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Huddling behavior in emperor penguins: Dynamics of huddling

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Abstract

Although huddling was shown to be the key by which emperor penguins (*Aptenodytes forsteri*) save energy and sustain their breeding fast during the Antarctic winter, the intricacies of this social behavior have been poorly studied. We recorded abiotic variables with data loggers glued to the feathers of eight individually marked emperor penguins to investigate their thermoregulatory behavior and to estimate their "huddling time budget" throughout the breeding season (pairing and incubation period). Contrary to the classic view, huddling episodes were discontinuous and of short and variable duration, lasting 1.6±1.7 (S.D.) h on average. Despite heterogeneous huddling groups, birds had equal access to the warmth of the huddles. Throughout the breeding season, males huddled for 38±18% (S.D.) of their time, which raised the ambient temperature that birds were exposed to above 0 °C (at average external temperatures of −17 °C). As a consequence of tight huddles, ambient temperatures were above 20 °C during 13±12% (S.D.) of their huddling time. Ambient temperatures increased up to 37.5 °C, close to birds' body temperature. This complex social behavior therefore enables all breeders to get a regular and equal access to an environment which allows them to save energy and successfully incubate their eggs during the Antarctic winter.

Keywords: Social thermoregulation; Energy savings; Emperor penguins; Antarctica

1. Introduction

The emperor penguin (*Aptenodytes forsteri*) is the only bird to breed during the severe Antarctic winter, far from the open sea or polynias where it feeds [1]. Breeding birds therefore undergo long periods of fasting. Both mates starve for about 45 days during the pairing period, while males alone take on the task of incubation, which adds another 65 days to their fast [2,3]. As a consequence, the reproductive success relies critically on the males' ability to make economic use of their body fuels. Emperor penguins are adapted to minimize heat loss [4], while maintaining their body temperature at a constant and high level [5–7]. The latter is especially important during incubation, because full embryonic development requires a temperature of about 35 °C [8]. Pioneering studies have suggested that the key for the breeding success of emperor penguins is huddling [2]. Ancel et al. [9] found that field metabolic rate of huddling birds was reduced by 16% when compared with penguins that were kept in small flocks and prevented from effective huddling. The classic view is that huddles are dense formations, which last for several hours [10] or even days [2]. These groups are viewed to move slowly, with the birds most exposed to the wind moving along the opposite flank of the group for protection. These huddles, formed during courtship and incubation in the colony, can be made up of more than hundreds of individuals, reaching densities of up to 10 birds/m^2 [2]. Kirkwood and Robertson [10] recorded ambient temperatures inside several huddles of at least 23 °C, while a measurement made by Jarman [11] into a huddle suggested that the ambient temperature may reach up to 30 °C.

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Besides these anecdotic reports and non-systematic measurements [10,11], the dynamics of huddling behavior of breeding emperor penguins in their colony during their winter fast had never been studied. Many questions remained to be answered, such as the occurrence of huddling along the nycthemeron, the duration of huddling bouts or the maximum ambient temperatures reached inside huddles. Similarly, the total time birds spend huddling during their breeding cycle (i.e. during the pairing and incubation period) had never been investigated. Huddling energetic benefits [9] also raise another question: do some birds preferentially gain from the group behavior? Emperor penguins are a social species, with no dominance hierarchy [12]: they do not defend any territory and their aggressiveness is minimal as very few struggles occur. We could therefore hypothesize that all individuals get the same benefits from huddling in order to succeed in breeding.

Consequently, the objectives of this study were (1) to characterize the occurrence and duration of huddling bouts and the microclimate created within huddles, (2) to compare individual behaviors in order to (3) estimate a “huddling time budget” for a standard breeding bird.

2. Materials and methods

2.1. Study location

The study took place at the emperor penguin colony of Pointe Géologie, Dumont d’Urville, in Adélie Land, Antarctica (66°40′S, 140°01′E). About 3000 pairs of emperor penguins make up this colony, with about 2500 incubating males during winter. The size of this colony has remained constant since the population halved in the late 1970s [13]. A meteorological station (Météo France), situated 500 m away from the colony, provided data for wind, temperature and solar radiation, averaged every 3 h.

2.2. Instruments and deployment protocol

In the middle of the pairing period, at the beginning of May 1998, three pairs were captured, of which males were equipped with an external time depth recorder (TDR, Mk5, Wildlife Computers, Redmond, Washington, USA, 50 g, 8 × 3.1 × 1 cm). In 2001, five pairs were captured of which the five females were equipped with an external TDR (Mk7, Wildlife Computers, 36 g, 9 × 2.4 × 1.2 cm) and an Argos-VHF transmitter (Sirtrack, Havelock North, New Zealand, 242 g, 13 × 5 × 3 cm). Their mates were equipped with a VHF transmitter (Sirtrack, 66 g, 10 × 1.5 × 1.5 cm).

Both mates of each pair were captured at the same time. To minimize stress, they were carefully restrained, with eyes covered. They were marked with colored strips of tape and devices were glued at the lower part of their back. To this end, a grid was worked into the feathers and covered first with Araldite (Vantico AG, Basel, Switzerland) and then a coat of mastic (resin). Loctite 401 (Henkel KGaA Technologies, Düsseldorf, Germany) was applied to the mastic and the back of the instrument, which was then glued to the mastic. All devices had been previously coated with black Tesa tape (Tesa Tape Inc., Charlotte, NC, USA) to match the color of the bird feathers. Two to three Colring ties (Legrand, Limoges, France), inserted under the grid, were used to secure the instrument onto the mastic. This attachment method allowed easy removal of the instruments in the field. All devices were still securely attached to birds after the 2.5 months of this study.

Mk7 recorded external temperature (range + 17 °C to + 42 °C; resolution 0.05 °C, accuracy 0.1 °C) and light intensity (range 0 to 252, arbitrary unit) every 10 s, while Mk5 recorded temperature (range −2.5 °C to + 22.7 °C; resolution 0.05 °C, accuracy 0.1 °C) and light intensity (arbitrary unit) every minute. These TDRs were calibrated in a thermostatic bath before and after deployment against a reference thermometer. The time response of this temperature sensor is estimated to be of about 5 min. Argos-VHF and VHF transmitters were used to locate the birds. All internal clocks were synchronized using GMT.

After the females came back from foraging at sea, on average 72 days after their departure, instruments of both males and females were removed in less than 1 min, by cutting through the mastic, and the pairs continued with their breeding cycle. All experiments were approved by the ethics committee of the French Polar Institute.

2.3. Data analysis

We used the term “breeding cycle” to describe the following two periods: the pairing period (when both mates are in the colony) and the incubation period (when only males stay in the colony).

Light intensity was used to calculate the time a bird spent inside a huddle. A light record of zero indicated its beginning, when the bird’s back was entirely covered by another bird situated behind it. A light value > 0 indicated the end of the huddle. Night-time light records averaged 60 (arbitrary units), while day-time light records reached 120. Records of zero could thus be used safely to identify periods when birds were in huddles. Additional information about the density of huddles was provided by temperature sensors, as surface temperature increased when birds moved closer to each other.

Huddling patterns were classified into two categories: “tight huddles” within which surface temperature rose exponentially to above 20 °C and “huddles” within which ambient temperature never rose to 20 °C. A threshold of 20 °C was chosen to discriminate these two categories because it is the upper critical temperature of emperor penguins [6,7].

In 2001, data loggers were attached to females only. However, since males typically initiate all movements within a pair [12] and both mates huddle strictly side by side, we could also deduce information about the behavior of males from these recordings.

In order to determine which huddling strategy is chosen by breeding birds, we investigated two variables that directly determine their huddling time budget: the number of huddling bouts made per day and the durations of these episodes. Data from 1998 were used to study huddling behavior throughout the breeding cycle whereas 2001 provided additional information