Studies on sleep patterns and sleep homeostasis in birds

van Hasselt, Sjoerd J.

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CHAPTER 9

Preparing to go wild: tracking migration patterns in barnacle geese

Sjoerd J. van Hasselt, Michiel P. Boom, Götz Eichhorn, Theunis Piersma, Niels C. Rattenborg, Peter Meerlo

Abstract

Sleep is a process that is thought to serve important restorative functions where a minimum amount of sleep is required. Yet, studies in birds have shown that there are phases of the year where sleep time can be greatly reduced. For instance, during the breeding season and long-distance flights. In the present pilot study, we explored whether a population of wild migratory barnacle geese (*Branta leucopsis*) that breeds in the Russian Arctic and overwinters along the Dutch coast might be suitable for future sleep studies. At the Russian study site in Tobseda, Nenets Autonomous Okrug, near the Barents Sea, geese can be captured after the breeding season when they are moulting and flightless. Fifteen geese were equipped with a harness containing GPS/GSM transmitters for wireless location determination. From these GPS transmitters, 4 out of 15 emitted a signal, one of which ultimately reached the wintering grounds in the Netherlands after a journey of 91 days and 3263 km. The data retrieved from these 4 loggers showed consistent routes, of which two went across Finland and the other in Estonia. We suspect that the other loggers may have failed because of problems with the solar-powered batteries, perhaps due to feathers covering the solar panel. Based on the experience gained with this pilot study, we propose that the Tobseda site is a suitable location for starting future experiments on sleep during breeding and migration in wild geese.

Introduction

Most of what we currently know about sleep regulation and function is derived from studies in a limited number of mammalian species. Sleep is considered to be homeostatically regulated which implies that a certain amount of sleep is needed after the preceding waking phase (Tobler and Borbély, 1986; Deboer, 2013). During the past few years, more sleep research is done in non-model organisms in a more natural setting, and this may yield valuable new insights that could contribute to a better understanding of the function and evolution of sleep (Rattenborg *et al.*, 2017). Particularly, studies in birds under (semi-)natural conditions, including our own studies in barnacle geese, have shown large phenotypical variation in sleep and strong effects of environmental conditions. We observed that geese slept 2 h less in summer compared to winter and in summer, sleep was more spread-out over the 24-h cycle as compared to a clear circadian sleep-wake distribution in winter (van Hasselt *et al.*, 2020c). Moreover, the geese in summer displayed a recovery response to sleep deprivation but this was completely absent in winter.

These studies on sleep patterns and homeostatic regulation of sleep in geese under semi-natural conditions do not only provide important insights by themselves, they may also serve as a basis for future sleep studies in wild populations. The barnacle goose may be an ideal species for such studies because these animals undergo certain periods of the year where time for sleep appears to be restricted. First, during the reproductive phase in Arctic Russia the birds are exposed to a 24-h light condition and continuous alertness may be required to guard their nest and young from potential dangers. Second, during the migratory phases in spring and autumn the birds fly on average 2964 km between Russia and the Netherlands (de Boer *et al.*, 2014). Additionally, barnacle geese are relatively large animals that are able to carry the necessary loggers for recording of sleep-wake patterns, as well as GPS transmitters to determine their location during migration (Lameris *et al.*, 2017).

In order to prepare for this future endeavour, we executed an explorative expedition to Tobseda, Nenets Autonomous Oblast, in the North of Russia, where a large colony of barnacle geese breeds. This study site is an abandoned village that has been used in the past for research on barnacle geese (van der Jeugd *et al.*, 2003; Eichhorn, *et al.*, 2009). The current field trips were undertaken to determine if this study site is suitable for sleep studies as well, i.e., for catching the geese, doing surgery, and safely return the birds to the wild. Moreover, we aimed to confirm the migration routes with new GPS transmitters to track their location.

Methods

For this study we used 15 wild-caught barnacle geese (8 males and 7 females). The animals were caught after their breeding season during moult in Tobseda, Nenets Autonomous Oblast, Russia (Figure 1). The geese were given a 16 g harness containing a 24 g GPS transmitter (Milsar Technologies S.R.L.; Feleacu, Romania). It was previously shown that the harness we used does not influence the timing of migration and reproductive success of barnacle geese (Lameris *et al.*, 2018). The GPS transmitter was positioned on the dorsal side of the animal between the wings (Lameris *et al.*, 2017). It contained a small solar panel to power the device. The GPS transmitter was programmed to record its position every 15 minutes, transmitting this data every 8 h to a GSM satellite to make the data accessible from anywhere on the globe with internet connection. Since our field site had no GSM coverage, we programmed the GPS transmitter to only send signals when the birds were outside of a pre-programmed geographical zone to save battery power. This geographical zone was set as the area north and east of the city Archangelsk (64.566438, 40.650125).

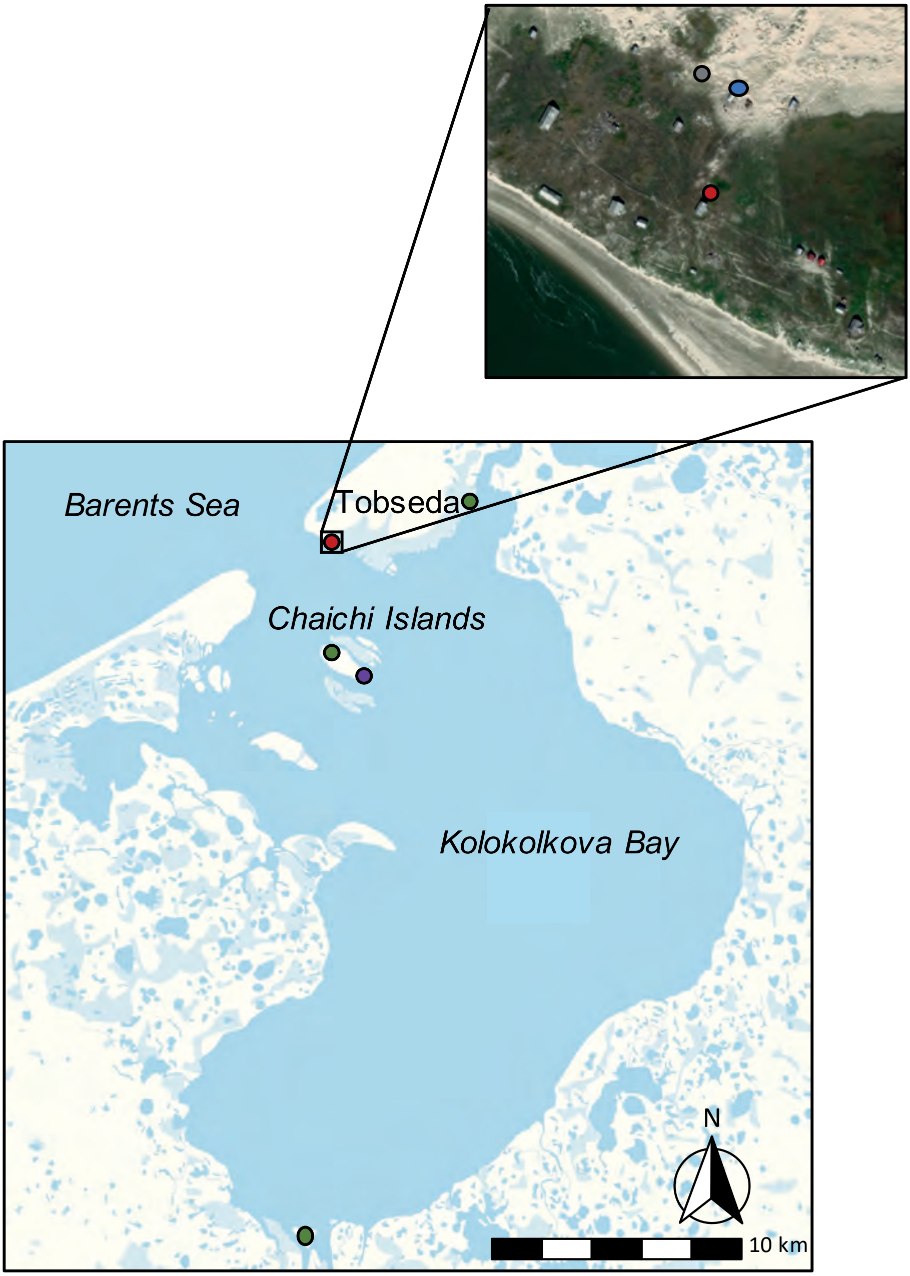

Figure 1. Study site in Tobseda. We stayed in an old weather station building that was situated in an abandoned fishing village of Tobseda (red dots). We caught barnacle geese for implantation twice on the Chaichi islands in summer 2018 (purple and green dot). We kept the geese in a small goose pen with food and water ad libitum and we equipped them with a harness containing a GPS logger in a small house next to goose pen (grey and blue dot, respectively).

Results

The local goose population had drastically decreased in 2018 compared to the last expedition in 2015, yet, we were able to catch sufficient geese at several locations (Figure 1). After deploying all the GPS transmitters on the geese, 4 out of 15 GPS transmitters sent its location successfully to the GSM satellite for data retrieval that covered the fall migration (Figure 2). We could observe a clear route during the autumn migration, where two geese flew over Finland and two over the Baltic states. From these 4 geese that sent its location, one made it through to the wintering grounds in the Netherlands after a journey of 91 days and 3260 km.

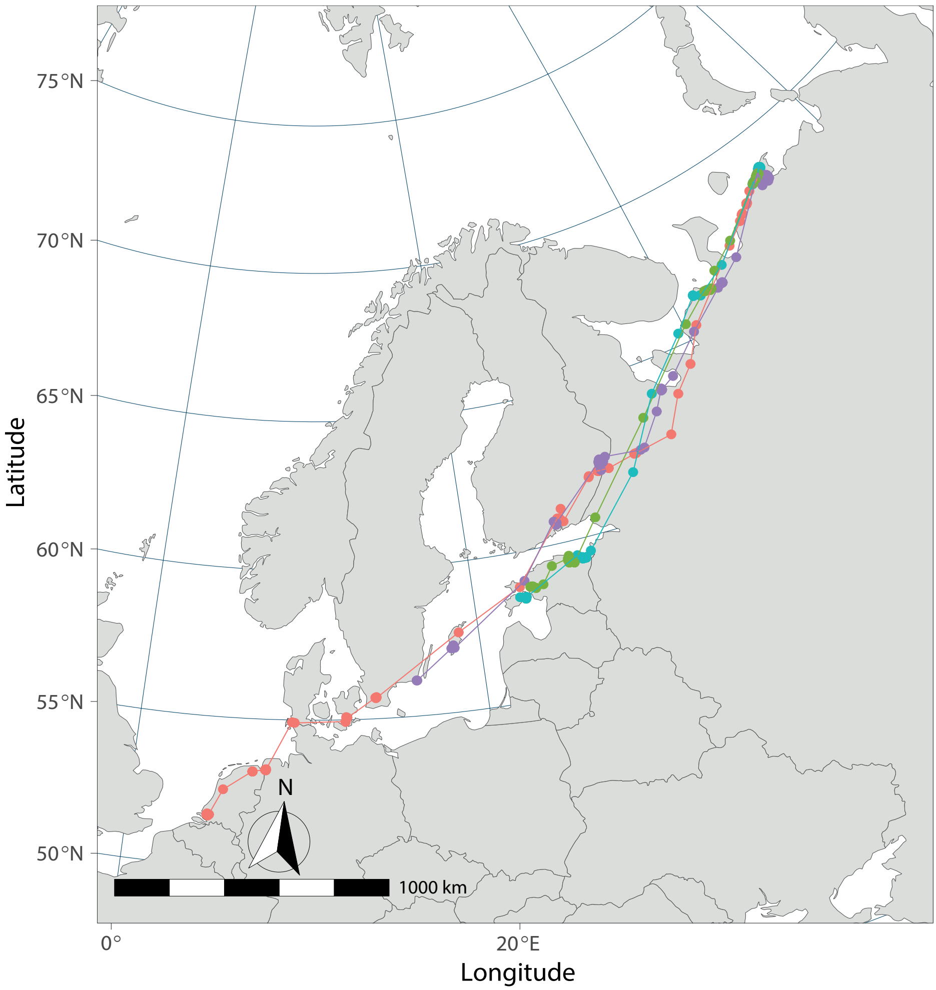

Figure 2. Migratory routes of 4 barnacle geese. Two barnacle geese migrated through Finland (red and purple) while the other two migrated via Estonia (green and blue). One of the GPS devices continued to send signals until the animal reached the wintering destination in The Netherlands (red).

Discussion

One explanation for the decrease in geese numbers in 2018 compared to 2015 might be that the birds were in general breeding further to the North due to climate change (Tombre *et al.*, 2019). Another explanation might be that the geese avoid Tobseda due to a recent increase in hunting activities in that area, although the latter has not been formally established (Lameris, 2020). Despite this reduction in the number of geese in Tobseda, we managed to catch sufficient animals, most of them on the 'Chaichi' (Russian for gull) islands. On these islands there are limited food-sources available which led to a lower overall body condition of the birds.

The migratory routes of the four geese that transmitted GPS signals were largely similar, yet two of them flew over the Baltic states while the other two flew over Finland. These migratory tracks are similar to earlier reported goose flights from the same field station (Eichhorn *et al.*, 2006).

The other 11 GPS transmitters did not send any data. We cannot exclude that these geese died before migration due to hunting, predation or age. However, it is more likely that the GPS devices did not send any data, perhaps as a consequence of a power failure. It might be, for example, that the solar panel was not sufficiently exposed. Alternatively, the devices may have suffered some other kind of technical malfunction that prevented it from sending the data. This idea is supported by one goose we caught that carried an identical GPS transmitter from another experiment. While the GPS transmitter was located on the correct dorsal position with a clearly exposed solar panel, we were unable to connect to the GPS device to retrieve the data. Further inspection of identical GPS transmitters that were used in another study showed that some devices had sudden steep drops in battery levels, indicating that the main problem was battery issues. Together, despite the setbacks of this experiment, this fieldwork in Tobseda provided us with useful insights and experience for conducting future studies on sleep in the high Arctic.

One of the large benefits of using GPS transmitters over GPS loggers is the possibility to access data on an online server at any time without the need of re-capturing the animals. For measuring EEG during migration, a similar situation would be ideal when also EEG data could be transmitted to a GPS satellite. EEG data would be larger in size compared to GPS data, however, with the recently developed 5g network this would not be an issue since a 5g network can transmit 0.12 Gb per second which could send an 8Gb file in just over one minute. Although the energy consumption of a 5g network is higher than the current 4g standard, new antennas are currently in development to significantly reduce this. Combining these new techniques, re-capturing of the animals becomes redundant. Also, the option becomes available to tag the animals on their wintering grounds in the Netherlands using cannon nets where resources are more easily available instead of the high Arctic.

Up until now, it still remains unknown whether migratory barnacle geese sleep during migration. Sleep has been recorded in a non-migratory species who engages in 6-day foraging flights (Rattenborg *et al.*, 2016). These birds use soaring and gliding flight techniques on rising air currents which enables them to briefly sleep in short episodes (Rattenborg *et al.*, 2016). The current hypothesis is that barnacle geese do not use soaring and gliding techniques in mid-air and instead need to flap their wings continuously where full attention might be needed, especially when flying in formation (Portugal *et al.*, 2014; Rattenborg *et al.*, 2016; Rattenborg, 2017). This could mean that sleep time is limited during flight. Instead, the geese may use stopovers to get sleep. In other words, stopover sites can have an additional function of recovering from sleep deprivation in addition to fuelling body reserves by foraging. The execution of this research in the future would yield important new insights in our understanding of sleep, sleep regulation and the evolution of sleep. To be continued…