Antarctic Science 26(5), 563–564 (2014) doi:10.1017/S0954102014000285

Short Note
Are environmental factors responsible for changed breeding behaviour in emperor penguins?

DANIEL P. ZITTERBART[1,2], SEBASTIAN RICHTER[2], GEORG SPIEKERMANN[1], LISA K. BEHRENS[1], JULIA REGNERY[1], RENÉ P. FONTES[1], THEDDA HÄNSSLER[1], GERT KÖNIG-LANGLO[1], ROLF WELLER[1] and BEN FABRY[2]

[1]*Alfred Wegener Institut, Helmholtz Zentrum für Polar und Meeresfoschung, Am alten Hafen 26, 27568 Bremerhaven, Germany*
[2]*Department of Physics, University of Erlangen-Nuremberg, Henkestrasse 91, 91052 Erlangen, Germany*
daniel.zitterbart@awi.de

Received 17 February 2014, accepted 27 March 2014, first published online 29 May 2014

Introduction

Emperor penguins (*Aptenodytes forsteri* Gray) are the only vertebrate species that breed during the Antarctic winter. From the beginning of the breeding season in April until fledging of the chicks in January, emperor penguins rely on the stability of sea (fast) ice. The International Union for Conservation of Nature (IUCN) has recently listed the species as 'near threatened' because the habitat of emperor penguins may deteriorate significantly over the coming years with the anticipated changes in sea ice conditions due to climate change. Since 2009, four emperor penguin colonies have been observed on ice shelves, as opposed to sea ice, during the breeding season (Fretwell *et al.* 2014). This striking change in their breeding behaviour was interpreted as an adaptation of emperor penguins to poor sea ice conditions.

Here we report that a large part of the emperor penguin colony at Atka Bay (Dronning Maud Land, Antarctica) moved onto the ice shelf during the 2013 breeding season. This colony has been regularly observed since 1981 but has never before been seen breeding, incubating their eggs, brooding or crèching on the ice shelf. Our observations concur with a recent report, which documented that altered breeding behaviour in emperor penguins has occurred almost simultaneously across Antarctica (Fretwell *et al.* 2014). Interestingly, the sea ice at Atka Bay has been stable for three consecutive seasons and thus cannot have triggered this change in behaviour. Rather, we present evidence of increased snow accumulation that has greatly improved the accessibility of the ice shelves around Atka Bay, and we discuss additional meteorological factors and local topographical conditions that may have contributed to the shift in breeding location from sea ice onto an ice shelf.

Materials and methods

The position of the emperor penguin colony at Atka Bay was photographed, and GPS coordinates were recorded, by researchers at Neumayer Station III during the 2013 winter. Snow accumulation has been recorded bi-weekly since January 1991 at 16 measurement points distributed over a 900 m^2 area *c.* 15 km away from the colony. Average daily wind speed and direction has been measured at the Neumayer Station weather observatory, *c.* 8 km from the colony, since January 1981. To quantify the easterly wind vector (90°, pointing in the direction from the sea ice towards the shelf ice drop), the wind speed was multiplied with the sine of the wind direction. Days with an average easterly wind speed > 10 m s^{-1} and wind direction that did not differ by > 45° between consecutive days were classified as days with 'strong and steady easterly winds'.

Observation

The colony is located at the south-west corner of Akta Bay (70°36'S, 8°08'W) where the penguins are present year-round, with the exception of March. A vertical rise of *c.* 15 m from the sea ice to the ice shelf makes it impossible for the penguins to climb onto the shelf. Snow ramps that provide access to ice shelves take a long time to build up and are found at only a few locations around the bay.

During the 2013 winter, a large part of the colony moved onto the ice shelf for the first time since the start of regular observations in 1981 (Fig. 1c; and Figs S1 & S2 found at http://dx.doi.org/10.1017/S0954102014000285). Solitary adult penguins or small groups of adults or near-grown juveniles have occasionally been sighted on ice shelves in previous years, but only during the summer. On 12 August 2013, part of the colony started to move onto the ice shelf. By 26 August 2013, *c.* 2000 emperor penguins (*c.* 70% of the colony) had relocated onto the shelf. Lost eggs were later found on the shelf, suggesting that the transition to the shelf occurred prior to hatching for some of the penguins. The penguins remained on the shelf until November when they gradually moved back to the sea ice.

In 2012–13, environmental conditions at Atka Bay were exceptional. In winter 2012, a large (40 km long) iceberg stranded in front of the bay and prevented the usual break-up

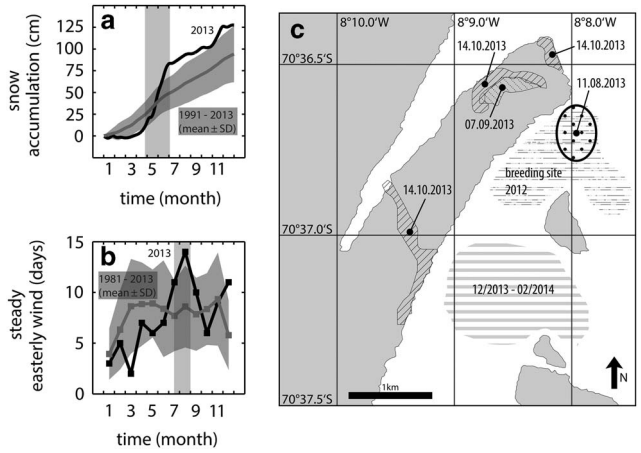

Fig. 1. a. Total snow accumulation. The rate of snow accumulation from mid-April to end of June 2013 (dotted area) was above the annual mean. From July 2013 onward, total snow accumulation (black line) was > 1 standard deviation (grey area) above the annual mean (grey line). **b.** Annual distribution of days per month with strong (> 10 m s^{-1}) and steady easterly winds. In 2013 (black line), the number of days per month with strong and steady easterly winds was > 1 standard deviation (grey area) above the annual mean (grey line) during July and August (grey area). **c.** Positions of the emperor penguin colony at Atka Bay during 2012 and 2013. The transition from sea ice (white) to ice shelf (grey) began on 12 August 2013.

of the sea ice during the summer. In addition, snow accumulation from April–June 2013 was exceptionally high (Fig. 1a). Together, these conditions favoured the emergence of flat snow ramps that provided easy access to the ice shelf. Furthermore, July and August 2013 had an unusually large number (> 1 standard deviation above the annual mean) of consecutive days with strong (> 10 m s^{-1}) steady easterly winds (Fig. 1b).

Discussion

Our observations are in line with recent reports of emperor penguins relocating onto ice shelves during winter. Such behaviour was first observed in 2009 and from 2011 onward in three other colonies (Wienecke 2012, Fretwell *et al.* 2014). The discovery of this unusual behaviour, in particular its sudden emergence at different and distant sites, has prompted speculation that emperor penguins relocate onto ice shelves in response to unfavourable sea ice conditions. Indeed, thinning sea ice occurred at three of the four sites. By contrast, the colony at Atka Bay had good sea ice conditions in 2013 yet relocated onto the ice shelf for the first time in at least 33 years. We hypothesize that unusually thick sea ice and high levels of snow accumulation from April–June 2013 lead to an early build-up of numerous flat snow ramps with a *c.* 15% incline (Fig. S1), making the transition from the sea ice to the ice shelf possible for the penguins. In addition, long phases of particularly strong easterly winds in July and August 2013 may have further pushed the colony onto the shelf, as a result of collective downwind movement of the penguins (Zitterbart *et al.* 2011, Waters *et al.* 2012). We found no indication that breeding on ice shelves was an adaptive process in response to marginal environmental conditions. Rather, in the case of the colony at Atka Bay, an unusual combination of topographical opportunities and weather conditions appear to have facilitated the colony's transition onto the ice shelf.

The recent occurrence of breeding on ice shelves at multiple emperor penguin colonies across Antarctica remains puzzling. Our data and observations suggest that snow accumulation enabling access to ice shelves is an important contributing factor that needs to be considered in order to understand this newly emerging breeding behaviour, and to reveal if this phenomenon is associated with recent climate change.

Acknowledgements

We would like to thank AWI Logistics for their invaluable support, Thomas Hollands for help with satellite imagery, and Werner Schneider for helpful comments and technical support. We thank 33 generations of winterers at Neumayer base for collecting environmental data. This study was funded by Deutsche Forschungsgemeinschaft (DFG) grant FA336/5-1 in the framework of the priority programme 'Antarctic research with comparative investigations in Arctic ice areas'. We also thank Professor Walton, Gerry Kooyman and one anonymous reviewer for their constructive comments. There are no competing interests.

Author contribution

Research design: DPZ. Data collection: DPZ, SR, GS, LKB, JR, RPF, TH, GKL and RW. Data analysis: DPZ and BF. Manuscript preparation: DPZ and BF.

Supplemental material

Two supplemental figures will be found at http://dx.doi.org/10.1017/S0954102014000285.

References

Fretwell, P.T., Trathan, P.N., Wienecke, B. & Kooyman, G.L. 2014. Emperor penguins breeding on iceshelves. *PLoS ONE*, **9**, 10.1371/journal.pone.0085285.

Waters, A., Blanchette, F. & Kim, A.D. 2012. Modeling huddling penguins. *PLoS ONE*, **7**, 10.1371/journal.pone.0050277

Wienecke, B. 2012. Emperor penguins at the West Ice Shelf. *Polar Biology*, **35**, 1289–1296.

Zitterbart, D.P., Wienecke, B., Butler, J.P. & Fabry, B. 2011. Coordinated movements prevent jamming in an emperor penguin huddle. *PLoS ONE*, **6**, 10.1371/journal.pone.0020260.