Temporal shift in timing of breeding of European starling (*Sturnus vulgaris* Linnaeus) population

Impacts of climate warming on wildlife are beginning to be seen across the Earth[1]. For example, numerous studies have reported that tree phenophases are being observed earlier in spring[2] and, that temperature change leads to rapid development in insects[3]. In bird species, these impacts often manifest in earlier clutch initiation dates. Climate change can have impacts on bird species and bird populations in different ways. For example, geographical distribution[4], disrupted synchrony between predator and prey[5], population dynamics[6], demography[7], migration phenology[8], breeding phenology[9], morphology[10], etc. The most common trait used in bird breeding phenology studies is the laying date of a species[11].

The aim of the present study was to examine how the timing of breeding of the European starling (*Sturnus vulgaris* Linnaeus) is related to local spring air temperature during the long time-period. The European starling is a semi-colonial, hole-nesting, short-distance migrant and common bird species in northwestern Croatia (predominantly ground foraging species). According to Gill and Wright[12], the studied bird species belongs to the family Sturnidae and order Passeriformes.

A nest box-breeding population of the European starling was studied during 1980–2016 in village Mokrice (46°00′N, 15°87′E), northwestern Croatia. The altitude of the study area is about 140 m amsl. It consists of mixed farming, and natural small mixed deciduous forests dominated by common oak *Quercus robur* and hornbeam *Carpinus betulus*. The European starling is a short-distance migratory bird species that builds nests in natural tree cavities or in the nest boxes. In this study, we have used wooden nest boxes for nesting (dimensions 16 cm × 16 cm × 25 cm, entrance hole varies from 4.5 to 5.0 cm in diameter). Monitoring of bird reproduction was enabled with the sliding top on the nest boxes. Generally, nest boxes are often used in ornithology for different studies[13,14]. All analysis of breeding dates was restricted to a first clutches (renests after failure of the first clutch and second clutch were not included). The birds studied generally lay one egg per day[15]. Dates were converted to numeric values, with 1 representing 1 March. The mean day of the beginning of European starling breeding, i.e. laying date, is an average date of the first layed egg in the first ten nests, so that the impact of possible fluctuation of individual pairs could be avoided. The studied species is known for intraspecific parasitism[16]. Parasitically laid eggs, mostly recognized by two eggs laid on the same day and by difference in colour, were excluded from the study. We compared the laying date to spring air temperature (°C) data for March and April (March/April). Numerous ornithologists/scientists worldwide have studied the relationship between timing of breeding and local spring air temperatures[17,18]. According to Bleu *et al.*[19], in order to estimate the advancement of the breeding season, female birds use temperature as a cue, before as well as during egg-laying. Data on the average March/April air temperature in Mokrice area for 1980 until 2016 were obtained by the Meteorological Office in Zagreb (station Maksimir) situated ca. 20 km from the study area. Statistical analysis of a long-term trend in clutch initiation and average air temperature was performed by linear regression analysis and Pearson's correlation using the SPSS 13.0 statistical package. *P*-values < 0.05 were considered statistically significant.

The mean first clutch initiation date varied from March 23 to April 16 (mean is 9 April). Significant negative correlation was found between the date of clutch initiation and year (Pearson's coefficient, $r = -0.454$, $P = 0.005$, $n = 37$; $y = 458.9 - 0.209x$; Figure 1). The laying date of the European starling advanced up to approximately eight days in the study period from 1980 to 2016. Average spring air temperatures (March/April) varied in the range from 2.46°C to 8.31°C (mean = 5.4°C) between 1980 and 2016 in the Mokrice area. During this period, average spring temperature in the study area significantly increased by 0.07°C per year ($r = 0.568$, $P < 0.001$, $n = 37$; $y = -133.1 + 0.072x$; Figure 2). Correlation between the clutch initiation date and average spring temperature was also found to be significant ($r = -0.651$, $P < 0.001$, $N = 37$; $y = 16.7 - 0.184x$; Figure 3). These results indicate association between a long-term spring temperature increase and timing of breeding onset of the European starling in northwestern Croatia.

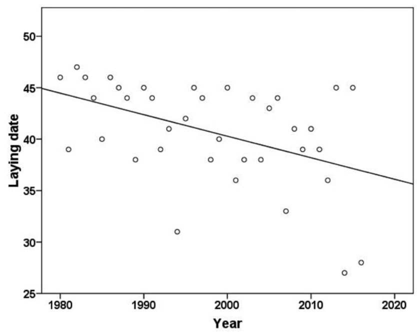

Figure 1. Trends in laying date of the European starling (*Sturnus vulgaris*) in northwestern Croatia, 1980–2016 (where 1 represents 1 March).

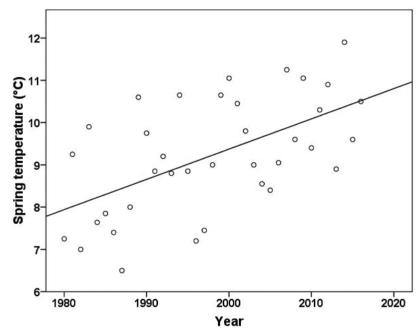

Figure 2. Correlation between average spring air temperature (March/April) and year in northwestern Croatia, 1980–2016.

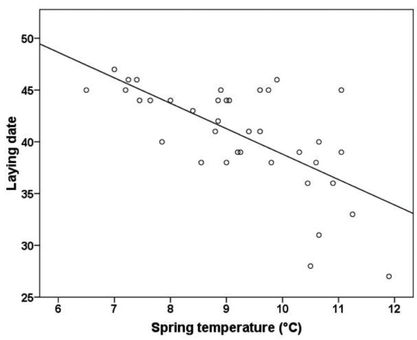

Figure 3. Correlation between the European starling laying date and average spring air temperature (March/April) in northwestern Croatia, 1980–2016 (where 1 represents 1 March).

Many bird species show advancing breeding phenology in the Northern Hemisphere and this can be linked with climate change. For example, Dunn and Winkler[20] demonstrated that tree swallow (*Tachycineta bicolor*) shifted significantly average breeding date nine days earlier than normal in North America. In Europe, McCleery and Perrins[21] found that clutch initiation date in the great tit (*Parus major*) advanced as a response to spring warming in the United Kingdom. The present study is based on the results of 37-year monitoring of the European starling breeding population in northwestern Croatia. Results indicate that the studied bird species began to lay eggs approximately eight days earlier in the researched area, in the period between 1980 and 2016. Conversely, according to Flux[22], the European starling population tended to breed successively later, and Dolenec[23] reported not-significant trend. Svensson[24] found low significant tendency towards earlier laying date of the European starling at five locations while at the other eight locations studied, no significant differences in laying date were detected. Nevertheless, different populations of the European starling show various responses to climate change. Difference in breeding phenollogy response has also been documented in other bird species[25]. The European starling population in northwestern Croatia is possibly following the food peak, as demonstrated by Visser *et al.*[26] for the great tit. According to these authors, timing of breeding shows corresponding year-to-year fluctuation, caused by phenotypic plasticity. According to Pautasso[27], further climate change could have a major impact on birds in many different ways; for instance, body size change or mismatches with their resources. Thus, future studies should consider possible interactions among these levels in order to devise effective conservation strategies.

1. Parmesan, C., *Annu. Rev. Ecol. Evol. Syst.*, 2006, **37**, 637–669.
2. Gaira, K. S., Rawal, R. S., Rawat, B. and Bhatt, I. D., *Curr. Sci.*, 2014, **102**, 1735–1738.
3. Jaworski, T. and Hilszczański, J., *Leśne Prace Badawcze (For. Res. Pap.)*, 2013, **74**, 345–355.
4. Lehikoinen, A. and Virkkala, R., *Global Change Biol.*, 2016, **22**, 1121–1129.
5. Both, C. and Visser, M. E., *Nature*, 2001, **411**, 296–298.
6. Wittwer, T., O'Hara, R. B., Caplat, P. Hickler, T. and Smith, H. G., *Oikos*, 2015, **124**, 1151–1159.
7. McCleery, R. H. and Perrins, C. M., *Nature*, 1998, **391**, 30–31.
8. Dolenec, Z. and Dolenec, P., *Turk. J. Zool.*, 2010, **34**, 267–269.
9. Källander, H., Hasselquist, D., Hedenström, A., Nord, A., Smith, H. G. and Nilsson, J.-Ĺ., *J. Avian Biol.*, 2017, **48**, 83–90.
10. Van Buskirk, J., Mulvihill, R. S. and Leberman, R. C., *Oikos*, 2010, **119**, 1047–1055.
11. Potti, J., *J. Ornithol.*, 2009, **150**, 893–901.
12. Gill, F. and Wright, M., *Birds of the World*, Princeton University Press, New Jersey, USA, 2013.
13. Dolenec, P., Kocijan, I. and Dolenec, Z., *Ethol. Ecol. Evol.*, 2011, **23**, 368–374.
14. Kocijan, I., Dolenec, P., Dolenec, Z. and Radović, A., *Curr. Sci.*, 2014, **107**, 1597–1601.
15. Dolenec, Z., Kralj, J., Mustafić, P. and Dolenec, P., *Pol. J. Ecol.*, 2008, **56**, 545–548.
16. Yom-Tov, Y., Dunnet, G. M. and Anderson, A., *Ibis*, 1974, **116**, 87–90.
17. Dolenec, Z., Dolenec, P. and Møller, A. P., *Curr. Zool.*, 2011, **57**, 414–418.
18. Artemyev, A. V., *Russ. J. Ecol.*, 2013, **44**, 239–246.
19. Bleu, J., Agostini, S. and Biarda, C., *Behav. Ecol.*, 2017, **28**, 793–802.
20. Dunn, P. O. and Winkler, D. W., *Proc. R. Soc. London, Ser. B*, 1999, **266**, 2487–2490.
21. McCleery, R. H. and Perrins, C. M., *Nature*, 1998, **391**, 30–31.
22. Flux, J. E. C., *Ornis Scand.*, 1987, **18**, 146–148.
23. Dolenec, Z., *Ornis Svecica*, 1999, **9**, 224–226.
24. Svensson, S., *Ornis Svecica*, 2004, **14**, 117–128.
25. Dunn, P. O., *Adv. Ecol. Res.*, 2004, **35**, 69–87.
26. Visser, M. E., Holleman, L. J. M. and Gienapp, P., *Oecologia*, 2006, **147**, 164–172.
27. Pautasso, M., *Ital. J. Zool.*, 2012, **79**, 296–314.

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Simple estimates for optimization of potassium nutrition in vineyards

Nutrient management, amount and application, is one of the most important aspects in agriculture, more so in horticultural crops which are usually heavy nutrient feeders. Nutrients affect quality and quantity of produce, but their injudicious use in the form of fertilizers results in soil and water pollution, thus damaging natural ecosystems which thrive therein[1–4]. Grape is one of the oldest cultivated crops of the world[5] and its adoption in India dates back to 1356–1220 BC (ref. 6). Cultivated grapevine area in India is currently at 122,000 ha with grape production touching 3.2 million tonnes (Mt). Grape is grown as a subtropical crop in Maharashtra, Andhra Pradesh, Karnataka, Tamil Nadu and western part of Madhya Pradesh. Grape plantations fetch higher yield and more income than most other field and fruit crops[7]. Good yield and better quality, together, are key drivers for optimum crop nutrition plans for vineyards. Optimization of nutrient application in vineyards, especially for potassium, is needed most as it accounts for a major portion of input costs.

Potassium not only plays a significant role in growth of vines but also the quality of grapes and grape juice, and therefore K nutrition draws significant attention of farmers. Potassium is involved in