Habitat selection and movements of Taiga Bean Geese *Anser fabalis fabalis* during spring and early summer

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Abstract
Habitats vary in terms of food and predation risk between each other and over time. The aim of this study was to describe the daily cycle of habitat selection and movements of Taiga Bean Geese *Anser fabalis fabalis* during spring and early summer. For that I used data from 11 Taiga Bean Geese marked with GPS-transmitters in Vilhelmina county, Sweden. I coded every position to a habitat and calculated length of movements between the positions. In most cases the geese spent the night at wetlands and agricultural fields, probably feeding, and the day close to lakes and streams, probably resting. The geese moved between those habitats in the morning and in the evening. These movements between habitats are more likely due to change in predation pressure than resource depletion of the first habitat.

Key words: Taiga Bean Geese, *Anser fabalis*, habitat selection, GPS, daily cycle

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Introduction

A habitat is made up of biotic and abiotic factors. Different habitats can differ in terms of food availability and predation risk. Theoretical models of depletion expect that the consumers will start at the patches with most food and then change to other habitats as depletion goes on. The change in habitat choice would take place when the rate of energy intake at the new habitat (including travel cost between habitats) is higher than the rate of energy intake in the first most profitable habitat (Bernstein et al. 1988, 1991, Comins and Hassel 1979). The importance of predation on habitat selection was studied by Dickman (2016). Dickman found that mice living with predators had other habitat preferences than mice living in predator free areas. The habitat selection due to predators is not necessary an adaption to a specific environment. Instead, the particular individual often choose habitat dependent of its current environment. The habitat selection can shift as the amount of predators is changing (Harvey 1991, Winandy et al. 2016, Werner et al. 1983). Temporal variation in predation can lead to temporal habitat use and foraging patterns (Biro et al. 2003, Lima and Bednekoff 1999). Werner and Hall (1988) found that habitat shift in Bluegilled sunfish Lepomis macrochirus was a trade-off between foraging rate and predation risk. The Blugilled sunfish undergoes many habitat shifts between the pelagic and littoral zone during its lifetime. The fishes shifted habitat when they had grown to certain sizes, where there was critical points in the trade-off between foraging rate and predation risk. Also Holbrook and Schmitt (1988) supported the idea that estimates of food and predation can be used for habitat selection. The trade-off between foraging rate and predation risk can show cyclic patterns and lead to cyclic habitat use (Dodson 1990). Therefore, the habitat selection pattern can say a lot about the ecology of the studied species.

The Taiga Bean Goose Anser fabalis fabalis is a herbivorous bird breeding in northern Europe. The eggs are laid in May and the juveniles start to fly in August (Svensson et al. 1999, Cramp 1977, Eriksson and Henricsson 1990). Not all individuals are breeding. The non-breeding birds are probably mainly younger birds but also adults which failed breeding. Those birds are often seen pairwise or in small groups (Eriksson and Henricsson 1990). The Taiga Bean Geese moult all primary and secondary feathers at the wing and all tail feathers in July which make the geese flightless for some weeks (Eriksson and Henricsson 1990). During this time, many of the none-breeders cluster in flocks at special moulting sites (Robson 1832). They often fly to these moulting sites in June (Salomonsen 1968, Nilsson et al. 2009).

At wintering and staging sites the Taiga Bean Goose mainly overnight at waters and spend the day feeding at agricultural fields (Nilsson and Persson 1984). In the breeding areas in northern Sweden and Norway the summer nights are brighter which theoretically would make it possible for the geese to feed also during the night. The predation pressure and the quality of food can also differ from the wintering and staging sites. Mattocks (1971) found that geese have hard to digest cellulose and therefore must eat a large amount of food every day. To concentrate their feeding to certain habitats in certain times they can optimize their energy intake and minimize predation risk. For Dark-bellied Brent Geese Branta bernicla bernicla it is showed that habitat shift may be due to depletion (Vickerey et al. 1995, Rowcliffe et al. 2001).

The movements of the Taiga Been Geese in the breeding areas are not very well studied. Ringing with neckbands, readable with field scopes, gives some information but almost only from the wintering and staging sites in Denmark and the southern parts of Sweden (Nilsson 2011). In the breeding areas of the Taiga Bean Goose there are few birdwatchers, the geese are more spread out in the landscape and and the observations are fewer (Nilsson 2011, Fransson and Pettersson 2001). Most of the observations in the breeding areas are concentrated to places regularly visited by birdwatchers.
The aim of this study is to describe the daily cycle of the Taiga Bean Geese in terms of habitat selection and movements, from finishing the spring migration in April or beginning of May until the movement to the moulting site in June. This will increase the understanding of which roles food availability and predation pressure play for the ecology of the Taiga Bean Goose.

Methods
In July 2014 and 2015 Taiga Bean Geese were marked at moulting sites in Vilhelmina county, Sweden. They were marked with white neck collars wearing solar GPS units (Ecotone Telemetry). The position data was sent by Short Messenger Service (SMS). Every individual also got an individual code written on the neck collar to make it possible to recognize a particular goose in the field. This study was performed in 2016 with start when the geese had finished the spring migration in April-May and ended when they started moving to the moulting area in June. Both the arrival in the spring and the movement to the moulting sites are often defined by a distinct longer movement (Salomonsen 1968, Nilsson et al. 2009). These movements were used to define the period for this study, which was between 55 and 68 days for the different individuals (Table 1). During this period the geese mainly were in Åsele lappmark (Sweden) and Nord-Trøndelag (Norway). I have included all geese (n=11) still delivering positions regularly during the period in this study. One of the geese was marked in July 2014 and the rest (10) were marked in July 2015. The time intervals between positions delivered from the transmitters differed between different transmitters and dates. The transmitters delivered positions with the intervals every whole hour, every even whole hour, every third hour (02, 05, 08, 11, 14, 17, 20, 23) or every sixth hour (02, 08, 14, 20). All timings in this report are in GMT+2 (Central Europe summer time).

<table>
<thead>
<tr>
<th>Code at neck collar</th>
<th>Finished spring migration</th>
<th>Migration to moulting site</th>
<th>Studied time (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S2</td>
<td>18-Apr</td>
<td>12-Jun</td>
<td>56</td>
</tr>
<tr>
<td>S6</td>
<td>14-Apr</td>
<td>19-Jun</td>
<td>67</td>
</tr>
<tr>
<td>S8</td>
<td>14-Apr</td>
<td>14-Jun</td>
<td>62</td>
</tr>
<tr>
<td>S9</td>
<td>28-Apr</td>
<td>28-Jun</td>
<td>62</td>
</tr>
<tr>
<td>S11</td>
<td>21-Apr</td>
<td>19-Jun</td>
<td>60</td>
</tr>
<tr>
<td>S12</td>
<td>21-Apr</td>
<td>15-Jun</td>
<td>56</td>
</tr>
<tr>
<td>S14</td>
<td>18-Apr</td>
<td>15-Jun</td>
<td>59</td>
</tr>
<tr>
<td>S17</td>
<td>18-Apr</td>
<td>24-Jun</td>
<td>68</td>
</tr>
<tr>
<td>S18</td>
<td>25-Apr</td>
<td>18-Jun</td>
<td>55</td>
</tr>
<tr>
<td>S19</td>
<td>24-Apr</td>
<td>23-Jun</td>
<td>61</td>
</tr>
<tr>
<td>S21</td>
<td>2-May</td>
<td>25-Jun</td>
<td>55</td>
</tr>
</tbody>
</table>

Habitat selection
Every coordinate was coded as a habitat manually by plotting the positions at a Google Earth satellite view. The habitats were classified in three categories: (1) waters, which included lakes, streams and shorelines (< 50 m from water); (2) feeding areas, which included wetlands and agricultural fields and (3) other habitats, for example forests and roads. The reason I combined wetlands and agricultural fields was that the geese showed similar patterns in the daily cycle for using of both habitats and I assume the geese visit both wetlands and agricultural fields to eat. For every point I also did an assessment of how sure I was that it was the correct habitat and if the goose was flying or not. An assessment of non-correct habitat is if I thought the goose were just flying over the habitat or if the delivered coordinate is an important mismatch from the correct position. The unsure points
represented 3.9 percent of the positions and the points from probably flying geese represented 2.4 percent of the positions. None of those positions are excluded from the analysis. To compare habitat-use during the day, I used data from all individuals (n=11) and compared times 02, 08, 14 and 20. Here category 3 (other habitats) was only represented by 3.2 percent of the points and was excluded from the analysis. As a proportion of the rest of the habitats, the total percentage of positions at wetlands and agricultural fields was compared between the four times of the day with an ANOVA in Microsoft Excel. To see how the daily cycle varied over the season I divided the season into six nine-day periods from April 18 to June 10. For this analysis, I had data from six individuals.

**Movements between habitats**
To understand when the main movements between the habitats occurred I looked at the percentage of habitat change during each 2-hour intervals (0-2, 2-4, etc.). For that I had data from 6 individuals from when spring migration was finished until June 10. The differences between time intervals were compared with an ANOVA in Microsoft Excel. The median distances of movements between habitats were calculated separately for each of these geese.

**Results**

**Habitat selection**
The geese showed differences in habitat selection between days and nights. Most of the activity at wetlands and agricultural fields was during the night while the geese were closer to water during the day (F = 15.86, P < 0.001) (Figure 1).

![Figure 1. Amount of observations at wetlands and agricultural fields as a proportion of the total amount of observations at waters, wetlands and agricultural fields. The rest of the observations are on lakes, streams and shorelines. Error bars represent 95% confidence interval. The time is GMT + 2 (Central Europe summer time).](image)

However, this pattern became more distinct later in the season compared to when the geese arrived in the spring. In the beginning of the studied period the geese were mainly close to waters while later in the season, most of the night positions were at wetlands and agricultural fields (Figure 2).

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Figure 2. The variation in circadian rhythm from April 18 until June 10 for six Taiga Bean Geese. The days are clustered in groups of nine days to reduce the number of points to mean instead.

Movements between habitats
There were two peaks when the geese changed habitat most frequent; in the morning and the evening while the geese where more sedentary to their habitat during the day and the night (Figure 3).

Figure 3. Average proportion of habitat change between positions with 2 hours in between. ($F = 4.21$, $P < 0.001$). The data is from all six Taiga Bean Geese delivering positions with at least 2-hours interval from arrival in spring until June 10. The values represent the average for the six individuals. Error bars represents 95 % confidence intervals.
The distance the geese flew when changing habitat varied between different individuals. The median length of those movements varied between 700 and 1900 meters between the individuals with a median of 1350 meters (Table 2).

<table>
<thead>
<tr>
<th>Code at neck collar</th>
<th>Median distance when changing habitat (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S9</td>
<td>1900</td>
</tr>
<tr>
<td>S12</td>
<td>1200</td>
</tr>
<tr>
<td>S14</td>
<td>1500</td>
</tr>
<tr>
<td>S17</td>
<td>1600</td>
</tr>
<tr>
<td>S18</td>
<td>700</td>
</tr>
<tr>
<td>S21</td>
<td>1000</td>
</tr>
</tbody>
</table>

**Discussion**

**Habitat selection**

The Taiga Bean Geese selected wetlands and agricultural fields mainly in the night and lakes, streams and shorelines mainly in the day, which is the opposite pattern compared to the wintering and the staging areas (Nilsson and Persson 1984). This pattern was more distinct in the end of the studied period. The switch in behavior between staging areas and breeding area can probably be explained by differences both in day length and predation pressure.

The nights are bright at this latitude during spring and summer, which makes it possible to feed during the whole night. The use of wetlands and agricultural fields in the night was low in the beginning of the study period but became higher later in the season when the nights also became brighter. Another reason for the low activity at wetlands and agricultural fields in the beginning of the season can be because of snow and ice cover at those habitats (SMHI 2016).

I argue that the reasons for the activity at wetlands and agricultural fields to be concentrated to the night can be predation by golden eagle *Aquila chrysaetos*. Golden eagles are predators of bean geese (Sulkava et al. 1984). Carcasses of geese probably killed by golden eagles have been found many times at moulting sites (pers.obs.). These observations indicate that predation of golden eagles can have a large impact on the geese. Carcasses from geese predated by golden eagle is distinguished from the ones predated by red foxes *Vulpes vulpes* because the eagles are not able to move the goose and the hole carcass will be found in one place, often an open area like a wetland. When golden eagles are hunting Taiga Bean Geese, the geese often flock on a lake and the eagles then give up (pers.obs). This behavior is probably explained by the geese being a too heavy prey to lift for the eagle. Bergo (1990) tested the lift capacity for four captive golden eagles and found that they had problems to lift weights of only one kilogram from flat ground even if they are capable to lift heavier weights from steep hills. It can be an advantage for the geese to be close to lakes and ponds in the daytime when the eagles mainly hunt.

There are also GPS-positions at roads and forests, which are habitats I had not expected the geese to select this time of the year. Some of the positions are probably a result of the goose flying over the habitat when taking the position or an imprecise position from the transmitter. However, in some cases there are many positions close to each other which indicate the positions really belong to the unexpected habitat. There can be plenty of possible explanations for that. Activity at roads and hills can be because the geese want to rest at places with good view (hills and roads) to be able to recognize predators. Activity in forests can probably be either because the geese hide or feed in the forest.
Movements between habitats
As mentioned above the movements between habitats are probably due to a cyclic change in predator pressure. There are other examples where predation induce cyclic pattern of habitat selection (Lima et al. 1999, Biro et al. 2003, Winandy et al. 2016, Dodson 1990). I argue it is unlikely that the observed patterns are due to limited resources. As geese are herbivores, the availability of resources does not differ between day and night. If depletion was the reason for the habitat switch, the geese should not necessary do the switches at the mornings and the evenings and the movements should more likely be to the same kind of habitat rather than a different kind of habitat. Also, the geese often returned to the same geographical place the next night or day. Even though the movements can have an advantage to avoid predators it also means a cost of energy. This cost will depend on the distances of the movements. Disturbance or change in land use in some habitats could mean that the geese must fly longer distances every day. For effective conservation of the Taiga Bean Goose it can be important to take the movements into account in landscape planning for example when building wind turbines and powerlines.

Based on the data one can conclude that none of the geese bred successfully. The juvenile bean geese are not able to fly until August and the adults stay with them whole summer (Salomonsen 1968). The geese in this study all did a lot of movements during the study period and all of them did a long movement to the moulting area in June. This strongly indicates that they did not breed successfully. However, two of the geese probably tried to breed which was indicated by a very sedentary period. After 10 days, they moved a lot again, which indicates that the breeding failed before the eggs were hatched (Cramp 1977). That none of the studied individuals bred successfully can be a random effect but it can also indicate that a low proportion of the entire population consists of breeding birds. However, the studied individuals are perhaps not a representative part of the entire population. It is possible that the white neck collars decrease the breeding success because the geese are easier to discover by predators. Also, all the geese were marked at the moulting sites, most of them the year before the study, when they were not breeding. If breeding birds had been caught instead they should probably have a higher breeding success compared to geese not breeding the previous year. Geese at moulting sites should more likely be young or bad breeders compared to the entire population.

This is probably the first study presenting quantitative data of habitat use during the daily cycle for the Taiga Bean Goose in the spring and the pre-moulting periods. The knowledge of the cyclic pattern in habitat use can be of importance to understand the ecology of the geese.

Acknowledgements
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