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Meteorological factors affecting the number of Weddell seals hauling-out on the ice during the molting season at Syowa Station, East Antarctica

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Abstract: Weddell seals show a clear diurnal haul-out pattern, while there have been few studies focusing on the influence of weather conditions. The present study investigates the relationship between the number of seals which haul-out on the fast ice and meteorological factors such as: air temperature, wind speed, humidity and irradiance in Syowa Station, East Antarctica. The number of seals was inversely related to wind speed ($P < 0.001$), and positively related to air temperature ($P < 0.05$), suggesting that seals may enter the water to avoid excessive heat loss when the weather condition was severe. The number of seals varied greatly on calm days (wind speed < 5.3 m/s and air temperature > -8.3°C), indicating that some other factors might influence the seal's decision to stay in the water.

key words: haul-out, Weddell seal, Syowa Station, wind speed, air temperature

Introduction

The Weddell seal (*Leptonychotes weddellii*) is normally found on fast ice areas of the Antarctic continent and adjacent islands (Stirling, 1969; Kaufman *et al.*, 1975). Mother Weddell seals arrive at tidal cracks in early austral spring and give birth to pups from late September to early November (Smith, 1965; Kooyman, 1968; Stirling, 1969). During lactation from October to December, mothers and pups go into the water progressively more often as the pup grows (Thomas and DeMaster, 1983). Males begin to join the breeding colony approximately when the first females haul out in September, and compete for underwater territories beneath the tidal cracks (Kaufman *et al.*, 1975). Once the pups wean in December, mating takes place in water (Cline *et al.*, 1971), and adult seals molt after mating (Thomas, 2002).

Weddell seals are able to rest, if not actually sleep, under the ice, surfacing only to breathe (Stirling, 1969). However, resting seals sometimes haul out on the ice and it is at this time they are most easily observed. Studies on the haul-out pattern of Weddell seals have shown that few Weddell seals haul out in the morning; most seals haul out in the afternoon from 1430 to 1700 during the molting season (Smith, 1965; Siniff *et al.*, 1971; Tedman and Bryden, 1979; Thomas and DeMaster, 1983; Erickson *et al.*, 1989; Lake *et al.*, 1997). Several researchers have suggested that the number of seals that

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haul out fluctuates depending on weather conditions, such as temperature, wind speed, solar radiation, cloud cover and snow (Matsuda, 1963; Smith, 1965; Siniff *et al.*, 1971; Lake *et al.*, 1997). Yet, there have been very few studies focusing mainly on the influence of weather conditions on the haul-out pattern of Weddell seals. For example, Lake *et al.* (1997) reported that wind speed was negatively correlated with the number of seals on the ice in January only. They suspected that females stay with their pups (born in October) even in strong wind during lactation. In the present study, observations were conducted during the molting season (late February through April) to exclude the effects of reproductive activities and the presence of pups. The effects of temperature, wind speed, humidity and irradiance on the haul-out number of Weddell seals were investigated.

Materials and methods

During the austral summer, large numbers of Weddell seals can be seen in the vicinity of the Japanese Antarctic station, Syowa (69°00′S, 39°35′E), which is covered by fast ice from austral spring to autumn (Haga, 1961; Matsuda, 1963). Around East Ongul Island, on which Syowa Station is situated, there are small islands, grounded icebergs surrounded by tide and shear cracks and floating icebergs accompanied by shear cracks. Newly formed ice in the wake of the icebreaker *Shirase*'s departure provided a favorable structure for Weddell seals to haul out of the water in late summer from March to April (Fig. 1). Weddell seals began to appear on the ice in early spring (September), and their population reached a peak during the breeding season in October

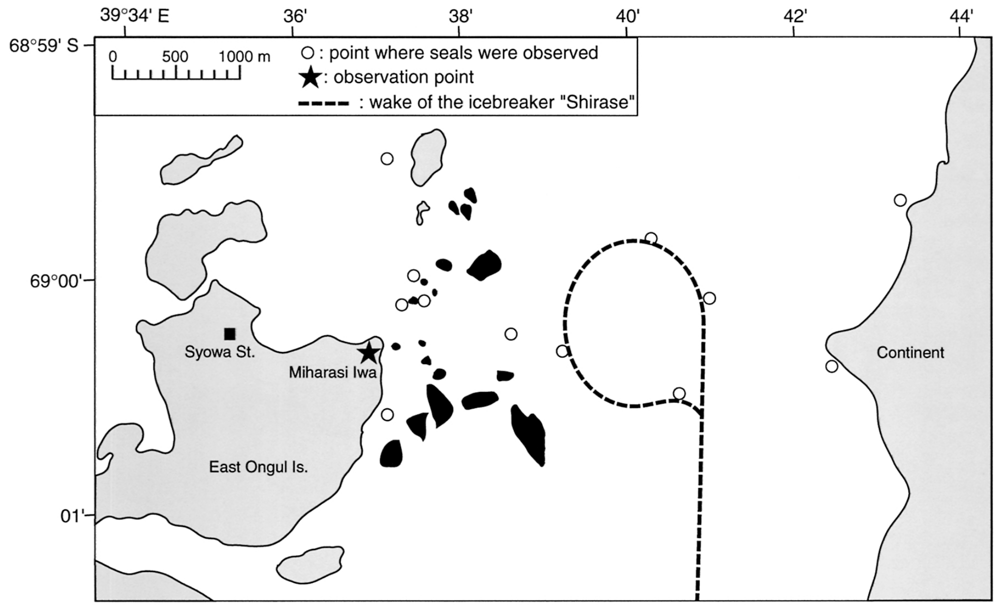

Fig. 1. The observation site in the vicinity of Syowa Station, East Antarctica. Land is represented by the color gray and iceberg by the color black. The sea was covered in fast ice during the study period.

and November (Hoshiai, 1981; Naito and Hoshiai, 1983). They were rarely seen from May to August.

We counted seals hauling out on the ice at a fixed point (Fig. 1) using binoculars (7×50, Carl Zeiss). Except for exceptionally low visibility days, the observations were carried out 1–4 times every day between 1500 and 1700 local time, when the most seals hauled out (Smith, 1965; Siniff *et al.*, 1971; Tedman and Bryden, 1979; Thomas and DeMaster, 1983; Erickson *et al.*, 1989; Lake *et al.*, 1997). The observation period was from February 26 to April 28, 1999, which coincided with the molting season of this species at the study site.

While crabeater seals (*Lobodon carcinophagus*) are occasionally found near Syowa Station in winter (Naito and Hoshiai, 1983), trips on the ice (30 times during the study period of 62 days) revealed only Weddell seals. Crabeater seals have a circumpolar Antarctic distribution, spending the entire year in the pack ice zone (Bengtson, 2002). Therefore, all seals counted at the study site, which was covered by fast-ice during the study period, were considered to be Weddell seals.

Meteorological data were provided by weather stations at the altitude of 18.4 m, close to the study area (Fig. 1). Katabatic winds flow predominantly from east to west near Syowa Station (the Bureau of Meteorology of Syowa Station, personal communication 1999). Therefore, Syowa Station is a good place to record the meteorological conditions at the study site (Fig. 1). Air temperature (℃), wind speed (m/s) at the height of 10.1 m from the ground, humidity (%) and irradiance (MJ/m^2) were recorded every hour. Data within ±1 hour of the seal count were used in analyses. Values are indicated as mean ±SD with the sample size in parentheses. We used StatView (ver 5.0) for statistical tests and considered results statistically significant if $P<0.05$. The significance of the partial correlation coefficients was determined using a *t*-test (Zar, 1984).

Results and discussion

The number of seals hauled out on the ice varied from 0 to 10 with the mean being 2.0±2.4 ($n=52$). Mean air temperature was –8.3±5.3℃ ranging from –22.6 to 1.7℃. Mean wind speed was 5.3±4.2 m/s ranging from 0.7 to 19.8 m/s. Mean humidity and irradiance were 64.3±10.4% and 0.6±0.5 MJ/m^2 ranging from 41.0 to 84.0% and from 0.0 to 2.0 MJ/m^2, respectively. Mean values are represented as vertical and horizontal lines in Fig. 2. The seasonal decrease in number of seals on the ice might reflect the seasonal movement of seals associated with fast ice conditions (Kooyman, 1968); however, the daily fluctuation in the number of seals is believed to correlate with the proportion of seals hauled out. To exclude the seasonal trend and correlations among all variables, partial correlation coefficients were calculated among all variables to examine the effect of weather conditions on the daily haul-out number of seals (Table 1). Wind speed and air temperature significantly affected the number of seals hauled out (Table 1, partial correlation coefficient $=-0.49$ and 0.34, $P<0.001$ and $P<0.05$, $n=52$, respectively), though there were no significant relationships between number of seals and days from Feb. 26, humidity or irradiance (Table 1). The present study indicates that the number of seals which hauled out was mostly affected by wind speed,

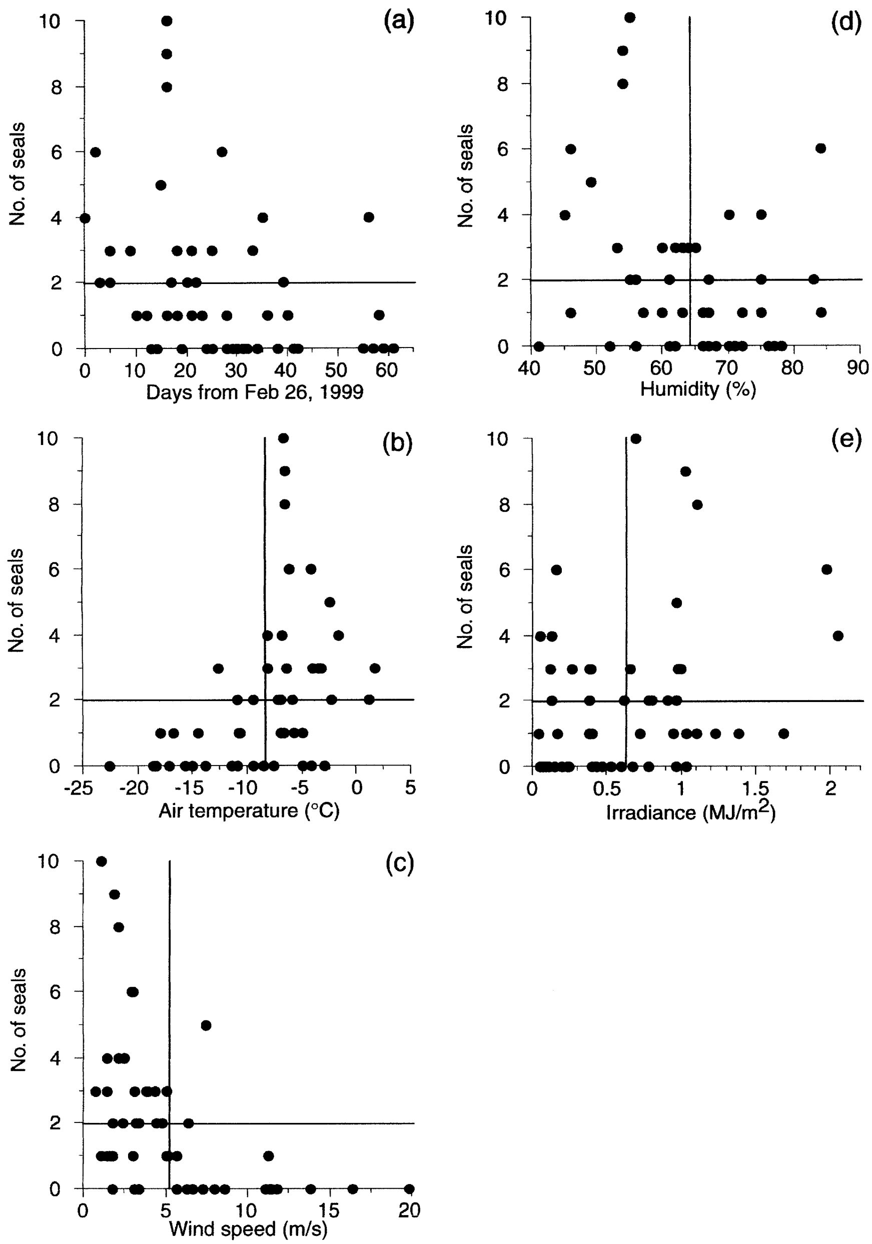

Fig. 2. Number of seals as a function of days from Feb. 26 (a), air temperature (b), wind speed (c), humidity (d) and irradiance (e) in the vicinity of Syowa Station, East Antarctica, 1999. Mean values of variables are indicated as horizontal (no. of seals) and vertical (other variables) lines.

Table 1. A matrix of partial correlation coefficients betweem no. of seals and parameters. N=52.

	No. of seal	Days from Feb. 26	Air temperature	Wind speed	Humidity	Irradiance
No. of seal	1	0.04	0.34*	−0.49***	−0.13	0.03
Days from Feb. 26	–	1	−0.56***	0.16	0.16	−0.63***
Air temperature	–	–	1	0.35*	−0.07	−0.29*
Wind speed	–	–	–	1	−0.07	−0.1
Humidity	–	–	–	–	1	−0.22

The significance of partial correlation coefficients was examined using a *t*-test (Zar, 1984).
* $P<0.05$, ** $P<0.01$, *** $P<0.001$.

as Smith (1965) reported. The cooling effect would be amplified by wind. Thus, seals might experience discomfort in windy weather. Therefore, the haul-out pattern could be a behavioral attempt at thermoregulation to prevent heat loss.

As shown in Fig. 2c, it is apparent that the number of seals hauled out was less on windy days (wind speed >5.3 m/s), but it varied greatly on calm days (wind speed <5.3 m/s). The number of seals varied on warmer days (air temperature >−8.3℃) (Fig. 2b). These results indicate that hauling out onto the ice may be one of several alternative responses to calm weather. The behavioral response is limited only during the stressful times of storm and cold days. There may be some other factors making seals decide to stay in the water on calm days. During late lactation, adult females with pups conducted deep foraging dives, and a larger percentage of time was used for repeated deep dives as the energy store was depleted (observed as a reduction in the index of fatness) (Sato *et al.*, 2002). In the molting season, physiological conditions such as the degree of molting, which motivates them to haul out on the ice, or/and the depletion in energy storage, which impels them to dive for foraging, may also affect their behavior. Studies focused on underwater behavior may also help to explain when they decide to haul out onto the ice or stay in the water on calm days.

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