Advanced spring arrival of avian migrants on Tipperne, western Denmark, during 1929-2008

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(Med et dansk resumé: Tidligere ankomst af trækfugle på Tipperne 1929-2008)

Abstract During the last decade, phenological studies have increased our knowledge on climate-induced changes in timing of avian migration. Much work has been done using long-term, standardised data. However, the vast majority of previous studies have focused on data covering 3-4 decades and limited to specific species groups. In the present study, we analysed temporal patterns in spring arrival of 43 taxonomically diverse Fennoscandian bird species based on a long-term data series covering 80 years (1929-2008) from the Tipperne reserve in westernmost Denmark. Furthermore, we assessed how spring arrival was related to variation in climate. Overall, spring arrival advanced by a mean of 0.26 days/year, corresponding to a three week advance during the 80 year study period. While short-distance migrants advanced on average 0.38 days/year, long-distance migrants only advanced 0.17 days/year. These patterns in first arrival dates were confirmed by patterns seen in arrival of the first five or ten individuals. Overall, changes in environmental conditions (temperature, precipitation and the North Atlantic Oscillation) during winter and spring explained much of the changes in phenology. Interspecific variation in response to climate is partly explained by different migration strategies.

Introduction

Understanding ecological impacts of global change – especially climate change – lies at the root of much recent biological research covering all trophic levels (Parmesan 2006). For northern Europe, climate change is expected to result in milder and wetter winters and increased spring temperatures, as well as dryer summers (IPCC 2010).

The current bird migration system in Europe emerged during the last ice age and has since evolved in an ever-changing world (Alerstam 1990, Berthold 2001). This dynamic system is currently facing global changes in climate and land-use at a rate and magnitude unlike any of the past (Huntley et al. 2008, Visser 2008).

Several studies on migration phenology in birds show a marked advance in spring arrival in recent decades suggesting that changes in migration phenology are correlated with variations in climate (reviewed by Lehikoinen et al. 2004 and Gordo 2007).

Table 1. Changes in date of first arrival for 43 migratory species estimated by linear regression. Negative slopes indicate earlier arrival. Slope mean is calculated for short-distance (a) and long-distance (b) migrants, and for all species considered. Migration distance (km), number of years (N), and mean arrival date (Julian day) for each species are also included. Statistically significant phenological changes (days/year) are marked with an * ($P < 0.05$, two-tailed; parentheses indicate non-significance ($P > 0.05$) when adjusting for multiple testing with the sequential Bonferroni procedure; see Methods for details). Species for which we were able to include dates when at least five or ten individuals had arrived are indicated with $.

*Ændringer i forårsankomsten af 43 arter af trækfugle, bestemt ved lineær regression. En negativ hældningskoefficient angiver tidligere ankomst. Gennemsnitsændringer er angivet for kort- (a) og langdistancetrækfugle (b), samt samlet. Desuden indgår en skønnet trækafstand for hver art, prøvestørrelsen N (år), gennemsnitlig ankomstdato (i Julianske dage, hvor 1=1. januar) og standardafvigelsen på denne. Statistisk signifikante fænologiændringer (dage/år) er markeret med *; parentes angiver, at ændringen ikke er signifikant efter Bonferroni-korrektion for multiple tests.*

a **Short-distance migrants** *Kortdistancetrækfugle*	**Migration distance** *Trækafstand* **(km)**	**N (years)** *Antal år*	**Mean arrival date** *Ankomstdato (gn.snit)*	**Standard Deviation** *Standard-afvigelse*	**Slope (days/year)** *Hældnings-koefficient (dage/år)*	**P**	**r^2**
Northern Pintail *Anas acuta*	2500	15	60	16.7	0.033	0.934	0.001
Northern Showeler *Anas clypeata*	1500	34	73	15.7	-0.183	0.413	0.021
Marsh Harrier *Circus aeruginosus*	3000	41	92	13.0	-0.615*	0.000	0.375
Pied Avocet *Recurvirostra avosetta* ($)	2500	37	72	10.7	-0.311*	0.0002	0.323
Grey Plover *Pluvialis squatarola* ($)	1500	48	104	25.4	-0.810*	0.0001	0.539
Common Redshank *Tringa tetanus* ($)	2500	44	79	9.5	-0.180(*)	0.004	0.180
Spotted Redshank *Tringa erythropus* ($)	1500	53	105	16.7	-0.622*	0.0001	0.604
Bar-tailed Godwit *Limosa l. lapponica* ($)	1000	45	82	18.9	-0.530*	0.0001	0.474
White Wagtail *Motacilla alba*	2000	43	80	12.8	-0.653*	0.0001	0.502
Dunnock *Prunella modularis*	2000	39	79	13.7	-0.317	0.068	0.087
Black Redstart *Phoenicurus ochruros*	2000	34	94	13.7	-0.133	0.543	0.012
Song Thrush *Turdus philomelos*	2000	41	72	13.6	-0.230	0.176	0.046
Common Chiffchaff *Phylloscopus collybita*	2500	40	93	14.3	-0.684*	0.0001	0.387
Blackcap *Sylvia atricapilla*	3000	41	118	11.6	-0.439*	0.001	0.246
Common Chaffinch *Fringilla coelebs*	1500	29	71	11.6	-0.314	0.145	0.077
Brambling *Fringilla montifringilla*	1500	40	93	10.1	0.037	0.767	0.002
Common Linnet *Carduelis cannabina*	2500	35	81	13.0	-0.583(*)	0.002	0.258
Mean *Gennemsnit*					-0.384		
Standard error *Standardfejl*					0.062		

This indicates that birds fine-tune their life history traits in accordance with local environmental conditions, at least when it comes to migration (see also Tøttrup et al. 2010).

Meltofte (1987) and Thorup (1998) reported advanced spring arrival in several waterbird species at the wetland reserve of Tipperne in westernmost Denmark and speculated that warmer climate may have been the driving factor. In this study, we investigate the patterns in timing of spring arrival on Tipperne during a longer time period and relate these directly to climatic variables. Among these, spring temperatures have increased since the 1980s, while they were relatively stable before that (DMI 2009).

As opposed to previous works in Europe, this study deals with standardised long-term data on passerine and non-passerine species from a single study site covering eight decades in a multi-species approach.

Material and methods

This study presents an analysis of long-term standardised bird observations (1929-2008) from Tipperne, located in the brackish lagoon Ringkøbing Fjord (55°53′ N, 8°13′ E) on the west coast of Denmark. See Meltofte (1987), Thorup (1998) and Meltofte & Clausen (2011) for details on the area and the observation routines.

The study represents the longest available data set on migration phenology of birds in Denmark, including the arrival dates of the first individual (i.e. date of first observation) of 43 species of common migratory birds. Furthermore, for 13 species of waders and terns we were able to include the date when a minimum of five or ten individuals had arrived (see Table 1). Data were compiled from original logbooks (1929-1973), from annual reports (1974-1994), and from digital records (1995-2008). Arrival dates for

b **Long-distance migrants** *Langdistancetrækfugle*	**Migration distance** *Trækafstand* **(km)**	**N (years)** *Antal år*	**Mean arrival date** *Ankomstdato (gn.snit)*	**Standard Deviation** *Standard-afvigelse*	**Slope (days/year)** *Hældnings-koefficient (dage/år)*	**P**	**r^2**
Garganey *Anas querquedula*	6000	42	97	10.8	-0.054	0.670	0.005
Common Sandpiper *Actitis hypoleucos* ($)	6000	66	124	6.6	-0.144*	0.0001	0.290
Black-tailed Godwit *Limosa limosa* ($)	6000	45	77	9.5	-0.163(*)	0.006	0.161
Common Greenshank *Tringa nebularia*($)	6000	65	114	13	-0.453*	0.000	0.658
Whimbrel *Numenius phaeopus* ($)	6000	66	116	11.7	-0.136(*)	0.025	0.076
Ruff *Philomachus pugnax* ($)	6000	58	88	16.7	-0.523*	0.0001	0.596
Little Tern *Sternula albifrons* ($)	5500	55	125	11.1	-0.041	0.469	0.010
Sandwich Tern *Sterna sandwicensis* ($)	5500	59	101	8.8	-0.158*	0.001	0.180
Arctic Tern *Sterna paradisaea* ($)	18000	64	109	5.9	-0.084(*)	0.005	0.120
Common Cuckoo *Cuculus canorus*	6000	45	126	4.7	-0.097	0.054	0.084
Common Swift *Apus apus*	9000	35	134	6.6	-0.249(*)	0.012	0.177
Sand Martin *Riparia riparia*	6000	41	121	13.2	-0.289	0.076	0.078
Barn Swallow *Hirundo rustica*	6000	50	112	9.1	-0.293*	0.0001	0.354
House Martin *Delichon urbica*	6000	42	126	6.7	-0.098	0.210	0.039
Tree Pipit *Anthus trivialis*	6000	39	115	7.4	-0.181	0.065	0.089
Yellow Wagtail *Motacilla flava*	6000	46	113	7.2	-0.158(*)	0.014	0.130
Common Redstart *Phoenicurus phoenicurus*	6000	42	117	6.2	-0.003	0.969	0.000
Northern Wheatear *Oenanthe oenanthe*	6000	44	96	10	-0.308(*)	0.004	0.180
Whinchat *Saxicola rubetra*	6000	43	120	6.7	-0.210(*)	0.004	0.186
Sedge Warbler *Acrocephalus schoenobaenus*	6000	45	122	5.3	-0.156(*)	0.002	0.199
Eurasian Reed Warbler *Acrocephalus scirpaceus*	6000	39	133	7.3	0.188	0.058	0.094
Common Whitethroat *Sylvia communis*	6000	38	124	6.7	-0.198(*)	0.022	0.137
Garden Warbler *Sylvia borin*	6000	40	133	6.5	-0.071	0.401	0.019
Willow Warbler *Phylloscopus trochilus*	6000	42	112	6.4	-0.209(*)	0.003	0.200
Spotted Flycatcher *Muscicapa striata*	6000	41	134	7.4	-0.176(*)	0.027	0.119
European Pied Flycatcher *Ficedula hypoleuca*	6000	44	122	6.7	-0.174(*)	0.010	0.146
Mean *Gennemsnit*					-0.171		
Standard error *Standardfejl*					0.027		
Overall mean Samlet *gennemsnit*					-0.255		
Standard error *Standardfejl*					0.033		

passerines were available mainly from 1960 onwards. Onset of fieldwork varied until 1972 (range: January 1 to May 12), whereupon observers stayed throughout the year. However, no observations have been made during December-February since the winter 1997-1998. We found no significant trend in onset of fieldwork during the period 1929-1972 (slope = 0.06, $r^2 = 0.06$, P = 0.11).

To avoid any potential effect of different levels of effort over the years (onset of fieldwork period), we only included arrival dates that occurred at least two days after onset of fieldwork. Furthermore, arrival dates from years where individual species were reported as wintering, or only leaving the area temporarily, as well as periods with incomplete coverage were omitted. One effect of these restrictions was that arrival data for Northern Shoveler *Anas clypeata*, which has a very early arrival, were only included for 34 of the 80 years. First observations of Common/Arctic Tern *Sterna hirundo/paradisaea* were registered as Arctic Tern due to the earlier arrival of that species (Meltofte & Faldborg 1987) and hence, Common Tern phenology is not treated here.

Climate data covering the entire period are available on the national level only and were obtained from the online archives of the Danish Meteorological Institute (DMI 2009). We used averaged three-month daily mean temperature (°C) and sum of precipitations (mm). Correlation with temperature and precipitation was assessed for January-February-March for species with a mean arrival date prior to April 15, and February-March-April for species arriving later. We used the North Atlantic Oscillation index (NAO) for the winter period (December-March) (Hurrell et al. 2003, Hurrell 2010). The NAO is defined as the difference in sea-level pressure between the subtropical centre

Table 2. Effects of Year, migration Distance, Temperature, Precipitation and NAO on first arrival day of 43 species during 1929-2008. We applied a General Linear Model approach on first arrival day of all species (see Table 1), initially including all variables as well as 2- and 3-way interaction terms. Non-significant variables and interaction terms were eliminated from the full model by a backward elimination process, keeping lower-level terms in the model when variables were included in significant higher-level interaction terms.
Effekter af år, trækafstand, temperatur, nedbør og NAO på første ankomst af 43 arter på Tipperne i perioden 1929-2008. Den generelle lineære model er fremkommet ved baglæns eliminering af ikke-signifikante led, som udgangspunkt indeholdt modellen alle variabler År, Afstand, Temperatur, Nedbør og NAO med 2- og 3-vejs interaktioner.

Variables *Variabler*	**DF**	**Estimate** *Estimat*	**Standard error** *Standardfejl*	**Mean square** *Middel kvadratafvigelse*	**F**	**P**
Year *År*	1	-0.0358	0.0036	80.66	100.73	<0.0001
Distance *Afstand*	1	-0.000017	7.0E-06	4.50	5.61	0.0179
Temperature *Temperatur*	1	-4.82	1.08	15.80	19.73	<0.0001
Precipitation *Nedbør*	1	-0.619	0.180	9.43	11.77	0.0006
NAO	1	-0.0827	0.0133	31.18	38.94	<0.0001
Year*Temp *År*Temp*	1	0.00245	0.00055	15.92	19.88	<0.0001
Year*Precip *År*Nedbør*	1	0.00031	9.1E-05	9.32	11.64	0.0007

(Azores) of high surface pressure and the sub-arctic centre (Iceland) of low surface pressure. This large-scale hemispheric oscillation has consequences for regional climate in Europe, with high NAO winters being associated with mild and wet winters in NW Europe and low NAO resulting in cold and dry winters (Hurrell et al. 2003). Winter NAO is widely used in phenological studies as a proxy of overall spring conditions (Forchhammer et al. 2002, Gordo 2007) and usually has a high explanatory power (Hallett et al. 2004).

Grouping of species according to the main wintering area of the populations occurring in Denmark was based on Bønløkke et al. (2007). Estimates of migration distances were determined using Google Earth (ver. 4.3), classifying trans-Saharan migrants as long-distance migrants (26 species) and all other migrants as short-distance (17 species).

All data were converted to Julian day (where 1 = January 1), and we used simple linear regression to determine species-specific changes in arrival dates over time. Additionally, a multiple regression analysis was performed where species-specific migration distance and three climate variables (temperature, NAO and precipitation) were included as predictor variables in a full linear model (proc GLM in SAS 2003) including all 2-way and 3-way interaction terms among predictors. From the full model we performed backward elimination of non-significant terms at $\alpha > 0.05$ (single variables were retained if included in a significant interaction term). Furthermore, models were evaluated using Akaike's Information Criterion (AIC, Burnham & Anderson 2002) to determine the best models (25 models in total).

Finally, we tested whether using first-arriving individuals as a measure of overall population arrival may be affected by changes in population size (Sparks et al. 2001) in three species (Common Redshank *Tringa totanus*, Black-tailed Godwit *Limosa limosa*, Ruff *Philomachus pugnax*) by excluding a period of marked population increase (1976-1986: Meltofte 1987, Thorup 1998).

When performing multiple tests (i.e. trends for all species), we adjusted the significance level by incorporating the sequential Bonferroni procedure (Rice 1989). The test results are ranked by their P-value (P_i) and will remain significant only if P_i is less than $\alpha/(1+k-i)$, where k = number of tests (43), i = the test result's rank and α = significance level (0.05; i.e. for smallest P-value: $P_1 < 0.05/(1+43-1) = 0.0012$). All statistical tests were performed using SAS 9.1 (SAS 2003).

Results

We found evidence of an overall mean advance in first arrival of 0.26 days/year (S.E. = 0.033, 43 species) (Table 1). The advance was significant ($P < 0.05$) in 27 species, and highly significant ($P < 0.01$) in 22 of these. However, advances remained significant in 14 species only after adjusting for multiple tests. Significant advances ranged from 0.81 days/year (Grey Plover *Pluvialis squatarola*) to 0.084 days/year (Arctic Tern) (Table 1). Three species showed an opposite trend (delayed arrival), none of these being significant.

Short-distance migrants advanced their arrival on average 0.38 days/year (S.E. = 0.062, 17 species), while long-distance migrants advanced 0.17 days/year (S.E. = 0.027, 26 species) (Table 1).

We found an overall earlier arrival in passerines of 0.23 days/year (S.E. = 0.039, 24 species), similar to that of non-passerines (0.29 days/year, S.E. = 0.060, 19 species). Waders showed a mean advancement of 0.39 days/year (S.E. = 0.074, 10 species). None of the three species of ducks considered advanced their arrival significantly. The only raptor included, Marsh Harrier *Circus aeruginosus*, arrived 0.62 days/year earlier during the period.

In the multiple regression analysis, migration distance and the three climate variables significantly explained the timing of migration (Table 2). We repeated the above tests including data from 1970-2008 only and achieved similar results. The results were confirmed by the AIC approach showing that all climate variables were represented in the selected "best" models (ΔAIC < 2, Table 3), with Year and NAO being consistently present.

The estimates of mean advance of first arrival indicated that short-distance migrants overall had larger changes in arrival over time (see above). However, this could only tentatively be confirmed by the multiple regression analysis (Year × Distance interaction: P = 0.066), meaning that the interaction term was not included in the final model.

Arrival dates of the first five or ten individuals showed smaller advances (0.26 days/year, S.E. = 0.047) compared to first arrival day of the same 13 species (0.32 days/year, S.E. = 0.067) (see Table 1 for details). First arrival of Common Redshank, Black-tailed Godwit and Ruff (slope -0.28 days/year) could have been slightly affected by the marked increase and subsequent decline in breeding populations during 1975-1985 (see Thorup 1998 and Meltofte 1987), but similar results (-0.29 days/year) were obtained after omitting the period 1976-1986.

Table 3. AIC selected best models on effects of Year, migration Distance (Dist), Temperature (Temp), Precipitation (Pre) and NAO on first arrival day for the period 1929-2008 for all species and for specific species groups. ΔAIC is a measure of the difference between a given model and the best model; when ΔAIC < 2 models are considered as equally good.

Sammenligning af de AIC-valgte bedste modeller for effekterne af år (Year), afstand (Dist), temperatur (Temp), nedbør (Pre) og NAO på ankomstdatoen for alle arter og for udvalgte grupper. ΔAIC er et mål for forskellen mellem en given model og den bedste. Modeller med ΔAIC < 2 betragtes som lige gode.

Model	**Δ AIC**
All species	
Year Dist NAO	0
Year NAO	0.132
Year Temp NAO	0.932
Year Pre NAO	1.193
Non-passerines	
Year NAO	0
Year Temp NAO	1.028
Year Dist NAO	1.265
Year Pre NAO	1.840
Passerines	
Year Temp NAO	0
Waders	
Year NAO	0
Year Temp NAO	1.450
Year Pre NAO	1.829
Year Dist NAO	1.838
Short-distance migrants	
Year Dist NAO	0
Year NAO	1.638
Year Temp NAO	1.781
Long-distance migrants	
Year NAO	0
Year Pre NAO	0.139
Year Dist NAO	0.726
Year Temp NAO	0.837

Discussion

The clear pattern of earlier arrival by 0.26 days/year for the 43 species combined is indicative of general phenological changes on Tipperne. Earlier arrival was best explained by winter NAO, spring temperature and precipitation, and migration distance, which all have had strong effects on migrants, although these have responded differently in accordance with species-specific migration strategies (e.g. Hüppop & Hüppop 2003).

The advancement of the arrival of passerines on Tipperne (0.23 days/year) is very similar to the 0.26 days/year found for passerines on Christiansø in the Baltic Sea (Tøttrup et al. 2006), and similar to the 0.19 days/year for passerines on Helgoland in the North Sea (Hüppop & Hüppop 2003). The overall advancement found by using the arrival of the first five or ten individuals (0.26 days/year) was smaller than that of first-arrivals of the same species (0.32 days/year). Such a difference, suggesting that the use of first arrivals slightly overestimates the trend, was also reported by Tøttrup et al. (2006).

Temporal patterns within each group confirm that long-distance migrants advanced their arrival less than did short-distance migrants. Thus, Grey Plover, Bar-tailed Godwit *Limosa l. lapponica* (the subspecies wintering in Europe arriving first at Tipperne), Spotted Redshank *Tringa erythropus*, Marsh Harrier, White Wagtail *Motacilla alba*, Common Chiffchaff *Phylloscopus collybita* and Common Linnet *Carduelis cannabina* all advanced their arrival more than any of the long-distance migrants (Table 1). Similar results have been reported previously, cf. the reviews by Lehikoinen et al. (2004) and Gordo (2007). Species wintering in W or SW Europe have experienced progressively higher temperatures in the non-breeding season during large parts of the study period. Hence a general advancement in the phenology of plants and prey (Menzel et al. 2006) - changes that could well trigger an earlier onset of spring migration. We found significantly earlier arrival in 10 of 17 short-distance migrants.

The smaller advance in phenology of long-distance migrants may be caused by factors operating during migration, because local conditions *en route* probably affect migration more strongly than conditions in the wintering area (e.g. Ahola et al. 2004, Tøttrup et al. 2008). Factors directly influencing migration speed are wind and precipitation, affecting migrants by interrupting, delaying, redirecting or speeding up migration (Berthold 2001). Stronger effects of climate change in northern latitudes (IPCC 2010) suggest an increasing need for adjusting the timing of migration *en route* during long-distance migration, e.g. by more rapid migration through Europe when conditions are favourable, as shown by Ahola et al. (2004) and Tøttrup et al. (2008). However, conditions in the non-breeding area may also influence timing of migration (e.g. Studds et al. 2008).

Long-term population declines throughout the last decades have been shown in many of the species included in this study, and especially in long-distance migrants (Sanderson et al. 2006, Heldbjerg & Fox 2008). However, we found no indication that population fluctuations affected trends in spring arrival, which is in agreement with Tøttrup et al. (2006), who found no influence of population trends on overall arrival patterns.

Both the backward elimination approach and the AIC selected best models provide evidence that environmental conditions prior to arrival explain a large part of the changes seen in spring migration phenology. Hence, NAO was consistently present among the best predictors of dates of arrival, which may explain why the birds arrived progressively earlier on Tipperne even before spring temperatures in Denmark began to increase in the 1980s. In Lithuania, Parmesan (2007) found high inter-specific variability in responses to climate, which is in agreement with the present results, showing species-specific changes in first-arrival dates ranging from a non-significant delay to a strong and highly significant advancement. As emphasized by Gordo (2007), single-site and local-scale meteorological data may not be representative of the conditions that avian migrants experience *en route* and may therefore not be the best predictors of migration phenology (but see Tøttrup et al. 2010). Short-distance migrants are affected by NAO throughout the year, even in their wintering areas (cf. e.g. Hüppop & Hüppop 2003), whereas long-distance migrants are directly affected during the European part of their migration only. However, in this study NAO was an equally strong predictor of spring arrival in both long-distance and short-distance migrants.

The non-breeding ranges of European birds are expected to shift northwards (Huntley et al. 2008, Visser et al. 2009), potentially leading to advanced arrival to breeding areas even with unchanged date of departure from the non-breeding area (Coppack & Both 2002). Bønløkke et al. (2007) and Kam et al. (2004) report that Bar-tailed Godwit (ssp. *lapponica*) now winters around the North Sea. In general, shortening of spring migration distances could potentially explain the strongly advanced arrival presented in the present study.

In turn, our overall results shed light on differences between short-distance and long-distance migrants in their adaptation to climate change with the first group responding to a larger degree compared to the latter. This could indicate that long-distance migrants adapt more slowly, resulting in shorter time for breeding and potentially mistimed breeding in this group. Overall, such changes would lead to a change in degree of inter-specific competition which should be considered in future conservation of migratory birds.

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Resumé

Tidligere ankomst af trækfugle på Tipperne 1929-2008
Det seneste tiårs studier af trækfuglefænologi har bidraget til forståelsen af klimaforandringers påvirkning af fugletrækket, og mange studier har påvist tilpasning i form af trækfugles tidligere ankomst til yngleområderne. De fleste

Klyderne ankommer nu mere end tre uger tidligere til Tipperne end de gjorde omkring 1930. Foto: Ulrik Bruun.

fænologistudier har imidlertid fokuseret på få arter – oftest spurvefugle – over perioder på 30-40 år. Yderligere indsigt i trækfugles tilpasning til klimaforandringer må nødvendigvis baseres på flere og taksonomisk mere forskellige arter, studeret over længere perioder på samme lokalitet.

I nærværende undersøgelse har vi analyseret ændringer i forårsankomsterne hos 43 fennoskandinaviske ynglefugle tilhørende forskellige taksonomiske grupper (Tabel 1) på baggrund af 80 års standardiserede observationer på Tipperne i Vestjylland.

Vi har ved hjælp af regressionsanalyser sammenholdt fænologimønstre med variationer i klimavariablerne temperatur, nedbør og den nordatlantiske oscillation (NAO). NAO er et mål for trykforskellen mellem luftmasserne ved Island og Azorerne og anvendes som indeks for vinterklimaet omkring Nordatlanten. Samlet set har trækfuglene på Tipperne fremrykket forårsankomsten med i gennemsnit 0.26 dage/år (Tabel 1), svarende til tre uger i løbet af den 80 år lange periode. Kortdistancetrækfuglene ankommer 0.38 dage/år tidligere (Tabel 1a), mens langdistancetrækfuglene blot har fremrykket ankomsten med 0.17 dage/år (Tabel 1b). Der er ingen signifikante forskelle mellem spurvefugle og ikke-spurvefugle.

Ved analyser på ankomsten af de første fem henholdsvis ti individer hos 13 udvalgte arter fandt vi samme fremrykning af ankomstdatoen (0.26 dage/år).

En multipel regressionsanalyse af ankomsten af alle arter viser, at ankomsten påvirkes signifikant af både NAO, temperatur og nedbør (Tabel 2). En udvælgelse af forklarende variable baseret på Akaike's Information Criterion viser, at NAO er den klimavariabel, der hyppigst optræder i de "bedste" modeller for forskellige fuglegrupper, men også temperatur, nedbør og trækafstand indgår i modellerne (Tabel 3).

Forårstemperaturens indvirkning på trækfuglefænologi, samt forskellen i tilpasningsevnen mellem kort- og langdistancetrækfugle, antyder, at der kan opstå konkurrencemæssige fordele for arter som overvintrer tættere på yngleområdet. Denne viden er vigtig i et bevaringsbiologisk perspektiv i en periode med stigende temperaturer.

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