Changes in the phenology of spring migrating passerines at Blåvand Bird Observatory, Denmark, 1984-2021

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(*Med et dansk resumé: Ændringer i forårstrækkets fænologi hos småfugle ved Blåvand Fuglestation 1984-2021*)

Abstract At Blåvand Bird Observatory, standardised ringing data have been collected for 36 years for monitoring of passerine migrants. Annual records of 18 species of caught and ringed passerines at Blåvand were analysed using linear regression to determine patterns in timing of migration and the influence of climate factors. Possible correlations between arrival, year, and the North Atlantic Oscillation (NAO) winter index were investigated. Short-distance migrants advanced their timing of migration more than long-distance migrants. On the contrary, for all long-distance migrants except Pied Flycatcher *Ficedula hypoleuca*, the last part of the caught and ringed migrant birds tended to delay their migration. Only four short-distance migrant species (European Robin *Erithacus rubecula*, Dunnock *Prunella modularis*, Goldcrest *Regulus regulus* and Common Chiffchaff *Phylloscopus collybita*) adjusted their timing of migration significantly to the NAO winter index.

Introduction

Climate change has caused phenological changes in plants and insects (Root *et al*. 2003, Menzel *et al*. 2006) leading to incidents of ecological mismatch between insects and several bird species, especially in northern regions (Post 2009, Both *et al*. 2010). To prevent such mismatch, birds are changing their phenology of migration (Berhold *et al*. 1998, Hüppop & Hüppop 2003). The result has been changes in arrival dates of multiple migrant species (Saino *et al*. 2010, Kullberg *et al*. 2015).

However, climate change is not the only factor that can influence the phenology of migratory birds in North-western Europe. The North Atlantic Oscillation (NAO) can also have an influence (Hüppop & Hüppop 2003, Vähätalo *et al*. 2004). The NAO index describes the annual fluctuation of atmospheric pressure at sea-level between the subtropical centre of high surface pressure (Azores) and the subarctic centre of low surface pressure (Iceland) over the long term (Hurrell 1995). High values of this index are associated with mild and moist winters in Northern Europe, whereas low values are associated with cold and dry winters (Hurrell 1995). Earlier spring arrival is associated with high NAO values, and later spring arrival with low NAO values (Forchhammer *et al*. 2002).

Birds wintering north of the Sahara tend to arrive at their breeding grounds as early as possible, because this gives benefits for the individuals that arrive early such as the best breeding territories, increased chances to find a mate, better quality of mates, increased chances for extra clutches, and higher survival rates for their offspring (Bearhop *et al*. 2005, Newton 2006). To arrive as early as possible, the wintering ranges of birds that winter north of the Sahara (short-distance migrants, referred to as SDM) have been shifted northwards (Austin & Rehfisch 2004, Maclean *et al*. 2008).

Current theories suggest that the spring migration of long-distance migrants (LDM) that winter south of the Sahara is triggered by endogenous processes (Coppack & Both 2002). Environmental factors in the wintering grounds are also thought to influence departure schedules (Berthold 1996). If both the timing and rate of migration are inflexible, birds might arrive at breeding grounds during early spring when conditions there are suboptimal (Both & Visser 2001, Penuelas & Filella 2001).

Understanding how the phenology of bird migration has changed over time requires constant sampling over multiple years. This can be achieved by standardised migration counts or mist-netting. By using standardised mist-netting, it is possible to study difference in migration timing and variation in timing between years. In this paper, data of 36 years of standardised mist-netting at Blåvand Bird Observatory is used. In the current study I investigated whether there is a relationship between climate change and the arrival date of migratory passerines, or whether variation in arrival dates can be explained by the NAO. Comparable studies have been conducted at other European bird observatories, e.g. Helgoland (Hüppop & Hüppop 2003), Ottenby, Falsterbo, Hanko and Capri (Jonzén *et al*. 2006).

Materials and methods

The gardens at Blåvand Bird Observatory (55°55′ N, 8°08′ E) and Blåvand Lighthouse (55°55′ N, 8°08′ E) are constant effort trapping sites. Both sites are situated at Blåvandshuk, the westernmost point of Denmark (Fig. A1 in the digital Appendix 1). In digital Appendix 1, the setup of the mist-nets used for ringing is illustrated.

Since 1984, a standardised method for ringing has been used at Blåvand Bird Observatory. Standardised ringing takes place between 1 March and 15 June for five hours a day, starting half an hour before sunrise following a manual (Blåvand Fuglestation 2017). In the garden of the bird observatory, 11 mist-nets of total length 128 m are used, while at the lighthouse 11 mist-nets of total length of 113 m are used.

Four years of the data from the 36 years were not used in the analysis, because there were missing periods of ringing activity (in 1986, 1990 and 1992). Additionally, the data of 1993 could not be found and therefore analysed. In the remainder of the 36 years there was a comparable ringing effort.

Weather data were downloaded from Wunderground.com (2022) with the location "Blåvand Oksby". The data of the NAO were downloaded from the National Centre for Environmental Information (2022). In order for the current study to be comparable with other studies, the NAO data were averaged over the December-March period, as was done by Hüppop & Hüppop (2003) and Stervander *et al.* (2005).

In the analyses, all the ringed birds were divided into two categories, SDM and LDM (Appendix 2). This step was based on comparable studies done at other bird observatories (see Jonzén *et al*. 2006, Tab. A1 and A2 in the digital Appendix 2). The dates are expressed as Julian days (1st of January = 1). The phase of migration was defined as the dates when the cumulative bird sum of the season reached 5%, 50% and 95%, as in Tøttrup *et al*. (2006). Species that were analysed were those species that had been caught for at least five days during each spring. Furthermore, seasonal sums of each species must have exceeded 20 individuals and must have been recorded in more than eight spring seasons.

A linear model was used to test whether there was a significant effect of climate change or the NAO winter index on the timing of migration. The variables that were tested were the NAO winter index, year, and timing of the migration of each species. The analysis was performed in RStudio (R Core Team 2021) with the help of packages "lme4" (Bates *et al*. 2015), "stats" (R Core Team 2021), and "tidyverse" (Wickham *et al*. 2019).

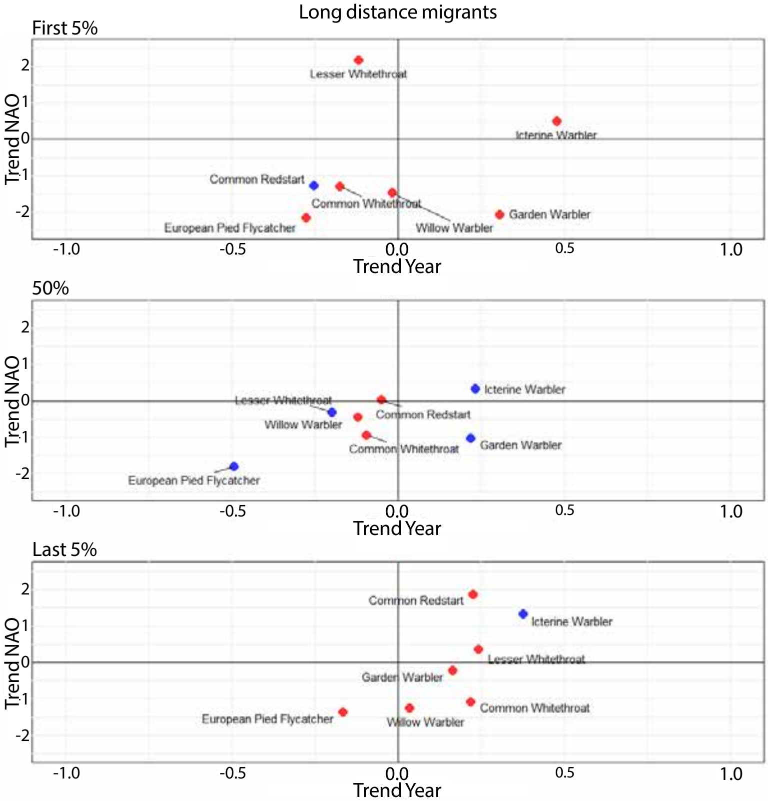

Fig. 1. Changes over the years and NAO values in all phases of migration of LDM species. The trend on NAO is given on the vertical axis, while the trend on years is given on the horizontal axis. Red dots with species name indicate a significant change in passage; blue dots indicate no significant change in passage.
Ændringer over årene og i forhold til NAO-indekset for langdistancetrækkende småfugle ved Blåvand, hvor ændringer i forhold til NAO vises på den lodrette akse, og ændringer i forhold til år ses på den vandrette akse. Røde prikker ud for arterne angiver signifikante ændringer med år, mens de blå prikker angiver ikke-signifikante ændringer i trækforløbet over årene.

Results

In total, 18 species met the criteria given above, and 11 of these species were SDM, while seven were LDM.

Of the seven analysed LDM species, five showed a significant trend towards earlier arrival of the first or median phase of the spring passage, while all species showed a delayed last phase of migration (Tab. A1 in the digital Appendix 2). With regard to individual species, Common Redstart *Phoenicurus phoenicurus* showed a significantly earlier arrival in the early phase of migration but had no significant trend in other phases of migration. Icterine Warbler *Hippolais icterina* and Garden Warbler *Sylvia borin* delayed their migration in all phases, but only the change in median spring passage was significant (Tab. A1, Fig. 1).

For LDM, the effect of the NAO had no significant impact on passage in any phase of migration (Tab. A1).

With regard to the 11 analysed SDM species, five species showed a trend towards an earlier passage through Blåvand in all phases of migration (Tab. A2). Another five species showed a trend towards earlier passage, but only in the first and median passage. Blackbird *Turdus merula*, Blackcap *Sylvia atricapilla*, Dunnock, and Song Thrush *Turdus philomelos* significantly advanced their first phase of migration. Blackbird, Chiffchaff, and Song Thrush significantly advanced their median spring passage. Chaffinch *Fringilla coelebs* significantly advanced the first phase of migration, but also significantly delayed the last phase of migration. Linnet *Linaria cannabina* was the only species where migration was delayed in all phases, and delay was significant in the first phase and in the median spring arrival (Fig. 2).

For four SDM species, the NAO winter index correlated negatively with their first phase of migration (Tab. A2, Fig. 3). For Dunnock, Chiffchaff and Robin, there was a significant advance in their first phase of migration. Goldcrest was the only species where the NAO significantly correlated with both the first phase of migration and the median spring passage of this species (Tab 2, Fig. 3).

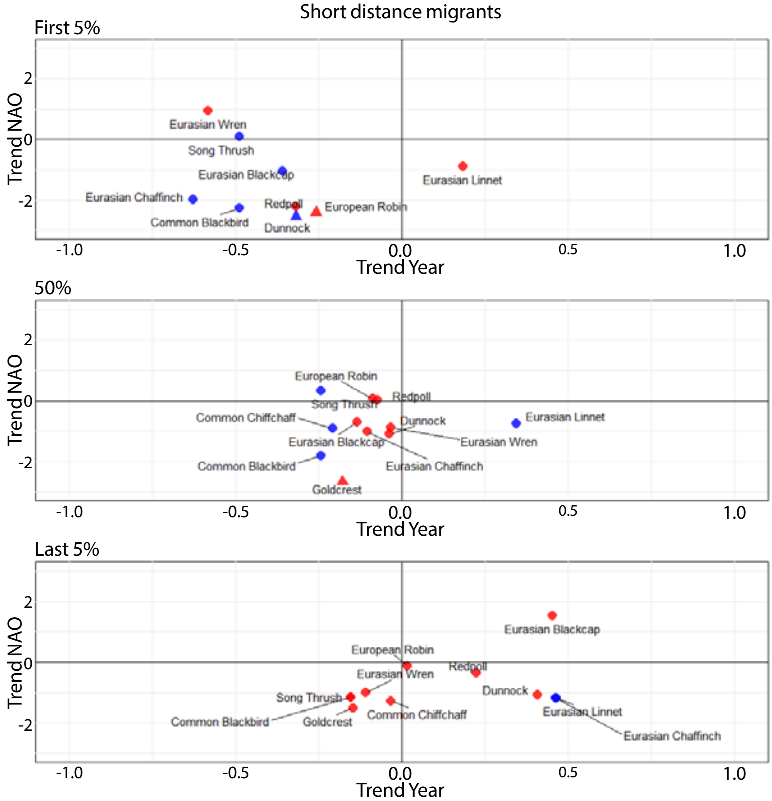

Fig. 2. Changes over the years and NAO values in all phases of migration of SDM species. Red dots with species name indicate a significant change in passage; the blue dots indicate no significant change in passage. Triangles indicate a significant change in relation to NAO; circles indicate no significant change in relation to NAO.

Ændringer over årene og i forhold til NAO-indeks for kortdistance-trækkende småfugle ved Blåvand, hvor ændringer i forhold til NAO vises på den lodrette akse, og ændringer i forhold til år ses på den vandrette akse. Røde prikker ud for arterne angiver signifikante ændringer med år, mens de blå prikker angiver ikke-signifikante ændringer i trækforløbet over årene. Trekanter og cirkler angiver hhv. signifikante og ikke-signifikante ændringer i forhold til NAO.

Discussion

Comparable studies have been conducted all over Europe. At Helgoland in Germany (Hüppop & Hüppop 2003, 2011) and at Ottenby in Sweden (Stervander *et al*. 2005), all LDM showed earlier median passage. At multiple European ringing sites (Ottenby and Falsterbo, Sweden; Hanko, Finland; Jomfruland, Norway; Capri, Italy), Jonzén *et al*. (2006) found that LDM arrived earlier over the years in all phases of migration, except for Spotted Flycatcher *Muscicapa striata*, but this species was not included in the current study. In the current study, however, Garden Warbler and Icterine Warbler showed delayed arrival instead of the advanced arrival like the other LDM. In Icterine Warbler, this delay could be explained by a different direction of migration, i.e. southeast. Other LDM have a more southwest-oriented migration route (Bakken *et al*. 2006, Bønløkke *et al*. 2006, Bird migration atlas 2022a, 2022b). In other European studies such a difference was not found (Hüppop & Hüppop 2003, Stervander *et al*. 2005, Jonzén *et al*. 2006).

Just like Stervander *et al*. (2005), Hubálek & Čapek (2008) and Gunnarsson & Tomasson (2011), but contrary to the study by Jonzén *et al*. (2006), LDM did not advance their passage through Blåvand more than SDM. This finding is also in agreement with the idea of Lehikoinen *et al*. (2004) that SDM can react better to local weather changes than LDM. In LDM, migratory activity is under endogenous control (Pedersen & Rytter 2018), but experiments have shown there is individual variation in the birds' response to photoperiodic cues triggering the initiation of spring migration (Coppack *et al*. 2003).

There are two hypotheses of the cause of the shifts in migratory phenology. One hypothesis is microevolution. Due to genetic variation in the timing of migration (Møller 2001, Pulido & Berthold 2003) and of selection for breeding earlier in Europe (Both & Visser 2001, Both *et al*. 2006), a change towards earlier arrival would be expected, as shown in most species in the current study. In some individual cases this shift has been demonstrated (Pulido & Berthold 2003, Bearhop *et al*. 2005). The other hypothesis is phenotypic plasticity, which is the ability of a genotype to produce different phenotypes in response to different environmental conditions (Gienapp *et al*. 2007). This interpretation has recently received increasing support (Gienapp *et al*. 2007).

The result found in the current study that the NAO had an effect only on the early phase of migration of the SDM corresponds with the results of Rainio *et al*. (2006). There could be several explanations as to why migratory birds react more strongly to the NAO in the early phase of migration compared to later phases. One explanation could be that only individuals that are in good condition can increase the speed of their migration. In milder winters (positive NAO) migrants are likely to have had better feeding conditions and as a result are better prepared for migration (Gunnarsson & Tomasson 2011). Another possible explanation is that the wintering range expands northwards during milder winters (positive NAO) and hence the distance between wintering and breeding grounds is reduced (Root 1988, Valiela & Bowen 2003, Austin & Rehfisch 2004).

The lack of an effect of the NAO on LDM could be explained by the fact that the NAO mainly influences winter conditions north of the Sahara (Hurrell 1995). Other climate cycles can also influence the migration speed and timing, such as found by Remisiewicz & Underhill (2022), where other climate indexes influence the passage of Willow Warblers through Poland.

In Chaffinch, it was surprising to see that the first phase of migration was advanced but that there was a delay in the last phase of migration. An explanation for this phenomenon may be that it is mainly the males that race towards the breeding grounds (Forstmeier 2002, Spottiswoode *et al*. 2006).

A remarkable result of this study was that Linnet was caught later each spring. Most of the Danish Linnet migrate towards the southwest (Bønløkke *et al*. 2006), but in the Netherlands, the timing of the passage of Linnet did not change over the same period (Trektellen 2022). With the first local young of the year fledging as early as late May (Blåvand Bird Observatory data), the delay of Linnet at Blåvand could be caused by increasing numbers of juvenile birds sampled close to the end of the season. An earlier start of the breeding season may be a reaction of the birds to climate change (Halupka & Halupka 2017).

Søderdahl & Tøttrup (2023) used ringing data from Blåvand Bird Observatory 2003-2021 to investigate whether there was a relation between climate change and timing of autumn migration. In their study, there was also a greater delay in SDM compared to LDM. This result indicates that for northern Europe SDM are better than LDM at adjusting their timing of migration to the changing climate.

For future studies, ringing in Africa would be very interesting because correlations and/or changes in departure dates as well as arrival dates could then be determined. Research conducted at bird observatories in southern Europe would also be very interesting because most research on phenology has been done at observatories at higher latitudes.

Catching for ringing at Blåvand Bird Observatory during 36 years has confirmed that several bird species have advanced their arrival in spring, especially among short-distance migrants. Jonas Gadegaard with Goldcrest photographed by John Frikke.
Fangst til ringmærkning på Blåvand Fuglestation i 36 år har bekræftet, at adskillige fuglearter har fremrykket deres ankomst om foråret, især blandt kortdistancetrækkerne.

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Resumé

Ændringer i forårstrækkets fænologi hos småfugle ved Blåvand Fuglestation 1984-2021

Klimaændringer har forårsaget fænologiske ændringer hos både planter, insekter og fugle på den nordlige halvkugle, hvilket har ført til ændringer i forekomsten af insekter og trækfugles ankomsttidspunkter på ynglepladserne. Flere fuglearter har derfor ændret deres trækfænologi for at sikre, at deres ankomst til ynglepladserne tilpasses forekomsten af insekter i yngleområderne. Dette fører til ændrede ankomstdatoer for flere trækfuglearter. Udover en tidligere ankomst til ynglepladserne, er mange fuglearter også begyndt af lægge æg tidligere på sæsonen. Udover det varmere klimas påvirkning af trækfuglenes fænologi i Nordvesteuropa, kan den nordatlantiske oscillation (NAO) også påvirke arternes fænologi.

Dette studie har undersøgt den mulige sammenhæng mellem klimaændringer og ankomstdatoen for langdistance- (LDM) og kortdistancetrækkende (SDM) spurvefugle ved Blåvand, samt variationen i arternes ankomstdato i forhold til NAO. Resultaterne blev sammenlignet med tilsvarende undersøgelser på andre europæiske fugleobservatorier (fx Helgoland, Ottenby, Falsterbo, Hanko og Capri).

På grund af de mange års standardiseret ringmærkning ved Blåvand, er disse data velegnede til at analysere de trækkende spurvefugles fænologi.

I perioden 1984-2021 var der 32 års ringmærkningsdata fra Blåvand Fuglestation, hvor der var en sammenlignelig ringmærkningsindsats, som kunne anvendes i analysen af spurvefuglenes trækfænologi om foråret. Data for i alt atten arter blev analyseret, hvoraf 11 arter var SDM og syv arter LDM. Arternes fænologi blev testet i tre forskellige faser af forårstrækket, hvor der var ringmærket henholdsvis 5 %, 50 % og 95 % af arternes samlede antal under forårstrækket.

Fem ud af de syv analyserede LDM viste en tendens i retning af en tidligere ankomst i den første (5 %) og mellemste (50 %) fase af forårstrækket, men broget fluesnapper var den eneste LDM-art, hvor også den sidste fase af forårstrækket blev fremrykket. NAO havde ikke en signifikant effekt på LDM-arternes fænologi i nogen af forårstrækkets tre analyserede faser.

Fem ud af de 11 analyserede SDM viste en tendens til tidligere træk gennem Blåvand i alle trækfaser. Yderligere fem arter viste en tendens til tidligere træk, men kun i den første og midterste trækfase om foråret. Tornirisk var den eneste art, hvor forårstrækket var signifikant forsinket i den første og midterste del af trækket. For fire af de undersøgte SDM-arter, var der en signifikant korrelation med NAO og arternes deres første fase af forårstrækket. Fuglekonge var den eneste art, hvor NAO korrelerede signifikant med både den første og midterste del af artens forårstræk.

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Appendix 1: https://pub.dof.dk/link/2024/4.appendix1
Appendix 2: https://pub.dof.dk/link/2024/4.appendix2

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