BEHAVIOURAL SLEEP IN A NORTHERN FUR SEAL, *Callorhinus ursinus*

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INTRODUCTION Comparative Sleep Research is one important way to understand the functions of sleep in different animals and their adaptations to different ecological situations (Webb, 1979; Allison and Chichetti, 1976; Zepelin and Rechtshaffen, 1974; and Tobler, 1984). The classical sleep stages, which were originally defined in humans (Berger, 1930) using Electron-cephalography (EEG), are in principle also present in all other mammalian and avian species (Tobler, 1984).

The study of sleep in aquatic mammals led to some very surprising results: (1) Dolphins, Porpoises and Otariidae (seals) showed uni-hemispheric Slow Wave Sleep (Quiet Sleep or "Deep Sleep"). This means that each brain hemisphere sleeps alternately, when the other one is awake or in a shallow sleep-stage (Mukhametov, 1984; Mukhametov *et al.*, 1988). (2) With the exception of the most primitive mammals, the egg-laying *Monotremata*, Dolphins and Porpoises are the only warm-blooded animals that never show any sign of Active Sleep (also called Paradoxical Sleep, REM (Rapid Eye Movements) -Sleep or "Dream-Sleep"). These almost unique features within the homoiothermic vertebrates may reflect the return of primary terrestrial ancestors of the modern whales and seals to an aquatic environment (Mukhametov 1984).

The aim of this study was to develop and test behavioural categories for seals in order to distinguish different stages of sleep and wakefulness and to compare these findings with EEC results.

METHODS Observations were made in a roofed open-air basin of approximately 3 x3 x 1.5m at the Black Sea Station of the Severtsov-Institute. The subject of this study, an approximately 7 year old female northern fur seal, *Callorhinus ursinus*, named "Mathilda", lived in different dolphinaria for more than 6 years. Before measurement started, she took about one week to adapt to the new surroundings. The observers were hidden from the animal in a hut which borders the basin. They looked out of a small window, which was above the wall of the basin' and allowed the observers to look down at the animal from a distance of about 2.5 m while sitting at a table. Registration of time and duration of main stages, such as Active Wakefulness (AW) - see below - and substages like swimming, grooming etc. (not included in this paper) was carried out with the help of a computer program (actogram), which was developed by the senior author of this study (Oleg Lyamin). Observations during night-time were only possible using a 100 Watt bulb, which hung approximately 2.5 m above the middle of the basin. Eye Configuration and AS-Phenomenons were observed using binoculars.

The experiment was sub-divided into 3 parts:

Stage I: Low water level (approx. 0.25m) and offer of a platform for resting (days 1-4).
Stage II: High water level (approx. 1.3m) without platform (days 5-34).
Stage HI: Same conditions as Stage I (days 35 and 36).

About twenty 24h continuous observation sessions were made alternately by 3-4 different observers, which were all experienced in the application of the behavioural categories. The adaptation time of about one week was used to modify the behavioural categories developed by Ursin and Sterman (1981) in adult cats, for studying sleep in seals:

Main stages:

Active Wakefulness (AW):

-General State (GS): typically movement (short episodes of quiescence possible).
-Body Position (BP): sitting, standing, walking or swimming.
-Head Position (HP): head up(right).
-Eye Configuration (EC): eyes permanently open.

Quiet Wakefulness (QW):

-GS: typically quiescence (short episodes of movement possible).
-BP: sitting or lying.
-HP: typically head down (if head up, only slightly moving).
-EC: eyes permanent open - periodically closed (not longer than 29 sec).

Changes between AW and QW were only registered, if the new stage is kept for more than 10 sec without coming back to the old one.

Quiet Sleep (QS):

-GS: quiescence.
-BP: lying or sitting.
-HP: typically head down (if head up, not moving).
-EC: eyes permanent closed for more than 30 sec.

Active Sleep (AS):

-GS: quiescence with frequent jerky body movements, most prominent at the head (neck), extremities, vibrissae, ears and nostrils.
-BP: lying (muscle hypotonia!).
-HP: head down (muscle hypotonia!).
-EC: generally closed or half opened. REM.

A change from QS to AS was only registered if.the AS phenomena had a longer duration than 30 sec.. In water, fur seals show a typical sleeping posture, the so called: "Ring". A distinction was made between QW and QS only through the frequency of movements and the time of eye-closure. A distinction between QS and AS was made from the presence of jerky body movements or REM; and in water, additionally by the sinking of the head with its nostrils under the water surface due to muscle hypotonia.

.RESULTS

Stage I: The amount of both sleep stages QS and AS increased from the first day to the fourth day of the experiment (7.1 - 19.8% vs. 0.9 - 4.4% of 24 h observation time respectively). At the same time, there was a decrease of both wakefulness-stages, particularly AW, from 39.0 - 27.8%. The animal slept exclusively on the platform (Fig. 1).

Stage II: The first 24 h after raising the water level and removing the platform at the fifth day of the experiment, "Mathilda" was in AW all the time, usually swimming. Within the 30 days of this stage in the experiment, she never showed less than 78.9% AW; QW increased from zero to 10.8%; QS from zero up to 15.5%: AS was not detected (Fig.l).

Stage III: After reducing the water level to Stage I conditions and offering again a platform for resting, the animal showed higher levels for QW (59.6 vs. 50.8%) and lower levels for AW (22.6 vs. 39.0% compared with Stage I). The amounts of both sleep stages QS and AS were slightly lower than in Stage I: QS (19.1 vs. 19.8%) and AS (3.0 vs. 4.4%) (Fig.l).

DISCUSSION Although the water level in Stage I of the experiment was very shallow, -"Mathilda" never slept in water, but exclusively on the platform. *Callorhinus ursinus* seems to prefer to sleep on land if it is available.

During the first 4 days, the increase of the amount of sleep on the one hand and the decrease of wakefulness on the other, reflects an increasing habituation of the animal to the new basin. We do not know whether this process had already reached its final stage, because we were forced to interrupt this at day 5 in order to have enough time for the main part of the experiment: the High Water level Conditions. These are in a way similar to open-sea conditions, in which *Callorhinus ursinus* live for more than two months every year, when they migrate from the northern North Pacific Ocean to more southern latitudes during autumn and on their way back in spring. During this time, the species must be able to sleep in the open sea and to survive with a smaller amount of sleep. Our data show a reduction of total sleep time (both QS and AS) from 24.2% to zero at the first day of Stage II and to a maximum of 15.5% at day 32.

The absence of AS for at least one month might be due to difficulties in detecting short and less prominent episodes of AS during sleep in water. Electro-physiological research on our species showed a clear reduction of the amount of AS in water to about 0.3%, compared with 3.6% on land (Mukhametov *et* a/., 1988). A comparison of our results with these data show a high degree of conformity (Table 1). We do not understand so far, how northern fur seals are able to survive long periods of at least one month with half the amount of sleep and less than 10% of AS compared with sleep on land.

If our results prove to be representative for this species (Oleg Lyamin will repeat the experiment with another two individuals of *Callorhinus ursinus*), then it would appear that sleep rebound is not used to compensate sleep deficiency (see the results of Stage in - there was even a reduction of total sleep time as well as both QS and AS compared with Stage I). Therefore, it might be possible that Otariidae seals are able to reduce their demand for sleep, even under physically exhausting conditions, to a surprisingly low level for higher mammals. This would be very interesting for all hypotheses on the functions of sleep (Webb, 1979; Karmanova, 1982; Meddis, 1975), especially AS (Fishbein and Gutwein, 1977; Vogel, 1979). Although it is not possible to detect such surprising results as the presence of uni-hemispheric sleep in some marine mammals, it is possible to achieve interesting knowledge about sleep in animals, using behavioural techniques only.

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Table 1 Comparison between our results and data obtained after Mukhametov *et al.* (1988) following EEG-investigations (Mean values for four individual seals). There is a general agreement between these two data sets.

	on Land EEC	on Land Behav.	in Water EEG	inWater Behav.
Awake	69.6 %	75.7-89.8%	83.8 %	78.9-100 %
Sleep	30.4%	08.0-24.2 %	16.2 %	00.0-15.5 %
Active Sleep	03.6%	00.0-4.4 %	00.3 %	00.0-00.0 %
Quiet Sleep	26.8%	07.1-19.8 %	15.9 %	00.0-15.5 %

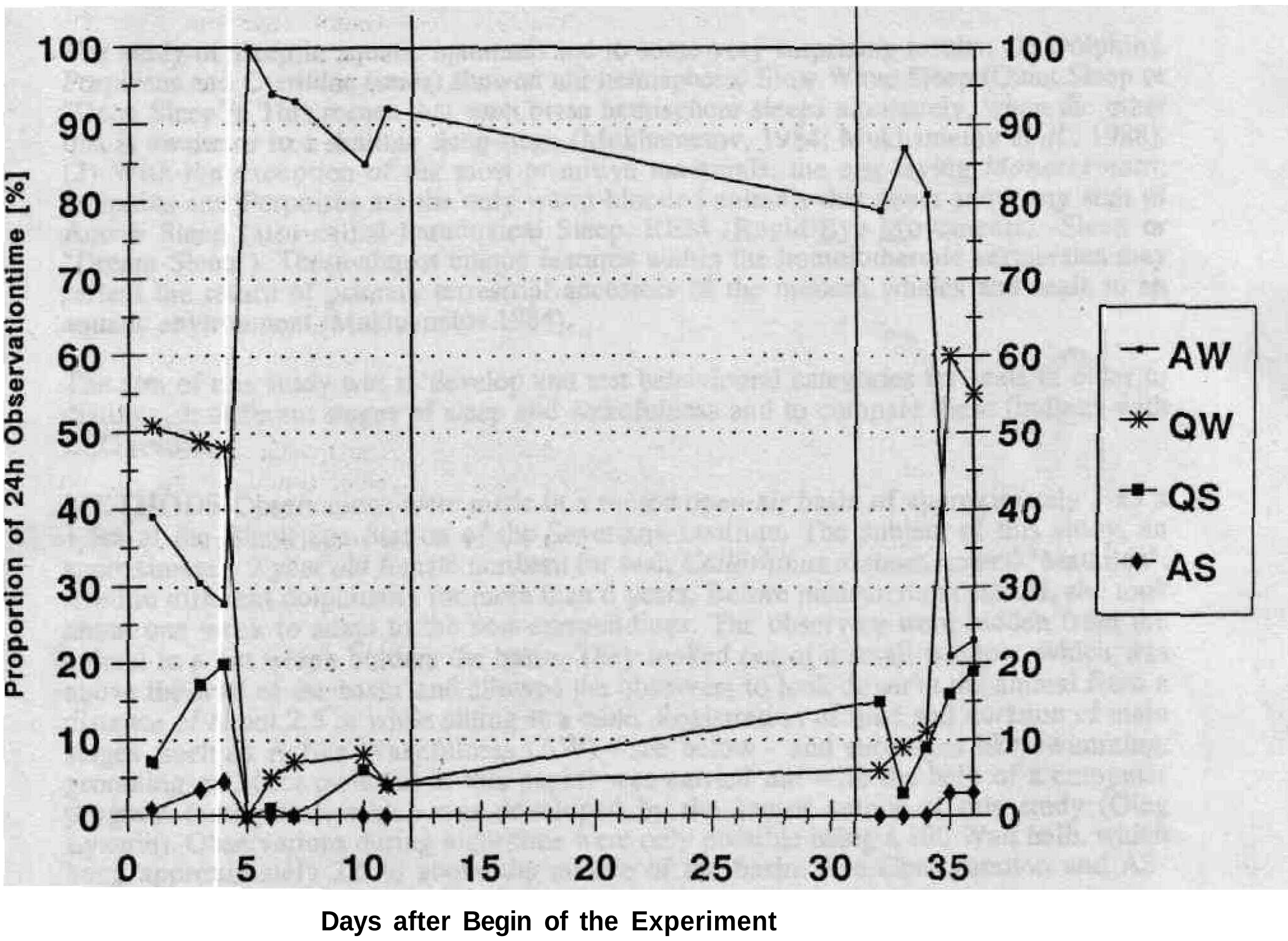

Fig. 1 Main Stages of the Sleep-Wakefulness-Cycle of the Northern Fur Seal "Mathilda" during the three stages of the experiment. Lines at day 12 and day 31 indicate that there are no data available within this period. Abbreviations - AW: Active Wakefulness; QW: Quiet Wakefulness; QS: Quiet Sleep; AS: Active Sleep.