ABSTRACT: Over the past century, average global temperature increased by an approximately of 0.6°C and it has been shown that global warming has been affecting many biological systems. Recent climate change has influenced birds in many ways. The aim of this work is to present trends in the first arrival date and potential impact of mean monthly temperature on the spring migration of the Pied Wagtail (*Motacilla alba*) in long-term study in northwestern Croatia (Mokrice rural area). The study was conducted during 1980–2011. The Pied Wagtail is a small, semi-hole nesting, migratory, insectivorous passerine breeding in Europe and Asia (also breeds in Morocco and western Alaska). This study didn’t show that over the research period the Pied Wagtail returned to their breeding sites significantly earlier. This can be explained with the fact that local temperatures for February/March, did not increase significantly (P > 0.05). The change in Pied Wagtail arrivals was very little and advanced 1.47 days (non-significant) over the study period (1980–2011).

KEY WORDS: Pied Wagtail, *Motacilla alba*, spring migration, trend, temperature

It is evident that the climate is changing (IPCC 2007). Climate variability and change impacts plants and animals in a number of ways (e.g. Hughes 2000, Root *et al.* 2003) and most of these changes are in the direction expected with warming temperature. According to Parmesan (2006), significant changes in biological systems have already been documented on all the continents. For example, studies of Lilac (*Syringa vulgaris*) in the western United States have shown an advance in flowering dates of two days per decade (Cayan *et al.* 2001), and amphibian breeding has advanced in United Kingdom by one to three weeks per decade (Beebe 1995). Recent climate change has also influenced birds in many ways. For instance, numerous papers have reported changes in clutch initiation date (e.g. Brown *et al.* 1999, Dolenec *et al.* 2009, D’Alba *et al.* 2010), several papers documented changes in clutch size (e.g. Møller 2002, Schaefer *et al.* 2006) and some papers illustrated changes in brood size (e.g. Dolenec 2009). Northward shifts in bird breeding ranges across Northern Hemisphere have also been linked with recent climate change (e.g. Thomas and Lennon 1999, Hitch and Leberg 2007). Furthermore, increasing evidence suggests that climate change has also impacted on avian migration phenology. Several bird species began to arrive progressively earlier in the past 30–40 years (e.g. Lehikoinen *et al.* 2004, Dolenec and Dolenec 2010a) and several
studies have confirmed the link between arrival date and spring temperature (e.g. Sokolov et al. 1998, Dolenec and Dolenec 2010b). In Poland (1970–1996), there were evidences for four out of 16 bird species of a significant trend towards earliness in recent years (Tryjanowski et al. 2002), in United Kingdom (1959–2005) for 11 out of 25 bird species (Croxton et al. 2006), in Switzerland (1981–2006) for out of 12 bird species (Christen 2007), in Russia (1971–2005) for three out of 16 bird species (Sokolov and Gardienko 2008) etc.

The aim of this work is to present trends in the first arrival date and potential impact of mean monthly temperature on the spring migration of the Pied Wagtail (Motacilla alba) in long-term study in north-western Croatia. The Pied Wagtail is a small, semi-hole nesting, migratory, insectivorous passerine breeding in Europe, palaeartic ecozone of Asia and also breeds in Morocco and western Alaska (Cramp 1998, Dolenec 2011). It belongs to the subspecies Motacilla alba alba (Vaurie 1959) in Croatia.

The study was conducted during 1980–2011, in Mokrice rural area (lat 46°00’N, long15°55’E; 6.4 km²; ca 140 m a.s.l.), north-western Croatia. Dates were converted to numerical values such that 1 February = 1, etc. Most research on the timing of arrival has examined the first arrival dates of species (e.g. Rubolini et al. 2007). First arrival date for each year was calculated as the average of the first five birds arrivals recorded for that year (method previously used by Both et al. 2005). The data were collected daily (sometimes in the morning and sometimes in the afternoon) by author who lives in the village Mokrice. According to Tryjanowski et al. (2005), a new problem presented here is that changes in first arrival date may be influenced by differences in detectability between species. Highly detectable species will be recorded with more accuracy and hence with greater likelihood of detection of change when present. But I can add that Pied Wagtail is highly detectable species, so there should be no problem in detection of the first arrival dates.

Among all meteorological parameters, I analysed local air temperature. Local temperature is often considered the most important factor influencing phenological performances of birds (e.g. Sokolov et al. 1998, Dolenec et al. 2011, Dolenec et al. 2012). Croatia’s temperature was measured as the mean of the average monthly temperature for the two months (February/March) best adjusted to the first arrival date for Pied Wagtail (method previously used by Gordon and Sanz, 2006). Values of temperature in 32 year period (from 1980 to 2011) were obtained from the Maksimir meteorological station (Meteorological Office in Zagreb), which is about 20 km from study area (February, mean = 2.2°C, SD = 2.88, range = -3.6°C to 6.9°C; March = 6.7°C, SD = 2.03, range = 1.7°C to 10.3°C; February/March, mean = 4.5°C, SD = 2.04, range = 0.3°C to 7.9°C).

![Fig. 1. Temporal trends (1980–2011, 1 February = 1) in first arrival dates of the Pied Wagtail in northwestern Croatia (Mokrice rural area) (y = 121.02 – 0.046x, P = 0.051).](image-url)
Correlations between arrival date and climatic factors were determined with Pearson’s correlation test. Trends were calculated by regression methods. Significance was set at \( P < 0.05 \) for all statistic tests. Data were analysed using SPSS v.13 for Windows.

The date of the first arrival of the Pied Wagtail in Mokrice area has ranged from February 24 to March 7 (mean = March 1, SD = 3.43) over the 32 years (1980–2011). First arrival date in the Pied Wagtail population did not statistically significant advance over 32-year period \( (r = -0.18, P = 0.331, N = 32; \text{Fig. 1}) \). The coefficient of regression (slope = –0.046) for research bird species indicates an earlier arrival of 0.046 days per year, or 1.47 days over the study period. Furthermore, there was no significant correlations between first arrival date and temperatures (February/March) \( (r = -0.22, P = 0.224, N = 32) \). The mean temperature in February/March and year (1980–2011) also did not significantly differ (statistical significance is marginal) \( (r = 0.35, P = 0.051, N = 32) \). This study didn’t show that over the research period the Pied Wagtail returned to their breeding sites significant earlier. This can be explained with the fact that local temperatures for February/March did not increase significantly \( (P > 0.05) \).

Some meta-analyses clearly reported that climate change patterns have resulted in phenological changes in numerous species in numerous areas (e.g. Parmesan and Yohe 2003). In general, during spring migrations, birds migrated earlier in warm years and later in colder years (e.g. Gordo and Sanz 2006, Dolenec and Dolenec 2011). In contrast to many previous studies examining relationships between climate and bird phenological events my study found non-significant long-term (over 32 years) trend toward earlier migration dates. This result makes sense since we also found no significant trend for increasing spring temperatures in northwestern Croatia during this time period \( (P > 0.05) \). Our results are in agreement with the data reported by several papers. Non-significant trends towards earlier or later timing of spring migration in Pied Wagtail (in the past 30–40 years) had been documented in the recent decade by several authors (e.g. Barret 2002, Zalakevicius et al. 2006). In contrast, several authors reported significant trends (e.g. Jenkins and Wotson 2000, Tryjanowski et al. 2002).

The birds face many challenges from climate change and inter- and intraspecies will be impacted to different degrees. Generally, among scientists, there is a growing concern about how global climate change may impact of plants and animals. Because of the complexity of the interactions between plants, animals and their environment, direct causal relationships are difficult to demonstrate and need long-term detailed studies of ecological processes (Sanz 2002). According to Schaefer et al. (2006), even if the dependency of many species on climatic factors is well known, the ecological context has a strong impact on how this dependency will influence a species response.

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