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Movements of walruses (*Odobenus rosmarus*) tracked with satellite transmitters between Central West Greenland and Southeast Baffin Island 2005-2008

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Abstract
Between 2005 and 2008 31 walruses were tagged at their wintering grounds in at Store Hellefiske Banke, Central West Greenland (n=23) and at their summering grounds of the coast of Southeast Baffin Island, Canada (n=8). The walruses were monitored for a total of 1029 days and tracked for 22142 km. The investigation documented a connection between the West Greenland walruses and the Eastern Baffin Bay walruses as 8 of the transmitters lasted long enough to show the migrations across the Baffin Bay from Greenland to Canada. The walruses left the Store Hellefiske Banke in the start of May (range: 29 April to 17 May) and it took on average 7 days to cross the 400 km over the Davis Strait. The migration routes were quite similar and took place at the most shallow and the narrowest part of the strait. In addition one flipper tag deployed off South Baffin island was recovered on a hunted male walrus on Store Hellefiske Banke, documenting the reverse migration as well. A partly sexual segregation was observed with males being further from shore, in denser ice, on greater depths and having a larger home range than females during the spring along the West Greenland coast. During autumn along the South East Baffin Island coast the dispersal was more condensed and the segregation was more pronounced. Again the males were further from shore, on greater depths and having a larger home range than females during this season. The spring dispersal and migration towards Canada was closely linked to the extent and retreat of the pack ice edge. Four different tag types were used with average longevity/maximum longevity as follows: Puck tag: 14/24 SPOT Implant tag: 36/66, SPOT Matchbox tag: 40/128 and Tusk tag, 50/69.

Key words: Walrus, Odobenus rosmarus, Davis Strait, migration, satellite telemetry,

Introduction

Atlantic walruses (*Odobenus rosmarus rosmarus*) occurs in areas covered with dense offshore pack ice during the winter and early spring (e.g. Born et al., 1994). Walruses prefer areas with shallow water with depths less than 50-100m (Fay 1982). In West Greenland the walrus occurs in two areas the Thule District between 76^{o} and $81^{o}45'$ N, where they occur year round and of Central West Greenland between $66^{o}30'$ and $70^{o}45'$ N, where they occur mainly in winter and spring (Born et al. 1994). The latter area has two well defined shallow areas on west of Disko ($69^{o}45'$ to $70^{o}45'$ N) and another larger area Store Hellefiske Banke ($66^{o}30'$ and $68^{o}15'$ N) west of the coastline between Aasiaat and Sisimiut (Born et al. 1994). In August the walruses are haul-out on land during their moulting period where the ice is melted in most regions.

Understanding the movement and behavior of the walrus is important for several reasons. The walrus is being hunted in both Greenland and Canada for subsistence hunting. For this reason it is important to understand the population size and structure and size as well as their seasonal presence in various regions. The walrus is facing other threats such as oil exploration and climate change in their ice associated environment. Again the understanding the potential impacts of such threats it is important to know the seasonal range of the walrus, their migration routes, their feeding areas as well as their relationship to the physical environment. These relationships include their preference for certain water depth in regions where the range as well as their seasonal preference and avoidance of certain ice conditions.

Several disciplines are available to study the above problem complexes. Aerial surveys are uses to observe the presence and uncorrected number of walruses on land, on ice or in the water (e.g. Born et al. in prep.; Heide-Jørgensen et al. in prep.; Born et al. in prep.). Satellite tracking generates correction factors for submerged animal when on land, on ice or in the water and provide information on distribution, critical habitats, migration routes, linkages between geographical regions as well as relations to the physical environment such as bathymetry, ice food etc.. Finally genetic studies provide an insight to the genetic relationship between the various stocks compared. Recent methods within the genetic field reveal insight into the population structure, migration rates and direction, historical population demography, the phylogenetics and potential historic bottlenecks.

Walruses have been hunted in Central West Greenland for centuries (Born et al. 1994). However, historical and current exploitation rates are relatively high and believed not to be long-term sustainable (Born et al. 1994, 1995, Anon. 1995, Witting & Born 2005, NAMMCO 2006, COSEWIC 2006).

Oil exploration has been intensified in the recent years around Greenland. Noise from seismic surveys, exploration drilling, production facilities or other traffic linked to Oil activities including helicopter transport an intensified shipping displace walruses from their wintering grounds on Store Hellefiske Banke, Disko Banke or other important feeding grounds. Oil spill is another potential problem linked to anthropogenic activities where the oils can affect the shallow feeding banks of the walruses, which may disperse the walruses to seek for food in other suboptimal regions.

A change in ice extent is likely to have an effect on the presence of the walruses. Walrus is only believed to be able to cope with ice thickness up to 20 cm thick Fay (1982). If the ice becomes thicker they must retreat to lighter ice conditions or moving pack ice or polynias. If on the other hand less or no ice will form in future warmer scenarios some of the ice related migratory patterns may change.

In order to contribute to the elucidation of several of the above outlined questions we examined the movements of 23 walruses tagged walruses of the part of Greenland and South East Baffin Island. Here we present the result of 23 walruses tagged in the pack ice on Store Hellefiske Banke during March-April between 1985 and 1988 and 8 walruses tagged at their summering grounds of the coast of South East Baffin Island during August-September 1987.

Material and methods

The tagging area

The walruses were either tagged at Store Hellefiske Banke during March-April in 2005 -2008 or at their summering grounds of the coast of South East Baffin Island during August-September 1987. The Store Hellefiske Banke extends from ca. 66^o to 68^{o}15‘ N and from 53^{o}15‘ to 56^{o}50‘ W with depths ranging from 20 to 200m. This highly productive bank, which is frequented by walruses during the spring, where they feed on primarily bottom dwelling species, that lives in such shallow water biotopes (Fay 1982). The South East Baffin Island archipelago extends north of Cumberland

Sound to Cape Dyer from ca. 64°50‘ to 66°45‘ N and from 61° to 63°40‘ W where shallow waters below 200m likewise are prevailing.

Tagging of the walruses

A 72 BRT trawler Nanna L. was used to enter the heavy pack ice 40-80 NM from the shore of West Greenland during the spring tagging. If the ice permitted it a 17 foot fiberglass boat with a 6 or 30 Hp engine was used to approach the walruses. During the autumn tagging the same trawler was sailed to South East Baffin Island over the Davis Strait from West Greenland where it served as the base Camp for the operation. In addition a 28” aluminum boat with two 125 HP motors was used to conduct the daily tagging trips to the haul-out sites, as this was smaller, faster and easier to operate. Navigation was conducted by GPS and MacSea and communication took place by VHF radios. HF radios as well as iridium satellite phones.

Number of walruses tagged

A total of 31 walruses were tagged in West Greenland in 2005 (n=3), 2006 (n=5), 2007 (n=6) and 2008 (n=9) and Canada in 2007 (n=8). For details on age and gender of the tagged animals see Table 1.

Instrumenting the walruses

For different transmitter types were used of which three were shot or harpooned into the skin of the walruses (implant tag, the puck tag or the matchbox tag) or mounted on the tusk of a tranquilized animal (tusk tag).

Implant tag: Three of the walruses (2005) were equipped with Implant tags which were flat, rectangular transmitters (2.0 × 1.0 × 9.6 cm, 74 g) of the SPOT 3 Type (Wildlife Computers, Redmond, Washington, USA). These were held in the blubber and skin of the walrus by broad, flexible, backward-projecting stainless steel fins (Fig. 1a). They were delivered in a cylindrical projectile shot from a modified air gun (Air Rocket Transmitter System, Heide-Jørgensen et al. 2001). The tag had a cutting blade at the tip that facilitated its entry, and broad flexible forward-projecting fins near its distal end to prevent over penetration. Upon attachment, only the distal 2 cm of the tag remained exposed to the outside of the animal. The projectile fell away from the tag upon impact and floated so it could be recovered and reused.

Puck tags: Ten of the walruses (2006: 5; 2007: 5) were equipped with Puck tags. These transmitters, also named Post tags (ST-24, Telonics Inc., Mesa, AZ) are puck-shaped (Ø5.2 × 2.8 cm; 91 g), as the name indicate. They were attached to the strong skin of the walrus with a pivoting harpoon head mounted on a 6.0 cm × 0.6 cm stainless steel post (Fig. 1b). They were delivered with an arrow (carbon shaft balanced with an internal lead rod) that fit loosely into the rear end of the transmitter and was shot from a compound crossbow (Barnett).

Match box tag: These transmitters were rectangular epoxy cast transmitters (3.0 × 1.8 × 4 cm, 60 g) of the SPOT-5 type (Wildlife Computers, Redmond, Washington, USA). They were deployed on the walruses using a CO_2-powered rifle (Model IM, DanInject, www.dan-inject.com) equipped with a telescopic sight. The transmitters were attached to the tough skin of the walruses using 6.5 cm long harpoon head-like stain-less steel anchor. All harpoon anchors of the three tags were developed by Mikkels Vaerksted ("Mikkel´s Workshop"; www.mikkelvillum.com). Main target site was the medial back thorax region in order to obtain signals at sea when the walrus surfacing to breathe.

Tusk tag: The walruses tagged with the SMRU tusk tags (Length: 10cm; Ø: 6 cm, 800 g) attached to the tusks of the walruses with Bandit stainless steel hose clamp system in addition to securing of the unit to the rinsed and filed tusks with cement and stainless steel screws (see further details in Lydersen et al. 2008). The walruses were all tranquilized by a dart containing Ketamine and Zolapine delivered by a DAN-INJECT CO_2 Injection Rifle, equipped with a telescopic sight. An antidote containing Antisedan was used in case the walruses made attempt to return into the water.

Biological measures

During tagging operation, the sex, length of tusk for approximately age determination was estimated visually. In addition the group structure, if any, and there age was registered. Photos were taken for evaluate the tagging operation relative to the longevity, quality and number of positions obtained.

Data collection and analysis

Data on movements and transmitter status were collected via the Argos Location Service Plus system (Toulouse, France; Harris et al. 1990) and received on line over the Internet and on CD-ROMs once per month. Locations are classified by the Argos system into one of six location classes (LC) according to level of accuracy (3, 2, 1, 0, A, B). Studies have shown that there can be significant error in all location classes (up to several kilometers), but that even the low accuracy locations may provide useful and valid information if they are appropriately filtered (e.g., Vincent et al. 2002). Thus, all location classes were used in the present study after being filtered by a SAS-routine, Argos_Filter V7.02 (Douglas 2006). The filter applies user-defined settings for maximum swim speed, turning angles between migration vectors relative to distance between successive locations, to filter out the locations, which doesn't meet the set criteria. The filter is comparable to the R-based SDA-filter (Speed, Distance, Angle) tested by Freitas et al. (2008). The filter settings for this study 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. In addition the Argos Filter v7.02 calculated the distances travelled and the migration speed. SAS V9.1.3 for windows was used to run the Argos Filter. Excel 97 (SR2), SAS Enterprice Guide V4.1 and StatView V5.0.1 were used for statistical analysis and graph presentations. The maps were generated using ArcMap (version 9.3). The bathymetrical depth contours are based on 1-degree resolution GEBCO data (version 1.00). Hawth's Analysis Tools V3.27 was used an extension to ArcMap to generate track-lines, Kernel Home Range and area calculations.

All transmitters were programmed to provide haul-out information. These results are presented together with the Aerial survey data in Heide-Jørgensen et al. 2009 and Stewart et al. 2009.

Results

Duration of contact

Tag type comparison

The duration of the tags varied considerably ranging from 7 to 128 days. The Puck tags showed the shortest average longevity (average: 13.9 days; range: 4-24 days), which was significantly shorter than the Tusk tags (average: 50.2 days; range: 15-69 days) and the Matchbox tags (average: 43.7 days; range: 7-128 days), but not significantly different from the Implant tags (average: 35.7 days; range: 7-66 days; Table 1&2). Despite longer average longevity of the Tusk tags these were not significantly different from the Matchbox or the Implant tags (Table 2). The longest lasting single tag was a Matchbox tag that transmitting for 128 days. The Matchbox, Implant and the majority of the Puck tags were deployed during heavy ice conditions in early spring from late March to early April, whereas the tusk tags were all deployed during the open water season. The physical conditions from ice and temperature in the spring deployments may have reduced the longevity of these tags.

Sex dependant longevity

In order to evaluate whether sex had an influence on the longevity of the remote deployed tags a one way ANOVA was conducted on these tags. The tags lasted significantly (p=0.0275) longer on the female walruses (mean longevity 50.0 days; n=9) than on the males (mean longevity 25.8 days; n=20).

Movements

Of the 23 walruses tagged with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008. Of these 6 transmitters lasted long enough to show the migration route over the northern Davis Strait to the Canadian summering grounds of South East Baffin Island (one returned to Greenland probably due to severe ice conditions). One adult female walrus with a puck tag that tagged on 10 April 2007 (#2007-17567), which stopped transmitting on 30 April was re-sighted on 23 August 2007 in the narrow strait north of Kekertuk Island (65^{o}37'N/62^{o}0'W) off Cumberland Peninsula (Fig. 3.) Finally additional three crossed the midline between Canada and Greenland during their spring movements. None of the 8 tags deployed on walruses on South East Baffin Island in August-September 2007 lasted long enough to document the routes and the timing of migrations from the South East Baffin Island region to Store Hellefiske Banke. However, one flipper tag (#41) deployed on a tagged male of South East Baffin Island (#2007-60027 on 3 Sept 2007 at 65^{o}03.9' N/ 63^{o}14.4'W) were recorded on a walrus shot in the pack-ice of West Greenland on 24 of April 2009 (67.21^o N 55.2 ^{o} W) (Fig. 5). This observation confirms, as could be expected, that the walruses have a seasonal pattern where they travels back and fourth between Greenland (spring: Store Hellefiske Banke) and Canadian (autumn: South East Baffin Island) waters.

Within Greenland two male walruses visited the Disko Bank (ID-# 2006-56574 and 2007-56574), but as the tags only lasted 11-13 days it was not possible to see how long they stayed in this area, whether they returned to Store Hellefiske Banke or whether this was a first step towards a northward migration. Additional two male walruses passed the Disko Island further west and went to Upernavik district (ID-#

2008-56572 and 2008-57100). Both turned southward again and an adult male #2008-57100 continued to move to Canada where contact was lost 7 June 2008. Walrus #2008-56572 a 3 year old calf accompanied by it mother went as far north as 73.450^{o}N, but returned southward to 72.450^{o}N where contact was lost on 3 June 2008. These two north migrating individuals could indicate that even though some walruses may migrate fairly far north maybe representing the outer extremes of the population range they will return south again. However, more and longer lasting tracking are needed to make any firm conclusions on this matter.

Comparisons of male and female distribution

Longitude and latitudinal comparisons

As seen from Fig. 6 the males had a somehow different distribution relative to the. The longitude was compared between the tagged males and females for the pre-westward migration period i.e. Julian Day being <120 (and <100 for #2008-56573). The males (average: -56.299^{o} W; n=564) were significantly further west ($p<0.0001$) compared to the females (average: -55.502^{o} W; n=173). The latitude was likewise compared and revealed that the males (average: 67.640^{o} N; n=564) were slightly but significantly further north ($p<0.0022$) compared to the females (average: 67.535^{o} N; n=173).

Although the migration speed of the males was slightly faster than the females the difference was not significant. However, for both males ($P=0.0015$; n=410) and females ($P=0.0039$; n=169) the autumn migration speed was significantly lower in compared to the spring (Males: Spring: 3.5km/h Autumn: 2.3km/h; Females: Spring: 3.4km/h Autumn: 1.8km/h).

Comparisons of Kernel Home Range

The 75% Kernel polygon for males during the spring period was 9542 km^2, which was 70% larger than for the females being 5623 was km^2 (Fig. 7). Similarly the 75% Kernel polygon for males during the autumn period was 84% larger for the males (5931 km^2) compared to the females (3218 km^2). It was likewise clear that the distribution was more dispersed during the spring compared to the autumn even without subtracting the land areas from the Kernel polygons. Males had a 61% and females a 74% larger dispersal during spring compared to the autumn.

Depth region preference comparisons

As significant differences were found for the spatial distribution the bathymetri under the obtained positions were tested as well. The bathymetry may indicate sex preferences linked to dive capabilities. Overall the males (average: 158m; n=1150) were at significantly deeper water ($p<0.0001$) compared to the females (average: 70m; n=616). During the spring (i.e. pre-westward migration period) the males (average: 229m; n=623) were likewise at significantly deeper water ($p<0.0001$) compared to the females (average: 81m; n=193). This was true ($p<0.0001$) during the autumn period in the Southeastern Baffin Island Archipelago Canadian Waters as well, where males on average were at 61m depth (n=471), whereas females were at lower depths (12m; n=358). The lower bathymetry preferences were partly affected by the land observations, which were all set to 0m. Excluding these from the Southeastern Baffin Island Archipelago autumn dataset the sex difference was still highly significant ($p<0.0001$). Females on average frequented lower water depths of 19m (n=244) whereas the males ranging further offshore were at deeper water averaging 93m (n=307). The seasonal bathymetry of the walrus positions for all 4 years (2005-2008) is illustrated in Fig. 8.

Distance from land comparisons

The distance to land was likewise calculated from the obtained positions providing a last way describing the regional preferences and segregation between males and females for all data. During the spring (i.e. pre-westward migration period) the males (average: 111km; n=623) were significantly further from Greenland ($p<0.0001$) compared to the females (average: 73km; n=173) (see also Fig. 6). During autumn the walruses at Southeastern Baffin Island Archipelago Canadian Waters were significantly closer to land. During this season the males again were further from land than the females ($p<0.0001$). Males on average were at 6.8km (n=471) away from the shore when including the land observations and 7.5km (n=365), when only using the “at sea” location distances. The corresponding distances for female walruses were on average were at 1.1km (n=358) away from the shore when including the land observations and 1.6km (n=252) when only using the “at sea” location distances.

Walrus distribution relative to changing ice conditions

In order to understand the seasonal patterns of the west-east movement of the walruses, ice data were extracted on 56^{o} N for all days of the four years the walruses were tracked (Fig. 9).

In all 4 years the walruses were present east of the dense pack with the majority of the observation distributed between 55^{o} to 56.5^{o} W prior to the westward migration. Most of the later westward migrations seems to be taking place in dense ice but as the walruses during these movements are heading further south

Discussion

Duration of contact

Tag type comparison

The average duration of the Puck (14 d) and the Implant (36 d) tags were comparable to the average longevities found on the Bering Sea walruses tagged in 2001, which were 20 and 22 days respectively (Jay et al. 2005). The matchbox tags clearly have a substantial potential for longer transmissions as one tag lasted as long as 128 days. However the average lifetime of 44 days are typically due to tearing of the transmitters as the walruses move through the dense pack ice and haul out on the ice. This is supported by the observation that males inhabiting denser pack ice further west and further north during spring have a shorter longevity of their tags (this study). The really short lasting tags (down to 7 days) are most likely due to either extreme behavior of single individuals and/or less successful deployments in terms where the tag was placed and how efficient the anchor was deployed. As for the tusk tags a significantly shorter longevity was observed from The longevity of the tusk tags on the South Eastern Baffin Island (50 days) walruses lasted significantly shorter compared to results obtained from the Svalbard area (278 days) even though the tags were from the same company (SMRU; Freitas et al. 2009). It is uncertain to what extent the differences were caused by the heavier haul-out and bottom substrate (rock versus sand), the age of the tags after production when deployed (2.5 year vs 0.5 year), the attachment, the size of the tusks or other reasons.

Sex dependant longevity

The reason behind the longer lasting tags on the female walruses is probably that the females may seek less rough ice conditions in order to protect their off spring. During the tagging operation the general observed pattern was that the male walruses were occupying denser ice further west of Store Hellefiske Banke at greater depths, compared to the female walruses often accompanied by one or two calves. Also the males were more active being further west further from land, exploring larger regions and migrating faster.

Movements

In Central West Greenland walruses winter at two disjunct near-shore foraging grounds: The southern ground in the Sisimiut-Aasiat area and the northern wintering ground off the west coast of Disko Island/Qeqertarsuaq (Born et al. 1994). The occurrence of walruses in these areas is most likely due to the availability of shallow grounds with suitable food and less severe ice conditions than further west. According to Born et al (1994) walruses are generally absent from the entrance to Disko Bay where water depths exceed 200 m. Therefore it has so far been uncertain whether any contact took place between the two areas separated by the deep trench southwest of Disco Bay. The present study clearly documents a connection between these two foraging grounds, which means that the animals from the two regions should be regarded as one population.

The documented contact between West Greenland and South Eastern Baffin Island fits well with the genetic comparisons between the two regions (Andersen et al. in prep). In this study 17 microsatellite markers were applied to all samples from West Greenland and South East Baffin Island including analyses of the D-loop variation. Walruses in West Greenland and at South East Baffin Island did not differ from each other but differed from both Northwest Greenland and East Hudson Strait walruses that were likewise investigated in the comparison. Hence the stock management of South East Baffin Island and in West Greenland must be coordinated as the common stock is being exploited by hunters from the two countries. Based on the lack of presence of the walruses of West Greenland during summer an autumn and a compilations of observation made between Greenland in the late spring Born et al. (1997) earlier suggested such a connection between the walruses in the two regions.

Comparisons of male and female distribution

The partly segregation of the two sexes is in accordance with distribution in other regions. In Southeastern Baffin Island the segregation was most expressed. The females was further north and had a more limited dispersal. Adult females with calves seem to occur more frequent at the sheltered inshore haul-out sites whereas the off-shore exposed rocks facing deeper waters have a higher proportion of adult males (Stewart et al. in prep). Aerial surveys and analyses of photos taken at haul out sites on South East Baffin Island documents that the different haul out sites are not equally populated by the different sex and age groups. Adult females with calves seem to occur more frequent at the sheltered inshore haul-out sites whereas the off-shore exposed rocks facing deeper waters have a higher proportion of adult males (Stewart et al. in prep). On the Greenland East Coast the two genders are likewise geographically separated during summer with females occurring further north than males. These findings have among other been documented during aerial surveys conducted in 2008 (Boertmann et al. 2009) and 2009 (Born et al. 2009). The segregation among the two genders has earlier been suggested for Northeast Greenland (e.g. Johansen 1910, Freuchen 1921, Born et al. 1997) as well as for Alaska and Svalbard (Fay 1982; Gjertz & Wiig 1995). The greater dispersal of males compared to females is consistent with the genetic findings, where significantly more males were identified as first generation migrants compared to females (Andersen et al. 2009). Males can hence be regarded as more exploratory in their movements and behavior. The seasonal wider dispersal during winter and spring compared to summer and autumn has likewise been documented for narwhals (*Monodon monoceros*) wintering in the Baffin Bay – Davis Strait region (Dietz et al. 2008).

Walrus distribution relative to changing ice conditions

The longitudinal movement of the walruses between Canada and Greenland is clearly linked the presence of ice. During winter the walruses from Southeast Baffin Island are most likely forced towards the east by the denser ice masses along the Canadian coast. The nearest region with shallow banks with depths less than 100m is Store Hellefiske Banke, West Greenland where much lighter ice conditions are prevailing due to the inflow of relatively warm north-flowing West Greenland Current being a branch of the Irminger Current (Riget et al. 2000). Fay (1982) explained how the Pacific walrus only can cope with ice thickness up to 20 cm thick, and if the ice becomes thicker they must retreat to lighter ice conditions or moving pack ice. The banks with areas < 100m depth have extensive concentrations of bivalves such as *M. truncate*, *S. groenlandicus*, *H. arctica* and *M. baltica*, which are potential food items to the walruses (Vibe. 1939; Petersen 1978; Lubinski 1980; Schmid and Piepenburg 1993). Before 1937 walruses were still hauling out on land and several islands between 67^{o}15 to 67^{o}47N between September-October and April (Born et al. 1994 and references therein). After 1937 the walruses stopped going on land in Greenland probably due to the extensive hunt in the region. As the walruses also before 1937 left the Greenland coast it is likely that a similar westward moment as the ice retreated, as seen in our tracking’s, took place in historic time as well. The earlier reappearing in Greenland might have been an effect of food limitation along the Southeastern Baffin Island Coast as the historic population size was much larger than today (Born et al. 1994 and references therein).

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References

Harris, R.B., Fancy, S.G., Douglas, D.C., Garner, G.W., Amstrup, S.C., McCabe, T.R., and Pank, L.F. 1990. Tracking wildlife by satellite: Current systems and performance. United States Department of the Interior, Fish and Wildlife Service, Fish and Wildlife Tech. Rep. **30**: 52 pp.

Born et al. 1994. The Atlantic walrus (*Odobenus rosmarus rosmarus*) in West Greenland. Meddr. Groenland, Bioscience **40**: 33 pp.

Freuchen 1921. Om Hvalrossens Forekomst og Vandringer langs Grønlands vestkyst (On the Walrus Distribution and Presence along the western coast of Greenland). Videnskabelige Meddelelser. Dansk Naturhistorisk Forening København 72: 237-249.(Translated: Fisheries Research Board Canada Translation Series 2383). 14 pp.

Johansen 1910,

Jay, C.V., M. P. Heide-Jørgensen A.S. Fishbach. M.V. Jensen D.F. Tessler & A V. Jensen 2006. Comparison of remotely deployed satellite radio transmitters on walruses. Marine Mammal Science 22(1): 226–236.

Andersen, L.W., E.W. Born, I. Gjertz, Ø.Wiig, L.-E. Holm, and 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.

Andersen, L.W. and E.W. Born. 2000. Indications of two genetically different sub-populations of Atlantic walruses (*Odobenus rosmarus rosmarus*) in West and Northwest Greenland. Canadian Journal of Zoology 78:1999-2009.

Andersen, L.W., E.W. Born., R E.A. Stewart, R. Dietz, D.W. Doidge, C. Lanthier 2009. A genetic comparison of West Greenland and Baffin Island (Canada) walruses: Management implication. NAMMCO paper, Copenhagen Meeting 23-27 November 2009.

Anon. 1995. Report of the ad hoc Working Group on Atlantic Walrus. In: North Atlantic Marine Mammal Commission (NAMMCO), Annual Report 1995. Tromsø, Norway, pp 101-119.

Anon. 2006a. Quotas for the catch of walruses during 1 August-1 December 2006. Press release 20 September 2006 (J.no. 66.22/04). Greenland Home Rule Government. Department of Fishery, Hunting and Agriculture (Nuuk).

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. 2003. Reproduction in male Atlantic walruses (*Odobenus rosmarus rosmarus*) from the North Water (N Baffin Bay). Marine Mammal Science 19: 819-831.

Born E.W., R. Dietz, M.P. Heide-Jørgensen, and L.Ø. Knutsen. 1997. Historical and present distribution, abundance and exploitation of Atlantic walruses (*Odobenus rosmarus rosmarus L*) in eastern Greenland. Meddr Grønland. BioScience 46: 1-70.

Born, E.W., and J. Böcher (ed). 2001. The ecology of Greenland. Ilinniusiorfik, Nuuk 2001 pp 429.

Born, E.W., M.P. Heide-Jørgensen, and R.A.Davis. 1994. The Atlantic walrus (*Odobenus Rosmarus rosmarus*) in West Greenland. Meddr Grønland, BioScience 40: 1-33.

Born, E.W., I. Gjertz, and R.R. Reeves. 1995. Population assessment of Atlantic walrus (*Odobenus rosmarus rosmarus*). Norsk Polar Medd 138: 100 pp.

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

COSEWIC. 2006. Assessment and update status report on the Atlantic walrus (*Odobenus rosmarus rosmarus*) in Canada. Committee on the status of endangered wildlife in Canada, Ottawa, ix 65 pp.(www.sararegistry.gc.ca/status/status_e.cfm).

Dietz, R., M.P. Heide-Jørgensen, P. Richard, J. Orr, K. Laidre and H.C. Schmidt 2008. Movements of narwhals (*Monodon monoceros*) from Admiralty Inlet monitored by satellite telemetry. Polar Biol. 31(11) 1295-1306.

.

Dunbar, M.J. 1956. The status of the Atlantic walrus *Odobenus rosmarus* (L.) in Canada. Int. Union. Protect. Nature. Proc. 5th Meet., Copenhagen 1954: 59-60.

Fay, F.H. 1982. Ecology and Biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. U.S. Department of the Interior Fish and Wildlife Service. North American Fauna 74: pp 279 .

Freitas C, Lydersen C, Fedak MA, Kovacs KM (2008) A simple new algorithm to filter marine mammal Argos Locations. Marine Mammal Science 24: 315-325

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

Gjertz, I., and Ø. Wiig. 1994. Past and present distribution of walruses in Svalbard. Arctic 47: 34-42.

Heide-Jørgensen, M. P., L. Kleivane, N. Øien K. L. Laidre and M. V. Jensen. 2001. A new technique for deploying satellite transmitters on baleen whales: Tracking a blue whale (*Balaenoptera musculus*) in the North Atlantic. Marine Mammal Science 17:949–954.

Heide-Jørgensen, M.P., E.W. Born, K.L. Laidre, S. Fossette, R.G. Hansen, R. Dietz, M. Rasmussen, and H. Stern 2009. Abundance and trends in abundance of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in Central West Greenland. NAMMCO paper, Copenhagen Meeting 23-27 November 2009.

Lubinski 1980

Lydersen C., J. Aars, K Kovacs 2008. Estimating the Number of Walruses in Svalbard from Aerial Surveys and Behavioural Data from Satellite Telemetry. Arctic 61(2) (June 2008):119– 128.

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

NAMMCO (North Atlantic Marine mammal Commision) 2006. Scientific Committee Report of the Thirteenth Meeting, Reine, Norway, 25–27 October 2005. NAMMCO /15/5. Presented at the Fifteenth Meeting of the Council, 14 – 16 March 2006, Selfoss, Iceland. http://www.nammco.no/webcronize/images/Nammco/766.pdf.

Petersen 1978

Schmid, M.K. and D. Piepenburg 1993. The Benthos zoonation of the Disko Fjord, West Greenland. Meddelelser om Grønland, Bioscience 37: 1-21

Stewart, R.E.A. 2008. Redefining walrus stocks in Canada. Arctic 61: 292-398

Stewart, R.E.A. 2008b. Can We Calculate Total Allowable Harvests for Walrus Using Potential Biological Removal? Canadian Science Advisory Secretariat Research Document 2008/025 16 pp. [I'll add URL later]

Stewart, R.E.A. et al. 2009. An estimate of the abundance of walruses along eastern Baffin Island, 2006-2008. NAMMCO paper, Copenhagen Meeting 23-27 November 2009.

Vibe, C.. 1939.Preliminary investigations on shallow water animal communities in Upernavik. and Thule districts (Northwest Greenland) with observations on the ice conditions. Meddelelser om Grønland 124: 1-42 + 4 plates.

Witting, L.W., and E.W. Born. 2005. An assessment of Greenland walrus populations. ICES J of Marine Sciences 62: 266-284.

Tables:

Table 1. Information on 31 walruses instrumented with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007.

Tagging year and # of tagged animals	Tag ID	Sex	Tusk Length (cm)	Estimated age	Tag Type	Tagging latitude	Tagging longitude	Tagging date (YeMoDa)	Date of last transmission	du (
2005 WG										
1	2005-56572	Male	30	14 years	SPOT5 Implant tag	68.250N	56.040W	25-Mar-2005	1-Apr-2005	
2	2005-56573	Female	30	14 years	SPOT5 Implant tag	68.250N	55.250W	25-Mar-2005	30-May-2005	
3	2005-56574	Male	50	24 years	SPOT5 Implant tag	68.209N	56.106W	26-Mar-2005	29-Apr-2005	
2006 WG										
4	2006-17763	Male	25	11-12 years	ST16?/Puck Tag	67.743N	55.984W	19-Mar-2006	26-Mar-2006	
5	2006-17765	Male	8	2-3 years	ST16?/Puck Tag	67.743N	55.984W	19-Mar-2006	12-Apr-2006	
6	2006-56571	Male	12	4-5 years	ST16?/Puck Tag	67.976N	56.244W	21-Mar-2006	11-Apr-2006	
7	2006-56570	Female	28	13 years	ST16?/Puck Tag	67.683N	55.999W	22-Mar-2006	6-Apr-2006	
8	2006-56574	Male		Adult	ST16?/Puck Tag	67.992N	55.696W	26-Mar-2006	6-Apr-2006	
2007 WG										
9	2007-56570	Male	15?	5-7 years	Matchbox	67.693N	54.880W	10-Apr-2007	17-Apr-2007	
10	2007-56573	Female	25?	10-12 years	Matchbox	67.648N	55.147W	11-Apr-2007	17-Aug-2007	
11	2007-56574	Male	15?	5-6 years	Matchbox	67.683N	54.987W	10-Apr-2007	23-Apr-2007	
12	2007-17567	Female	15?	5-6 years	Puck tag	67.635N	54.842W	10-Apr-2007	30-Apr-2007	
13	2007-17759	Male	38?	18-20 years	Puck tag	67.813N	54.825W	10-Apr-2007	24-Apr-2007	
14	2007-57100	Male	10?	4-5 years	Puck tag	67.658N	54.842W	10-Apr-2007	14-Apr-2007	
2007 SEBI										
15	2007-08198	Male	10	20+	Puck tag	64.970N	63.417W	22-Aug-2007	9-Sep-2007	
16	2007-02508	Female	20	9	Puck tag	65.600N	62.573W	23-Aug-2007	28-Aug-2007	
17	2007-60021	Male	30	14	Tusk tag	65.648N	62.478W	25-Aug-2007	12-Oct-2007	
18	2007-60022	Male	37	17	Tusk tag	65.648N	62.478W	25-Aug-2007	30-Oct-2007	
19	2007-60023	Female	25	11	Tusk tag	65.948N	62.257W	30-Aug-2007	3-Nov-2007	
20	2007-60024	Female	29	13	Tusk tag	65.948N	62.257W	30-Aug-2007	7-Nov-2007	
21	2007-60026	Male	41	19	Tusk tag	65.066N	63.239W	3-Sep-2007	18-Sep-2007	
22	2007-60027	Male	40+	19+	Tusk tag	65.066N	63.239W	3-Sep-2007	11-Oct-2007	
2008 WG										

23	2008-56570	Female	s	13-14 years	Matchbox	67.773N	54.640W	2-Apr-2008	29-May-2008
24	2008-56571	Male	35	10+ years	Matchbox	67.698N	54.650W	2-Apr-2008	26-Apr-2008
25	2008-56572	Calf	6	3 years	Matchbox	67.693N	54.812W	2-Apr-2008	3-Jun-2008
26	2008-56573	Female	L: 20 R: 15	10 years	Matchbox	67.687N	54.988W	4-Apr-2008	29-Apr-2008
27	2008-56574	Male	12-15	6-7 years	Matchbox	67.675N	54.886W	2-Apr-2008	1-May-2008
28	2008-57098	Male		5-6 years	Matchbox	67.590N	54.782W	2-Apr-2008	3-May-2008
29	2008-57099	Female	L: 6 R: 20	10 years	Matchbox	67.631N	54.710W	4-Apr-2008	5-Apr-2008
30	2008-57100	Male		5 years	Matchbox	67.675N	54.003W	4-Apr-2008	7-Jun-2008
31	2008-57101	Male		20+ years	Matchbox	67.772N	55.045W	4-Apr-2008	15-May-2008

All

Table 2. Comparison of the longevity of the 4 tag types deployed on the walruses during the present investigation of 30 walruses instrumented with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007.

Tag Type	Average	Std Dev	Min	Max	N	Tukey-Kramer and Fisher PLSD post Hoc comparisons
Puck Tag	13.9	7.0	4	24	10	B
Implant tag	35.7	29.5	7	66	3	A, B
Matchbox*	43.7	33.8	7	128	11	A
Tusk tag	50.2	21.0	15	69	6	A
Grand Total	34.3	27.9	7	128	30	

** One transmitter (2008-57099) lasting only 1 day was left out (average with all units: 40.2 days)*

Figure 1.

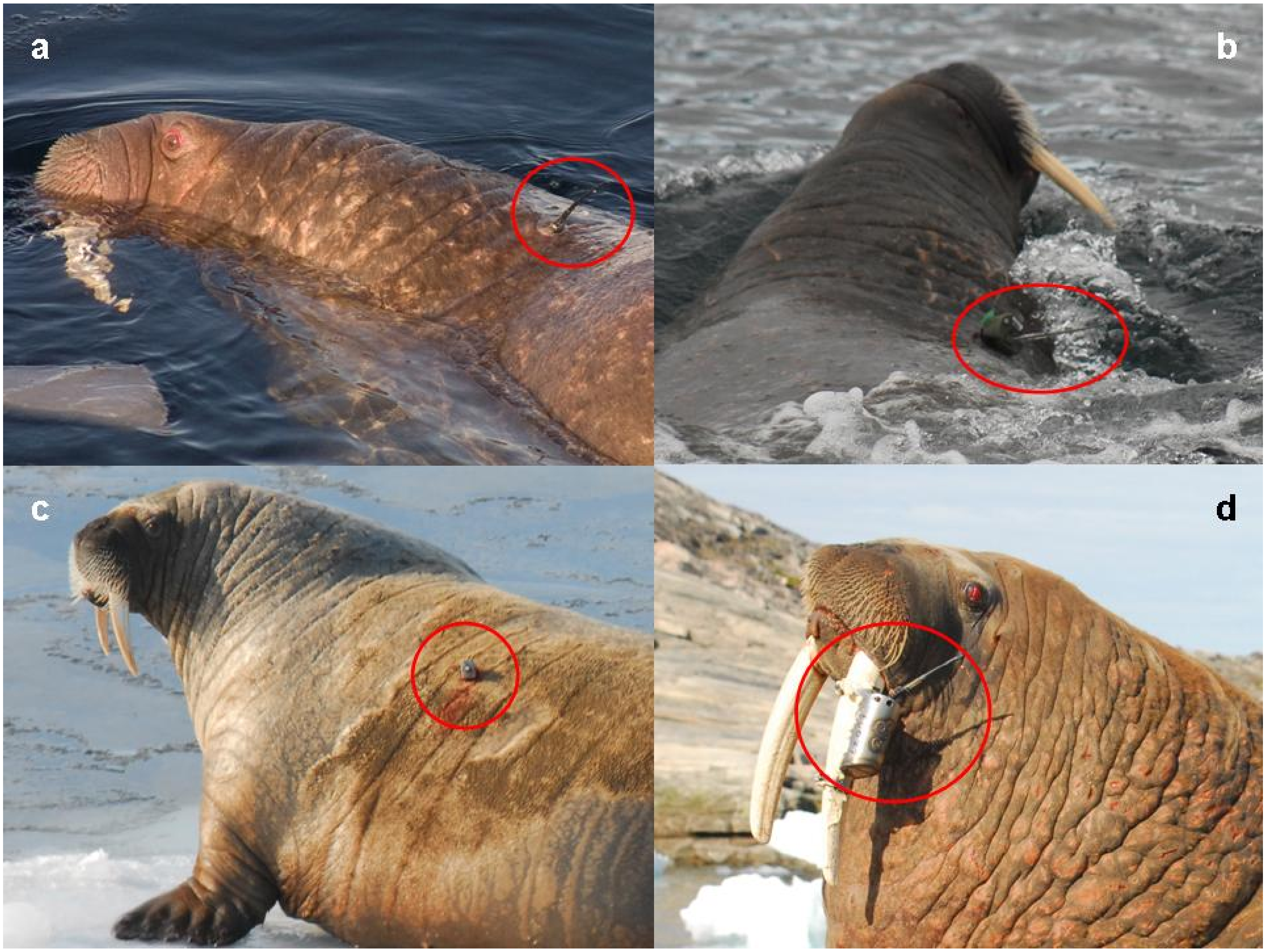

Figure 1. Photos showing the 4 types of transmitters used. Picture a) Implant tag from Wildlife computers, b) Puck tag from Telonics, c) Matchbox tag from Wildlife Computers and d) Tusk tag from Sea Mammal Research Unit. Transmitters highlighted within red circles.

Fig. 2.

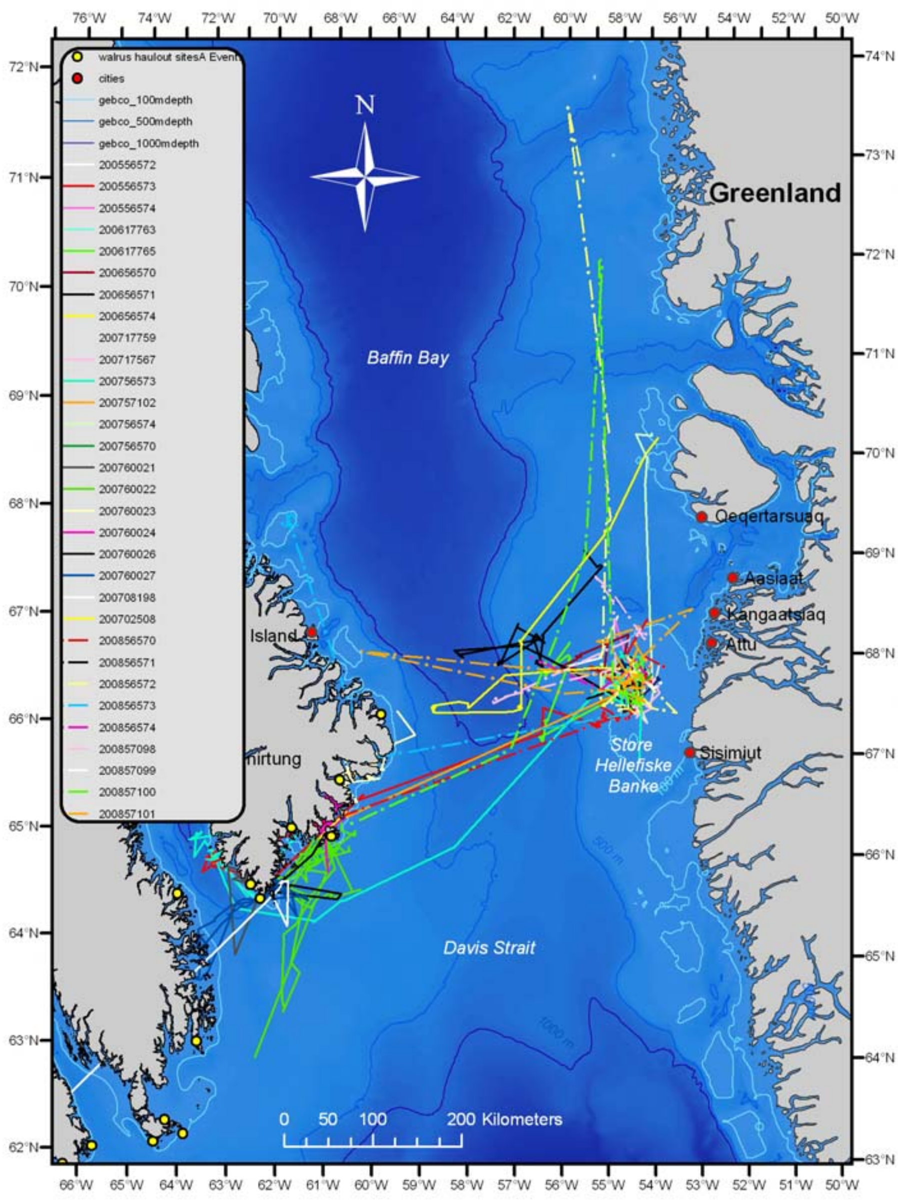

Fig. 2. Tracklines from 31 walruses tagged with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007. Of these 6 transmitters lasted long enough to show the migration route over the northern Davis Strait to the Canadian summering grounds of South East Baffin Island, one nonfunctional tag was re-sighted in SEB and additional three crossed the midline between Canada and Greenland during their spring movements.

Fig. 3.

Figure 3. An adult female walrus re-sighted 23 August 2007 in the narrow strait north of Kekertuk Island (65^{o}37'N/ 62^{o}0'W), Souteast Baffin Island with a calf of the year and a Puck tag still attached on its back (within red circle) after 135 days. The walrus was tagged on 10 April 2007 (#2007-17567), and stopped transmitting on 30 April 2007.

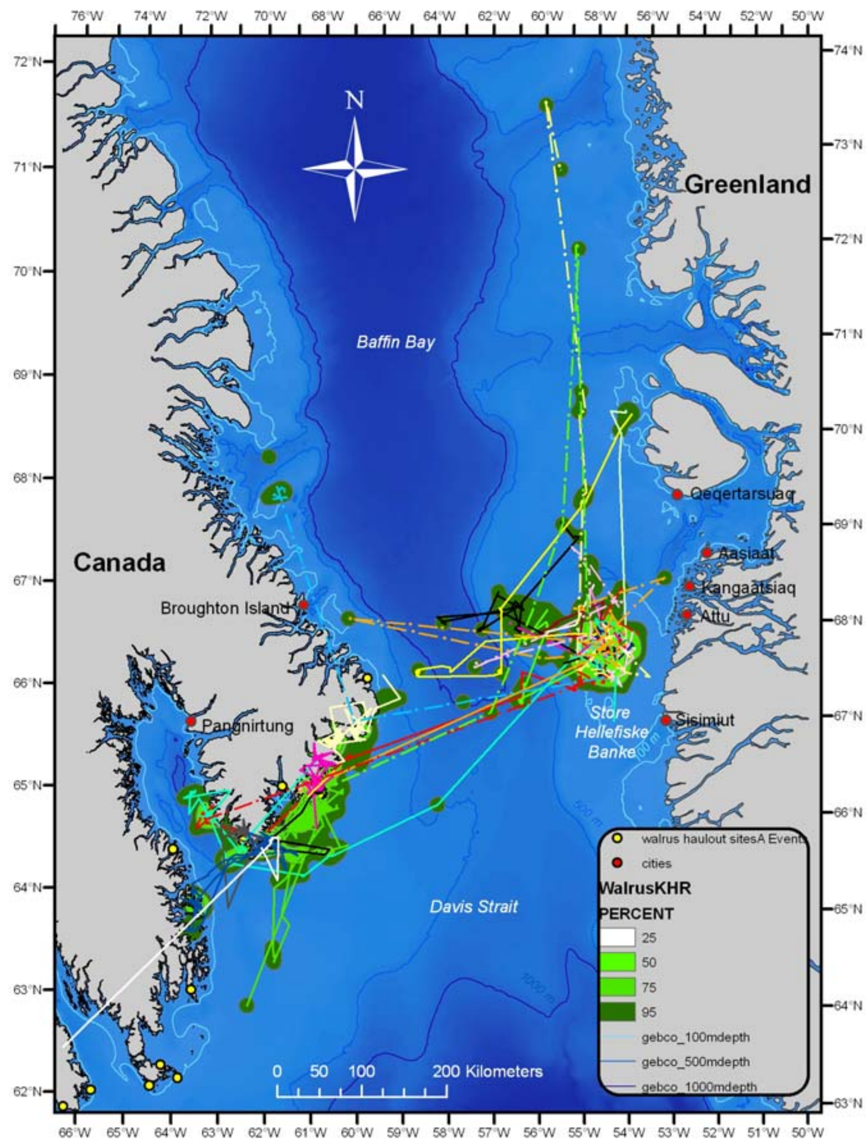

Fig. 4. Tracklines and Kernel Home Range polygons from 31 walruses instrumented with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007.

Figure 5. Photos a walrus tagged male of South East Baffin Island (#2007-60027 on 3 Sept 2007 at 65°03.9’ N/ 63°14.4’W, Upper photo) with in flipper tag (#41), which was recorded on a walrus shot in the pack-ice of West Greenland on 24 of April 2009 (67.21° N 55.2 ° W; lower photo).

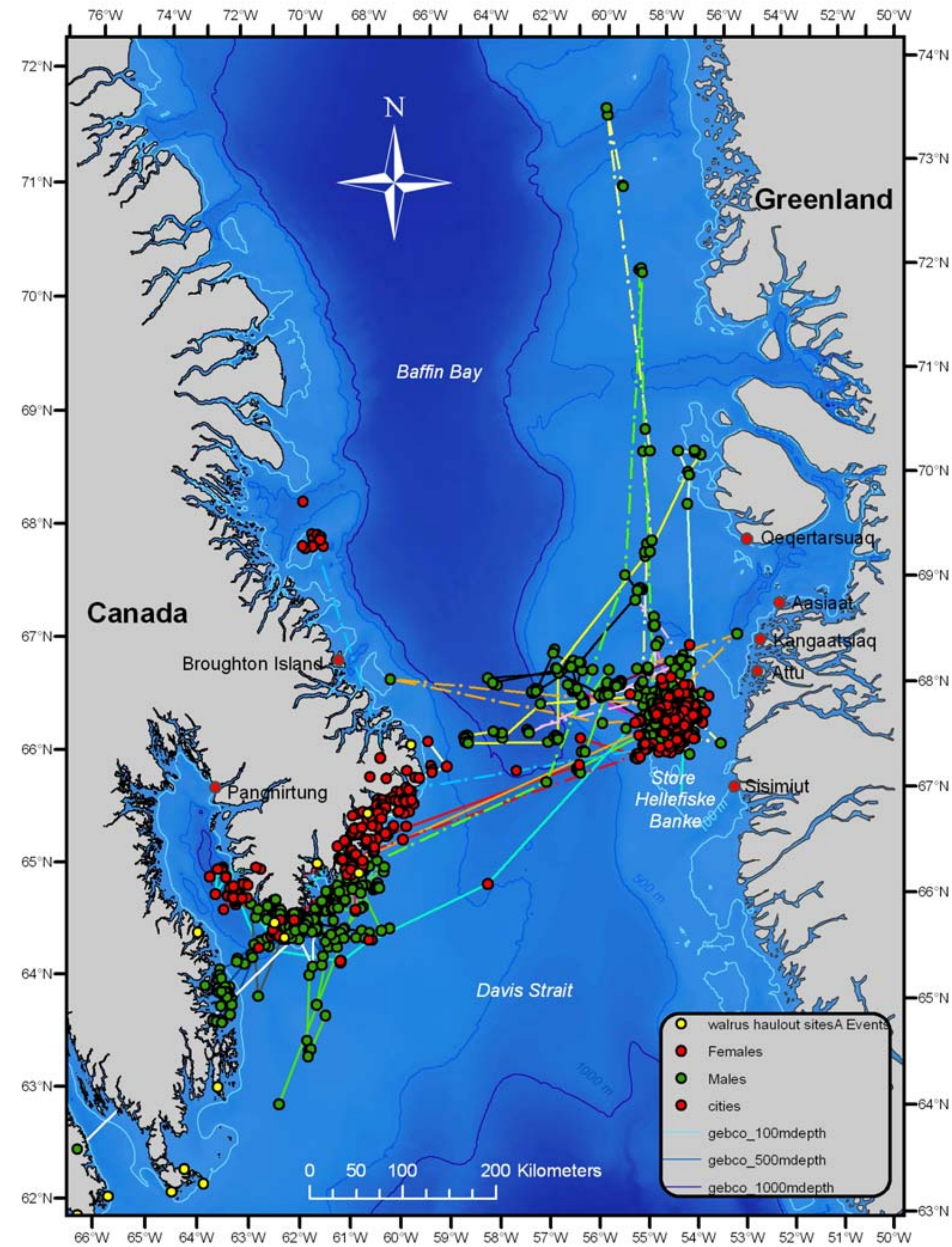

Fig. 6. Positions 20 male (green) and 11 female (red) walruses instrumented with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007.

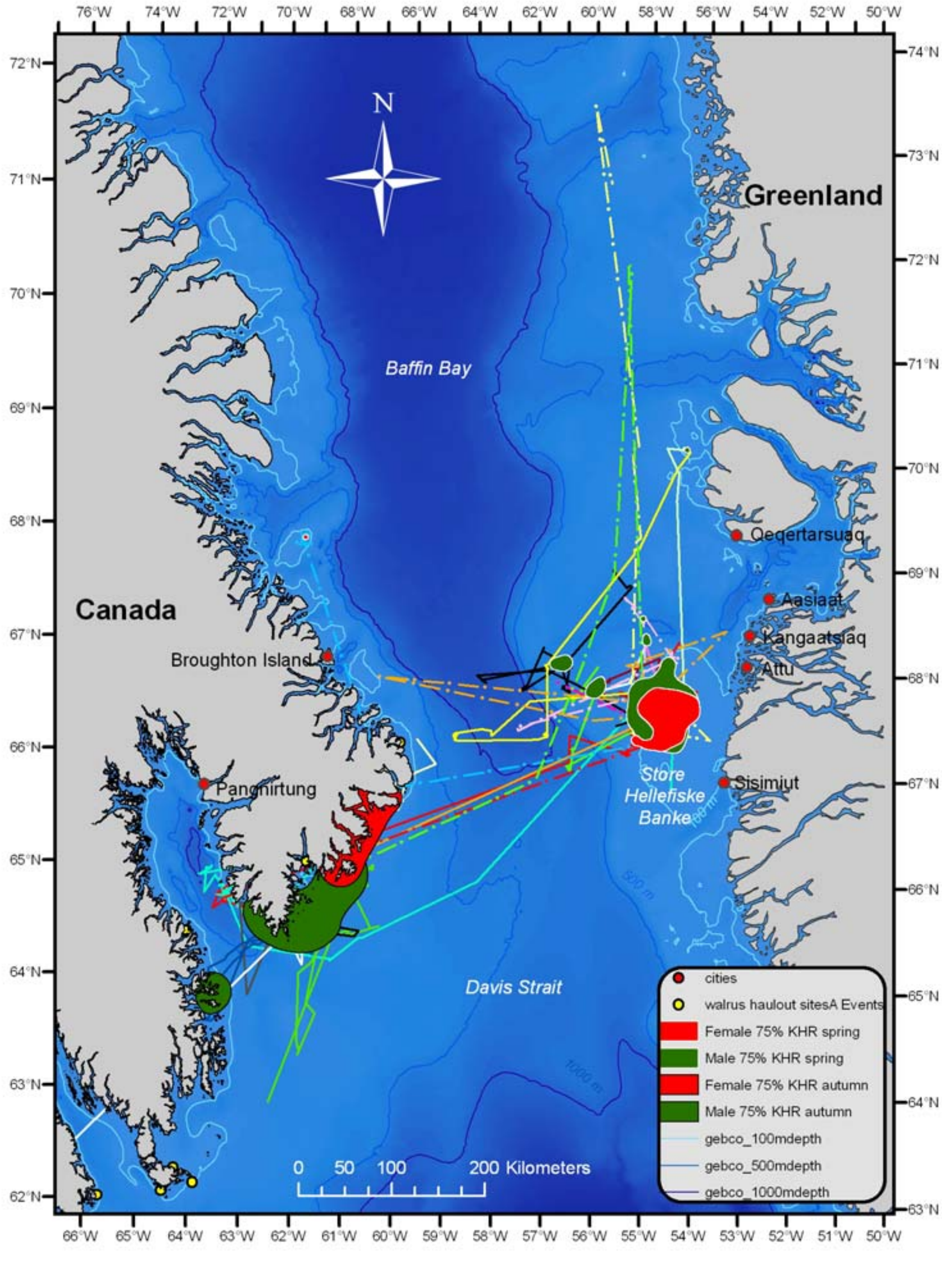

Fig. 7. Kernel Home Range Polygons (75%) during spring and autumn for 20 male (green) and 11 female (red) walruses instrumented with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007.

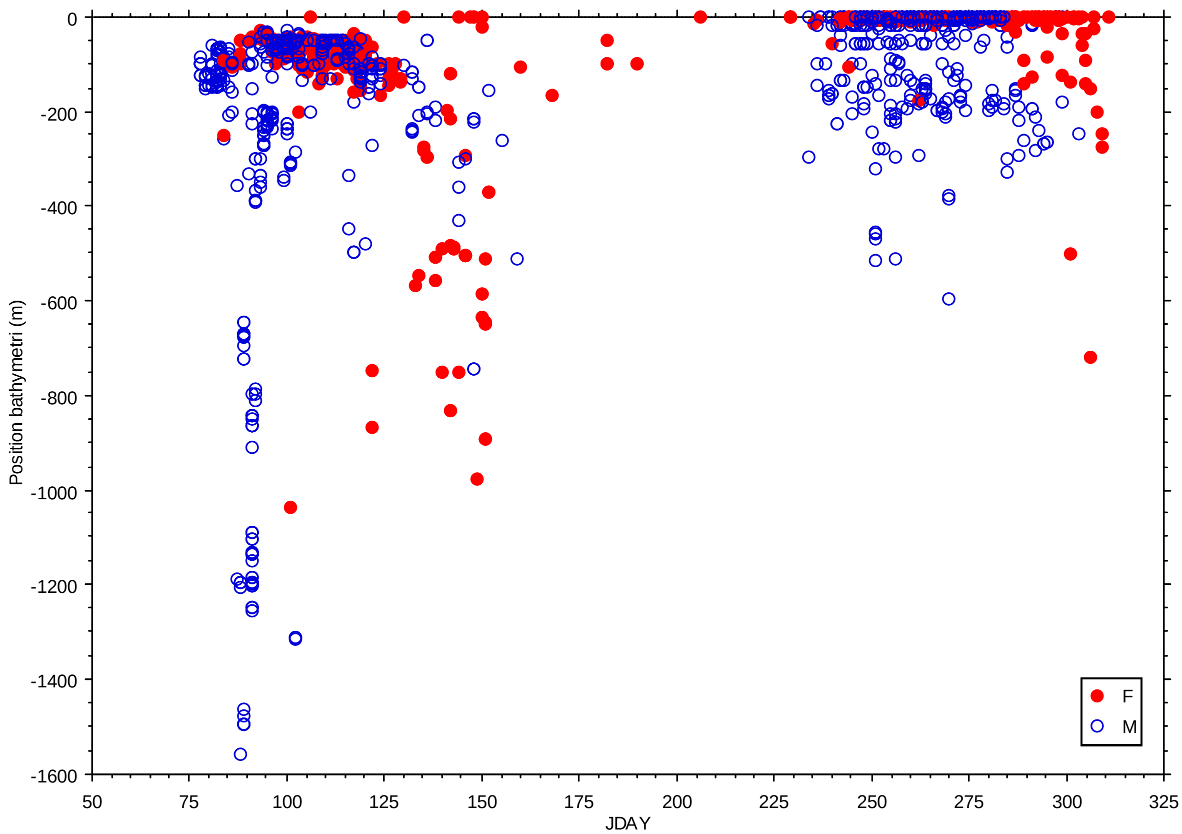

Fig. 8. Bathymetry under the positions of 20 male (blue) and 11 female walruses (red) relative to Julian Day. The Walruses were instrumented with satellite-linked transmitters at Store Hellefiske Banke during March-April 2005-2008 and at South East Baffin Island August-September 2007.

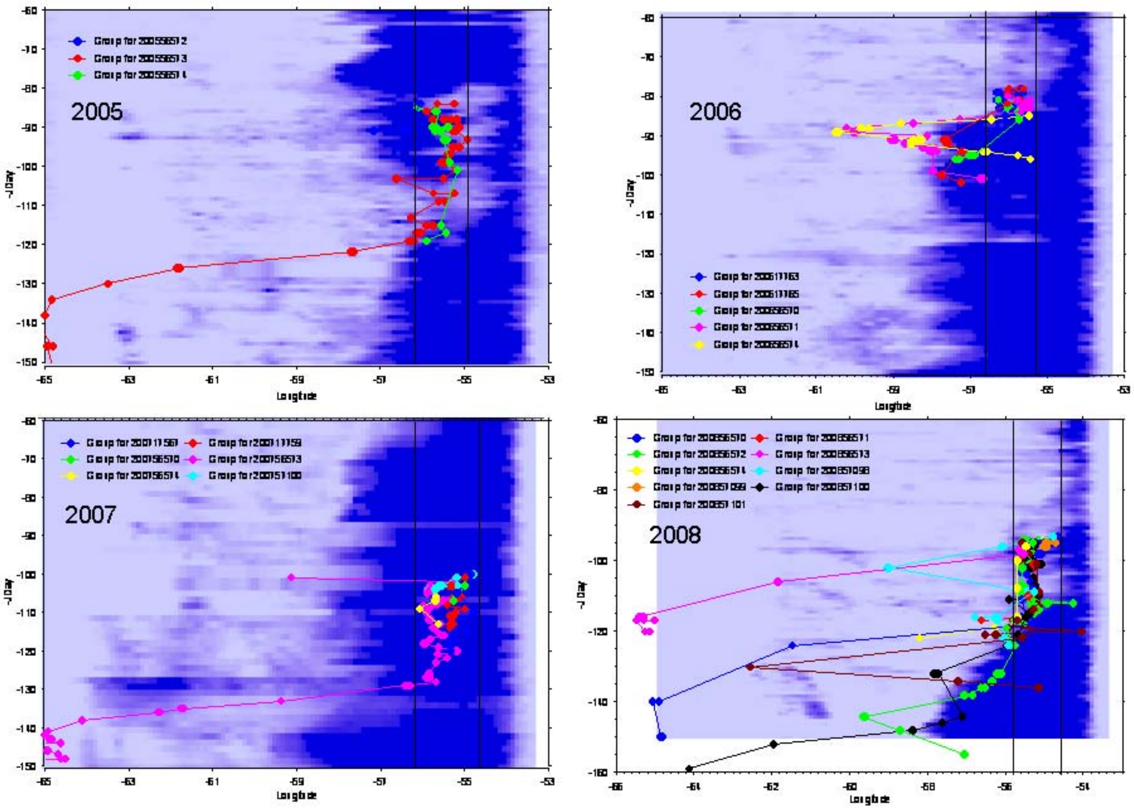

Fig. 8. Longitudinal movements of individual walruses in across the Davis Strait from 68^o to 64.5^{o}N relative to Julian day for the for tracking years (2005-2008) with longitudinal ice coverage for 67.5^{o}N.