length, 1.39–2.85 mm in diameter) of the grubs within the seed. Each fruit when dissected had around 10–15 live, fully developed adults.

In jamun both whole fruit as well as seed are economically important. Considering the vast damage it can cause and the ability to build up in huge numbers (~85 per fruit) in overlapping generations, *A. kerrichi* can become a major problem to jamun growers. Further, larval feeding affects seed viability and rate of germination. As the critical stage for infestation is G2, application of safe botanical pesticides at this stage may help reduce seed borer infestation.

1. Patel, V. B., Pandey, S. N., Singh, S. K. and Bikash, D., *Indian J. Hortic.*, 2005, **62**, 244–247.
2. Rajesh, K., Ramamurthy, V. V. and Sharma, G., *Biol. Forum.*, 2010, **2**, 1–5.
3. Ramteke, V. and Kurrey, V. K., *Popular Kheti*, 2015, **3**, 188–190.
4. Butani, D. K., *Insects and Fruits*, Periodical Expert Book Agency, Delhi, 1979, p. 415.
5. Noyes, J. S., Universal Chalcidoidea Database. World Wide electronic publication, 2019; http://www.nhm.ac.uk/chalcidoids
6. Gadallah, N. S., Ghahari, H., Felipo, F. J. and Fischer, M., *Zootaxa*, 2015, **3794**.
7. Girault, A. A., *Can. Entomol.*, 1916, **48**, 337–344.
8. Boucek, Z., *Australasian Chalcidoidea (Hymenoptera), A Biosystematic Revision of Genera of Fourteen Families, with a Reclassification of Species*, CAB International, Wallingford, UK, 1988, p. 832.
9. Xiao, H., Xu, L., Huang, D. and Zhao, Z., *Phytoparasitica*, 2006, **34**, 261–264.
10. Jun Abe, Kamimura, Y., Kondo, N. and Shimad, M., *Behav. Ecol.*, 2005, **14**, 34–39.

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Interannual variation of clutch initiation of the great tit (*Parus major* Linnaeus) in relation to the local air temperature

The average global climate is changing rapidly[1] and increasing evidence indicates that global warming has consequences on numerous plant and animal species. Previous studies have shown significant fluctuations in the date advancement among wild species phenology in relation to warm springs. For instance, according to Szabó *et al.*[2], four out of six investigated plant species in Hungary showed a significant advance in flowering dates by 1.9–4.4 days per decade, and the wood frog (*Rana sylvatica*) showed a trend toward earlier emergence by 19 days[3]. In bird species, these impacts often manifest in geographical distribution[4], population size[5], interaction between bird species and other species[6], etc. However, long-term observations were mainly focused on spring migration[7–9] and breeding phenology[10,11] variations. Moreover, while most of the previous long-term monitorings were focused on interannual fluctuations of bird phenology in northern and western Europe, very few were conducted in southeastern Europe.

Here, I investigate how the timing of the great tit *Parus major* (Linnaeus, 1758) breeding was related to local spring surface temperatures. The trend of laying dates (first clutch) during the 33-year period (1984–2016) was examined. Great tit is a common, small resident and hole-nesting passerine species in the forests of northwestern Croatia[12].

Monitoring was done from 1984 until 2016, in the rural area of village Mokrice (lat. 46°00′N, long. 15°87′E, alt. 140 m, northwestern Croatia). This research area has a mixed landscape with small mixed deciduous forest. The dominant tree species in small forests are pedunculate oak (*Quercus robur*) and hornbeam (*Carpinus betulus*). In this study, wooden nestboxes of identical sizes were used (internal dimensions = 12 × 12 × 23 cm) and their entrances (diameter = 3.2 cm) were located at ca. 18 cm from the bottom of the nestbox. All the nestboxes were installed on the trees at 2.5 m above the ground, and at approximately 50 m distance from each other. Numerous ornithological studies have used nestboxes because of easier access to the eggs and hatchlings[13,14]. All boxes were cleaned after nesting period (August). The great tits lay one egg per day and modal clutch size is 11 eggs (Z. Dolenec, unpublished data). During the 33-year study period, nesting of 1,184 pairs of great tits was observed. The nestboxes (approximately 40–50 per year) were checked every five or six days during the breeding period in March and April to monitor egg laying. The day the first egg was laid was registered as the date of breeding onset. Only the breeding onset of the first ten pairs was calculated as the mean first laying date per year. The first clutches were only included for this study. Dates are expressed as progressive days, where 1 = 1 March. Fluctuations in laying date of the great tit in Mokrice were examined in relation to the mean local spring surface temperature variations. This method was also used by others[15]. The average surface temperature (March–April) was obtained from the meteorological station Maksimir (Meteorological Office in Zagreb); ca. 20 km from the study area, 123 m asl. Regression analysis and correlation were used to determine the association between the timing of laying on the one hand, and year and surface temperature on the other (tested using Pearson's correlations with two-tailed *P*-values). Data are presented as mean ± SD. Results of statistical procedures were considered significant with $P < 0.05$.

Mean spring surface temperature (March–April), from 1984 until 2016, was 9.3°C (SD = 1.34, range 6.5–11.9°C) in the study area. Mean surface temperature in March–April significantly increased by 2.5°C during the breeding period (1984–2016; Pearson's coefficient, $r = 0.565$, linear regression, slope = 0.078, $n = 33$, $P = 0.001$) (Figure 1). The mean first laying date was 31 March (SD = 5.96, range from 18 March until 14 April). Clutch initiation date of the great tit in northwestern Croatia significantly advanced by 0.21 days per year over the 33-year period ($r = –0.347$, slope = –0.214; $n = 33$; $P = 0.048$) (Figure 2). Fluctuations in breeding date were significantly correlated with mean spring surface temperature ($r = –0.526$, slope = –2.533, $n = 33$, $P = 0.002$) (Figure 3). The present results indicate that the breeding phenology of the great tit responded to increasing mean spring surface temperatures in the study area.

Numerous studies have documented an advance in the date of laying in many different bird species (passerine and non-passerine) over an approximately 40-year period. For example, D'Alba *et al.*[5] found that the average breeding date of common eiders (*Somateria mollisima*) had shifted significantly earlier for an average of 8 days in southwestern Iceland; Dolenec and Dolenec[16] found that the blackcap (*Sylvia atricapilla*) also shifted the breeding date significantly earlier for an average of 12 days in northwestern Croatia. The present results indicate that the great tit responded to increase in the mean spring surface temperature by advancing clutch initiation by 7 days over the study period. The advance of great tit's breeding date was documented in several breeding phenology studies[17–19]. In contrast, Visser *et al.*[20] did not find advancement in breeding phenology of the great tit in the Netherlands during 1973–1995. According to Bauer *et al.*[21], inter-study comparison is rather inconclusive, mainly due to the different lengths of monitoring period. Phenological mismatching issue is moreover complicated by the fact that climate changes do not affect different populations within the same species in the same way. For example, the great tit population in Wytham Wood (UK) shows trend

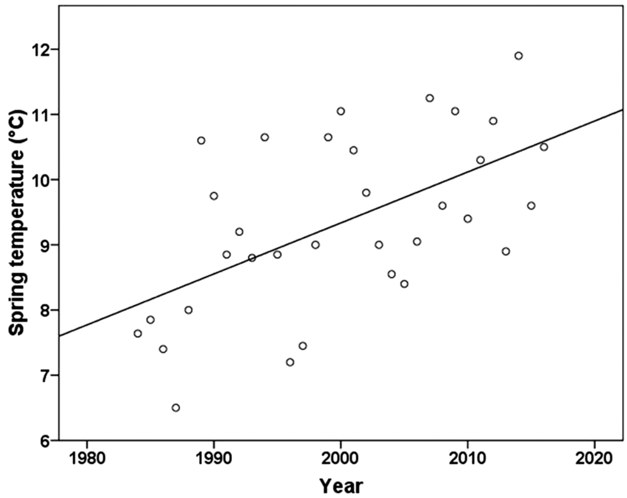

Figure 1. Relationship between year and average March–April surface temperature in northwestern Croatia, 1984–2016.

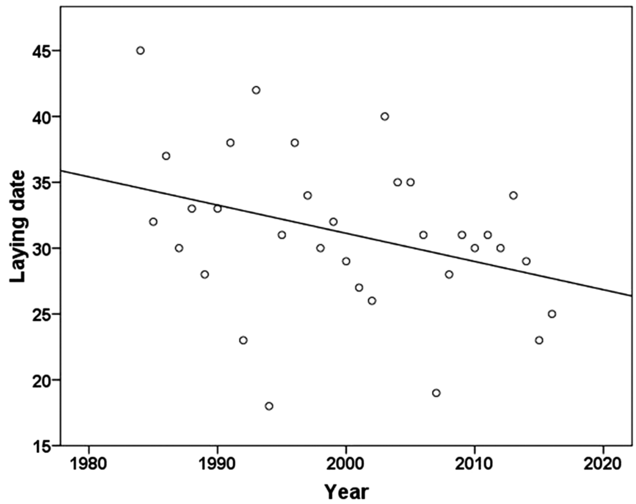

Figure 2. Relationship between year and laying date of the great tit *Parus major* in northwestern Croatia, 1984–2016 (1 = 1 March).

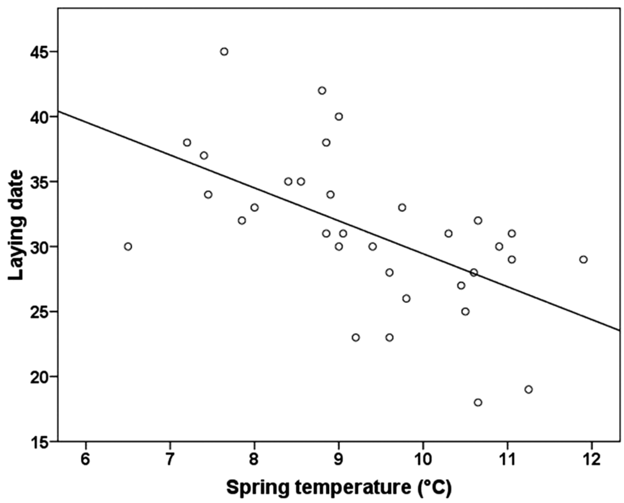

Figure 3. Relationship between average March–April surface temperature and laying date of the great tit *Parus major* in northwestern Croatia, 1984–2016 (1 = 1 March).

of earlier reproduction, but if spring temperatures grow rapidly and reproduction starts too early, hatchlings are born earlier than caterpillar growth shows its peak[22]. On the other hand, although synchronization between the breeding time and caterpillar abundance peak food could be the main factor that pressures laying date advancement. According to some studies[23], great tit populations in Hoge Veluwe (Holland) did not change their reproductive timing, although the insect that they feed on, winter moth, advanced its reproduction[20].

A growing number of studies show the shifts in bird phenology in response to climate warming. However, there is still a large amount of unexplained variation in the magnitude of those responses across different species and geographic areas and further studies are necessary to get better insight into influences of climate changes on bird phenology.

1. IPCC, Working Group I Technical Support Unit. Climate Change 2013. The Physical Science Basis. Part of the Working Group I Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (eds Stocker, T. F. *et al.*), 2013.
2. Szabó, B., Vincze, E. and Czúcz, B., *Int. J. Biometeorol*., 2016, **60**, 1347–1356.
3. Klaus, S. P. and Lougheed, S. C., *Ecol. Evol.*, 2013, **3**, 835–845.
4. Lehikoinen, A. and Virkkala, R., *Global Change Biol*., 2016, **22**, 1121–1129.
5. D'Alba, L., Monaghan, P. and Nager, R. G., *Ibis*, 2010, **152**, 19–28.
6. Donnelly, A., Yu, R. and Liu, L., *Int. J. Biometeorol*., 2015, **59**, 1007–1017.
7. Dolenec, Z. and Dolenec, P., *Turk. J. Zool*., 2010, **34**, 267–269.
8. Kullberg, C., Fransson, T., Hedlund, J., Jonzén, N., Langvall, O., Nilsson, J. and Bolmgren, K., Change in spring arrival of migratory birds under an era of climate change, Swedish data from the last 140 years. AMBIO44, (Suppl. 1), 2015, pp. S69–S77.
9. Dolenec, Z., *Acta Zool. Bulg*., 2018, **70**, 523–526.
10. Skwarska, J. *et al.*, *Pol. J. Ecol.,* 2012, **60**, 187–192.
11. Dolenec, Z., *Šumarski List*, 2018, **142**, 381–386.
12. Kirin, T., Kralj, J., Ciković, D. and Dolenec, Z., *Šumarski List*, 2011, **135**, 467–475.
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., Dolenec, P. and Møller, A. P., *Curr. Zool*., 2011, **57**, 414–418.
16. Dolenec, Z. and Dolenec, P., *J. Environ. Biol*., 2011, **35**, 625–627.
17. McCleery, R. H. and Perrins, C. M., *Nature*, 1998, **391**, 30–31.
18. Matthysen, E., Adriaensen, F. and Dhondt, A. A., *Global Change Biol*., 2011, **17**, 1–16.
19. Källander, H., Hasselquist, D., Hedenström, A., Nord, A., Smith, H. G. and Nilsson, J.-Ĺ., *J. Avian Biol.*, 2017, **48**, 83–90.
20. Visser, M. E., van Noordwijk, A. J., Tinbergen, J. M. and Lessells, C. M., *Proc. R. Soc. B*, 1998, **265**, 1867–1870.
21. Bauer, Z., Trnka, M., Bauerová, J., Možný, M., Štěpánek, P., Bartošová, L. and Žalud, Z., *Int. J. Biometeorol*., 2010, **54**, 99–111.
22. Cresswell, W. and McCleery, R., *J. Anim. Ecol*., 2003, **72**, 356–366.
23. Van Noordwijk, A. J., McCleery, R. and Perrins, C. M., *J. Anim. Ecol*., 1995, **64**, 451–458.

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