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BREATHING AND HEART RATES OF THE SOUTHERN ELEPHANT SEAL, *MIROUNGA LEONINA* (L.)

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(with three tables and one text figure)

ABSTRACT

KENNY, R., 1979 (20 vii): Breathing and heart rates of the southern elephant seal, *Mirounga leonina* (L.). *Pap. Proc. R. Soc. Tasm.*, 113: 21-27. ISSN 0080-4703. Department of Zoology, James Cook University, Townsville, Queensland, Australia.

Observations were made on resting southern elephant seals, *Mirounga leonina* (L.), on the beach. The breathing pattern of pups is typically regular with rapid, shallow inhalations. With increasing age a rhythmic pattern of alternating apneic and eupneic phases is developed. Apneic periods of similar duration to previously recorded dives were observed from adult seals. The heart rate decreases with increasing age; rates recorded from cows increased at the cessation of lactation and the onset of the breeding season; at other times rates from adult males and females were similar. Body temperatures were higher at the onset of the winter sea-going period than at other times of the year. The histology of the lungs and thyroid glands is typically mammalian.

INTRODUCTION

The physiology of the Pinnipedia has been reviewed by Harrison and Kooyman (1968). In general, statements on the physiology of the southern elephant seal *Mirounga leonina* (L.) have been concerned with body temperature (Laws 1956) and haematology (Bryden and Lim 1969; Seal *et al.* 1971; Lane *et al.* 1972). Few observations on breathing or heart rate have been found in the literature. Harnisch (1937) noted the frequency of breathing from a captive animal and Paulian (1957) recorded the number of inhalations between dives in the wild.

The physiology of the northern species, *M. angustirostris* including breathing and heart rates has been studied by Bartholomew (1954) who has commented on the irregular rhythm of the breathing pattern.

Swindle (1926) suggested the possibility of amphibious mammals "training" for diving, Bryden and Lim (1969) commented on changes in blood characteristics in elephant seals at the age of going to sea and Lane *et al.* (1972) suggested an increased diving potential in adult animals.

A general account of the biology of *M. leonina* at Macquarie and Heard Islands, where these observations were made, is given by Carrick *et al.* (1962).

METHODS

The present observations were made on resting elephant seals, on the beach at Macquarie Island (long. 159° E., lat. 54° S.) and Heard Island (long. 73° E., lat. 53° S.) between February 1948 and April 1951. Breathing rates were counted for several consecutive minutes from 194 individuals; 46 of the records were for periods exceeding 20 min. The heart rates of 278 individuals were obtained by direct observation of the movement of the body wall for a period of at least 1 min. The majority of observations were made during the breeding season (October-November) and the adult moulting period (February-April) but occasional records are available from winter months.

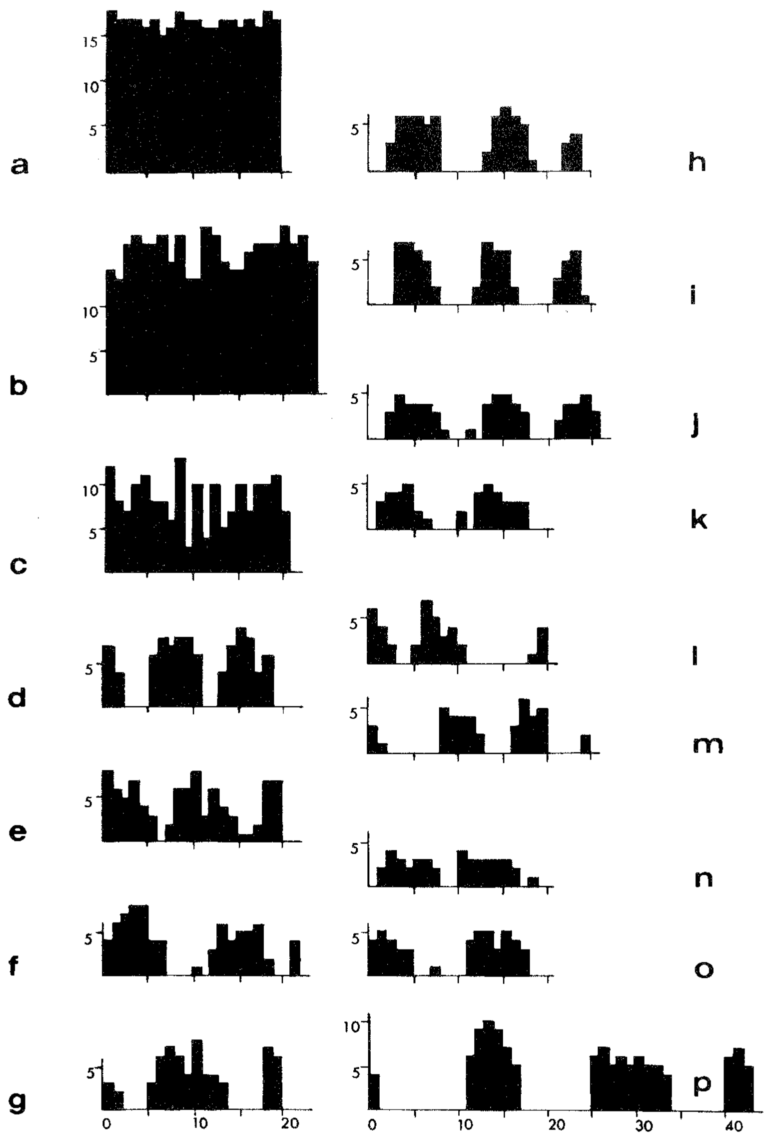

FIG. 1.- Selected examples of breathing patterns of elephant seals. horizontal axis - time in minutes; vertical axis - number of inhalations per minute. a,b.- pup; c.- young female prior to leaving beach; d,e.- pregnant female; f,g.- female lactating; h,i.- female after pup weaned; j,k.- young bachelor male; l,m.- old bachelor male; n,o.- harem bull; p.- bull moulting.

In conjunction with these observations other physiological data were noted. Rectal temperatures, recorded during daylight hours with a long stem mercury thermometer inserted to a depth of 0.2 m are available from 32 seals. Haematological information was recorded from 14 animals.

Lung (19 seals) and thyroid (24 seals) tissues from selected individuals were examined histologically. The samples were fixed in Bouin's fluid and stored in 4 per cent buffered formalin. Following paraffin embedding and sectioning, the tissues were stained with haemotoxylin and eosin for microscopic examination.

BREATHING RATE

The most striking features of the results are the variable rhythm of breathing apparent in the majority of adult seals and in contrast to this the more regular pattern of the younger seals. The extremes noted were 27 inhalations per min (male pup) and an apneic period of over 10 min (adult male, moulting). Details, from selected subjects, observed for approximately 20 min are shown in fig. 1.

The breathing of the pups is typically shallow, rapid, comparatively regular and at the rate of 10 to 20 inhalations per min. Some young animals showed tendencies towards the varied breathing rhythm of the adult. In general these animals were observed during April, just prior to going to sea for the winter period.

All the adult elephant seals observed had lower respiratory rates than those of young seals and showed some form of rhythmic variation of breathing rate. In general the pattern is one in which some minutes of eupnea are followed by a period of apnea of variable duration. These apneic phases may commence following either an inhalation or an exhalation, although the former pattern is more common.

The depth of the inhalations during eupnea and immediately preceding apnea varied considerably. In some individuals the breathing was deeper immediately preceding apnea while in others there did not appear to be any change from the comparatively shallow breathing of the eupneic phase. Similarly the initial inhalations following the pause in breathing varied considerably in depth.

The length of the period of apnea increases with age and the time of interspersed eupnea tends to decrease.

As an arbitrary comparison of the respiratory rate in elephant seals of differing age and activity, the mean number of inhalations over a period of 20 min have been calculated and are presented in table 1. The breathing rate is higher in young animals than in adults and among the adults varies with the activity pattern of the individuals. The variation for adult males in differing activity phases is considerably less than for females. The difference between the breathing rates of the adult males and females is more marked during the early summer pupping and mating haul-out than during the moulting period.

Development of the apneic pattern with increasing age supports the speculations of Swindle (1926), Bryden and Lim (1969) and Lane *et al.* (1972) that diving potential and ability are enhanced with age.

Harnisch (1937) observed variable respiratory rhythms and periods of apnea of 6 min duration from a zoo specimen of *M. leonina* and dives of 11 min were recorded by Paulian (1957) in the wild. Periods of submergence of 5 to 10 min alternating with periods of ventilation were noted by Laws (1956). The present results demonstrate that adult elephant seals on land experience apneic periods of similar duration to typical dives.

TABLE 1

MEAN NUMBERS OF INHALATIONS FOR 20 MINUTES
(commencing at the beginning of a period of eupnea),
calculated from all observations

pup	286	female		male	
		after weaning pup	108	immature	88
		pregnant	87	harem bull	48
		lactating	69	young bachelor	45
		moulting	48	old bachelor	41
				moulting	57

A similar respiration pattern was recorded from the northern elephant seal *M. angustirostris* by Bartholomew (1954) with a maximum inhalation rate of 23 per min and periods of apnea exceeding 8 min duration. Spontaneous variable breathing rhythms have also been observed from other aquatic mammals including the Florida manatee (Parker 1922; Scholander and Irving 1941), polar bear (Swindle 1926), fin whale (Gunther 1949), dugong (Kenny 1967) and various pinnipeds (Harrison and Kooyman 1968).

HEART RATE

The data from heart rate observations have been arranged by age and sex in table 2. The extremes recorded were 96 beats per min from a pup (age, approximately 1 month) and 23 from a bachelor bull. This follows the pattern noted from other mammals with the rate decreasing with increasing age and size.

The heart rates observed from pups were significantly higher (Student's "t" test, 1% level) than those from other sections of the population. Heart rates of immature seals were higher than those of adults (5% level) with the exception of cows after weaning their pups. The differences between the rates observed from different adult groups were not significant, except for those from cows at the end of the lactation period and the onset of the breeding season; these were significantly higher (1% level) than other adult heart rates.

Observations at 5 min intervals on individual seals showed changes in heart rate of up to 10 per cent without alterations in the activity pattern of the individual. No regular pattern of heart rate variability relative to breathing rhythms was noted, although Bartholomew (1954) observed a 15 per cent reduction of heart rate during apneic periods for *M. angustirostris*. Further, differences in heart rate before and after periods of apnea, similar to those recorded during experimental dives of other seal species (Harrison and Kooyman 1968) were not observed. Scholander (1940) has noted that reduction of heart rate is more marked during diving than during periods of apnea on land.

BODY TEMPERATURE

The mean elephant seal body temperature was 36.2°C, with a maximum of 38.4°C (immature male, April) and a minimum of 34.8°C (harem bull, October). This mean is similar to that given by Laws (1956) but he recorded a wider range of temperatures, in particular from moulting animals. Temperatures from immature seals ranged higher than those of adults in a pattern similar to the trend mentioned by Bartholomew (1954) for *M. angustirostris*; however, the records from the two groups were not significantly different.

All temperatures recorded in April (36.7 to 38.4°C) prior to the seals leaving the beaches, were above the mean value and higher than any breeding season or summer records.

TABLE 2

HEART RATES OF ELEPHANT SEALS

	Number of Observations	Heart rate, beats per minute max.	min.	mean	S.D.
pups	38	96	69	81	±5.7
male					
immature	58	71	35	54	±5.2
harem bulls	14	47	31	40	±2.8
old bachelors	18	50	23	36	±3.9
young bachelors	15	46	33	41	±3.1
moulting	26	50	26	43	±4.8
female					
immature	61	76	38	54	±5.4
pregnant	10	42	39	41	-
lactating	20	51	34	40	±2.6
after weaning pup	11	64	58	62	±1.3
moulting	7	51	39	47	±2.4
whole sample	278	96	23	53	

TABLE 3

ELEPHANT SEAL BLUBBER TEMPERATURES ^{o}C (APRIL)

	Air	Blubber depth 1cm	5cm	10cm	Rectal
immature female	3.9	31.6	34.7		37.1
immature male	5.4	31.6	33.9		36.7
immature male	4.4	31.4	34.5		37.9
adult female	5.6	31.8	33.8		36.8
adult male	5.3	29.4	32.8	36.1	37.1

A series of subcutaneous temperature readings was taken from recently killed elephant seals. These are listed in table 3. The major shift in the heat gradient occurs in the skin and outer section of the blubber.

HAEMATOLOGY

The mean haemoglobin content of the southern elephant seal was 23.9 gm/100 ml of blood, which is similar to the figure given by Lane *et al.* (1972). The mean value for red cell counts was 3.39 x 10^6/ml. This is higher than the figure given by Lane *et al.* (1972) but similar to that given by Bryden and Lim (1969). The calculated oxygen capacity of 32.04 volume per cent is considerably lower than the value stated by Scholander (1940) but similar to that given by Lane *et al.* (1972).

HISTOLOGY OF LUNG

In view of the variable patterns of breathing associated with different ages and the lengthening of the apneic periods with increasing size, specimens of lung from elephant seals, selected to include a range of sizes, were examined microscopically. Measurements of alveolar diameter (mean of 12 from each sample) were made using an eyepiece micrometer.

The typical mammalian pattern of change in lung micro-anatomy applied, with alveolar size increasing regularly with body length. The smallest alveolar diameter, 0.03 mm, was recorded from a pup 1.29 m long and the largest, 0.12 mm, from an adult female 2.72 m in length.

No special micro-anatomical modifications were observed.

HISTOLOGY OF THYROID

The differences in breathing and heart rate associated with size and seasonal activity patterns prompted the histological examination of thyroid tissue samples.

The size of thyroid cells varied little in material from seals of different size or killed at different seasons, ranging from 0.013 mm to 0.017 mm in diameter. No obvious differences in amount of intracellular vacuolisation were noted.

The diameter of the follicles (mean of 12 follicles considered to be in maximum cross section) increased regularly with body length. The smallest noted was 0.09 mm from a pup 1.28 m long and the largest was 0.25 mm from a male 3.79 m in length. In a similar manner Harrison and Kooyman (1968) described a straight line relationship for the increase of thyroid weight relative to body weight in the harbour seal. Comparison of follicle sizes from seals of similar size at different times of the year showed little variation.

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