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Diving and haul-out patterns of walruses *Odobenus rosmarus*
on Svalbard

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Abstract Nine male walruses were equipped with dive recording devices in Svalbard to investigate walrus diving and haul-out behaviour in late summer. Dive information on 6,018 dives was collected by 3 satellite linked dive recorders. Additional dive information on 7,769 dives was obtained from 3 time depth recorders. The deepest dive recorded was 67 m, but mean depth of foraging dives was 22.5 m. The longest-lasting dive recorded was 24 min, but mean duration of foraging dives was 6 min. The walruses, on average, spent 56 h in the water followed by 20 h hauled out on land.

Introduction

Walruses (*Odobenus rosmarus*) are the largest of the Arctic pinnipeds (Born et al. 1995). They associate with drift ice, upon which they prefer to rest, but if ice is not available they haul out on land (Fay 1981). In summer walruses, and especially males, rest and moult while hauled out on land at traditional sites often situated close to their feeding grounds (Tsalkin 1937; Mansfield 1958; Fay 1982). Walruses are highly social and gregarious; they haul out in large numbers lying closely packed (Fay 1982).

Walruses are stenophagous, relying on molluscs for most of their food (Fay et al. 1977). This food is normally taken at depths of less than 80 m (Vibe 1950; Fay 1982; Fay and Burns 1988). Little detailed information is known about walrus diving in general. However, detailed dive data from one walrus, obtained through the use of a Time Depth Recorder (TDR), was published by Wiig et al. (1993). This instrumented adult male walrus spent prolonged times at sea diving continuously to the bottom for long periods (Wiig et al. 1993). Periods of intense diving were interrupted by periods of rest at the surface and by trips ashore (Wiig et al. 1993). Based on results from one animal, Wiig et al. (1993) found a mean dive depth of ~20 m and a mean dive duration of ~5 min. This is similar to values reported by Fay (1982) and Born and Knutsen (1997) based on visual observations.

When not swimming and diving, walruses tend to haul out and rest for periods of up to several days (Miller 1976; Hills 1992; Born and Knutsen 1997). Two main patterns of haul out were observed in Alaska (Hills 1992). One was 2–4 days at the haul-out site followed by 7–10 days at sea; the other a daily pattern where the walrus undertook daily trips to sea from the haul out. In Greenland, the average haul-out time on land was 34 h followed by an average of 81 h at sea, but this varied substantially between years (Born and Knutsen 1997).

Satellite telemetry locations provided by the Argos Data Collection and Location System (ARGOS) are assigned a location quality code representing a presumed level of precision. The location quality is dependent on the number of uplinks received by the satellite for each overpass and the pass duration (Harris et al. 1990). However, there are indications that the precision levels are much lower than that suggested by ARGOS (Goulet et al. 1999). Burns and Castellini (1998) found that, in polar regions, ARGOS precision quality does not permit discrimination between foraging or haul-out areas that are within 5–10 km of each other. ARGOS position data are therefore not suited to determine precisely where walruses are feeding when the haul-out sites and feeding areas are closely situated. The present study, therefore, does not focus on location data. ARGOS location data from these same animals have previously been published by Wiig et al. (1996).

The aim of the present study is to describe walrus diving and haul-out behaviour in Svalbard in late summer.
Materials and methods

Fieldwork was conducted at Tusenøyane, southeastern Svalbard (~77°N 22 E), in July and August 1991 and August 1993.

In 1991, walruses were immobilised with intramuscular injections of etorphin HCL and reversed with diprenorphin HCL (C-Vet, Bury St Edmunds, Suffolk, UK) (see Griffiths et al. 1993). In 1993, walruses were immobilised with intramuscular injections of a combination of medetomidine HCL (Farmos, Turku, Finland) and ketamine (Nycomed Pharma, Asker, Norway). The medetomidine component was reversed by the experimental alpha-2 antagonist RX821002A (2-methoxydiazoxan) (Institut de Recherche Pierre Fabre, France).

In 1991, five adult male walruses were equipped with both a Telonics ST-3 Platform Transmitter Terminal (PTT) (Telonics, Phoenix, Ariz.) (see Wiig et al. 1996) and Wildlife Computers Mk. 3 TDR (Wildlife Computers, Redmond, Wash.) (see Wiig et al. 1993). The Mk. 3 TDRs had 256 Kbytes memory and were housed in 15 cm x 2.6 cm titanium tube. The ST-3 PTTs transmitted position data only, and were programmed for a duty cycle of 18 h on/18 h off, repetition rate 75 s.

In 1993, Wildlife Computers ST-6 PTTs (see Wiig et al. 1996) and either a Wildlife Computers Mk. 3 TDR or a Wildlife Computers Mk. 5 TDR were deployed on four adult male walruses. The Mk. 5, which is 6.4 cm x 3.8 cm x 1.3 cm, has 512 Kbytes memory. The ST-6 PTTs transmit position data as well as diving data (SLDR Satellite Linked Dive Recorders). The diving depth data were transmitted as a histogram with each dive recorded according to its deepest point. The durations of the dives were also transmitted as histograms. Dives had to be deeper than 2 m to be registered as dives. The histogram depth intervals were: 2–5 m, 6–15 m, 16–29 m, 30–49 m, 50–75 m and >75 m. The histogram duration intervals were: 0–1 min, 1–4 min, 4–7 min, 7–10 min, 10–13 min and >13 min. In addition, the ST-6 PTT gave the depth of the deepest daily dive. The ST-6 PTTs were programmed for continuous transmission, when wet, with a repetition rate of 60 s.

The PTTs and the TDR Mk. 3 were all attached to the walrus’s tusk using steel bands (Band-it, Houdaiver, Colo.) The Mk. 5 was first fastened in an aluminum bracket before this was fastened to the side of the tusk with steel bands.

TDRs were retrieved opportunistically, if the tagged animals were located at a haul-out site suitable for immobilisation. This was, however, first attempted after more than 1 week of deployment.

The data from the TDRs were analysed using software supplied by the manufacturer (Wildlife Computers, Redmond, Wash.). TDR-data was first adjusted for drift in depth settings through use of Zero-Offset-Command (ZOC), and then analysed with a Dive Analysis (DA) program.

From the dive records produced by the three TDRs, eight variables were selected to classify the dive types that were performed during the deployment period. Five of the variables were selected following Schreer and Testa (1995, 1996): (1) bottom time divided by dive duration; (2) bottom time divided by maximum depth; (3) maximum depth divided by dive duration; (4) average ascent rate divided by average descent rate; and (5) average descent rate divided by average ascent rate. Three additional parameters were selected as in Lesage et al. (1999): (6) maximum dive depth; (7) dive duration, and (8) bottom time = the time interval spent at depths ≥85% of the dive’s maximum depth.

The multivariate statistical techniques employed to classify the dives into groups were performed by following the methods and cluster solutions described in Kraft et al. (2000). Briefly, the selected variables were introduced into a Principal Components Analysis (PCA, SAS Institute) to reduce multilinear and the number of variables, as recommended in Hair et al. (1998). New uncorrelated variables from the PCA with eigenvalues > 1 or which explained more than 5% of the total variance were kept and used as input variables into a complete linkage hierarchical clustering analysis (SAS Institute). The hierarchical clustering analysis was executed to determine the appropriate number of clusters representing the data set and to set the initial seed points as also recommended in Hair et al. (1998). This acquired information was then utilised to perform a k-means cluster analysis (SAS Institute) on the retained uncorrelated variables from the PCA. The results from the k-means clustering analysis contained information about each dive’s cluster-type membership.

TDR data, from animals equipped with both TDR and SLDR, were transformed into SLDR data format by assigning the depth and duration of each dive to the appropriate bin. Paired t-tests were used to determine if the observed differences in the number of dives from the TDRs and SLDRs, for the same animal in the same time period, varied significantly from zero (see Burns and Castelli 1998).

Diving sessions were considered to start when a walrus left its haul-out site and started diving U-shaped dives deeper than 10 m (see Table 2). The diving period ended when the walrus hauled out again. Haul out was considered to be the period when the walrus was hauled out of the water, i.e. dry. If consecutive haul-out periods were separated by wet periods shorter than 15 min, then the consecutive haul-out periods, including the wet times, were grouped as one.

Results

Nine adult male walruses were equipped with TDRs or SLDRs (Table 1). Eight of these were equipped with

Table 1  Walruses equipped with Time Depth Recorder (TDR) or Satellite Linked Dive Recorders (SLDR) on Svalbard in 1991 and 1993 (T = Telonics, W/C = Wildlife Computers)

<table>
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<th>Walrus no.</th>
<th>Tagging date</th>
<th>PTT expired</th>
<th>PTT deployment period (days)</th>
<th>PTT no. of dive days</th>
<th>No. SLDR dives depth/ duration</th>
<th>TDR type</th>
<th>Recovered TDR</th>
<th>TDR deployment period (days)</th>
<th>TDR no. of dives</th>
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