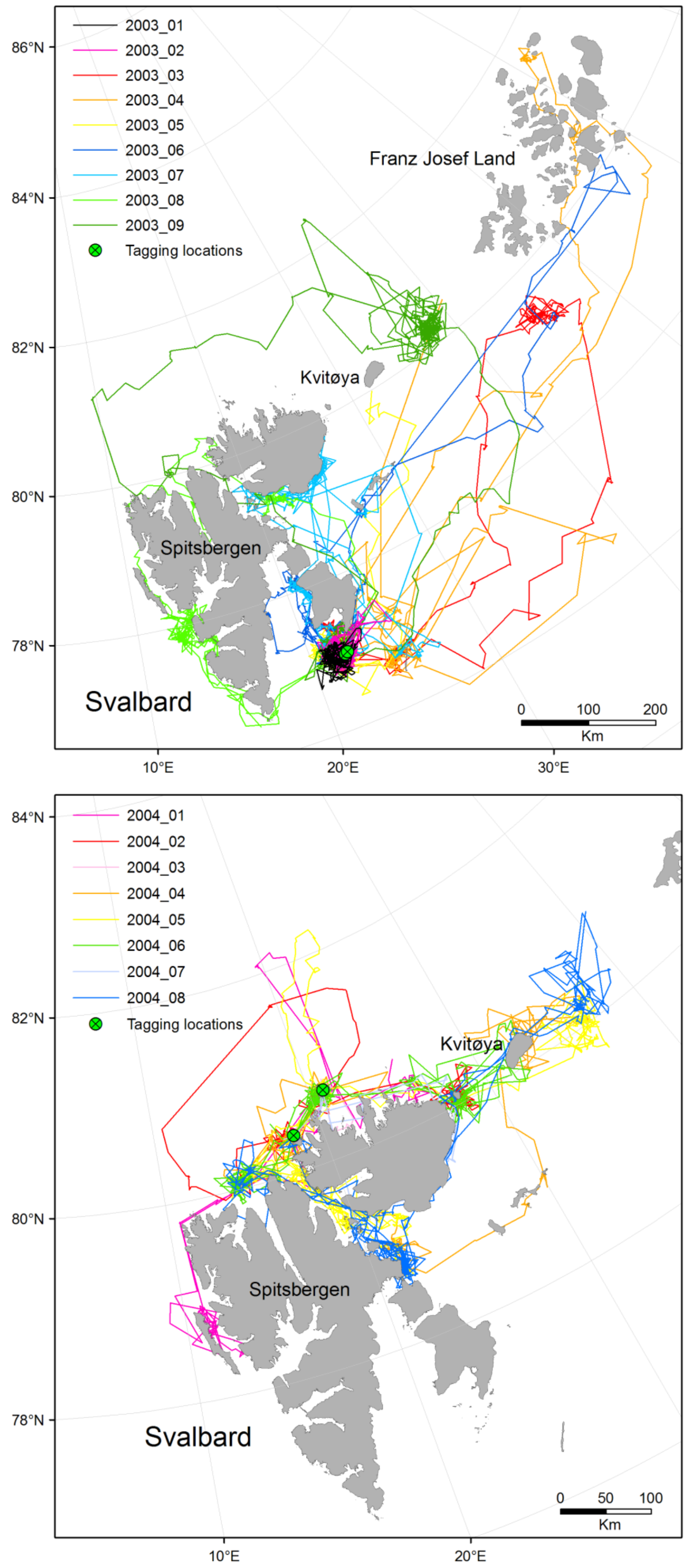

__Fig. 3.__ Tracks of 17 male walruses equipped with satellite-relayed data loggers in Svalbard in 2003 and 2004. (From Freitas et al. 2009).

were affected by water depth and distance to the coast, but these variables had no effect on walrus habitat use during the winter. Sea ice concentration was the most important environmental variable determining their habitat choices during the winter season, though there were clearly other factors influencing where animals occurred in winter that are currently unaccounted for in these analyses. The (male) walruses in this study did little benthic diving during winter, suggesting that they did not feed much during the time that they are known to breed (Fig. 4). Instead, they remained in areas with high ice coverage, far from their coastal

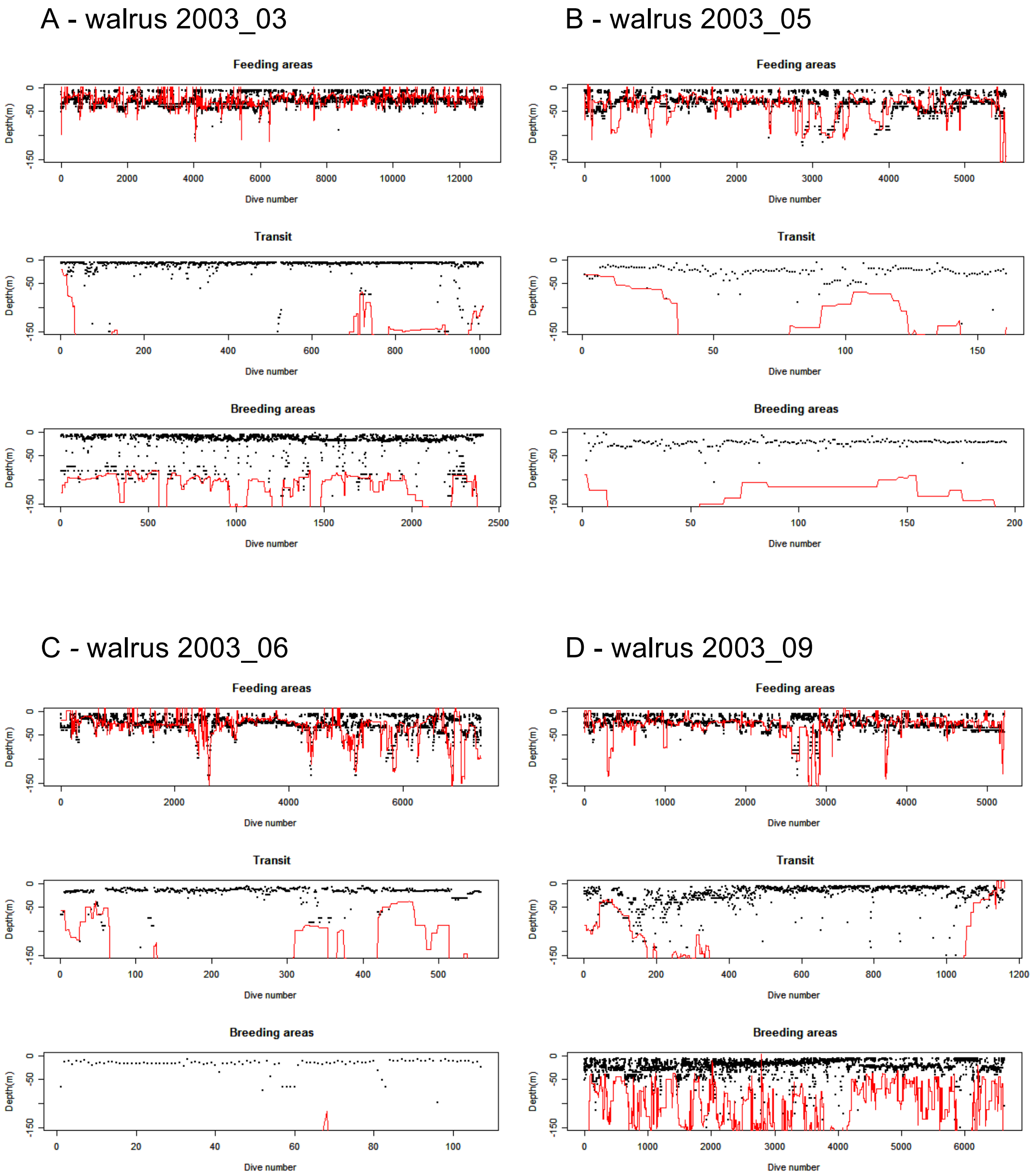

Fig 4. *Maximum depth of the dives recorded from four of the tracked walruses in summering areas, wintering areas and during transit between these areas. Sea bottom depth (≤150 m) is also shown (red line; From Freitas et al. 2009).*

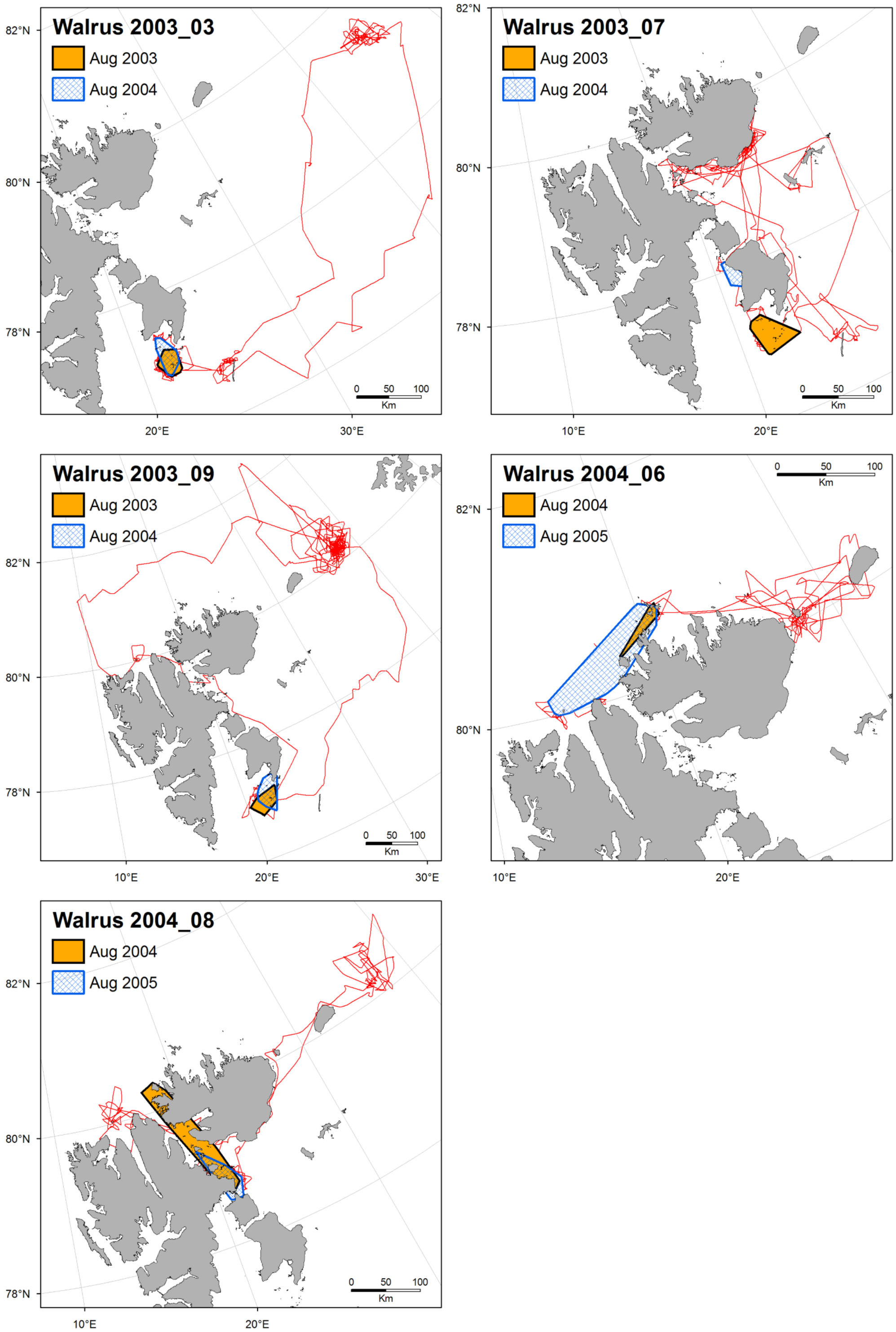

Fig 5. *Home ranges (100% minimum convex polygons) used by five walruses for which data were available for the month they were tagged (August 2003 or August 2004) and for August the following year. The complete tracks for these animals are also presented. (From Freitas et al. 2009).*

summering areas, spending much of their time hauled out or in surface waters. We therefore suggest that Freitas et al. (2009) have identified the breeding areas for these males during these two breeding seasons.

When the breeding season was over, those walruses with SRDLs that were still transmitting locations (N=5) showed high site fidelity to the previous year's summering area. Home range (100% minimum convex polygons) overlaps for individual animals during the month of August were as high as 71%, with a mean value of 35.0±12.7% (Fig. 5).

1.3 Diving

The diving data collected in 2003 and 2004 are not yet analyzed in detail, but preliminary analyses have been performed to explore benthic/non-benthic diving behaviour patterns in order to interpret walrus space use (Fig. 4). However, a study of walrus diving based on data from three satellite transmitters and three Time-Depth Recorders (TDRs) in the 1990s was published by Gjertz and colleagues in 2001 (Gjertz et al. 2001). This study was conducted in the area around Tusenøyane in southeastern Svalbard during July–August 1991 and 1993. Based on analyses of close to 8,000 dives from the TDRs, dive-shape analyses suggested that 40% of all dives were foraging dives and that these dives were on average 6 min long and to a depth of 23 m. Maximum recorded values were 24 min and 67 m. All of the approximately 6,000 dives recorded by the satellite transmitters in this early study were shallower than 50 m. In terms of activity budgets, the walruses were found to spend an average of 17% of their time hauled-out on land, 39% of their time in the water at the surface, and 44% of their time submerged. The modest maximum dive records in this study are likely related to the shallowness of the study area rather than the diving capacity of walruses. In this context it should be mentioned that the average maximum dive values recorded for the 17 walruses in the 2003–2004 studies were 368 m (range: 150–490 m) and average maximum duration was 37 min (range: 14–47 min).

1.4 Correction factors for aerial survey

An aerial survey of walruses was conducted in Svalbard during August 2006; haul-out behaviour information from the SRDLs was used to create a correction factor for animals not present on-shore when the survey was flown (Lydersen et al. 2008). For these calculations we used a haul-out behaviour data set from 30 days post-tagging for each walrus (N = 23; here the SRDLs from 2002 are included since they transmitted during the period of concern which was August-September), starting 24 h post-drugging to reduce potential bias in behaviour due to residual effects from the drug. Some of the SRDLs gave haul-out information for more than a year and for these tags (N=5) the period 1–30 of August in the year post-tagging was also included in the analyses. This resulted in haul-out records for 30 days for 6 individuals in 2002, 9 in 2003, 11 in 2004, and 2 in 2005 (N=28 total, see Fig. 6).

Haul-out behaviour data were not complete for the whole 30 day period for all of the 28 records (Fig. 6). However, the mean fraction of time for which data-coverage was achieved by the SRDLs was high (0.96 ± SD 0.09; range 0.63–1 of the total time), and for 18 of the 28 records the coverage was 100 %. The average duration of haul-out periods was 29.8 h (SD = 14.7 h, range 2–68 h) and the corresponding values for the at-sea periods were 85.6 h (SD = 44.7 h, range 5–236 h). Because haul-out proportions were not influenced by wind-chill or time of day during this late summer period (see Lydersen et al. 2008 for details), the authors based the estimate of the proportion of animals at-sea during the survey on the overall average proportion based on the 28 August records. This average was 0.750. The variance of log (prop. in sea/[1 – prop. in sea]) was 0.106. However, the walruses did not haul-out randomly (Fig. 6); correlation in haul-out patterns existed among individuals. Walruses tagged at the same time exhibited some synchronicity in their subsequent haul-out patterns even though they rarely hauled-out simultaneously again at a given site (see Lydersen et al. 2008 for details). This was revealed by the over-dispersal

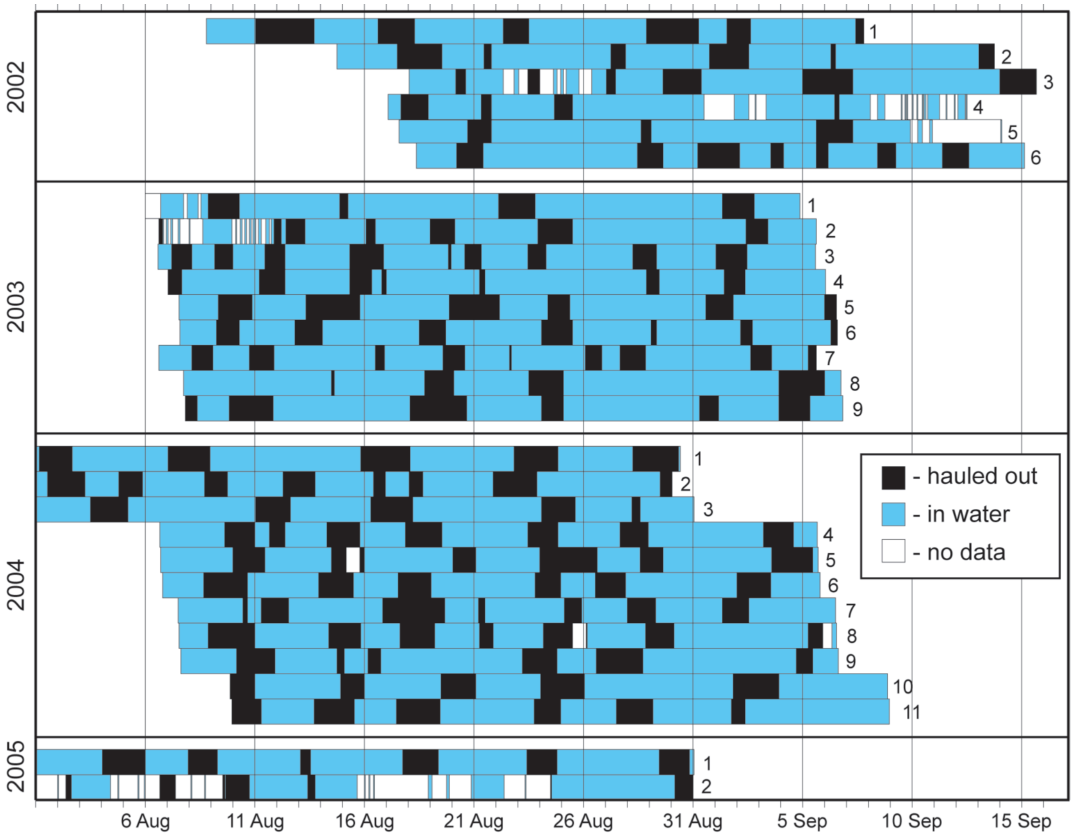

Fig 6. *Haul-out chronologies for 28 walrus data sets from 2002–2005 based on information from satellite relayed data loggers (SRDLs) deployed on the tusks of the animals. Haul-out information from the first 30 days of deployment, starting 24 h post-handling, was included in this study in addition to haul-out data from the 30 first days of August for SRDLs that transmitted for more than one year (walrus 1, 2 and 3 in 2004, and 1 and 2 in 2005). The figure illustrates that individual walruses, within years, tend to be hauled-out (and thus also at-sea) at the same time and more frequently than at random. (From Lydersen et al. 2008).*

parameter from a logistic regression model, where some of this over-dispersion was due to a weak year-effect. Since the survey was conducted in a year without telemetry data, the deviance accounted for by year was retained in the model (see Lydersen et al. 2008 for details). The variance in individual time at-sea was thus multiplied by the over-dispersion parameter to achieve a corrected standard error around the estimate. The 95% CI based on this parameter corresponded to a proportion between 0.717 and 0.781 at-sea (Lydersen et al. 2008).

2. AERIAL SURVEY

An aerial survey was flown for walruses in Svalbard 1–3 August 2006 (Lydersen et al. 2008). This period was chosen since the coastal areas in the Archipelago were free of annual sea ice at this time and the southern edge of the northern pack-ice was situated far north of Svalbard, at about 82°N. At this latitude the ocean floor is located at 4,000–5,000 m depth and thus is not suitable feeding habitat for walruses. It was therefore assumed that walruses hauling out in the Svalbard area at this time would do so at terrestrial haul-out sites. Also walruses that had been equipped with SRDLs that had moved away from Svalbard during other seasons, had all had returned to Svalbard in August. Finally, this period is also the period for which most behavioural data were available for construction of a correction factor (see section 1.4).

All known terrestrial haul-out sites for walruses in Svalbard (N=79) were surveyed using a helicopter flying at about 300 m (~1,000ft). If walruses were present at a given site they were observed easily from this altitude and digital pictures were taken of the group of animals. Because of the large size of walruses and the magnification and manipulation options possible when using high-resolution digital pictures, potential reader biases during counts were found not to be a problem (multiple, independent counts by a series of 3 observers were identical). Thus, it is reasonable to assume that all walruses hauled-out on land in Svalbard were accounted for during the survey, and there is thus no uncertainty involved in the total count. Walruses were present on 17 of the haul-out sites in numbers ranging from 1–133. The total number of animals counted on-shore was 657. Application of the correction factor developed above (section 1.4) produced an estimated number of walruses at-sea when the survey was flown of 1,972 (95% CI: 1661–2341). Combining these two numbers, the total number of walruses in Svalbard in August 2006 was 2,629 (95% CI: 2,318–2,998; Lydersen et al. 2008).

3. BLUBBER AND FATTY ACIDS

Blubber biopsies, taken vertically through the skin and the entire blubber down to, but not including the muscle layer, were collected from 18 adult male walruses when the animals were anaesthetized in connection with deployment of the SRDLs. The biopsies were taken using a custom-made hollow, stainless steel tube attached to an electrical drill, enabling a clean, fast coring of the blubber layer through the walruses' strong and thick dermis (Fig. 7), as described in Skoglund et al. (2010).

The fatty acid (FA) composition of the dermis and the outer and inner blubber layers in these biopsies were determined. These three layers differed significantly from one another in their FA compositions. Generally, the inner blubber contained more long-chained monounsaturated,

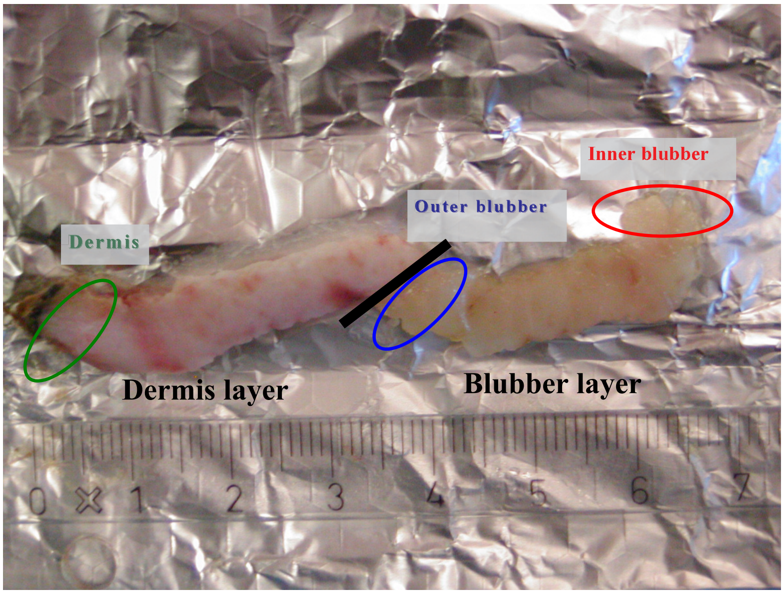

Fig. 7. *Photo of a walrus blubber core. Circles indicate areas sampled to represent, - dermis, outer and inner blubber (from left to right; scale in cm.). The black line indicates the transition between the dermis and the blubber layer. (From Skoglund et al. 2010).*

saturated, and polyunsaturated FAs, while the outer blubber and dermis contained more short-chained monounsaturated FAs (Skoglund et al. 2010). This stratification is similar to what has been observed in many other marine mammal species. However, differences between layers were less pronounced in the walruses compared to most other species, possibly because the extremely thick overlying dermis of walruses likely provides an insulating shield that affects the FA composition of the outer blubber. Using tusk volume as a proxy for age, the FA composition of the outer blubber and dermis were found to be significantly correlated with age. This correlation was very pronounced for the dermis (see Skoglund et al. 2010) and warrants further investigation as a potentially minimally invasive, inexpensive method for age determination in this species.

FA composition of walrus blubber was also compared to FAs in a selection of potential prey species in an attempt to shed light on walrus diets (Skoglund et al. 2010). The FA composition of the potential prey organisms was significantly different from that of the blubber of the walruses, but the inner blubber was more similar to potential prey species than the outer blubber or dermis. The FA composition of the inner blubber most closely resembled the FA composition of the lipids in *Mya truncata* and *Buccinum* spp. which are thought to be the most important prey species for walrus in Svalbard (Gjertz and Wiig 1992).

4. POLLUTION

A study investigating the use of skin biopsies for assessing levels of organochlorines (OCs) in walruses found a significant relationship between levels in this tissue and what was found in the blubber (Wiig et al. 2000). This study was based on blubber and skin samples from 10 adult male Pacific walruses (*O. r. divergens*). Subsequently, blubber biopsies from 25 adult male Atlantic walruses from Svalbard and 28 walruses of different sex and age from Franz Josef Land (collected in 1993) were analyzed for various OCs. Relatively high levels were found in the

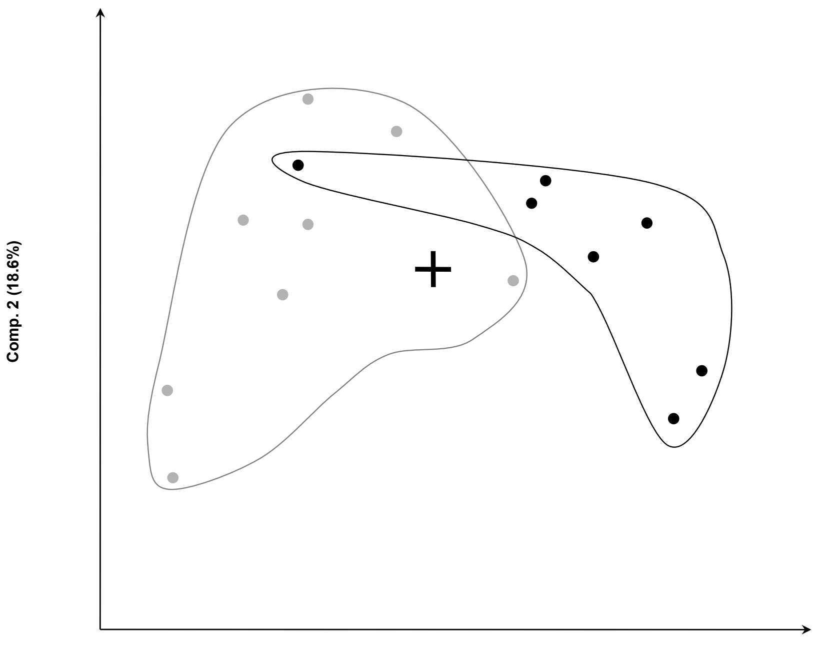

Fig. 8. *Principal component analyses plot showing the relation between the fatty acid profile from individual male walruses with high (black dots) and low (grey dots) contaminant levels. (From Wolkers et al. 2006).*

Svalbard samples (ΣPCB: 8,659 ± SD 6,560 ng/g lipid [range: 1,220–25,187]; p,p DDE: 1,499± 302 ng/g lipid [range: 166–5,121]; Wiig et al. 2000); the Svalbard OC values were up to 10 times higher than what was found in the Franz Josef Land samples. This difference was attributed to the sex and age variation among the samples from the two locales. The Svalbard sample consisted of only adult males, which is the age/sex group that traditionally has the highest OC levels among pinnipeds. The blubber samples collected in Svalbard 10 years later (N=17, 2002–04) were analyzed for a wide range of contaminants including those analyzed by Wiig et al. (2000). Even though this more recent study (Wolkers et al. 2006) analyzed more PCB congeners than did Wiig et al. (2000; 63 vs 7 congeners) this new study found much lower levels. For example, PCB 153 (which is a good reference congener for PCB exposure due to its persistence) levels were about 4 times lower in 2002–2004 compared to 1993, while DDE levels were about 10 times lower in the more recent samples (Wiig et al. 2000, Wolkers et al. 2006). These low levels are in accordance with the general pattern of decreasing exposure to PCBs and DDTs in the Arctic environment (AMAP 2004).

The most striking finding in the study by Wolkers et al. (2006) was the enormous variation in contaminant levels among individuals, despite the homogeneous nature of the age and sex (all adult males) of the animals sampled and the fact that they were from a restricted area. ΣPCB varied between 264–12,702 ng/g lipid, p,p DDE varied between 5–5,065 ng/g lipid and Σchlordanes between 265–37,699 ng/g lipid. The most logical explanation for this variation is that animals with the higher levels feed at higher trophic levels, probably targeting seals as was also suggested by Wiig et al. (2000). A comparison of the FA composition of the inner blubber layer of walruses with high and low levels of contaminants (Fig. 8) reinforced the hypothesis that the high level of variation in OC levels among individuals is diet-related (Muir et al. 1995, Wolkers et al. 2006).

5. HEALTH AND DISEASES

Information regarding health and diseases is limited for walruses. Serum chemistry values for free-ranging animals have been determined based on blood samples from 17 adult male walruses from Svalbard (Tryland et al. 2009). These were the same animals that showed great individual variation with respect to OC levels (see: Wolkers et al. 2006) and potential effects of this variation on serum chemistry were also investigated. Twenty-seven various enzyme, protein, metabolite, mineral, and hormone values were measured to provide baseline data for future health-related studies of walruses both in the wild and in captivity. Significantly lower levels of inorganic phosphate were found in the group of walruses with high OC-levels, but this was the only difference found among the groups with high and low OC levels. The biological significance of the lower inorganic phosphate is unknown (Tryland et al. 2009). Blood samples from these same 17 adult male walruses from Svalbard were part of a larger serosurvey for *Toxoplasma gondii*, primarily in arctic foxes (*Alopex lagopus*) but also in various birds and mammals from Svalbard (Prestrud et al. 2007). *T. gondii* is a protozoan parasite for which felids are the final host; a wide range of birds and mammals serve as intermediate hosts. *T. gondii* has been implicated as a mortality factor for arctic foxes in Svalbard (dead foxes with toxoplasmosis have been recorded multiple times) and since no felids are present in the Archipelago samples from various other species, including walruses, were analyzed to shed light on other possible transmission routes (Prestrud et al. 2007). One of the investigated walruses was seropositive showing that *T. gondii* is present in the marine food chain in Svalbard. One route for walruses to be infected could be from eating seals. Although no other investigation has found seropositive seals in the North Atlantic, this is a common finding among various seal species from Alaska and northern Canada (see Prestrud et al. 2007 for details).

6. CAMERA SURVEILLANCE OF HAUL-OUT SITES

In 2007 a camera surveillance programme was initiated at selected walrus haul-out sites in Svalbard. The main goal of this programme was to study the temporal dynamics of terrestrial haul-out site use. Knowledge regarding how individual walruses use various haul-out sites is available from the satellite tracking project. However, larger scale dynamics of how the sites themselves are being used at various times of the year and between years are not known. It is clear that there is a strong seasonal pattern of utilization at some sites in Svalbard; one much visited haul-out site (Richardlaguna at Prins Karls Forland) is occupied only from May until it is abandoned in late July/early August every year. This occupancy pattern is independent of disturbance or sea ice patterns and is likely part of an annual cycle with respect to distribution and movements of walruses within this population. Another aspect of this camera surveillance programme is to evaluate potential effects on the haul-out behaviour of walruses caused by human visitation to these sites.

Three sites have been monitored every year since 2007, while data have been collected at two sites for only one year each, due to logistical problems with the cameras themselves or logistical servicing of the sites (See Fig. 1 for monitoring sites). Each monitoring system consists of a 5 m tall aluminum mast with a camera and battery case attached toward the top of the mast. The camera is operated by a control box that switches the camera on each hour, after which it zooms in to the desired section, takes a picture and then turns off again. The cameras are deployed in early summer and retrieved in the autumn; they are "normal" off-the-shelf digital cameras that take a 2–3 Mb picture each hour.

Fig 9. *Picture taken by the surveillance camera at Lågøya showing the walrus haul-out, visiting tourists and the tourist ship in the background.*

Walruses are counted in each picture. When many animals are present it is hard to get an exact number due to the density of animals and the relatively low angle of the cameras. It is however easy to get a relative number and assess whether the group is getting larger or smaller. The main analyses of this dataset will pertain to the manner in which the walruses frequent these haul-outs. This baseline information will be used to assess whether visitors to these sites change the general trends in haul-out dynamics. Information on the timing and size of visiting groups is available from records housed at the office of the Governor of Svalbard. Additionally, both people and boats are generally documented by the cameras (Fig. 9).

7. OTHER STUDIES

Walruses found in Svalbard today are mainly males (both immature animals and adults). But in the north-eastern corner of the Archipelago females and calves are regularly observed in increasing number in recent years. Information on the distribution of sex and age classes within this population before it was hunted almost to extinction is scarce, but, distribution is likely to have been quite different from today. In an attempt to study this issue, mandibles from walruses hunted in Tusenøyane during the 19th century (N=591) were measured to explore the sex ratio in the early harvests (Wiig et al. 2007); this is facilitated by the marked sexual dimorphism in this species, in which males are the much larger sex. A discriminant function, based on measurements of mandibles of known-sex walruses harvested in the Canadian Arctic, was developed and applied to the historic Norwegian catch samples. The resulting analyses showed that the sex ratio in this catch was 67% males and 33% females, suggesting that female walruses were previously more common in south-eastern Svalbard than they are in recent history (Wiig et al. 2007).

Genetic samples from walruses in Svalbard collected in 1993 and 2004, together with samples of walruses from the Pacific Arctic and the Laptev Sea were used in a study to determine whether walruses from the latter area constitute a separate sub-species (Lindqvist et al. 2008). The study concluded that the Laptev walruses are the westernmost population of the Pacific walrus subspecies and not an independent taxon. Two other genetic studies using microsatellite loci have focussed on the relationships of various sub-populations of Atlantic walruses; both concluded that East Greenland walruses are a separate sub-population from animals in the Svalbard-Frantz Josef Land group (Born et al. 2001, Andersen et al. 2009).

Walruses are benthic feeders that presumably have considerable impacts on the benthic community when they occur at high densities. Weslawski et al. (2000) explored the possible impacts that the large walrus hunting removals had on the benthic food web in Svalbard. The walrus population in Svalbard prior to hunting was assumed to consist of 25,000 walruses (Weslawski et al. 2000). Assuming that walruses would have consumed about 400,000 tonnes of benthic organisms annually, Weslawski et al. (2000) concluded that a major shift in the food web must have occurred after the walruses were almost eliminated from this ecosystem. This undoubtedly benefitted other benthic feeding animals such as eiders (*Somateria molissima*) and bearded seals (*Erignathus barbatus*), both of which are currently abundant species in Svalbard.

Walruses are predominantly benthic feeders, but they have also been documented to prey on various species of birds throughout their distributional area, including Svalbard (f. inst. Mallory et al. 2004, Gjertz 1990). In 2009, several walruses were observed hunting flightless pink-footed geese (*Anser brachyrhynchus*) in the south-eastern parts of Svalbard (Fox et al. 2010). The walruses attacked from below, breaching in the middle of the swimming goose flock, taking birds using their mouths or flippers. The prey was sometimes handled at the surface but most of the captured geese were taken underwater. During this encounter two different walruses were observed swimming on their backs manipulating geese with their mouth, tusks, and flippers. Walruses also consume both bearded seals and ringed seals on occasion in Svalbard (pers. obs.).

8. FUTURE RESEARCH

Future plans for research include continuation of the regular aerial surveys of the Svalbard fraction of the Svalbard–Franz Josef Land population to monitor abundance trends (at 5-year intervals). A synoptic aerial survey of the whole population including the Russian territories has high priority and has been planned, but for various reasons it has not yet been possible to conduct this work. Continuing the camera surveillance in order to get a long enough time trends and large enough sample sizes to perform the necessary statistical analyses of haul-out chronologies with a reasonable accuracy also has high priority. Stock structure also requires research attention. Currently, the genetic relationship between walruses in the Pechora and Kara Seas compared to those in the Svalbard–Franz Josef area is unknown. Material is currently being collected to address this issue. In relation to climate change issues, plans exist to track animals over multiple years in order to study individual responses to changes in ice conditions. This work involves a new iteration of tag design. We are developing a new tusk-mounted GPS tag, powered by solar cells. Possible future dietary shifts, due to climate change induced alterations of the marine ecosystem, will also be assessed via stable isotopes and fatty acid analyses at regular intervals.

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