Spring migration of birds in relation to North Atlantic Oscillation

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A b s t r a c t. Long-term spring phenological instants of 57 migratory bird species, i.e. arrival in summer visitors and departure in winter visitors, were recorded in South Moravia (Czech Republic) from 1952 through 2001 and evaluated for annual correspondence with the North Atlantic Oscillation (NAO) weather system. The migration instants occurred significantly earlier following positive winter/spring NAO index values (causing periods warmer than normal in Europe) in a number of short-distance migrants with a European winter range (e.g., *Alauda arvensis, Columba palumbus, Corvus frugilegus, Motacilla alba, Phoenicurus ochruros, Phylloscopus collybita, Serinus serinus, Sturnus vulgaris, Vanellus vanellus*), whereas they did not correlate with NAO in most long-distance migrants having a sub-Saharan winter range (e.g., *Acrocephalus* spp., *Anthus trivialis*, *Apus apus*, *Cuculus canorus*, *Delichon urbica*, *Ficedula albicollis*, *Hippolais icterina*, *Hirundo rustica, Jynx torquilla*, *Lanius collurio*, *Locustella* spp., *Muscicapa striata*, *Oriolus oriolus*, *Phylloscopus sibilatrix*, *Riparia riparia*, *Streptopelia turtur, Sylvia* spp.). The winter/spring (especially February and March) NAO conditions thus affect the migration timing of short-distance migrants that winter in western or southern Europe, and could explain their earlier than normal arrival that had been observed in Europe since the 1980s.

Key words: phenology, migration, weather, climate, temperature, NAO

Introduction

Recent climate warming is often regarded as the cause of the advanced spring arrival and egg-laying dates of migratory birds that has been recorded in Europe and North America since the 1980's (e.g., F o r c h h a m m e r et al. 1998, W i n k l e r et al. 1999, B o t h & V i s s e r 2001, S o k o l o v 2001, Z a l a k e v i c i u s & Z a l a k e v i c i u t e 2001). An approach to test this hypothesis could be to evaluate whether the bird arrival data correlate with some global measure of the weather/climate change. It has been demonstrated that El Nińo/Southern Oscillation (ENSO) system of ocean and atmosphere circulation in the tropical Pacific affects the biota in the Americas, Australia, southern Asia and eastern Africa either directly, through extreme precipitation or temperature, or indirectly, through ecosystem changes (J a c o b s et al. 1994, K a r l et al. 1995, S i l l e t t et al. 2000, N o t t et al. 2002, S t e n s e t h et al. 2002). Another major mode of the world climate variability is the North Atlantic Oscillation (NAO) that profoundly affects the weather in continental Europe and eastern North America (W a l l a c e & G u t z l e r 1981, B a r n s t o n & L i v e z e y 1987, H u r r e l l 1995, Y o o & D ' O d o r i c o 2002). The NAO system can be expressed quantitatively using simple monthly, seasonal or annual indices that make a correlation analysis possible and relatively easy. A number of papers have reported a correspondence between the NAO fluctuation and plant phenology (P o s t & S t e n s e t h 1999, C h m i e l e w s k i & R o t z e r 2001, P o s t et al. 2001), cephalopod migration (S i m s et al. 2001), marine fish migration (A l h e i t & H a g e n 1997, R e i d et al. 2001),

mammalian population dynamics (P o s t & S t e n s e t h 1999, T k a d l e c 2000, P o s t & F o r c h h a m m e r 2002, S t e n s e t h et al. 2002) or the avian breeding phenology and productivity (F o r c h h a m m e r et al. 1998, P r z y b y l o et al. 2000, S a e t h e r et al. 2000, B o t h & V i s s e r 2001, S o k o l o v 2001, M ø l l e r 2002, N o t t et al. 2002, S a n z 2002). However, the effect of NAO on the variability of bird migration instants in Europe has not been studied until very recently (F o r c h h a m m e r et al. 2002, J o n z é n et al. 2002, T r y j a n o w s k i et al. 2002, H ü p p o p & H ü p p o p 2003).

Material and Methods

S t u d y   a r e a

Observations of birds were carried out in the Břeclav area (48°40'–48°50'N, 16°30'–17°00'E) of South Moravia, Czech Republic. The relief is a mostly flat to slightly undulating lowland (150 to 200 m a.s.l.), formed largely by accumulations of Pleistocene loess and riverine sand deposits on Pliocene sedimentaries. The climate is relatively dry and warm (annual precipitation 550 mm; annual mean air temperature 9.5 °C (January -1.8 °C, July 19.1 °C). There are agroecosystems (mostly arable fields), forest ecosystems (floodplain forests, subxerophilic mixed deciduous oak stands), fishponds and big water reservoirs (Nové Mlýny) in the wider area. Local community is composed of about 150 species of breeding terrestrial and water birds (H á j e k 1992, Š ť a s t n ý et al. 1996, H u b á l e k 1997, Z u n a - K r a t k y et al. 2000), and many migrants use the area for stopovers.

B i r d   p h e n o l o g y   d a t a

Longitudinal records of migratory birds were documented from 1969 through 2001. Spring phenological instants recorded for each species involved the first occurrence (spring arrival) in summer visitors, and the last occurrence (spring departure) in winter visitors. In addition to the author's observations, data of H á j e k (1992) were used for the years 1952 to 1969. Total length of the period thus covered 50 years (1952–2001), and 57 common bird species with a distinct pattern of spring phenology and a sufficient number of annual records were selected for the correlation and regression analysis.

N o r t h   A t l a n t i c   O s c i l l a t i o n   d a t a

Monthly (January; February; March; April) and seasonal (December to March, DJFM; January to March, JFM; February to April, FMA) NAO indices for particular years 1952 through 2001 were extracted from the Internet at http://www.cgd.ucar.edu/~jhurrell/nao.html (H u r r e l l 1995: NAO_H) and http://www.cpc.ncep.noaa.gov/data/teledoc/nao.html (B a r n s t o n & L i v e z e y 1987: NAO_{BL}; W a l l a c e & G u t z l e r 1981: NAO_{EA}, the East Atlantic Pattern). The indices are based on normalized sea-level pressure differences between two points or areas: (1) Ponta Delgada (Azores) and Stykkisholmur/Reykjavik (Iceland) in the eastern sector of North Atlantic (NAO_H); (2) the central latitudes (35°N–40°N) and Greenland (NAO_{BL}, reflecting thus spatially a more broad-scale atmospheric pressure pattern in the western North Atlantic sector); and (3) NAO_{EA} covers the eastern North Atlantic sector. The positive NAO index generally shows that the atmospheric pressure over the subtropical part of the North Atlantic is higher than normal while that over

the northern sector of the North Atlantic is lower than normal; this increased pressure difference between the two sectors results in more and stronger storms crossing the Atlantic Ocean and, in turn, causing warm and wet weather (especially in winter) in northern and central Europe. The negative NAO index reflects an opposite pattern of height and pressure anomalies over these sectors; this reduced pressure gradient results in fewer and weaker storms crossing the Ocean, bringing cold air to northern (and central) Europe and moist, often cold air into the Mediterranean (H u r r e 11 1995).

Statistical analysis

Calendar data of phenological instants were transformed into sequential numbers (e.g., 1 for 1st January, 32 for 1st February, 60 for 1st March, 91 for 1st April, 121 for 1st May 1; in leap-years, the sequential numbers were corrected by adding 1, starting from 1st March). Linear correlation and regression models were then used to examine relationships between avian spring phenological instants of particular bird species and the three NAO indices (NAO_H, NAO_{BL}, NAO_{EA}); Pearson's correlation coefficient values were calculated and statistical test done for all comparisons using SOLO 4.0 (BMDP Statistical Software, Los Angeles, CA).

Results

The late-winter and early-spring NAO weather system conditions affected significantly the spring arrival (in summer visitors) or departure (in winter visitors) instants of some bird species (Tables 1 and 2, Fig. 1). The species significantly inversely correlated with both the 'JFM' and 'FMA' seasonal NAO indices (i.e., the phenological instants occurred earlier following the January-February-March and February-March-April seasonal air pressure difference in the North Atlantic higher than normal) were *Alauda arvensis, Anas crecca, Aythya ferina, Bucephala clangula, Columba palumbus, Corvus frugilegus, Gallinago gallinago, Mergus merganser, Motacilla alba, Phoenicurus ochruros, Phylloscopus collybita, P. trochilus, Pyrrhula pyrrhula, Regulus regulus, Remiz pendulinus, Saxicola torquata, Serinus serinus, Sterna hirundo, Sturnus vulgaris, Sylvia atricapilla, Tringa glareola, Turdus philomelos* and *Vanellus vanellus.* In some species, there was a single statistically significant seasonal (either 'JFM' or 'FMA') NAO index (*Acrocephalus scirpaceus, Anas querquedula, Charadrius dubius, Hirundo rustica, Luscinia megarhynchos, Phylloscopus sibilatrix, Streptopelia turtur, Sylvia communis, Tringa nebularia, T. totanus*), whereas the remaining species did not correlate with NAO at $p<0.05$: *Acrocephalus arundinaceus*, *A. palustris*, *A. schoenobaenus*, *Actitis hypoleucos*, *Anthus trivialis*, *Apus apus*, *Cuculus canorus*, *Delichon urbica*, *Ficedula albicollis*, *Hippolais icterina*, *Jynx torquilla*, *Lanius collurio*, *Locustella fluviatilis*, *L. luscinioides*, *L. naevia*, *Motacilla flava*, *Muscicapa striata*, *Nycticorax nycticorax*, *Oriolus oriolus*, *Riparia riparia*, *Sylvia borin*, *S. curruca*, *S. nisoria* and *Upupa epops*.

The winter NAO_H index (DJFM data, not given in Table 1) correlated significantly ($p<0.01$) with phenological instants of *Columba palumbus* (-0.45), *Mergus merganser* (-0.68), *Phylloscopus collybita* (-0.49)*, Sturnus vulgaris* (-0.44), *Tringa nebularia* (-0.51) and *Vanellus vanellus* (-0.40). According to monthly NAO indices (data not given in Table 1), the number of avian species significantly ($p<0.05$) correlated in their phenology with NAO_H/NAO_{EA} during January, February, March and April were 8/8, 12/12, 9/13 and 3/3, respectively. Therefore, the NAO conditions especially in February and March have

Spring phenology instants of 57 migratory bird species in South Moravia, 1952–2001, with the number of years (n), the mean date of arrival or departure (mm/dd), principal wintering area (W), and Pearson's correlation coefficient value (r) between the avian phenology data and the mean seasonal indices (JFM, January to March; FMA, February to April) of NAO_H (H), NAO_{BL} (BL) and NAO_{EA} (EA); r values in bold are significant ($p<0.05$). The bird species are arranged according to the mean arrival/departure date.

Bird species	n	Mean date	W	JFM			FMA		
				H	BL	EA	H	BL	EA
Alauda arvensis [A]	49	02/28	E	-.16	-.09	**-.47**	**-.35**	-.19	**-.31**
Sturnus vulgaris [A]	50	03/01	E	**-.51**	**-.44**	**-.43**	**-.53**	**-.45**	-.28
Mergus merganser [D]	18	03/05	E	**-.61**	**-.60**	**-.47**	**-.59**	**-.54**	-.33
Turdus philomelos [A]	39	03/08	E	+.06	+.25	**-.33**	-.06	+.15	**-.44**
Corvus frugilegus [D1/2]	35	03/09	E	**-.52**	**-.41**	**-.62**	**-.55**	**-.38**	**-.54**
Motacilla alba [A]	47	03/10	E	-.11	-.08	**-.42**	**-.31**	-.22	**-.45**
Vanellus vanellus [A]	47	03/11	E	**-.34**	-.28	**-.39**	**-.42**	-.27	**-.29**
Aythya ferina [A]	24	03/12	E	**-.46**	**-.45**	**-.50**	**-.42**	-.40	**-.42**
Anas crecca [A]	23	03/15	E	**-.42**	**-.51**	**-.52**	**-.42**	**-.51**	-.34
Pyrrhula pyrrhula [D]	27	03/19	E	-.14	-.15	**-.39**	-.18	-.27	**-.52**
Bucephala clangula [D]	30	03/20	E	-.10	-.20	**-.52**	-.26	-.21	**-.57**
Columba palumbus [A]	38	03/23	E	**-.55**	**-.55**	**-.38**	**-.58**	**-.56**	-.19
Phylloscopus collybita [A]	36	03/23	E	**-.60**	**-.52**	**-.40**	**-.54**	**-.44**	-.20
Phoenicurus ochruros [A]	38	03/24	E	**-.38**	**-.33**	**-.54**	**-.34**	**-.32**	**-.42**
Saxicola torquata [A]	35	03/24	E	**-.46**	**-.40**	-.02	**-.47**	**-.46**	+.14
Regulus regulus [D]	23	03/26	E	**-.44**	**-.55**	-.26	**-.49**	**-.62**	-.21
Anas querquedula [A]	29	03/26	A	-.28	-.30	**-.36**	-.19	-.22	-.23
Gallinago gallinago [A]	26	03/26	E	**-.56**	**-.48**	-.29	**-.43**	-.30	+.04
Serinus serinus [A]	38	03/30	E	**-.44**	**-.36**	-.23	**-.34**	-.29	-.06
Remiz pendulinus [A]	37	03/30	E	**-.38**	-.26	**-.58**	**-.49**	**-.39**	**-.41**
Tringa totanus [A]	27	04/01	E	**-.46**	**-.39**	-.33	-.24	-.27	-.13
Sylvia atricapilla [A]	33	04/03	E	-.12	-.15	**-.53**	-.10	-.24	**-.56**
Phylloscopus trochilus [A]	37	04/06	A	-.18	-.19	**-.44**	-.20	-.25	**-.42**
Hirundo rustica [A]	46	04/09	A	-.17	-.26	-.03	-.20	**-.34**	-.01
Charadrius dubius [A]	33	04/10	E	**-.48**	**-.38**	-.07	-.15	-.25	+.11
Anthus trivialis [A]	45	04/12	A	+.18	+.08	+.13	+.11	+.07	-.11
Motacilla flava [A]	35	04/12	A	-.30	-.15	-.12	-.19	-.24	+.13
Jynx torquilla [A]	42	04/13	A	-.08	-.16	-.12	-.15	-.07	-.29
Nycticorax nycticorax [A]	18	04/13	A	-.34	-.23	-.22	-.21	-.21	-.15
Upupa epops [A]	38	04/14	A	-.21	-.12	-.31	-.13	-.14	-.27
Sylvia curruca [A]	44	04/15	A	-.12	-.03	-.14	-.05	+.09	-.03
Ficedula albicollis [A]	45	04/16	A	+.10	+.17	-.03	+.15	+.13	-.08
Acrocephalus schoenobaenus [A]	32	04/19	A	-.26	-.13	-.07	-.17	-.25	+.03
Actitis hypoleucos [A]	41	04/20	A	-.00	-.02	-.13	-.08	-.17	-.26
Delichon urbica [A]	40	04/21	A	+.24	+.23	+.06	+.29	+.13	+.17
Phylloscopus sibilatrix [A]	30	04/21	A	+.00	-.06	**-.36**	+.14	+.01	**-.41**
Cuculus canorus [A]	50	04/22	A	-.13	-.21	-.14	-.09	-.23	-.10
Luscinia megarhynchos [A]	39	04/23	A	**-.36**	-.31	+.02	-.26	-.23	+.24
Tringa nebularia [A]	29	04/23	E	**-.45**	**-.42**	**-.56**	-.27	-.30	-.23
Locustella luscinioides [A]	28	04/24	A	-.16	-.23	-.06	-.30	-.37	-.14
Streptopelia turtur [A]	34	04/24	A	-.22	-.25	**-.39**	-.08	-.18	-.23
Sylvia communis [A]	44	04/24	A	**-.33**	**-.33**	-.12	-.26	-.21	-.04
Riparia riparia [A]	23	04/25	A	-.13	+.13	-.28	+.08	+.12	-.35
Tringa glareola [A]	31	04/26	E	**-.39**	-.33	-.21	**-.45**	-.33	+.03
Sterna hirundo [A]	29	04/27	E	**-.43**	**-.52**	-.01	**-.53**	**-.36**	+.01

Table 1 – continued.

|										
Sylvia borin [A]	37	04/29	A	-.26	-.29	-.11	-.19	-.20	-.04	
Apus apus [A]	37	04/29	A	-.17	-.20	.25	-.12	-.01	-.27	
Acrocephalus arundinaceus [A]	31	04/30	A	+.24	+.20	-.02	+.10	+.03	-.12	
Acrocephalus scirpaceus [A]	22	05/02	A	-.34	**-.44**	-.20	**-.45**	**-.45**	-.06	
Locustella naevia [A]	26	05/04	A	-.12	-.21	-.03	+.03	-.04	+.01	
Oriolus oriolus [A]	42	05/05	A	+.12	+.15	-.08	+.13	+.17	-.15	
Hippolais icterina [A]	44	05/07	A	-.04	-.07	+.15	+.07	+.08	+.14	
Locustella fluviatilis [A]	29	05/07	A	+.23	+.26	-.03	+.16	+.25	-.13	
Muscicapa striata [A]	33	05/07	A	+.08	-.07	-.03	+.06	-.02	-.12	
Sylvia nisoria [A]	41	05/07	A	-.05	+.05	-.12	-.04	-.02	-.10	
Lanius collurio [A]	31	05/09	A	+.01	-.16	-.06	-.15	-.22	-.10	
Acrocephalus palustris [A]	24	05/10	A	+.05	-.10	-.03	-.38	-.38	-.24	

[A] arrival of the first bird; [D] departure (the last observed bird in the spring); [D1/2] departure of about half of the wintering population. Principal wintering area (W): E, southern, western or central Europe, Mediterranean; A, sub-Saharan Africa (or southwestern Asia).

Table 2. Regression ($y = a + b.x$) of 18 selected bird species on seasonal NAO index (see Fig. 1).

Bird species	W	NAO index		Regression slope (*b*)	Intercept (*a*)	R^2
		Type	Season			
Alauda arvensis	E	EA	JFM	-8.5757***	58.71	0.216
Sturnus vulgaris	E	H	JFM	-2.4273***	60.26	0.261
Corvus frugilegus	E	H	JFM	-1.4594**	69.87	0.275
Columba palumbus	E	H	JFM	-2.8513***	83.05	0.308
Phoenicurus ochruros	E	EA	JFM	-5.7958***	83.44	0.306
Remiz pendulinus	E	EA	JFM	-8.5900***	89.97	0.338
Phylloscopus collybita	E	H	JFM	-2.2751***	84.23	0.356
Phylloscopus sibilatrix	A	H	JFM	+0.0008	111.31	0.000
Sylvia atricapilla	E	EA	JFM	-4.9794**	93.40	0.282
Sylvia curruca	A	EA	JFM	-1.1621	105.36	0.018
Charadrius dubius	E	H	JFM	-2.4511**	100.26	0.231
Actitis hypoleucos	A	H	JFM	-0.0652	110.08	0.000
Hirundo rustica	A	EA	JFM	-0.7587	99.47	0.006
Delichon urbica	A	EA	JFM	+0.2758	111.03	0.001
Ficedula albicollis	A	H	JFM	+0.2707	105.87	0.011
Muscicapa striata	A	H	JFM	+0.1748	127.38	0.006
Hippolais icterina	A	H	FMA	+0.2002	127.19	0.004
Cuculus canorus	A	H	FMA	-0.2552	112.19	0.009

W, principal wintering area. NAO index type: EA, NAO_{EA}; H, NAO_H). Other abbrevations as for Table 1. **, significant at $p<0.01$; ***, significant at $p<0.001$.

a profound effect on many early-spring migrants that usually winter in western or southern Europe (Mediterranean). On the other hand, NAO does not seem to affect significantly the timing of long-distance migrants arriving in Central Europe later, having wintering grounds largely in sub-Saharan Africa. The seasonal (JFM) NAO_H index explained on the average 18% (range 1–37%) variability in the phenological instants of the 25 short-distance migrants, whereas only 4% (range, 0–13%) variability in the 32 long-distance migrants; the difference between the two categories of migratory birds is highly significant ($p<0.001$) as found with either t-test or nonparametric Mann-Whitney two-sample test.
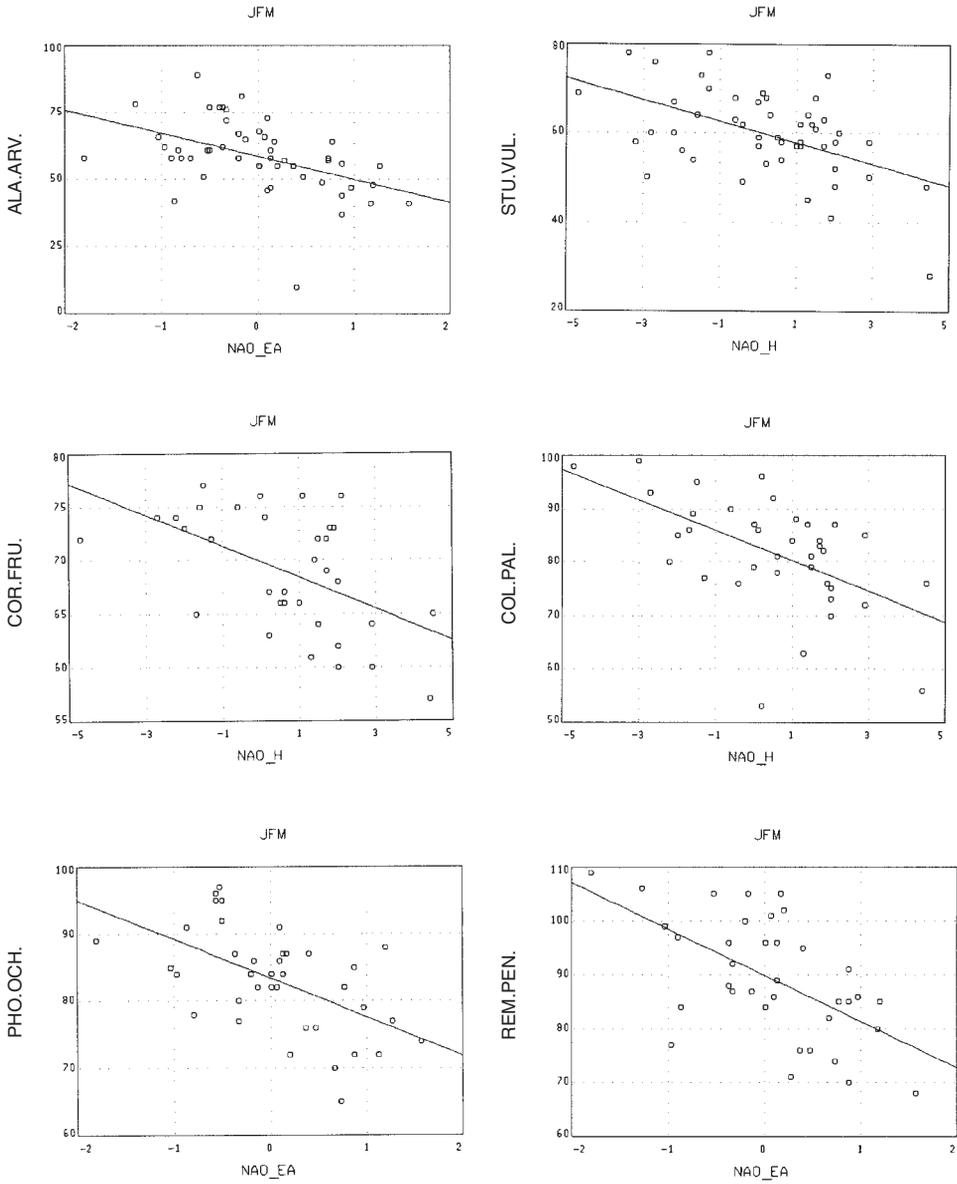
Fig. 1. Scatter plot diagrams of relations between seasonal (JFM or FMA) NAO indices (NAO$_H$ or NAO$_{EA}$) and spring migration instants in 18 selected bird species (acronymes) in South Moravia, 1952–2001. Y-axis shows calendar data of the phenological instants transformed into sequential numbers. For the regression analysis, see Table 2.
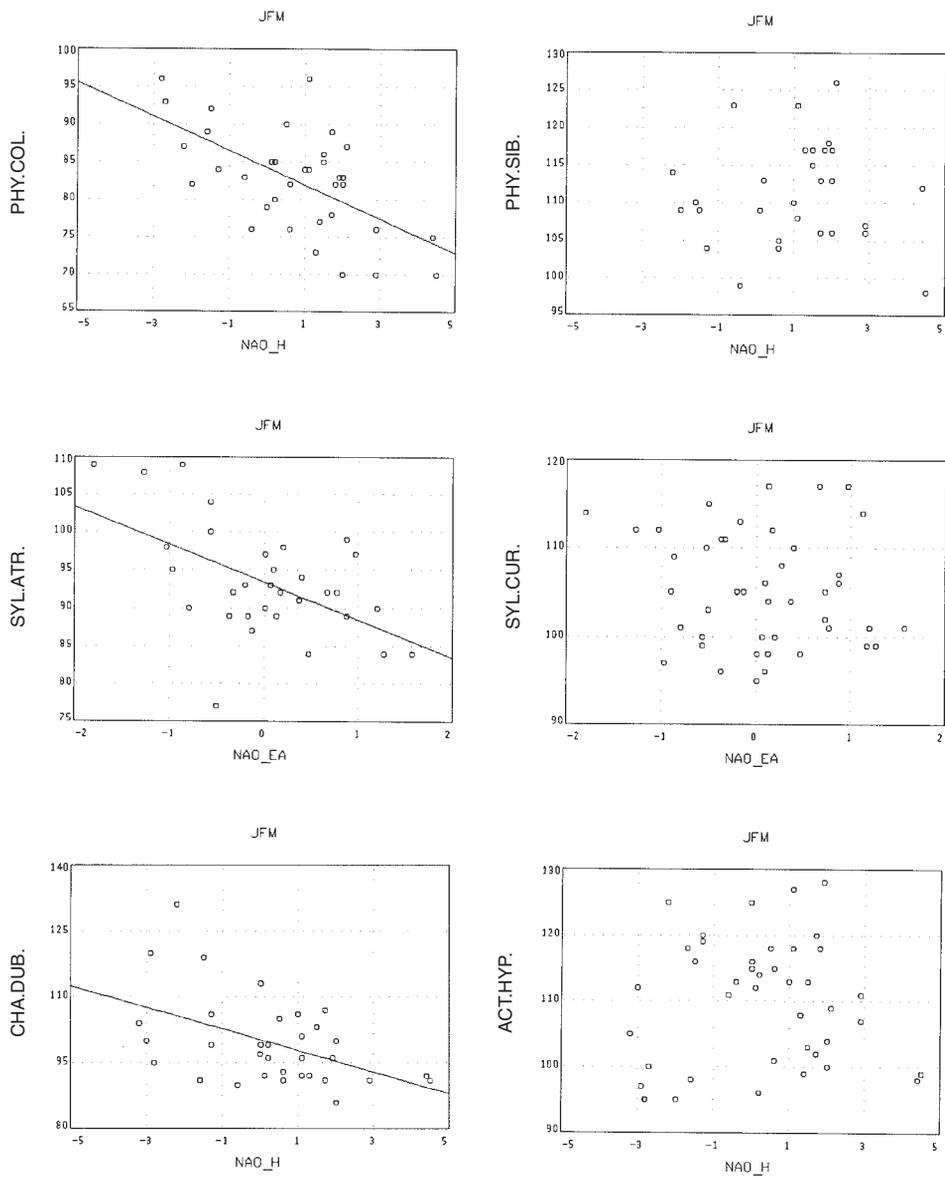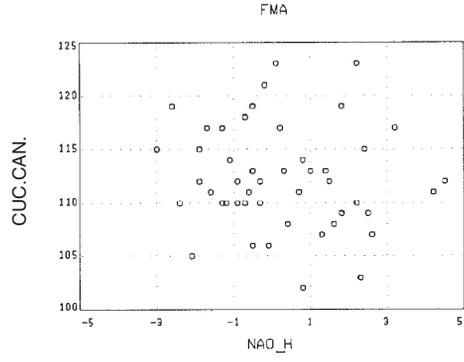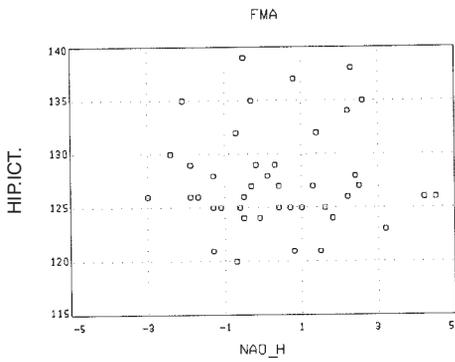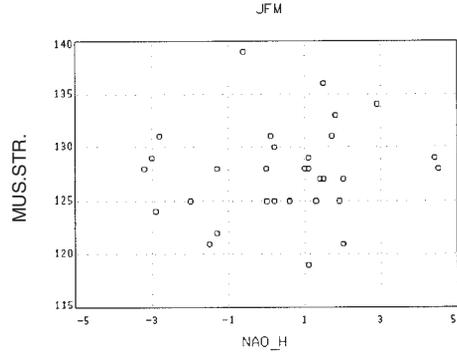
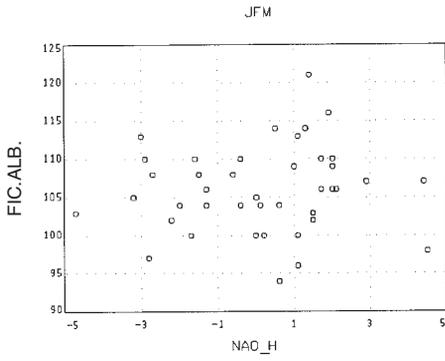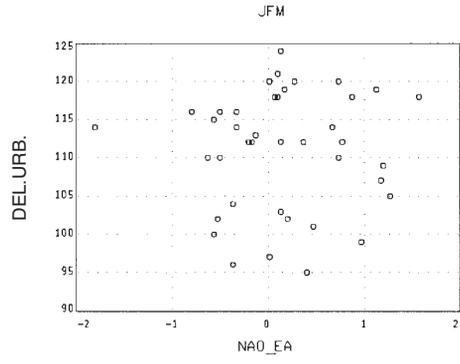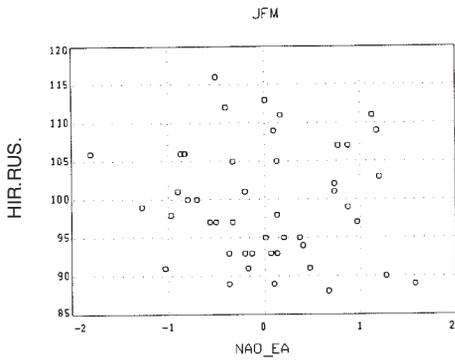**Fig. 1** – continued.

Fig. 1 – continued.

Discussion

T r y j a n o w s k i & S p a r k s (2001) suggested that the relationship between arrival date and population size should be considered in particular bird species: an increasing population of *Lanius collurio* showed an advanced arrival in western Poland during 1983–2000. In the present study, usually common and abundant avian species were taken into account whose population sizes did not change considerably with time. The exceptions with the population steadily low (l), on decline (d) or increasing (i) were *Acrocephalus* spp. (d), *Anas* spp. (d), *Ficedula albicollis* (i), *Gallinago gallinago* (d), *Lanius collurio* (i), *Motacilla flava* (d), *Nycticorax nycticorax* (l), *Sylvia nisoria* (l), *Tringa nebularia* (l), *T. totanus* (d), *Upupa epops* (d) and *Vanellus vanellus* (d) (H á j e k 1992, Š ť a s t n ý et al. 1996, H u b á l e k 1997, etc.). However, the results yielded in these species do not seem to contradict the general conclusion that long-distance migrants are not affected significantly with the NAO activity, in contrast to short-distance migratory species.

The positive NAO index values mean generally a stronger than usual subtropical high pressure center and a deeper than usual subarctic atmospheric low. The increased pressure difference causes intense atmospheric mass circulation resulting in more winter storms crossing the Atlantic Ocean on a more northerly track, a milder winter and the whole year in Europe, and specifically a warmer (but drier) than normal weather over central Europe (H u r r e l l 1995). For the Czech Republic, a significant correlation was found between the winter (DJFM) NAO_H index and local winter air temperature ($r = 0.78$), but that between this index and winter precipitation ($r = -0.30$) was insignificant (T k a d l e c 2000). The milder temperatures associated with the positive NAO phase lead to higher invertebrate loads in spring which might benefit short-distance migrants more than long-distance migratory species (N o t t et al. 2002).

Three indices that characterize NAO were used in this study. Although NAO_H and NAO_{BL} correlated well (r value for JFM season was 0.87), NAO_{BL} seemed to be less sensitive in the phenology of European migratory birds (in terms of the number of significant correlations with avian species) than NAO_H, probably because it describes weather conditions in the western sector of the North Atlantic and may thus be more relevant for the North American continent than for Europe. The eastern Atlantic measures NAO_H and NAO_{EA} were comparable in their phenological sensitivity although they did not correlate well (r value for JFM season was very low, 0.17): in contrast to NAO_H, NAO_{EA} revealed a marked correspondence between NAO activity and phenological instants in *Alauda arvensis, Bucephala clangula, Motacilla alba, Pyrrhula pyrrhula, Sylvia atricapilla* and *Turdus philomelos*, whereas NAO_H, contrary to NAO_{EA}, yielded significant correlations with phenological data of *Charadrius dubius, Gallinago gallinago, Larus ridibundus, Regulus regulus, Saxicola torquata, Serinus serinus, Sterna hirundo*, *Tringa totanus* and *T. glareola*. At present, it is difficult to evaluate which of the two indices is better for the use in the European phenology; they might be used as complementary measures.

In an earlier study, a cluster analysis of temporal spring migration patterns of birds in Moravia between 1881 and 1960 revealed several groups (called 'migrons') of co-related avian species: the first ('Mediterranean') migron consisted almost exclusively of short-distance migrants wintering in southern or western Europe (*Alauda arvensis, Sturnus vulgaris, Fringilla coelebs, Columba palumbus, Motacilla alba, Vanellus vanellus, Turdus philomelos, Erithacus rubecula, Scolopax rusticola*), whereas the remaining migrons had been called 'African' in that they involved long-distance migrants *Hirundo rustica, Jynx*

torquilla, Delichon urbica, Cuculus canorus, Luscinia megarhynchos, Streptopelia turtur, Apus apus, Oriolus oriolus and *Coturnix coturnix*, i.e. species having their winter quarters in sub-Saharan Africa (H u b á l e k 1985). In the present study, the seasonal winter/spring NAO index did not correlate significantly with the arrival of a vast majority of long-distance migratory bird species wintering in tropical and southern Africa (only 2 of 32 those species tested revealed significant both 'JFM' and 'FMA' seasonal measures). Timing of their departure from the winter grounds must therefore be based on principles other than the weather system fluctuation at northern latitudes. However, significant inverse relationship was found between the arrival of nearly all (22) short-distance migrants wintering in western and southern Europe (25 species tested) and the seasonal winter/spring NAO index, indicating that a higher than normal air pressure difference over the North Atlantic during the winter/spring (especially in February and March) determines an earlier than normal arrival of these birds in Central Europe. This result is not in accord with a very recently published study of F o r c h h a m m e r et al. (2002), who found no significant difference in the effect of NAO on spring arrival between long-distance and short-distance migrants (but only three species of each group were tested) breeding in Norway, although it corresponds well with the results of N o t t et al. (2002).

Positive values of the winter NAO index prevailed in 11 out of 15 years between 1987 and 2001 (H u r r e l l 1995), as did the bird phenological data in South Moravia during the same period: earlier than normal early-spring bird instants occurred in 12 out of 15 years, whereas those markedly later than normal in one year only (H u b á l e k 1997, H u d e c et al. 1999, unpublished data for 1998–2001). The present study revealed that the NAO weather system affects spring phenological instants in a number of bird species and that this effect could explain the earlier than normal arrival of common migratory species (e.g., *Alauda arvensis, Sturnus vulgaris, Vanellus vanellus*, *Columba palumbus, Motacilla alba, Phoenicurus ochruros, Phylloscopus collybita* and *Serinus serinus*) that has been observed in Central Europe since the 1980s. When we accept that the NAO system is an indicator (or even the proximate causative mechanism) of the climate change, then the earlier than normal spring arrival of migratory birds should be considered as both a result of, and evidence for, the climate warming in the last two decades.

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