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Moulting southern elephant seals, *Mirounga leonina* (L.) and local weather conditions, on Livingston Island, South Shetland Islands

ABSTRACT: Moulting southern elephant seals, *Mirounga leonina* (L.), were counted in 17 discrete wallows at Walker Bay on Livingston Island in the South Shetland Islands between 2 January and 16 February 1994. Daily weather conditions were also recorded. It was also found that, although there were no overall correlations between wind scale, air temperature, sunshine, precipitation, sea roughness and cloud cover with seal numbers, there were conditions on specific days that affected the movements of seals between wallows. Most notably, it was found that numbers of seals decreased when they were exposed to winds, and that they often sought out more sheltered sites nearby.

Key words: Antarctica, moult, southern elephant seals.

Introduction

Southern elephant seals, *Mirounga leonina* (L.), congregate at specific locations in order to breed and to moult. At Macquarie Island, north of the Antarctic Convergence, moulting takes place between November and April, depending on the age and sex of the animal. Adult males tend to moult later than females and juveniles, normally hauling out between the beginning of February and mid-May; cows typically moult between December and the end of March; and juveniles begin to arrive to moult in mid-November reaching a peak in numbers in mid-December and most have left by late January (Hindell and Burton 1988, Le Boeuf and Laws 1994). Because the South Shetland Islands are further south, breeding and moulting seasons begin later than at Macquarie Island. Sierakowski (1991) recorded a high of 624 seals at Admiralty Bay, King George Island, South Shetlands, on 16 January in 1988, and a high of 638 seals at the same location on 5 January 1989. Lesiński (1993) recorded 623 seals at King George Island on 5–6 January 1990.

Elephant seals undergo a visually conspicuous moult as sheets of cornified epidermis with old hairs slough off. Choice of a site at which to moult seems to depend on the geographical characteristics of the site itself (Fedak *et al.* 1994). It is also possible that the choice is determined, at least in part, by a combination of climatic factors, including the degree to which site is protected by or exposed to prevailing winds. In order to test this hypotheses, research was conducted on a population of juvenile southern elephant seals during the moulting period on Walker Bay, Livingston Island, South Shetland Islands between 2 January and 16 February 1994. The aim of the research was twofold: first, to conduct a census of the seals, and second to assess the impact, if any, of daily weather conditions on the number of seals present.

Materials and methods

Walker Bay (62°39'S, 60°38'W), located on the southern central coast of Livingston Island in the South Shetland Islands (Fig. 1), is on a spit of land 1.6 km long with a ridge about 100 m high running NW to SE. The terrain is ice-free in the austral summer and is predominantly hard-packed sand with some moss beds. The extreme south-west comprises flat rocks and stony beaches. Beaches and tussocky grass are the preferred haul-out sites of southern elephant seals (Ling and Bryden 1981), and although Walker Bay has no tussock grass, there are abundant flat expanses of sand protected from off-shore winds by outcrops of rock. In an aerial survey conducted in the 1960s, Aguayo (1970) counted between 10239 and 11003 southern elephant seals on Livingston Island, which were far more numerous than other pinniped species (211–223 Weddell seals; 278–391 crabeaters; 23 leopard seals; and 200–210 Antarctic fur seals).

Southern elephant seals at Walker Bay were counted on 46 consecutive days (2 January to 16 February 1994) by three independent observers. Most seals observed were juveniles (i.e. males between one and six years of age, and females between one and four years of age). Adult females began to arrive mid-January, but numbers remained low, and large bulls were not observed until mid-February.

For the purposes of this study, a "wallow" was defined as a group of five or more seals lying close enough to be touching for at least half of the body length. Seals lying peripheral to the wallow (i.e. forming part of the group, but not touching a neighbour) were counted separately. Weather data were recorded daily before and after the count. These included wind direction (prevailing offshore winds blew from E to NNE from the ice cap which covers much of

Livingston Island, and onshore winds blew from S to SSW from the sea); approximate wind speed and sea roughness using the Beaufort Scale, ranging from calm (0) to near gale (7); air temperature; cloud octas (measured as covering between 0/8 [clear] and 8/8 [overcast] of the sky); precipitation (snow, hail, sleet, hard rain, drizzle, or none); and sunshine (none, hazy, partial or full).

Results

The number of juvenile male seals at the study site dropped from 339 on 2 January to 90 on 16 February 1994, with a population peak of 371 on

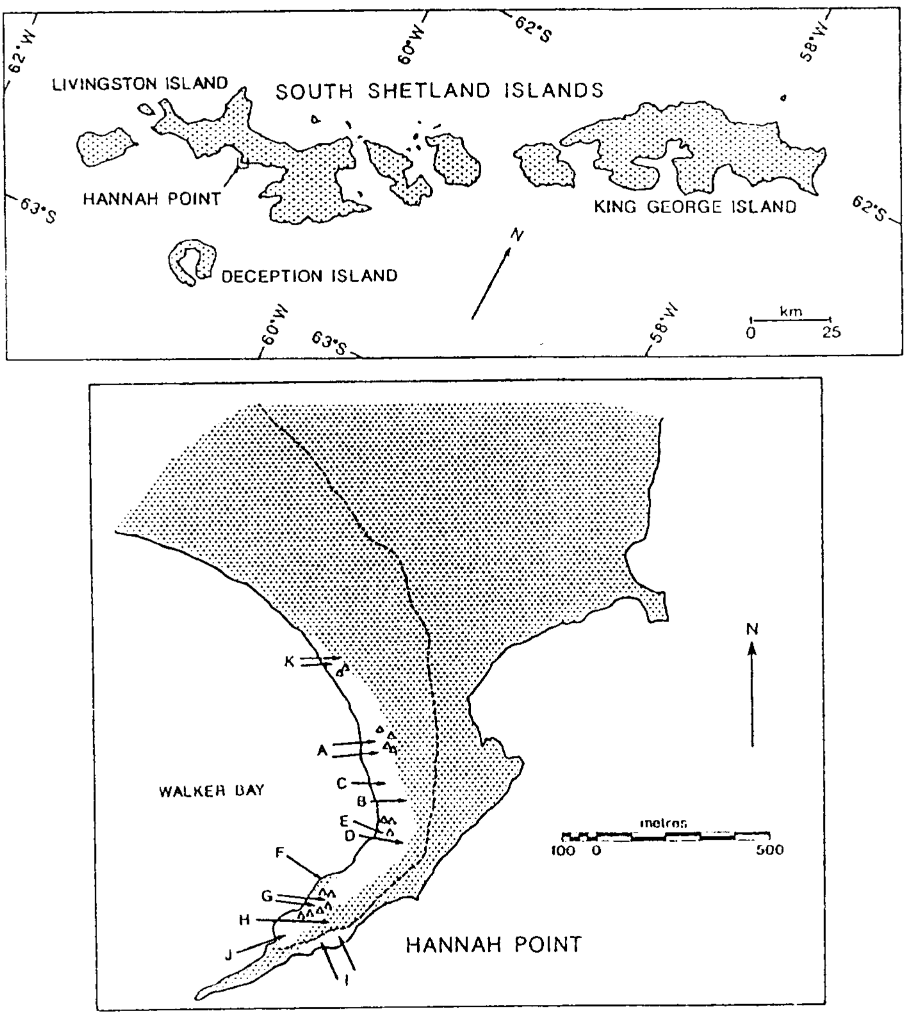
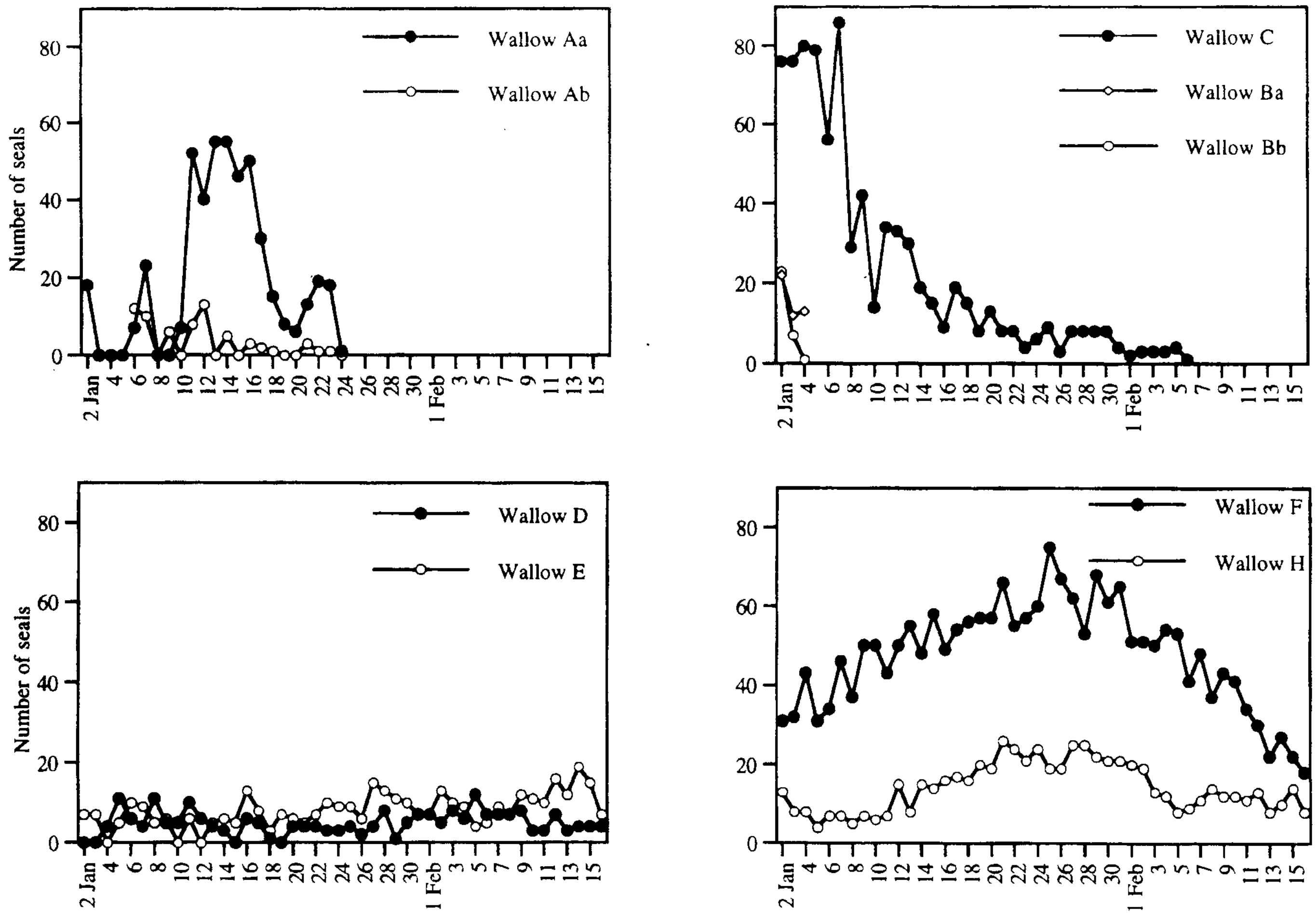


Fig. 1. The South Shetlands, showing Walker Bay on Hannah Point, Livingston Island. The lower map shows the location of the 17 wallows at Walker Bay. The shaded areas represent land covered by the ice cap, while the unshaded areas represent the ice-free beaches. Δ represents outcrops of rock and boulders.



Number of seals
Wallow Aa
Wallow Ab
Wallow C
Wallow Ba
Wallow Bb
Wallow D
Wallow E
Wallow F
Wallow H
2 Jan
1 Feb

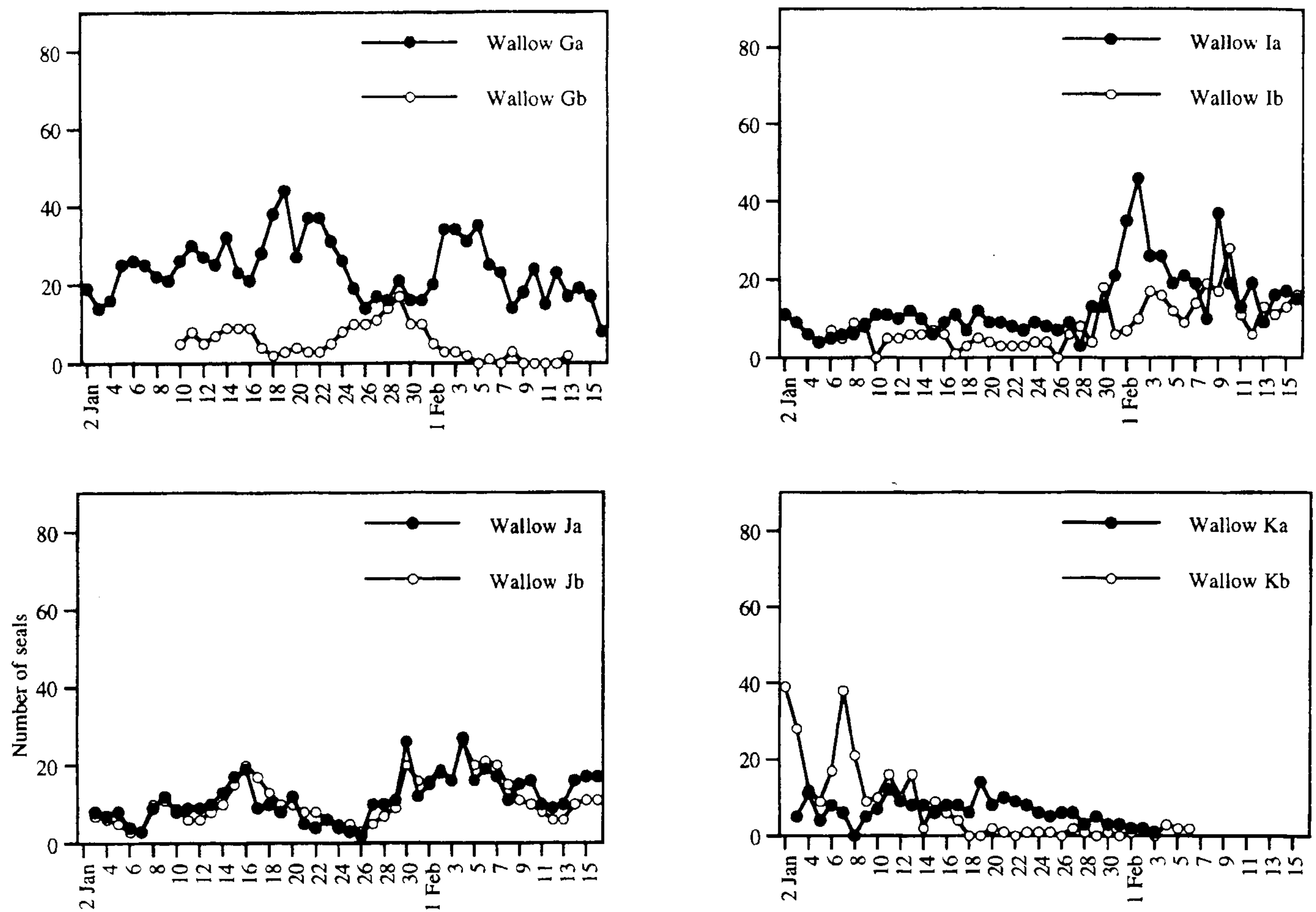


Fig. 2. The number of seals in individual wallows at Walker Bay between 2 January and 16 February.

3 January (Cruwys and Davis 1994). There was a steady decrease over the period of observation with the exception of 21 January to 4 February when numbers remained relatively constant. The seals gathered into 17 discrete wallows (shown on Fig. 1). Nine of these wallows (D, E, F, Ga, H, Ia, Ib, Ja and Jb) were occupied continuously over the whole study period, and eight wallows (Aa, Ab, Ba, Bb, C, Gb, Ka and Kb) were abandoned permanently by 6 February (Table 1). Table 1 also lists each wallow with its type of ground cover, distance from the sea, and whether sheltered from off-shore or on-shore winds.

Figure 2 shows the numbears of seals in each wallow, including main· increases and declines. Sudden increases in numbers in some wallows occurred after declines of numbers in other wallows, suggesting that seals moved between sites. The clearest example is between Wallows Ga and Gb, where numbers of seals in Ga increased, while numbers of seals in Gb declined, and vice versa. This pattern can also be seen on some days in Wallows Ia and Ib and in Wallows Ka and Kb.

Table 2 lists the dates of the main increases and declines in seal numbers in each wallow with weather conditions for each. Table 3 catalogues the wind direction on these dates, coupled with whether or not the wallows offered shelter from the prevailing wind. It can be seen that the main declines in numbers occured on days when the wallows were not protected from the prevailing wind; increases occurred on days when the wallows were protected from the prevailing wind. Wallows Aa, Ab, C, Ga, Gb, Ia, Ib, Ka and Kb were only sheltered from some winds, and were exposed to others; these wallows had the greatest fluctuations in numbers (Fig. 2). Wallows Ba and Bb were exposed to both on-shore and off-shore winds and were abandoned early in the season. Wallows D, E, F, H, Ja and Jb were protected from both on-shore and off-shore winds. Numbers of seals in Wallows D and E remained relatively constant. Seal numbers in Wallows F and H increased until late January, after which numbers declined, and seal numbers in Wallows Ja and Jb increased after late January.

Air temperature ranged between 8.5°C on 8 January to —1,0°C on 29 January. Wind speed was recorded as Beaufort Scale 4 and above on six separate occasions (2 – 5 January; 8 – 10 January; 15 – 16 January; 25 January; 28 – 30 January; and 7 – 8 February). Wind direction was off-shore on 27 days, and on-shore on 19 days. Precipitation was variable, although the most frequent observation was none (29 days). Cloud octas showed complete cloud cover on 23 days, and a cloud-free day on 12 January only. Full sunshine was recorded on two days (12 and 24 January), and there were 30 sunless days.

Nonparametric correlations indicated that there were no strong significant relationships between the number of seals at a wallow and air temperature ($r=0.26$, $P=0.013$); wind speed ($r=0.30$, $P=0.014$); wind direction ($r=0.41$, $P=0.008$); sea roughness ($r=0.24$, $P=0.057$); precipitation ($r=0.01$, $P=0.486$), cloud cover ($r=0.15$, $P=0.166$) or sunshine ($r=0.05$, $P=0.365$).

Discussion

The numbers of juvenile moulting seals at Walker Bay reached a peak of 391 on 3 January, and then began to decline. This is later than the peak of numbers of seals at Macquarie Island (Carrick *et al.* 1962), but corresponds to studies of other South Shetland Islands populations observed during the moulting season (Sierakowski 1991, Lesiński 1993). This difference reflects a regional variation in elephant seal moulting times, probably because the South Shetland Islands lie further south than Macquarie Island.

Precipitation, wind speed, cloud cover, the amount of sunshine, sea roughness and temperature appeared to have no overall effect on seal movements (as indicated by the low correlations). However, there were incidences on specific days where the weather conditions clearly affected seal movements. On 8 January, when the temperature rose to 8.5°C, cloud cover thinned, winds were recorded at scale 6, and there was hazy sunshine, the number of seals in Wallow C had dropped from 86 to 29 by the following day. It is possible that this site, with its large number of tightly-packed seals, simply proved too hot. Numbers

Table 1

Physical characteristics of the 17 wallows at Walker Bay, Livingston Island, South Shetland Islands

Wallow	Ground cover	Distance from sea	Sheltered	Period of occupation
Aa	Waterlogged moss pools of water	50 m	From off-shore winds	Abandoned after 24 January
Ba and Bb	Sand with pools of water	50 m	From no winds	Abandoned after 4 January
C	Flat rocks and sand; pools of water	5 m	From off-shore winds	Abandoned after 6 February
D	Compacted sand and copper breccia	50 m	From on-shore and off-shore winds	Continuosly occupied
E	Sand and shale	5 m	From on-shore and off-shore winds	Continuosly occupied
F	Compacted sand	10 m	From off-shore and on-shore winds	Continuously occupied
Ga	Pebble beach	20 m	From on-shore winds	Continuously occupied
Gb	Pebble beach	10 m	From off-shore winds	Abandoned after 5 February
H	Sand with boulders	70 m	From off-shore and on-shore winds	Continuously occupied
Ia	Sand with boulders	10 m	From on-shore winds	Continuously occupied
Ib	Sand with boulders	10 m	From off-shore winds	Continuously occupied
Ja and Jb	Flat rocks	2–5 m	From off-shore and on-shore winds	Continuously occupied
Ka and Kb	Sand with boulders	5 m	From off-shore winds	Abandoned after 2 February

Table 2

Days on which seal numbers rose and fell substantially and corresponding weather conditions at Walker Bay

Date	Wallows affected	Wind direction	Wind scale	Air temp.	Sunshine	Precipitation	Sea roughness	Cloud cover
Increases on:								
7 January	Aa Ab C Kb	Off-shore	1	7.0	None	Rain	Moderate waves	7
11 January	Aa Ab C	Off-shore	1	4.0	None	Snow	Small waves	8
17–19 January	Ga	On-shore	1–3	2.0–7.0	None/hazy	None	Ripples	6–8
20–22 January	Aa	Off-shore	2–3	1.5–3.0	None/hazy	None/rain	Small waves	7–8/fog
28–30 January	Gb	Off-shore	1–5	0.0–3.0	None	None	Small waves	8
31 January — 4 February	Ga Ia Ja Jb	On-shore	2–5	0.0–3.0	None	None/snow	Small waves	8
9 February	Ia	On-shore	1	0.5	None	Rain	Small waves	Fog
Decreases on:								
2–5 January	Aa Ab Ba Bb Kb	On-shore	3–6	2.0–6.0	None	None/rain	Whitecap waves	7–8
8 January	Aa Ab C Ka Kb	On-shore	6	8.5	Hazy	None	Whitecap waves	7
10 January	C Ib	On-shore	6	4.0	Hazy	None	Small waves	2
17–19 January	Aa C	On-shore	1–3	2.0–7.0	None/hazy	None	Ripples	6–8
20 January	Ga	Off-shore	3	2.0	None	Rain	Small waves	Fog
24 January	Aa	On-shore	2	3.0	Full	None	Whitecap waves	1
28–30 January	Ga	Off-shore	1–5	0.0–3.0	None	None	Small waves	8
8 February	Ga Ia	Off-shore	4	0.0	None	None	Ripples	8
11 February	Ga Ia	Off-shore	2	2.0	None	Sleet	Breaking waves	Fog

of seals in Wallows Aa, Ab, Ka and Kb also declined on 8 January, although not to the same extent as the much larger Wallow C. These findings were similar to those of Tierney (1977), who established that there were no correlations between wind run, temperature, and wind chill, and southern elephant seal numbers, but that individual behaviour contradicts these general results. (Tierney observed that a heavy snowfall caused 14 animals to move away from the beach to a more sheltered site).

Although overall weather patterns have no consistent effect on seal numbers, Tables 2 and 3 indicate that some increases and decreases in individual wallows are associated with wind direction ($r=0.41$; $P=0.008$). For example, Figure 2 shows that numbers in Wallow Gb increased 28 – 30 January, while numbers in Wallow Ga declined. Winds were off-shore (Beaufort Scale 1 – 5) during this period, and Gb offered shelter that Ga did not. Conversely, numbers in Ga increased after 16 January and after 1 February when numbers in Gb declined. Winds were on-shore (Beaufort Scale 1 – 5). This suggests that seals moved from an exposed site to a sheltered one if conditions became uncomfortable, although the distances involved between sites were usually small (the distance between Wallows Ga and Gb was 10 m). Individual seals in these wallows, easily identified by scars and other marks, were observed to be following this pattern. Seals were also observed moving between Wallows Ia and Ib in February, and between Wallows Ka and Kb in early January (Fig. 2).

Table 3

Days on which seal numbers rose and fell substantially, wind direction, and which wallows offered shelter on those days

Increases on	Wallows affected	Sheltered from wind
7 January	Aa Ab C Kb	Yes
11 January	Aa Ab C	Yes
17 – 19 January	Ga	Yes
20 – 22 January	Aa	Yes
28 – 30 January	Gb	Yes
31 January – 4 February	Ga Ia Ja Jb Ia	Yes
9 February	Ia	Yes
Decreases on		
2 – 5 January	Aa Ab Ba Bb Kb	No
8 January	Aa Ab C Ka Kb	No
10 January	C Ib	No
17 – 19 January	Aa C	No
20 January	Ga	No
24 January	Aa	No
28 – 30 January	Ga	No
8 February	Ga Ia	No
11 February	Ga Ia	No

Of Wallows Aa, Ab, C, Ga, Gb, Ia, Ib, Ka and Kb, which offered only partial shelter from the wind, only Ga, Ia and Ib were occupied for the entire period of observation. Ga was a relatively clean and dry wallow protected from on-shore winds, and Wallow Gb, only 5 m away, offered protection from off-shore winds (there were no off-shore winds recorded after 13 February, and so it is possible that the remaining 10 or so seals in Wallow Ga might have moved to Wallow Gb if the winds had been off-shore). It is likely that the seals at Wallows Ia (protected from on-shore winds) and Wallow Ib (sheltered from off-shore winds) were following a similar pattern.

Table 2 shows that the wind was off-shore on 7 January (Beaufort Scale 1), but changed to on-shore (Beaufort Scale 6) the next day. This caused a decline in numbers in five wallows (Aa, Ab, C, Ka and Kb). The reverse situation occured on 10 – 1 January, where the wind changed from on-shore (Beaufort Scale 6) to off-shore (Beaufort Scale 4), and numbers of seals in three wallows (Aa, Ab and C) increased.

Wallows D, E, F, H, Ja and Jb offered protection from both on-shore and off-shore winds, but although numbers of seals in Wallows D and E remained relatively constant throughout the period of observation, numbers in the other wallows were variable. These wallows were dry sites on compacted sand and rocks, and there is some suggestion that seals tend to occupy wet, muddy sites at the beginning of the moult, but move to drier sites once new hair growth has begun (Fedak *et al.* 1994). This may be because moulting is an energetically demanding period (Fay and Ray 1968, Boyd, Ambom and Fedak 1994), and wet, muddy wallows of tightly-packed seals allow the necessary high skin temperature to be maintained, but allow some energy conservation. When the moult is complete, and the high temperature is no longer required, the seals move away from the muddy wallows to drier ones in order to keep their new hair cleaner (Fedak *et al.* 1994). It is possible that the variation in seal numbers might be attributed to this factor operating simultaneously to the climatic conditions.

Conclusions

In summary, the data in Tables 2 and 3 and Figure 2 indicate that wallows that offered no protection from the winds (Wallows Ba and Bb) were abandoned after a storm early in January; Wallows that offered protection from on-shore and off-shore winds (Wallows D, E, F, H, Ja and Jb) showed either relatively constant numbers or increases in numbers of seals during the period of observation; wallows that offered protection from either on-shore or off-shore winds (Wallows Aa, Ab, C, Ga, Gb, Ia, Ib, Ka and Kb) were subject to sudden fluctuations in seal numbers.

Clearly seals do not move each time the wind changes direction (hence the low correlation of $r = 0.41$), but at least some fluctuation in numbers can be attributed to this factor. It was also found that although there was no overall correlation of air temperature, sea roughness, cloud cover, sun, precipitation and estimated wind speed with seal numbers, there were weather conditions on specific days that affected seal movements. These are tentative conclusions based on data from a single season, and more research is necessary to ascertain the precise movements of individual seals between and within wallows.

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Streszczenie

Słonie morskie (*Mirouga leonina* (L.)) były liczone w 17 oddzielnych legowiskach w rejonie Walker Bay wyspy Livingston w archipelagu Szetlandów Południowych (fig. 1), pomiędzy 2 stycznia i 16 lutego 1994 r. Charakterystyka fizycznych cech środowiska legowisk jest przedstawiona w tabeli 1, zaś liczba fok w każdym legowisku pokazana jest na rys. 2. Nie stwierdzono wyraźnej korelacji pomiędzy liczbą fok a temperaturą powietrza, opadami, nasłonecznieniem, zachmurzeniem czy stanem morza. Jednocześnie zaobserwowano, że warunki panujące w ciągu pewnych dni wpływały na przemieszczanie się fok pomiędzy legowiskami (tab. 2). Zauważono, że liczba fok w legowisku zmniejszała się, gdy zwierzęta były wystawione na wiatr; szukały one bardziej zakrytych miejsc w pobliżu (tab. 3 i fig. 2).