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Visual monitoring of heartbeat and respiration in Antarctic seals

ABSTRACT: Heartbeat and respiration of southern elephant seals (*Mirounga leonina*), Weddell seals (*Leptonychotes weddellii*) and Antarctic fur seals (*Arctocephalus gazella*) were monitored simultaneously using a visual and non-intrusive method, at King George Island, South Shetland Islands. All three species demonstrated sleep apnoea with reduced heart rate. In adult elephant seals, heartbeat fell 18% in apnoea; spells lasted up to nine min, usually ending in disturbance from conspecifics or human visitors. Slight human disturbance (notably slight noise) reduced time spent in apnoea from over 40% to 4%, significantly reducing the frequency of falling into apnoea and increasing mean heartbeat. Further disturbance resulted in head raising, aggression, scratching, rolling and movement away. The visual monitoring of heartbeat and respiration can be used with resting or slightly disturbed animals but not when major body movements occur.

Key words: Antarctica, pinnipeds, heartbeat, respiration.

Introduction

Antarctic seals hauling ashore to rest or moult are subject to disturbance by human visitors, who by approaching the seals singly or in groups, watching and photographing, elicit varying levels of response. It is particularly frequent near scientific stations, which receive a lot of interest from tourists and are often visited.

Human disturbance of Antarctic fauna has been previously studied. Changes in heartrate and rate of respiration in gentoo penguins (*Pygoscelis papua*), monitored by a non-invasive technique (*i.e.* one that did not involve handling or instrumenting individuals), were found effective as indicators of disturbance by humans, conspecifics and predators (Nimon *et al.* 1994, 1995, Nimon and Stonehouse 1995).

Both respiration and heartbeat in resting seals have previously been monitored using non-intrusive techniques (*e.g.* Bartholomew 1954, Blackwell and LeBoeuf 1993) in northern elephant seals (*Mirounga angustirostris*).

This study relates changes in rates of heartbeat and respiration, monitored by a non-invasive technique, to non-human and human-induced disturbance in three species, southern elephant seals, *Mirounga leonina* (Linnaeus, 1758), Antarctic fur seals, *Arctocephalus gazella* (Peters, 1875) and Weddell seals, *Leptonychotes weddellii* (Lesson, 1826). The study forms part of a long-term programme investigating human impacts on Antarctic flora and fauna (Stonehouse 1994), and long-term studies of sea mammal distribution and human impacts at *Henryk Arctowski* Station and neighbouring shores of Admiralty Bay (Ciaputa and Salwicka 1997, Salwicka and Sierakowski 1998, Stonehouse 1999).

Materials and methods

The study was carried out on King George Island (South Shetland Islands), in the vicinity of the *Henryk Arctowski* Station (62°09'54"S and 58°27'45"W) from November 28th 1996 to February 28th 1997 and from January 12th to February 28th 1998.

A resting subject was approached quietly to within 3 m without invoking signs of awareness. Choosing vantage points from which nostrils and thorax were visible, the observer counted directly and/or recorded by video camera (a) impact of the heart on the thoracic wall, (b) respiratory movements of the thorax, and (c) closure of the nostrils and mouth. In this study both heartrate and respiration of individual seals were monitored, without touching, handling or instrumenting the subjects. Visually, either parameter could be monitored singly, but the video camera proved more reliable for recording both simultaneously, providing repeatable and simultaneous counts and a record of associated behaviour.

Parameters were recorded as numbers of inspirations and heartbeats per half-minute. For reporting and calculation, recorded values were doubled to appear as respirations and heartbeats per minute. The periods of observation were given as a number of 30 s intervals. All statistical analyses were performed with the help of Statistica for Windows (StatSoft 1999).

The shortest observations used in analysis lasted 5 min., the longest 60 min. Most continuous runs ended with a change in the animal's behaviour, for example shifting position so that heartbeat or respiration were obscured. Such shifts usually, though not always, followed a change in the subject's environment, most often physical disturbance from another seal, occasionally a change of wind, or disturbance from approaching humans. The technique could be continued during mild disturbance, for example during slight shifts of posture in response to movements of a neighbour in the wallow. However, major body movements obscured the respiratory and pulse signals, ending observations.

Results

Data from southern elephant and Weddell seals are divided into three groups: male, female and immature animals. Among Antarctic fur seals, only immature males were present. Within each group mean rates of heartbeat and respiration were calculated (N = number of 30s interval records), the latter derived only from video records. Differences in rates for different age and sex groups were tested with One-Way Breakdown ANOVA, which showed significant differences in mean heart rates ($F_{6.3335} = 90.09$, $p < 0.001$) and in mean respiration rates ($F_{6.834} = 46.80$, $p < 0.001$).

Table 1 summarises heartbeat and respiration data derived from 95 undisturbed seals. Visual records are of heartbeat alone. Video records are simultaneous counts of heartbeat and breathing recorded by video camera.

Table 1

Heartbeat and respiration in undisturbed southern elephant, Weddell and Antarctic fur seals: summary of observations.

	Elephant seals			Weddell seals			Fur seals
	Males	Females	Young males	Males	Females	Young males	Young males
Heartrate							
No. of subjects	30	24	5	7	10	1	18
Observation time (30s)	1210	984	123	402	301	22	309
Mean	56.63	52.98	59.43	64.63	52.27	61.73	70.70
SD	14.41	13.93	14.65	9.67	8.27	6.24	18.75
Respiration							
No. of subjects	2	17	5	1	8	1	18
Observation time (30s)	61	472	123	16	239	22	309
Mean	3.82	4.23	5.78	8.50	7.38	8.00	4.69
SD	1.42	1.78	2.06	2.00	3.61	2.51	1.77

Detailed comparison of means between the groups was accomplished with the help of Tukey Honest Significant Difference test (HSD). Among elephant seals, females had significantly lower mean heart rate than adult and immature males (HSD, $p < 0.001$). No significant difference was noted between adult and immature elephant seals (HSD, $p > 0.05$). Among Weddell seals females had lower mean heart rate than males (HSD, $p < 0.001$). No significant differences were noted between immature and adult Weddell seals (HSD, $p > 0.05$). Mean heartbeat was highest of all in young male fur seals and was significantly different from elephant and Weddell seal groups (HSD, $p < 0.001$). Antarctic fur seals also provided the highest recorded value of 108 heart beats min^{-1}. The lowest means were observed in mature female elephant and female Weddell seals, and they did not differ significantly (HSD, $p > 0.05$).

There was no significant difference between the mean respiration rates in adult males and females elephant seals (HSD, $p > 0.05$), although the means for females and immature males were higher than that of adult males (HSD, $p < 0.001$). No significant differences in respiration rates were observed among Weddell seals (HSD, $p > 0.05$). Mean respiration rate of fur seals was not different from any of the elephant seals means (HSD, $p > 0.05$), but was significantly lower than those of Weddell seals (HSD, $p < 0.001$). Weddell seals had the highest mean respiration rates of all the groups (HSD, $p < 0.001$), also providing the highest recorded value of 16 inspirations per minute.

All groups except male Weddell seals were recorded in apnoea, but visual observations confirmed that these too closed their nostrils and suspended breathing during undisturbed deep rest. Table 2 shows differences in heart rates during eupnoea and apnoea on land in undisturbed subjects. A female elephant seal showed the longest single spell, and females spent the highest proportion of their undisturbed resting time (47%) in apnoea, closely followed in both by adult and immature males of the same species. Female Weddell seals spent 34% of resting time in apnoea; we have no equivalent sample for males. Immature fur seals in comparison rarely entered apnoea (3%), and their mean length of time in apnoea was the shortest of all the groups. Both findings are consistent with their restless and relatively intermittent sleeping behaviour ashore.

Differences in heart rates for different age and sex groups, for different levels of rest, were compared using two-tailed Student-t tests. In changing from eupnoea to apnoea mean heart rate fell 18% in adults and 27% in immature males of elephant seals. For Weddell seals only the 17% reduction in female Weddell seals heart rates was significant. Differences between apnoeic and eupnoeic heart rates in immature Weddell and fur seals, were non-significant.

Elephant seals lying prone and with eyes closed were usually switching between eupnoea with relatively high heart rate (tachycardia) and apnoea with reduced heart rate (bradycardia). Slight noise or physical disturbance from conspecifics or humans, below levels that caused opening of the eyes and major body movements, invoked only slight physiological change in eupnoeic subjects. Those in apnoea usually reverted to eupnoea, indicated by resumption of breathing and sometimes, though not always, near-simultaneous increase in heart rate. In the absence of further disturbance apnoea was usually resumed. Continuing disturbance led to opening of the eyes and small comfort movements.

Table 2
Differences between apnoeic and eupneic heart rates in three species of Antarctic seals.

	Elephant seals			Weddell seals			Fur seals
	Males	Females	Young males	Males	Females	Young males	Young males
Number of subjects	2	17	5	1	8	1	18
Observation time (30s)	61	472	123	16	239	22	309
Max duration of apnoea (30s)	13	18	14	–	8	6	5
% of time in apnoea	44%	47%	41%	–	34%	32%	3%
Heartbeat in apnoea							
Mean	44.30	42.25	48.78	–	46.35	65.71	60.00
SD	9.11	7.01	10.82	–	8.67	7.06	26.34
Heartbeat in eupnoea							
Mean	54.24	52.05	66.97	60.00	55.82	59.87	70.99
SD	8.04	6.43	12.14	4.26	7.73	5.04	18.48
Reduction of heartbeat in apnoea, as % of mean rate in eupnoea	18%	18%	27%	–	17%	-10%	15%
t-test value	4.46	15.76	8.73		8.29	-1.97	1.17
Significance level	**	**	**	–	**	n.s.	n.s.

Eupnoeic and apnoeic heartbeat min^{-1} within groups were compared by two-tailed Student t-test. ** denotes highly significant difference ($p < 0.001$), n.s. no significant difference ($p>0.05$).

Table 3
Breathing, heartbeat and apnoeic spells in female southern elephant seals, undisturbed and disturbed by natural causes (*e.g.* conspecifics, birds, wind) and humans.

	Non disturbance	Natural disturbance	Human disturbance
No. of subjects	17	8	4
Observation time (30s)	472	241	151
% observation time in apnoea	47	24	4
No. of apnoea spells $hour^{-1}$	9.66	10.46	1.53
Mean HB/min	47.42	52.19	54.34
Mean breath/min	2.23	2.98	4.46

Thus in circumstances of slight disturbance, physiological changes were more sensitive indicators of response than behavioural changes. A similar sequence was noted in Weddell seals: no comparable observations were possible in Antarctic fur seals.

Table 3 compares rates of respiration and heartbeat and incidence of apnoea in female elephant seals both undisturbed, and slightly disturbed by conspecifics or humans. Disturbance reduced the percentage time spent in apnoea from 47% (see also Table 2) to 24% when caused by conspecifics and to 4% when caused by humans. Frequencies of apnoeic spells were similar for the two groups under natural conditions ($\chi^2 = 0.8$, df = 1, $p > 0.05$) but significantly lower in elephant seals disturbed by humans ($\chi^2 = 7.32$, df = 1, $p < 0.05$). The mean rates were compared with Kruskal-Wallis ANOVA, which showed that the increases were statistically significant in both heartbeat ($H_{2.870} = 116.53$, $p < 0.001$) and respiration ($H_{2.870} = 101.78$, $p < 0.001$). The increase in mean rates was due to the shortening of apnoea duration with natural and human disturbance, when animals never reach the levels of rest observed in undisturbed subjects.

Discussion

Both respiration and heartbeat in resting seals have previously been monitored using non-intrusive techniques. Bartholomew (1954) and Blackwell and LeBoeuf (1993), studying sleep in northern elephant seals, *Mirounga angustirostris*, monitored breathing visually. Our study appears to be the first in which both heartbeat and respiration were monitored simultaneously by visual methods alone, and the first to record data from Antarctic fur seals. Mean heart and respiration rates obtained by visual methods are comparable with those obtained electronically by other researchers. Despite their limitations, visual methods offer clear advantages in situations where it is important not to associate the presence of humans with trauma from handling and instrumentation.

Sleep apnoea has been noted in northern elephant seals by Bartholomew (1954), Castellini *et al.* (1986), Blackwell and Le Boeuf (1993), Castellini (1994), and Castellini *et al.* (1994a and b), in southern elephant seals by Kenny (1979), and in Weddell seals by Kooyman and Campbell (1973), and Castellini *et al.* (1992). Though not unexpected, it does not appear to have been recorded previously in Antarctic fur seals.

The shortest lengths of apnoea recorded in our study, 1–2 minutes in immature fur seals, compare with those recorded for weaner elephant seals under laboratory conditions (Huntley *et al.* 1984). Such short spells appear to typify young seals: sleep apnoea generally lasts longer in adults. Our longest spells of apnoea, recorded in southern elephant seals, were shorter than the longest land records for northern elephant seals (Blackwell and Le Boeuf 1993); the northern species also spent a higher proportion of time in apnoea.

Guidelines for tourists issued by the International Association of Antarctica Tours Operators, (IAATO 1991) required visitors to remain 15 ft (5 m) from hair seals, as from other forms of wildlife, a distance at which proponents agreed seals showed little or no overt response. A limit of 50 ft (15 m) for fur seals reflected the likelihood of this more aggressive group attacking intruders. More recent guidelines, amended to meet requirements of Recommendation XVIII-1 of the 1994 18th Antarctic Treaty Consultative Meeting, specify no distances, but require visitors not to approach or photograph birds or seals "... in ways that cause them to alter their behaviour". This amended criterion is more difficult for operators to monitor or enforce, and more difficult for visitors of goodwill to meet because of their limited familiarity with seal behaviour. A seal that moves away from a visitor has clearly been disturbed. What of one that merely opens its eyes or raises its head: are these small movements to be regarded as signs of disturbance?

Our observations indicate that a seal may have been significantly disturbed, in the sense of having emerged from apnoea to eupnoea, before any of these signs become overt. The change in behaviour signalling this shift – resumption of respiration – is unlikely to be detected casually. It is worth observing that such shifts occur also spontaneously without any human impact, but the disturbance significantly increases their frequency.

Populations of southern elephant seals, the species most likely to be affected by visitors to *Henryk Arctowski* Station, has been monitored since the opening of the *Actowski* Station in 1977. The southern elephant seals numbers were stable in this study area for the last 15 years (Salwicka and Sierakowski 1998).

Numbers are falling at Marion Island, where a study (Wilkinson and Bester 1988) was undertaken to determine whether human activities contributed to the decline. No differences were recorded in breeding success between sites where contacts with humans were frequent and those that were rarely visited. At *Arctowski* Station, breeding is over by the start of the summer influx of human visitors: any possible adverse effects on populations is more likely to be due to interference during moult. Of this there is currently no evidence, though in view of increasing numbers of tourist visitors (Ciaputa and Salwicka 1997), monitoring will continue.

Our results indicate that human disturbance can lead to reduced apnoea occurrence in southern elephant seals resting on land. Apnoea, through reduced respiration, might be a strategem in conserving water and energy in this species, particularly during its prolonged fasting periods of breeding and moulting (Huntley *et al.* 1984, Blackwell and Le Boeuf 1993). Therefore, during those periods specific care should be taken to avoid human induced disturbance to seals.

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Streszczenie

Rytm pracy i oddychania słoni morskich, *Mirounga leonina* (Linnaeus, 1758), fok Weddella, *Leptonychotes weddelli* (Lesson, 1826) oraz uchatek antarktycznych, *Arctocephalus gazella* (Peters, 1875) badano za pomocą nieinwazyjnej metody wizualnej. Prace prowadzono w sąsiedztwie Polskiej Stacji Antarktycznej im. *Henryka Arctowskiego*, na Wyspie Króla Jerzego (Szetlandy Południowe), podczas dwóch sezonów letnich 1996/97 i 1997/98. U wszystkich trzech gatunków zaobserwowano apneę (bezdech) podczas snu, której towarzyszyło spowolnienie rytmu pracy serca (Tab. 1). U dorosłych samic słonia morskiego szybkość pracy serca w apnei zmniejszała się o 17%, a bezdech trwał do 9 minut (Tab. 2), kończąc się najczęściej w reakcji na aktywność osobników sąsiadujących lub odwiedzających ludzi. Odgłosy przebywających w pobliżu ludzi (rozmowy, odgłosy chodzenia po kamienistej plaży) powodowały zmniejszenie czasu, jaki liniejące słonie morskie spędzały w apnei z ponad 40 do 4% (Tab. 3). Znacząco zmniejszyła się też częstotliwość zapadania w apneę, a wzrósł średni rytm pracy serca. Dalsze niepokojenie powodowało podnoszenie głowy, agresję, drapanie się, przewracania i ostatecznie ucieczkę. Wizualna metoda rejestrowania rytmu pracy serca i oddychania może być wykorzystywana do obserwacji spokojnie odpoczywających lub lekko zaniepokojonych płetwonogich. Jednak gwałtowne ruchy zwierzęcia mocno zaniepokojonego uniemożliwiają jej stosowanie.