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Influence of temperature on the timing of spring arrival and duration of migration in Arctic goose species at a central European stopover site

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Many birds are advancing their migratory phenology and arriving earlier at their spring staging areas in response to climate warming. The duration of the spring migration of geese depends on the interaction between feeding conditions and dates. We studied White-fronted Geese *Anser albifrons* and Bean Geese *Anser fabalis* in north-eastern Poland (one of the coldest areas in the country lowlands), where one of the main central European stopover sites for staging geese is the Biebrza Basin White-fronted Goose and Bean Goose first arrival dates (FADs) in north-eastern Poland were negatively related to local mean spring temperature in January–March during 1996–2015, but FADs of both species (median 28 February) neither differed nor advanced significantly. Total numbers of birds in 10-day periods during 2008–2014 were also analysed. The stay duration of both goose species at the Biebrza stopover site (based on 10-day periods during 2008–2014) varied from 5 to 10 10-day periods. Numbers of geese were positively correlated with local mean temperature and depended on ice cover: both these factors govern accessibility to water and foraging grounds. We suggest that, given the area's prevailing harsh weather conditions, temperature seems to be the crucial factor affecting the extent of ice cover as well as plant growth, which in turn affects goose migration phenology.

1. Introduction

The influence of climate change on avian behaviour has been widely documented in recent years (Crick & Sparks 1999, Tryjanowski *et al.* 2005, Gordo 2007, Knudsen *et al.* 2011, Meissner *et al.* 2015). Many avian studies have focused on trends in clutch initiation dates, especially among European species. Earlier clutch initiation dates have been linked in several species with increasing spring temperatures (Crick & Sparks 1999, Rubolini *et al.* 2007). However, climate change affects bird behaviour in different ways, influencing the condition of breeding and non-breeding birds not least through changes in the timing of migration (Both *et al.* 2006, Rubolini *et al.* 2007). In recent years, many birds have been reported to advance their migratory phenology, arriving earlier to their breeding areas in response to climate warming (e.g., Tryjanowski *et al.* 2002, Lehikoinen *et al.* 2004, Visser & Both 2005). In the case of geese the progress of migration depends on a series of factors from one end of their flyway to the other that affect the ability of birds to reach their breeding sites in the best condition and at the most appropriate time in order to maximise their reproductive output (Duriez *et al.* 2009).

Many studies of goose migration phenology have been carried out in western and northern Europe, mostly relating to departure from the wintering grounds of geese (e.g., Duriez *et al.* 2009, Fox *et al.* 2010, Fox & Walsh 2012). However, less is known about these patterns at central and eastern European staging sites, such as the Biebrza Basin in NE Poland, which is the most important Polish spring stopover site for Greater White-fronted Geese *Anser albifrons* (Ławicki *et al.* 2010, Polakowski *et al.* 2011, Polakowski & Kasprzykowski 2016). Lying in one of the coldest parts of Poland, the Biebrza Basin has a relatively short growing season, and snow and ice cover prevail for the longest period (Górniak 2000). The onset of spring is amongst the latest anywhere in the Polish lowlands, coming about two weeks later than in most other, warmer parts of the country (Górniak 2000).

We studied two Arctic nesting goose species, the White-fronted and Bean Goose *Anser fabalis*, which migrate from their wintering grounds in western Europe to their Arctic breeding areas, staging at several sites (Madsen *et al.* 1999, Ławicki *et al.* 2010, Rosin *et al.* 2012, Wuczyński *et al.* 2012). Geese stop over at refuelling sites on route to accumulate fat stores for migration and for subsequent investment in reproduction (e.g., Drent *et al.* 2007, Hübner *et al.* 2010). While many goose species spend the winter at relatively short distances away from Biebrza (in western European countries, e.g., Madsen *et al.* 1999, Fox *et al.* 2010), increasing numbers of White-fronted and Bean Geese are remaining in western and southern Poland (Ławicki *et al.* 2010, Wylegała & Krąkowski 2010, Rosin *et al.* 2012, Wuczyński *et al.* 2012). It may be expected, therefore, that by wintering nearer to north-eastern Poland, these geese can react quickly (in 1–3 days based on sequential resightings of migrating collared individuals via www.geese.org) to milder weather conditions and the phenology of spring plant growth. Studies have shown that when the distance between successive stops is relatively short, geese use the conditions at one site as a basis for deciding whether to migrate further, responding with great flexibility to changes in the weather (Tombre *et al.* 2008).

The aim of our study was to analyse the staging duration of both goose species at the Biebrza stopover site in response to weather factors. We hypothesised that White-fronted and Bean Geese would react to the global warming trend by advancing the timing of their arrival in north-eastern Poland. Moreover, we also predicted that the mean spring temperature (January–March) would affect the specific timing and numbers of geese, especially under harsh climatic conditions. Owing to the key role played by access to open water at spring staging sites (crucial for drinking and roosting), we also expected that ice cover would influence the occurrence of both goose species.

2. Materials and methods

2.1. Study area

We conducted our study throughout the North Podlasie Lowland (NE Poland). This region, 16,000 km^2 in area, is dominated by agriculture (65%), including arable land, mostly with annual crops (43%). Forests cover 29% of the region, while meadows and pastures are situated mainly in the extensive network of river valleys (19%). The most important spring stopover sites for migratory geese are in the valleys of the Rivers Biebrza and Narew as well as the Siemianówka Reservoir (Ławicki *et al.* 2012). The birds are observed mainly in the Biebrza Basin, which is one of the most important spring staging areas for geese in the country, where more than 100,000 individuals may congregate at one time (Ławicki *et al.* 2010, 2012, Polakowski *et al.* 2011, Polakowski & Kasprzykowski 2016). In contrast to many other central European sites along their flyway (e.g., Wuczyński *et al.* 2012, Jankowiak *et al.* 2015), these birds are less disturbed here, as the majority of the area is protected in the form of a national park and a Natura 2000 SPA (e.g., Percival *et al.* 1997, Jankowiak *et al.* 2015). The Biebrza Basin includes the middle and lower courses of the Biebrza valley and the middle part of the Narew valley; it was described in detail and mapped in Polakowski & Kasprzykowski (2016).

The climatic conditions in north-eastern Poland are relatively harsh, with a mean annual temperature of 6.2–6.8°C, which is 3–4 degrees lower than the mean for the rest of Poland (Górniak 2000). The onset of spring begins 4–14 days later in the Biebrza Basin than in other parts of Poland and the growing season is short, lasting only about 200 days (Górniak 2000). The number of days with snowfall (60–80) is higher than in central and western Poland (20–60 days, Górniak 2000, Institute of Meteorology and Water Management – unpubl. data). Winter is relatively long, with snow cover lasting for 85–96 days (Juśkiewicz-Swaczyna 2010), which is the longest period in Poland (Górniak & Piekarski 2002).

2.2. Methods

In the first set of analyses, we took the first arrival date (FAD) to be the first observation of each species for each spring. FAD records of the two Arctic goose species in NE Poland (mainly Biebrza Basin) were provided by volunteer birdwatchers. Data were collected in 1996–2015 by one of the authors (MP) as well as 15–28 coordinated observers frequently searching for geese in the field from January to March. The most active observers have been named in the Acknowledgements. The data collected appear to reflect the actual arrival date (i.e., the date when the first individual arrived at the site), owing to the relatively easy detection of birds and the fairly large involvement of observers in recording bird arrivals. The correlation between the FAD in a given year and the mean spring temperature describing the 90-day period from January till March (hereafter referred to as "mean temperature") was tested using the Spearman rank correlation (Sokal & Rohlf 2001). The mean temperature was chosen because this parameter is commonly used in many other, similar studies (e.g., Fox & Walsh 2012, Meissner *et al*. 2015). This statistical method, again, often used in similar research, was chosen because of the small sample size (Sparks & Tryjanowski 2005). It is worth adding that there was no significant trend in temperature over the years 1996–2015 in the study site (Fig. 1). The same method was used for analysing the trend of goose arrivals in consecutive years, and the Wilcoxon test was used to analyse the differences in arrival dates between the two goose species in consecutive years. The arrival date was expressed as 1 = 1 January, 2 = 2 January, etc. Weather data were obtained from the Tutiempo (2016) website for the weather station in the city of Bialystok, which lies in the central part of the study area.

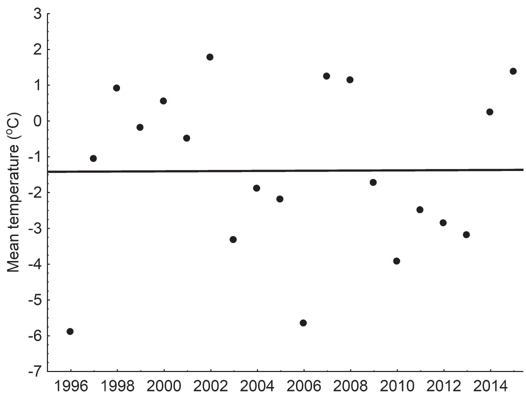

Fig. 1. Trends in spring temperatures (January–March) in 1996–2015 (Spearman rank correlation, $r = -0.01$, $p = 0.960$, $n = 20$).

In the second set of analyses, the duration of goose migration in the Biebrza Basin in 2008–2014 was estimated on the basis of 210 counts (average: 30 counts/season). All seasons were divided into 10 ten-day periods, starting 1–10 February and ending 1–10 May. We carried out the censuses mainly at the sites where geese congregate every year (Polakowski *et al.* 2011, Polakowski & Kasprzykowski 2016), but other sites in the study area were also checked. As the foraging and roosting sites are located nearby, at the same sites or 1–3 km away (Polakowski *et al.* 2011), we performed the censuses throughout the day, focusing on the foraging grounds. We may have overlooked some birds, but these will have been few in number and will have had only a marginal effect on our results. Geese were counted by species and numbers of individuals in all flocks with the use of spotting scopes.

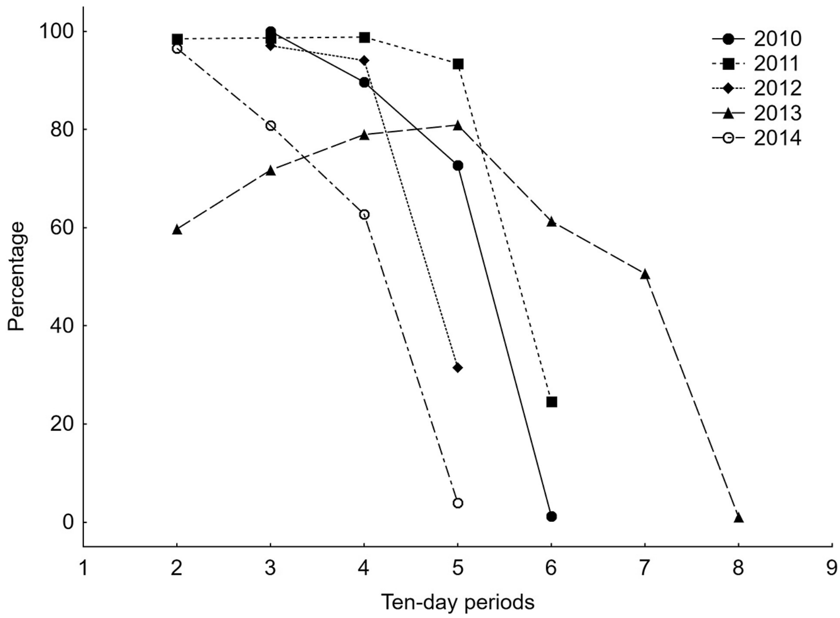

Fig. 2. Trends in ice cover during consecutive 10-day periods in 2010–2014 (1 – first 10-day period of February, 9 – third 10-day period of April).

We analysed the duration of goose migration in each year (season). We also calculated the proportion of birds in each 10-day period (mean and SE over years) relation to the total number of geese in the season, to study the course of the peak. Spearman's correlation was further used to examine the relationship between the numbers of geese in 10-day periods from when the geese first appeared to the migration peak in each season, and local temperature (mean temperature of the corresponding 10-day period). The numbers of geese were transformed logarithmically in order to approximate them to the normal distribution. Only results with a probability of $\alpha \leq 0.05$ were considered as statistically significant. One-way ANOVA and Tukey post-hoc were used to study the differences in goose numbers in relation to the three levels of ice cover (estimated by observers in the field, according to classes 0–33%, 34–66% and 67–100%), measured during each 10-day period. The level of ice cover was negatively related to temperature and varied between seasons (Fig. 2). In February (i.e., the first month of surveys) the level of ice cover was 93.3% of the total surface area of water (SE = 3.52), in March it was 48.3% (SE = 9.18) and by the end of April nearly all the ice had melted (2.9%, SE = 2.86); later there was no more ice. The exception was 2013, when the ice cover persisted for a record long period (Fig. 2). The values are reported as means ± SE. All calculations were performed using Statistica 10.0 (StatSoft 2012).

3. Results

White-fronted Geese arrived in north-eastern Poland between 21 January (2015) and 23 March (2006) (median FAD: 28 February). The earliest arrival of Bean Geese was also on 21 January (2015) and the latest on 24 March (2005) (median FAD: 1 March). FAD did not differ between the two species (Wilcoxon test, $z = 1.22$, $P = 0.224$, n = 20 years).

Despite the visible trend suggesting that both goose species were arriving earlier, there was no statistically significant advancement in FADs over the 20 years of this study (Spearman rank correlations, $P > 0.516$, in both cases, Fig. 3). The arrival of White-fronted Geese was significantly correlated with the mean temperature of spring (Spearman rank correlations, $r = -0.73$, $P = 0.001$, $n = 20$, Fig. 4). Similarly, the arrival of Bean Geese was significantly correlated with the mean temperature of spring (Spearman rank correlations, $r = -0.68$, P = 0.002, n = 20). As the springs got warmer, goose arrivals advanced (Fig. 4).

During the seven seasons from 2008 to 2014,

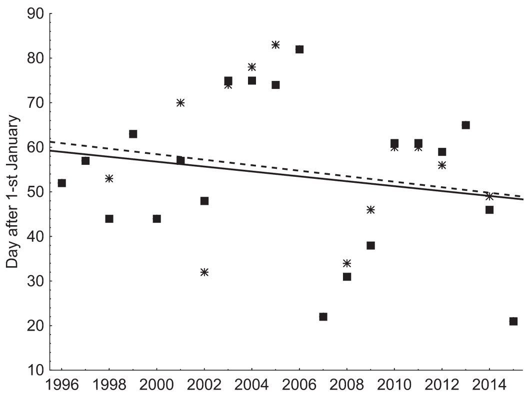

Fig. 3. Trends in arrival dates (10 = 10 January, etc.) of Greater White-fronted Goose *Anser albifrons* (squares, solid line) and Bean Goose *Anser fabalis* (asterisks, dashed line) in 1996–2015.

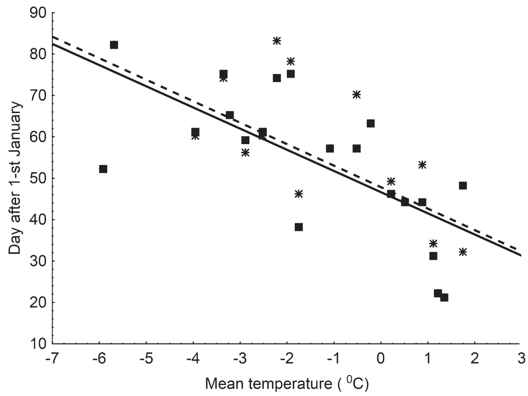

Fig. 4. Correlation between mean temperature of spring (January–March) and the date of arrival (10 = 10 January, etc.) of Greater White-fronted Goose *Anser albifrons* (squares, solid line) and Bean Goose *Anser fabalis* (asterisks, dashed line).

numbers of White-fronted and Bean Geese peaked in the Biebrza Basin within one month, i.e., from mid-March (the second 10-day period) until mid-April (Fig. 5). The highest mean value was noted in late March. The longest duration of stay of both goose species at the Biebrza stopover site was in 2008 (10 10-day periods), while the shortest was in 2011 (5 10-day periods). The total number of geese noted in 10-day periods was positively correlated with the mean temperature of the 10-day period (Spearman correlation, $r = 0.73$, $P < 0.001$, $n = 35$, Fig. 6). We also found that the impact of ice cover on goose numbers was significant: the highest numbers of birds were counted when the ice level of was the lowest ($F_{2,16} = 4.78$, $P = 0.023$). The difference between the first and the third levels of ice cover was significant (Tukey post-hoc test $P = 0.022$, Fig. 7).

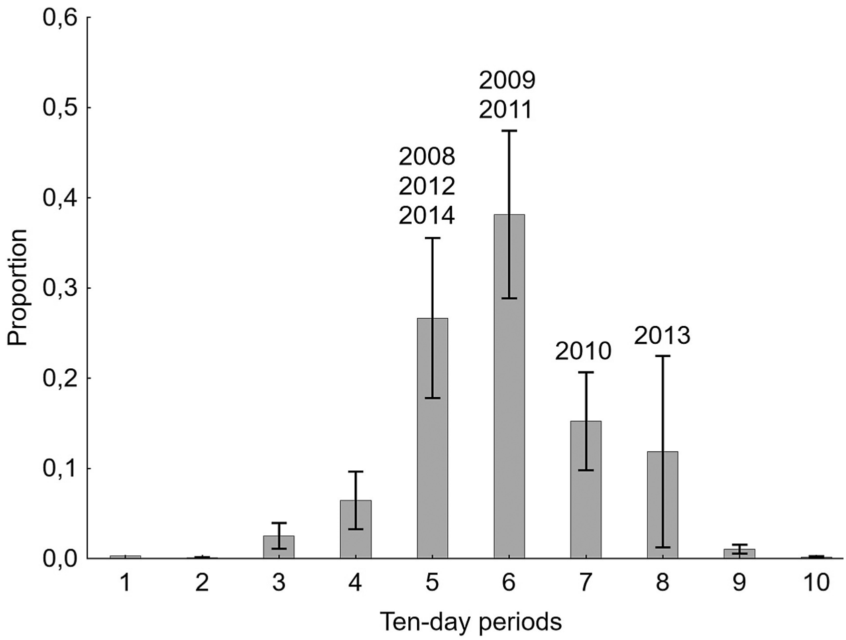

Fig. 5. Proportion of birds in consecutive 10-day periods in relation to the total numbers of geese noted in each season (mean and SE) of two goose species (Greater White-fronted Goose *Anser albifrons* and Bean Goose *Anser fabalis*) at the Biebrza stopover site in 10-day periods (1 – first 10-day period of February, 10 – first 10-day period of May). The years with peak numbers are given above the columns.

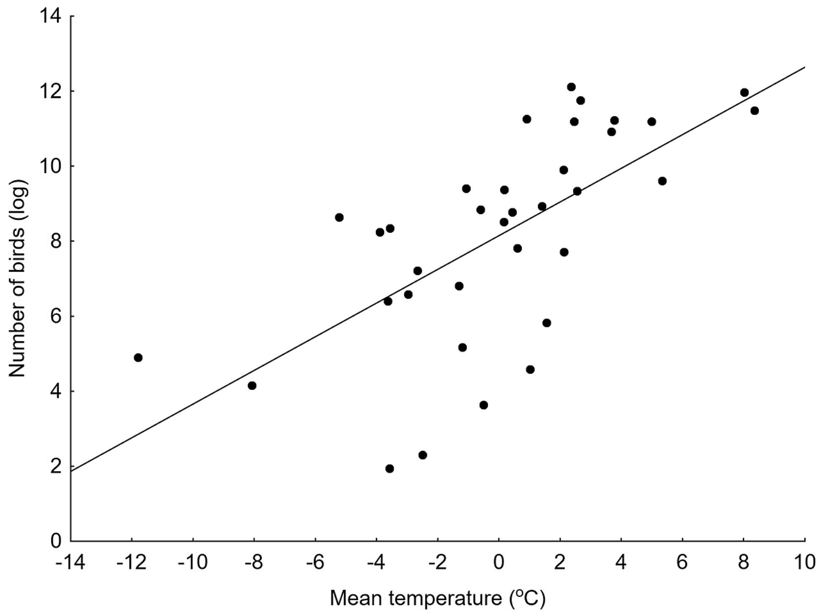

Fig. 6. Correlation between the total number of geese (Greater White-fronted Goose *Anser albifrons* and Bean Goose *Anser fabalis*) recorded in 10-day periods and the mean temperature in the corresponding 10-day period (periods range from the early February till the end of April).

4. Discussion

It is well known that the climate warming is taking place at the global scale and is having an influence on birds (Crick & Sparks 1999, Tryjanowski *et al.* 2005, Gordo 2007, Knudsen *et al.* 2011, Meissner *et al.* 2015). Therefore, we can predict that Arctic goose species would respond to overall increasing trend in temperature in Europe by arriving earlier at their spring sites in NE Poland. However, this trend was not observed in our results. The most likely explanation for this is the lack of an increase in temperatures in January–March over the study period. The north-eastern Poland lies in the harshest climate of the country, where the onset of spring is relatively late, temperatures are low and the availability of foraging and roosting areas is limited for a longer period of time (Polakowski & Kasprzykowski 2016).

Geese aim to arrive at their breeding grounds as early as possible in order to obtain a nest site and increase their chances of breeding success (e.g., Kokko 1999, Berthold 2001, Prop *et al.* 2003). On the other hand, they need to undertake their migration towards that goal in a way that ensures a sequential improvement in their accumulating bodily resources in preparation for further migration and ultimately reproduction, although too much fat can also slow birds down (Schaub *et al.* 2008, Farmer & Parent 1997, Kear 2005, Nolet 2006, Drent *et al.* 2007, Hübner *et al.* 2010). Therefore, there seems to be a compromise between arriving late enough to encounter the best guaranteed foraging and roosting conditions in the harsh north-eastern Poland environment and arriving early enough to build up a sufficient store of energy for further migration and ultimately for breeding.

Temperature has a significant influence on the arrival and the number of individuals of both goose species, seeming to play a crucial role by influencing the onset of the spring migration along the flyway. Temperature affects snow and ice melt, therefore governing access to roosting and foraging areas. Temperature is regarded as a climate indicator (e.g., Bauer *et al*. 2008), since it influences the degree of ice cover on waterlogged areas in river valleys during early spring (Górniak 2000). Geese require access to optimal food resources and often follow the onset of plant growth while migrating (the “green wave” hypothesis; Schwartz 1998, van der Graaf *et al.* 2006, Gordo 2007, Duriez *et al.* 2009). In the Biebrza Basin their behaviour is specific, as they prefer foraging on meadows and pastures in the river valleys, away from arable land (Kear 1970, Patterson 1991, Polakowski & Kasprzykowski 2016). Access to roosting and foraging grounds is closely as-

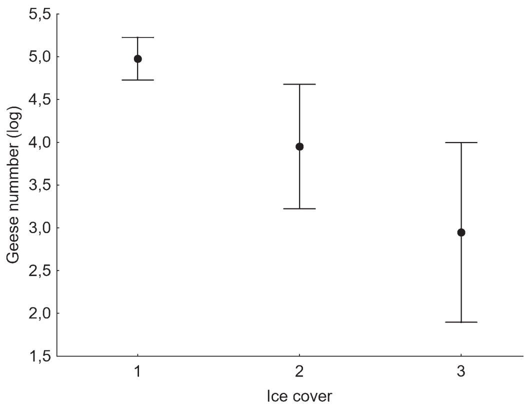

Fig. 7. The summed number of both species of geese (log) for three classes of ice cover (I: 0–33%, II: 34–66%, III: 67–100% ice cover).

sociated with the extent of ice cover, especially during early spring. The smallest ice cover seems to provide the best conditions because it facilitates access to the roosting and foraging grounds. Otherwise, ice cover creates less favourable conditions, with feeding areas flooded and consequently also unavailable for drinking water, for which birds are prepared to fly quite long distances (Kear 2005). Ice cover also affects accessibility of the area to mammalian predators as well as hunters, photographers and observers: geese react to the last mentioned as if they were predators (Jankowiak *et al.* 2015). Predators can easily access the area when it is covered with ice. Therefore, the protection of a large part of the study area as well as the ice-free, open water limits human disturbance, thereby benefiting the staging geese.

In conclusion, it would seem that Arctic geese migrating in spring across north-eastern Poland have not significantly advanced their arrival in response to local weather conditions over the last two decades, although warmer springs do still result in earlier arrivals of birds. The harsh weather of north-eastern Poland produces very specific conditions for spring staging geese: the area is less attractive during long-lasting ice cover and when low temperatures maintain the snow cover, so that geese cannot use the foraging grounds. Our results suggest that geese react flexibly to year-to-year differences in the timing and rapidity of the thaw, but have exhibited only weak, non-significant trends with regards to the advancement of migration timing in recent years. Temperature here seems to be crucial, affecting the extent of ice cover as well as plant growth, which in turn influences goose migration phenology.

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Lämpötilan vaikutus hanhien kevätmuuton saapumisaikoihin ja viipymiseen levähdysalueilla Keski-Euroopassa

Ilmastonmuutos on aikaistanut monien lintujen muuttoa ja saapumista pesimäalueille. Hanhien kevätmuuton kestoon vaikuttavat yhdessä ravintotilanne ja fenologia.Tässä tutkimuksessä selvitettiin tundrahanhen (*Anser albifrons)* ja metsähanhen (*Anser fabalis)* viipymistä levähdys-ja ruokailualueilla koillis-Puolassa vuosina 1996–2015. Tämä alue on yksi tärkeimmistä kevätmuuton levähdysalueista Keski-Euroopassa, mutta myös yksi kylmimmistä alueista Puolan alangolla. Tundra- ja metsähanhen saapumispäivät kyseiselle levähdysalueelle korreloivat negatiivisesti kevään lämpötilan (tammi–maaliskuu) kanssa. Saapumispäivä ei kuitenkaan ollut aikaistunut tutkimusjakson aikana.

Lintujen kokonaismäärää tutkittiin lisäksi 10-päivän jaksoissa kevään ajan. Lintujen viipyminen levähdysalueella vaihteli viidestä kymmeneen 10-päivän jaksoon. Hanhien määrä korreloi positiivisesti paikallisen lämpotilan kanssa, ja siihen vaikutti myös jääpeitteen määrä. Näyttää siltä, että alueen suhteellisen kylmissä sääoloissa lämpötila on tärkeä tekijä, joka vaikuttaa jään määrään ja kasvien fenologiaan, ja siten hanhien muuton ajoittumiseen.

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