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Source: Folia Zoologica, 65(3) : 200-207

Published By: Institute of Vertebrate Biology, Czech Academy of Sciences

URL: https://doi.org/10.25225/fozo.v65.i3.a4.2016

Folia Zool. – 65 (3): 200–207 (2016)

Weather influence on the abundance of bird species wintering in three Mediterranean ecosystems

Christos K. SOKOS[1,2], Periklis K. BIRTSAS[1,2], Petros C. PLATIS[2] and Konstantinos G. PAPASPYROPOULOS[2]

[1] *Wildlife Laboratory, Department of Forestry and Management of Natural Environment, Technological Education Institute of Thessaly, End of Mavromichali Str., 431 00 Karditsa, Hellas (Greece); e-mail: sokos@vet.uth.gr*

[2] *Research Division, Hunting Federation of Macedonia and Thrace, Ethnikis Antistasis 173-175, 551 34 Thessaloniki, Greece*

Received 4 November 2015; Accepted 23 August 2016

Abstract. Many migratory bird species winter in southern Europe and weather influences their abundance, distribution, arrival and departure dates. This study compares the influence of air temperature and precipitation on abundance of waterfowl (*Anas* spp., *Anser albifrons* and *Fulica atra*), woodcock (*Scolopax rusticola*), skylark (*Alauda arvensis*) and meadow pipit (*Anthus pratensis*), representative species of wetland, woodland and farmland ecosystems, in Hellas (Greece). The harsh winter of 2001-2002 led initially to the increase of waterfowl abundance, however the prolonged cold weather forced the birds south. The following year's counts showed an increase of larger bodied and a decrease of smaller bodied waterfowl species. In forestland, the woodcock abandoned its mountainous wintering area in low temperatures and its abundance decreased the year following the harsh winter. Precipitation during November and December influenced negatively the abundance of woodcocks along the studied route probably due to their increased dispersion. In farmland, the preliminary results did not indicate any clear relation between the abundance or departure of skylarks and meadow pipits and air temperature and precipitation. A trend of skylarks to stay longer in the study area was observed with lower air temperatures in March. The influence of meteorological conditions differs from species to species due to their various ecological demands and different habitats. Future climate change is expected to influence abundance, duration of stay and the distribution of wintering birds.

Key words: migration, arrival, departure, duration of stay, Mediterranean, climate change

Introduction

The influence of meteorological conditions on migration is complex and may differ according to species, region, season and year (Shamoun-Baranes et al. 2006). Bird migration phenology has been studied widely not only to estimate the ecological effect of worldwide climate change (MacMynowski & Root 2007, Adamik & Pietruszkova 2008), but also to improve migratory species' management (Ferrand & Gossmann 2001).

Future climate change is expected to affect species migration and other weather-dependent biological phenomena (Gordo & Sanz 2005). According to the studies of Berthold (1996), Pulido et al. (1996) and Tryjanowski et al. (2002), the influence of meteorological parameters (e.g. temperature, precipitation) on migration is usually more significant for short-distance migrants, that travel short distances, than long-distance migrants, that migrate to long distances. Long-distance migrants are also influenced by factors such as photoperiod and behaviour, which are governed by genetics (Berthold 1996, Pulido et al. 1996, Tryjanowski et al. 2002).

In northeast Europe the spring arrival of short-distance migrants that winter in western or southern Europe occurs significantly earlier in warmer years (Sokolov et al. 1998, Hubálek 2003). During a cold spell in late winter or the beginning of spring, waterfowl species can opt to move south or stay and wait. The second option is more advantageous than moving south and consuming energy when they would have to move north several days or weeks later for the spring migration. However, when the cold spell exceeds the fasting autonomy this decision is erroneous and mortality can occur (Suter & van Eerden 1992). In warmer years, short-distance migrants delay their autumn departure and use the available resources of their breeding areas (Jenni & Kery 2003). Additionally, the arrival of some species in wintering areas can be delayed, such as the woodcock in Hellas (Birtsas et al. 2013).

Migration has been studied thoroughly by many researchers, with emphasis on the spring arrival dates of birds in central and northern Europe. Nevertheless, few studies are available on the influence of weather on the phenology of wintering bird and their duration of stay in southern Europe (Sanz 2002, Birtsas et al. 2013), and even fewer regarding bird wintering in southeastern Europe. Southern Europe is a climatic region where the effects of future climate change, warming and drought have been predicted to be intensive and these changes will most likely effect bird migration (Lelieveld et al. 2012, Ozturk et al. 2015). This study aimed to investigate how meteorological conditions influence the abundance of representative bird species in three Mediterranean ecosystems: wetland, woodland and farmland. Even though the data are preliminary in some cases, the examination of different ecosystems permits a better understanding of responses to weather between species.

Material and Methods

To examine the influence of meteorological conditions on bird wintering, we selected common and characteristic short-distance migrants of three Mediterranean ecosystems: waterfowl species in wetlands, woodcock in woodlands, and the skylark and meadow pipit in farmlands. This study took place in three representative ecosystems of Macedonia and Thrace in Northern Hellas (Fig. 1).

Due to the short study period in each year (2-4 months, when differences in vegetation and other factors were of minor significance) and the count methods employed, any variation in bird detection probability was expected to be low. Moreover, no serious disturbance by human activities took place in the study areas (hunting is prohibited in most areas where waterfowl species were counted and in the case of woodcock, skylark and meadow pipit the number of visits by hunters was very low). In a few cases waterfowl and skylark flocks flew for short distances after predator attacks and then returned to the study area; consequently any bias by disturbance was also expected to be low. The statistical analysis was performed using IBM SPSS 22.0 with a significance level of $P = 5$ %.

Waterfowl counting methods

Evros Delta is the most important wetland for wintering waterfowl in Hellas (Handrinos 1991, Kazantzidis & Noidou 2008). The wetland is located in northeastern Hellas with a mean monthly winter (December-February) precipitation of 69.3 mm/month and a mean air temperature of 5.9 °C (Tutiempo.net 2015). For the three winters of 2000-2001, 2001-2002 and 2002-2003, five duck species of the genus *Anas* (*A. platyrhynchos*, *A. penelope*, *A. crecca*, *A. acuta*, *A. clypeata*), the greater white-fronted goose (*Anser*

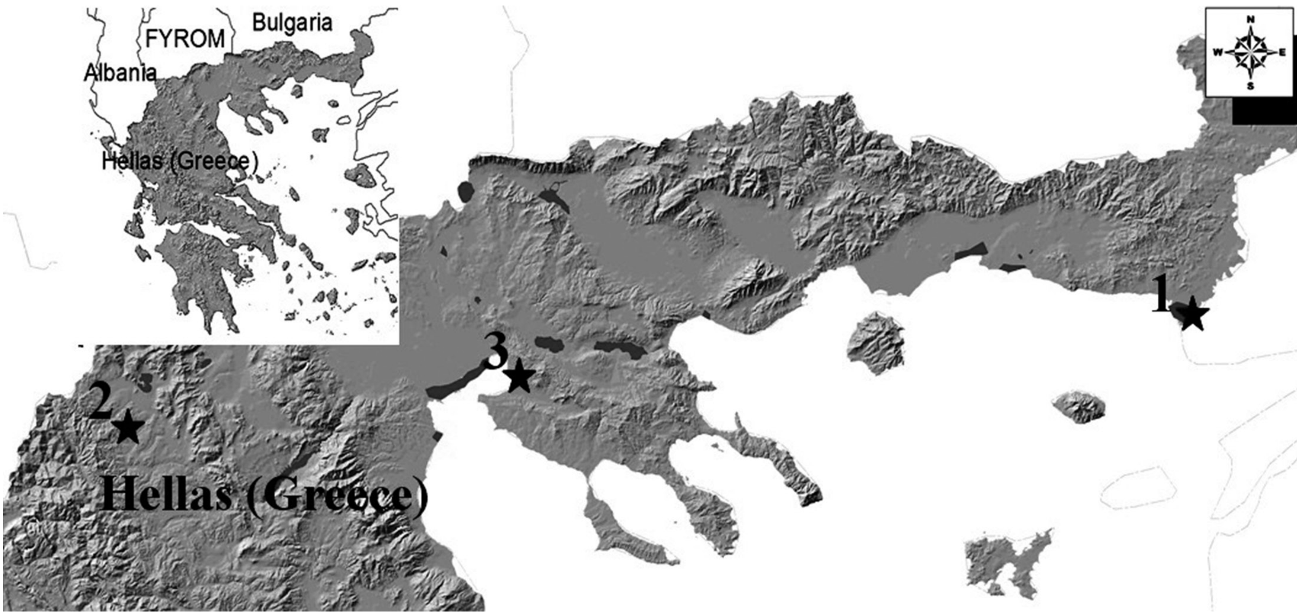

Fig. 1. Study areas: (1) study area for waterfowl in Evros Delta (40.767422°, 26.068696°, altitude: 1 m), (2) study area for woodcock near Kastoria city (40.365423°, 21.248447°, altitude: 703 m), (3) study area for skylark and meadow pipit near Thessaloniki city (40.534084°, 22.982812°, altitude: 1 m).

albifrons), and the coot (*Fulica atra*), were counted in Evros Delta. The same researcher visited the wetland once in the middle of each month and counted the birds from ten standard observation points that covered the majority of the wetland. Visual counts were performed using a telescope (20-60 × 80) early in the morning, using the same observation points and following the same route in each visit.

After examining the main descriptive statistics of the waterfowl counts (Zuur et al. 2010), and due to the small number of counts performed (nine counts in three months for three years for each species), non-parametric statistical analysis was used to test for differences in the estimates between months and years. The analysis included two within subject factors (year and month). However, as there is no non-parametric equivalent of the two-way repeated measures ANOVA, the Related-Samples Friedman's Two-Way ANOVA by ranks was applied, once for the year factor (2000-2001, 2001-2002 and 2002-2003), once for the month (December-February), and once for their interaction. This test is suitable for the analysis of related samples (Gray & Kinnear 2012). This lead to three related samples for years, while for the months the number of related samples was 3 years × 3 months. The same number of samples was analyzed for the interaction of years*months.

Woodcock counting methods

Hellas is a wintering region for the woodcock and the majority of recovered ringed birds originate from Finland and Russia (Akriotis & Handrinos 2004). The study was performed in a mountainous area near the city of Kastoria. The study area is covered with deciduous woodlands and cereal cultivations and its altitude ranges from 650-1000 m. The climatic data of the study area were obtained from the database tutiempo.net for the Kastoria Airport (latitude: 40.446388°, longitude: 21.277622°, altitude: 604 m) located about 10 km northeast of the study area.

Over 12 years (1992 to 2006, apart from 1996 and 1997) the same researcher made 267 field trips from November to February. Woodcocks were spotted with the help of two pointing dogs with similar ability each year (Gutzwiller 1990). In each trip, the survey with the pointing dogs lasted four hours and a distance of 5 km was covered along the same route, passing through different woodcock microhabitats. Each woodcock spotted by the pointing dogs was recorded only once, even if spotted a second time during the same field trip (for a full description of this method see Birtsas et al. 2013).

A univariate General Linear Model (GLM) was used to explore the effect of year, month, mean air temperature and precipitation, and their interactions on woodcock abundance. As an outlier (Zuur et al. 2010), the 2002-2003 period (following the harsh weather of 2001-2002) was excluded from this analysis due to the seriously decreased woodcock populations observed throughout the country (Thomaides et al. 2011). Levene's test was used to check the homogeneity of variances (Zar 1996).

Skylark and meadow pipit counting methods

Long-term data on the abundance of wintering farmland birds in Hellas were unavailable. For this reason we conducted a four year study on two common farmland birds: the skylark and the meadow pipit. Abundance of these species was examined using the line transect method (Bibby et al. 1992) in a lowland farmland area near the coast that lacked snow cover. The study area was located within the farm of the Aristotle University of Thessaloniki in Macedonia, Northern Hellas, and the line transects covered a total distance of two kilometers in cereal crops and set-aside land. The transect lines were positioned across the center of each field in order to limit any influence of the field margins (Bibby et al. 1992). One or two field visits were realized every 15 days in 2004 and from 2009 to 2011 leading to a total of 23 visits that took place from the second half of February until the first half of April each year.

During each count, the same researcher walked slowly along the middle of the transect line combining regular stops and marking on a map the skylarks and meadow pipits observed within a 50 m range around the transect (Lokemoen & Beiser 1997, Ribic & Sample 2001). Skylarks and meadow pipits, usually in flocks,

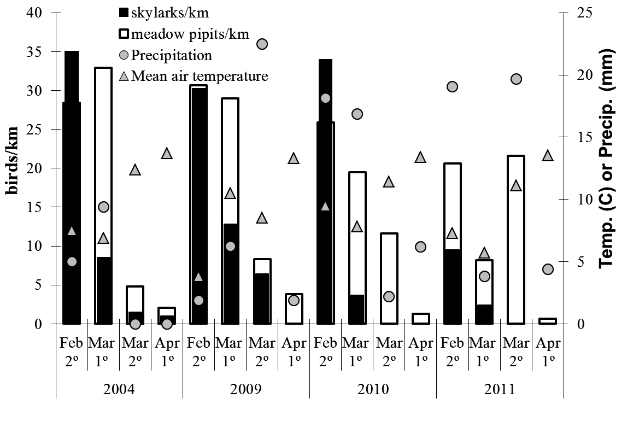

Fig. 2. Skylarks and meadow pipits per km and per visit in the corresponding fortnight (15-day period). Mean air temperature and total precipitation of the 15-day periods are presented.

Table 1. Abundance of waterfowl in Evros Delta (individuals), month mean air temperature (T °C) and total precipitation (P mm). In brackets the percentage of change with the corresponding month. In the last line temperature and precipitation are multiplied as an index of weather conditions, a higher value means better conditions for waterfowl.

Species	2000-01			2001-02			2002-03		
	Dec	Jan	Feb	Dec	Jan (% by Dec 01)	Feb	Dec	Jan (% by Jan 01)	Feb
A. plat	14630	6682	1774	12887	1228 (–90.5%)	1129	10495	9075 (+35.8 %)	1520
A. pen	16567	18115	3072	33756	2139 (–93.7%)	240	8036	6007 (–66.8 %)	5304
A. crec	23402	19014	6005	10048	2435 (–75.8%)	2275	4801	6340 (–66.7 %)	223(-)
A. acuta	1655	275	4531	1179	163 (–86.2%)	122	4246	1282 (+366.2 %)	2925
A. clyp	2270	366	2660	1670	72 (–95.7%)	108	2444	1653 (+351.6 %)	571(-)
A. alb	0	185	267	49709	434 (–99.1%)	44246	2365	32704 (+17577 %)	26901
F. atra	6992	19057	1340	12651	3056 (–75.8%)	3849	1946	15493 (–18.7 %)	3979
Total	65516	63694	19649	121900	9527 (–92.18%)	51969	34333	72554 (+13.9 %)	40629
Temp (T)	8	7.2	7.3	2.4(-)	4(-)	8.5	5.1	7.3	1.6(-)
Precip (P)	74.17	36.06	6.09	59.43	27.69	25.65	74.69	88.89	72.91
T × P	593.4	259.6	44.4	142.6	110.8	218	380.9	648.9	116.7

Table 2. Results from the Friedman's test for waterfowl abundance counted in Evros Delta (individuals).

Relation (waterfowl counts)	Test statistic	*P*-value
Year 2001 – year 2002 – year 2003	4.667	0.097
Dec 2000 – Dec 2001 – Dec 2002	0.857	0.651
Jan 2001 – Jan 2002 – Jan 2003	8.000	0.018*
Feb 2001 – Feb 2002 – Feb 2003	2.000	0.368
Dec 2000 – Jan 2001 – Feb 2001	0.286	0.867
Dec 2001 – Jan 2002 – Feb 2002	10.571	0.005*
Dec 2002 – Jan 2003 – Feb 2003	3.429	0.180

Table 3. Results of GLM on effects of precipitation (*P*), mean air temperature (Tmean), year, month and their interactions with woodcock abundance. Model 1 examined the relations for all studied period from November to February. Model 2 examined the relations for two months December and January. Model 3 examined the relations for November and December. P^a In bold the significant *P* values for three tests with $P < 0.016$ according to Bonferroni correction.

Source of variation	Model	df	F	*P*	P^a
P	1	93	6.379	**0.014**	**0.014**
Tmean	1	93	0.542	0.464	0.464
Year	1	93	6.929	**0.000**	**0.000**
Month	1	93	3.113	**0.032**	0.032
year*Tmean	1	93	0.430	**0.056**	0.056
P	2	44	0.008	0.928	0.928
Tmean	2	44	3.827	**0.059**	0.059
Year	2	44	7.390	**0.000**	**0.000**
P	3	59	6.524	**0.014**	**0.014**
Tmean	3	59	0.076	0.784	0.784
Year	3	59	2.977	**0.005**	**0.005**

were easily detected from this distance when they took flight. The counts were performed each morning between dawn and four hours after dawn (Ribic & Sample 2001). Counts were not conducted on rainy days or when wind speeds exceeded 5 Beaufort.

Results

Waterfowl wintering in a Mediterranean wetland

The study period can be divided into two sub-periods, the first comprising the winters of 1999-2000 and 2000-2001 (waterfowl counts commenced in 2000) with mild mean air temperatures of 6.03-7.5 °C and the second, colder, sub-period comprising the winters of 2001-2002 and 2002-2003 with mean air temperatures of 4.6-4.9 °C. The low air temperatures that prevailed in December 2001 caused an initial increase of waterfowl by almost 186 % compared to the previous year (Table 1). However, in the following month of January 2002 waterfowl counts decreased probably as a result of the prolonged low temperatures. A similar, but smaller, decrease was also caused by the cold spell of February 2003.

In December 2001 the increase of *A. albifrons* numbers was significant, being 165 times more than those of the previous year. Comparing the counts of December 2001 to January 2002, it can be seen that *A. albifrons* had greater movability, as their abundance reduced by about 99.1 % followed by *A. clypeata* with a 95.7 % reduction in numbers. *F. atra* and *A. crecca* showed the lowest decrease in numbers (75.8 % decrease) for the same time period.

The meteorological data show that January 2001 and January 2003 had similar mean air temperatures, however, a different composition of species can been seen when comparing the abundance of waterfowl following the cold spell. The larger bodied species of *A. albifrons*, *A. platyrhynchos* and *A. acuta* showed increased abundance, whereas the smaller bodied taxa (*A. penelope*, *F. atra*) decreased in number.

Analysis using the Friedman test (Table 2) proved that in terms of the year factor no significant relation exists between annually counted birds (although it does exist for a $\alpha = 0.10$ significance level). However, a significant relation is observed in the January comparison for the month factor. The pairwise comparisons showed that a statistically significant difference exists between the waterfowl counts of January 2002 and January 2003 (P = 0.023). Additionally, the pairwise comparisons for the interaction also reveal differences between December 2001 and January 2002 (P = 0.023), and December 2001-February 2002 (P = 0.010). No other significant differences exist (Table 2).

Woodcock wintering in mountainous woodland

The mean abundance of woodcocks during November, December, January and February was 4.37 birds/trip (SE ± 0.297, range 0-12). The abundance of woodcocks did not change significantly (F = 0.963, df = 93, P = 0.414) between months. The lowest yearly mean abundances of woodcocks were observed in 2001-2002 and 2005-2006, with 1.83 and 1.66 birds/trip, respectively. The characteristic common to both these years was the cold winter weather that caused the woodcocks to almost completely abandon the study area.

As presented in Table 3, the GLM (model 1) revealed that both year and month have a significant effect. Precipitation is also a significant factor (P = 0.014), in contrast to the mean air temperature which is not significant (P = 0.464). The mean air temperature was found close to the significance level (P = 0.059) only during the colder months of December and January (model 2).

Although a little too bit conservative, we also used the Bonferroni correction due to multiple tests (three different regression models). Thus, the significant P values for three tests were below to 0.016. After the correction less statistically significant relations were found for the three models as shown in the last column of Table 3.

Departure of skylark and meadow pipit from low-lying farmland

During 2004 and 2009 skylarks departed the farmland area later than in 2010 and 2011 (Fig. 2). The opposite trend was found for meadow pipits, especially in 2004, when they departed earlier, and 2010 and 2011, when they departed later than other years. However, air temperature and precipitation in the study area appeared to have no clear impact on the abundance or departure of either skylarks or meadow pipits. Nevertheless, in the second half of March 2009 which presented lower temperatures than other years, a trend of skylarks to stay in the study area longer than usual was recorded (Fig. 2).

Discussion

The phenology of wintering bird species and duration of stay were examined in three different ecosystems in southern Europe. This study allowed the comparison between species and habitats, taking into account the influence of meteorological factors. Different responses were found. Waterfowl in Evros Delta showed the highest variability in abundance, followed by woodcock in mountainous woodland and species common to farmlands.

In Evros Delta, the low air temperatures recorded in 2001-2002 initially increased the abundance of waterfowl, possibly due to the arrival of these birds from northeast Europe (Hagemeijer & Blair 1997, Kazantzidis & Noidou 2008). Several studies have reported that low air temperatures increase the abundance of waterfowls in wintering areas (Shy 1996, Gordo 2007, Kazantzidis & Noidou 2008, Gehrold et al. 2014). Nevertheless, prolonged low temperatures force waterfowl to move further south and therefore their abundance in Evros Delta decreased, a fact also confirmed by other studies focusing on prolonged severe weather conditions (Dimitrov et al. 2005, Kazantzidis & Noidou 2008). In February 2003, the region's low air temperatures also seemed to cause the decrease in numbers of some smaller species, possibly forcing them to move south. However, many birds remained in the area during this cold month, especially *A. albifrons*, probably opting to stay closer to their breeding areas (Suter & van Eerden 1992).

The most characteristic observation is that the low air temperatures recorded in winter 2001-2002 caused numerous greater white-fronted geese to migrate from northeastern Europe to Hellas. In this winter, 49709 *A. albifrons* were recorded in Evros Delta alone; a number that had never been recorded anywhere before in all the country (Handrinos 1991, Kazantzidis & Noidou 2008). From 2004 to 2007, the number of *A. albifrons* counted wintering in Evros Delta ranged from 686 to 1936 individuals (Kazantzidis & Noidou 2008). Consequently, the cold spell caused an increase in the abundance of larger bodied species, whereas the numbers of smaller bodied birds decreased. This was to be expected, since larger waterfowl species are more resistant to cold (Owen & Black 1990), thus they can remain in one area whereas smaller species are forced to move further south.

Similarly to the waterfowl, during the cold spells of 2001-2002 and 2005-2006, woodcock abundance decreased in the study area of Kastoria. It is possible that this species left the upland woodlands for lowlands with more favorable weather conditions near the coast (Arizaga et al. 2015). It is noteworthy that these cold winters also seem to cause the decrease in woodcock numbers in the next wintering period, as in the winter of 2002-2003, the abundance of woodcocks in the study area was 34.3 % lower. Additionally, the numbers of woodcock recorded in all the country were lower in the year following cold winters (2002-2003 and 2006-2007) (Thomaides et al. 2011). Tavecchia et al. (2002) also found that low air temperatures decrease the survival rates of woodcocks that winter in France.

The highest numbers of woodcocks were recorded in the first twenty days of December. One possible reason for this may be the additional arrival of woodcocks due to the temperature decrease in northeast Europe (Birtsas et al. 2013). However, in November and December, the increase of precipitation decreased woodcock numbers along the 5 km survey route. This may be attributed to the fact that precipitation increases the availability of food (earthworms) in drier areas of lower altitudes and thus high precipitation possibly causes dispersion of woodcocks, which in turn decreased the population density recorded in the wetter mountainous study area. Consequently, in these months rain is crucial for soil humidity and increases the availability of earthworms (Boggus & Whiting 1982, Arizaga et al. 2015). Later in winter, soils are usually already saturated, but the air temperature is lower, often below 0 °C, and this second factor also decreases woodcock abundance, but not significantly in our Mediterranean area (Table 3). The reduced numbers recorded in cold winters are to be expected because woodcock is very sensitive to adverse, winter, weather conditions (Tavecchia et al. 2002, Boos et al. 2005). Arizaga et al. (2015) observed fewer woodcocks in mountain pastures than in meadows located at lower altitudes and, attributed this to air temperature since mountainous areas experience more frosts, thus making it harder for the species to locate and consume its prey of earthworms.

No clear relation between the abundance or departure of skylarks and meadow pipits with air temperature or precipitation was found in the low lying farmland of Thessaloniki. However, a trend of skylarks to stay longer in study area can be recorded during lower temperatures. Askeyev et al. (2009) observed an earlier return of skylark to the Volga-Kama region of the Tatarstan Republic of Russia during warmer years. In Poland, skylarks and other short-distance migrants display a correlation with spring temperatures and return earlier in warmer years (Tryjanowski et al. 2002). A future study over a longer time period and including a higher variability of meteorological parameters is necessary to examine bird departures and reveal possible significant relations.

The results of this study show that meteorological conditions influence species to a different degree as they have varying ecological demands and inhabit different ecosystems. Birds that obtain their prey by searching in water, such as waterfowl, or in soil, such as the woodcock, are influenced more by weather conditions than birds that search their food above the soil as skylark and meadow pipit. Both waterfowl and woodcock face difficulties finding food when water freezes (Tavecchia et al. 2002, Duriez et al. 2005, Newton 2007, Gehrold et al. 2014). On the contrary, skylarks and meadow pipits find their food on the ground of agricultural ecosystems with seeds, leaves and invertebrates, whose availability is not significantly influenced by temperature fluctuations (Newton 2007). Moreover, weather conditions and micro-habitats are usually more variable in mountainous ecosystems than in low lying farmland areas. In this case, soil moisture and precipitation are important factors for woodcock (Arizaga et al. 2015) and influence its dispersion. In contrast, no influence of precipitation was observed in the migratory behaviour of skylark and meadow pipit.

Future predicted climate change and temperature increase are expected to reduce the abundance of some short-migrant species that winter in southern Europe, e.g. geese, or to change the composition of waterfowl species present within a wetland. However, temperature increase could also enhance the survival of some vulnerable species, such as woodcock, and thus increase their numbers. Changes in air temperature and precipitation are also expected to alter the distribution of migratory species, as in the case of woodcock and waterfowl. Thus, in mountainous areas migratory birds may increase their abundance during winter, because they will not be forced to move to lowlands near the coast to find more favourable mild weather conditions.

It is predicted that mean air temperature values will continue to rise in the Mediterranean (Lelieveld et al. 2012, Ozturk et al. 2015). Lelieveld et al. (2012)

analyzed long-term meteorological datasets along with regional climate model projections for the 21st century, and predicted a continual, gradual and relatively strong warming of about 3.5-7 °C between the 1961-1990 reference period and the period 2070-2099. Consequently, long-term bird monitoring in different ecosystems is essential to evaluate the influences of climate change on avifauna and to take appropriate measures for the conservation and management of migratory species.

Acknowledgements

We would like to thank all the reviewers whose suggestions contributed to the improvement of this manuscript.

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