under the microscope (Figure 1 *d*). Eggs became greenish-grey prior to hatching, which took place after an incubation period of 4.10 ± 0.23 days (range 3–5 days).

Newly hatched first instars (1.5–2.5 mm long) were bright green and showed semilooper movements. They were usually found clumped on the edges of neem leaves feeding in a frenzied manner, skimming of the epidermal layer of the leaves from between the veins. First-instar duration was 3.25 ± 0.12 days (range 2–4 days). Second instar was also green and 7–9 mm in size, with a duration of 2.85 ± 0.15 days (range 2–4 days). Third instars were similar to the second instar in shape and structure, but grew to 1.2–2.0 cm and had an instar duration of 3.00 ± 0.09 days (range 2–4 days). They moved around actively in search of food and cut leaves rhythmically in semi-circles. Fourth instar was also green with a duration of 3.30 ± 0.12 days (range 3–4 days). Fifth instar was the largest (4.2–5.3 cm), fed voraciously and developed in 4–5 days (4.50 ± 0.13 days; Figure 1 *e*). It became sluggish, stopped feeding and began to burrow into moist soil to form pre-pupa. Pre-pupa was green in colour and showed flicking movements on being disturbed (1–2 days; 1.20 ± 0.08 days). Immobility of pre-pupa followed by browning marked the start of pupal stage (Figure 1 *f*). Pupal stage lasted for 13–15 days (13.90 ± 0.28 days). Adults eclosed from the pupa and were creamish in colour with brown patterns on the wings (Figure 1 *b* and *c*). They mated for 1–2 min after 2–3 days of emergence and laid eggs within 24 h of mating. They mated a maximum of three times in their lifetime. Males survived for 5.80 ± 0.20 days (range 5–7 days), while the female longevity was 8.60 ± 0.45 days (range 8–11 days). A female laid 527.10 ± 25.30 eggs in her lifetime with an average of 126.50 ± 21.68 eggs per day for up to 3.5 ± 0.27 days. About 95.41 ± 0.59% eggs were found viable.

The results indicate *C. cornaria* to be a fast-growing insect with a voracious appetite. Genus *Cleora* has been previously found to cause major damage in mangroves in Thailand[15] and Kenya[16]. It has also been reported as pest in tea gardens[17] and teak plantations[18] in India. In view of previously reported tendency of the genus to be a major pest of many trees and the increased incidence of its species *C. cornaria* on neem, we should consider revising its status from a minor to that of a potential major pest.

1. National Research Council, *Neem: A Tree for Solving Global Problems*, National Academy Press, Washington, DC, 1992, p. 139.
2. Anon., *Bois For. Trop.*, 1988, **217**, 33–47.
3. Chaturvedi, A. N., *UP For. Bull.*, 1988, p. 50.
4. Chopra, R. N., Nayar, S. L. and Chopra, I. C., *Glossary of Indian Medicinal Plants*, Council of Scientific and Industrial Research, New Delhi, 1956, p. 33.
5. Ketkar, C. M., Final Technical Report, Khadi and Village Industries Commission, Directorate of Non-Edible Oils and Soap Industry, Hyderabad, 1976, p. 279.
6. Luscombe, D. K. and Taha, S. A., *J. Pharmacol.*, 1974, **26**, 110–111.
7. Ahmed, S. and Grainge, M., *Ecol. Bot.* 1986, **40**, 201–209.
8. Jotwani, M. G. and Srivastava, K. P., *Pesticides*, 1981, **15**, 19–23.
9. Moges, Y., Sub-report No. 4, FARM Africa/SOS, Sahel, 2004.
10. Siddiqui, S., *Curr. Sci.*, 1942, **11**, 278–279.
11. Tewari, D. N., *Monograph on Neem*, International Book Distributor, Dehra Dun, 1992, p. 236.
12. Beeson, C. F. C., *The Ecology and Control of the Forest Insects of Indian and the Neighboring Countries*, Government of India Press, New Delhi, 1953, 2nd edn, p. 767.
13. *Daily News Activist*, 4 February 2010.
14. *Hindustan Times*, 5 February 2010.
15. Piyakarnchana, T., *J. Sci. Soc. Thailand*, 1981, **7**, 33–36.
16. Mwangi, J. G., Eastern Arc Mountains Information Source; 2004; http://www.easternarc.org/html/NewPestK.html
17. Das, S., Mukopadhyay, A. and Roy, S., *J. Biopestic*. 2010, **3**, 016–019.
18. Nair, K. S. S., *Tropical Forest Insect Pests: Ecology, Impact and Management*. Cambridge University Press, 2007, p. 404.

ACKNOWLEDGEMENTS. We thank Dr Sushila Joshi, Division of Entomology, Indian Agricultural Research Institute, New Delhi for identification of the insect and the Department of Higher Education, Govt of Uttar Pradesh, Lucknow for providing a grant under the Centre of Excellence programme.

Received 29 April 2011; revised accepted 2 March 2012

GEETANJALI MISHRA
OMKAR*

Centre of Excellence in Biocontrol of Insect Pests,
Department of Zoology,
University of Lucknow,
Lucknow 226 007, India
**For correspondence.*
e-mail: omkaar55@hotmail.com

Egg-laying trends in black redstart (*Phoenicurus ochruros* Gmelin)

Since the mid-1970s, temperature has increased due to climate change[1] and this change is already affecting many plants and animals on the globe[2]. Most of these changes are as expected for the warming temperature[3]. According to Parmesan[4], advance in spring events has been registered in all continents, except the Antarctic. For instance[5], two frog species in their northern range limit in the United Kingdom spawned two to three weeks earlier in 1994 than in 1978. According to Najmanova and Adamík[6], among the studies on vertebrates, birds play the main role in our understanding of the responses of animals to climate change.

During the last 40 years birds have shown significant changes in their phenology, demographic factors, etc. For example, changes in population dynamics[7], brood size[8,9], egg dimensions[10], earlier arrival[11,12], etc. Numerous studies have demonstrated advances in laying dates of birds in the last several decades. Crick *et al.*[13] reported that 51 of 65 species showed a trend towards earlier nesting between 1971 and 1995. According to these authors, mean advancement in the 20 species in which the trend was most marked was 8 days (range: from 4 to 18 days). Furthermore, coefficient of variation for Blackcap (*Sylvia atricapilla*) indicates a 12-day shift toward earlier breeding over the whole period of the study (1979–2009)[14].

We examined the influence of long-term temperature effects on breeding date in black redstart (*Phoenicurus ochruros* Gmelin), which is a common bird species in the study area. This is a small (13 g, 14.5 cm), semi hole-nesting and insectivorous passerine species breed in the West Palaeoarctic in middle latitudes[15]. The birds in our study area belong to the subspecies *Phoenicurus ochruros gibraltariensis*[16].

Data were collected between 1989 and 2010 for black redstart in Mokrice village (46.00°N; 15.55°E, altitude = 140 m asl, northwestern Croatia). This area has mostly mixed landscape with small deciduous woods. The study area was visited daily during the breeding season. The term 'laying date' is defined as the date when the first egg in a clutch was layed. The number of nests in the sample varied from year to year (range being 10–17 nests per year, total = 230 nests). Only first clutches were included in the study. All observations from 1989 to 2010 were recorded by the present authors (1989–2002, Z. Dolenec; 2003–2010, Z. Dolenec and P. Dolenec). Here, the dates are expressed as progressive days (where 1 indicates 1 April). Average temperature was calculated from the average temperatures for April. This is the month when most black redstarts make their first reproductive attempts; so our assumption is that the April temperature would be the most important environmental factor influencing the onset of timing of breeding. Local spring temperature was obtained from the weather station at Maksimir – Meteorological Office in Zagreb (ca. 20 km from the centre of the research area, 123 m asl). Average monthly air temperature in Mokrice village for April from 1989 to 2010 was 11.7°C (SD = 1.509, range from 8.2°C to 14.5°C).

All the statistics was performed on average values per year and tested using Pearson's correlations with two-tailed *P*-values. The threshold for statistical significance was set at the $P = 0.05$ level. Statistical analyses were performed using the SPSS 13.0 statistical package. Correlation and regression analysis was used for revealing connections between timing of breeding on the one hand, and spring temperature and year on the other hand.

The average first laying date (1989–2010) was 17 April ± 6.4 days. First

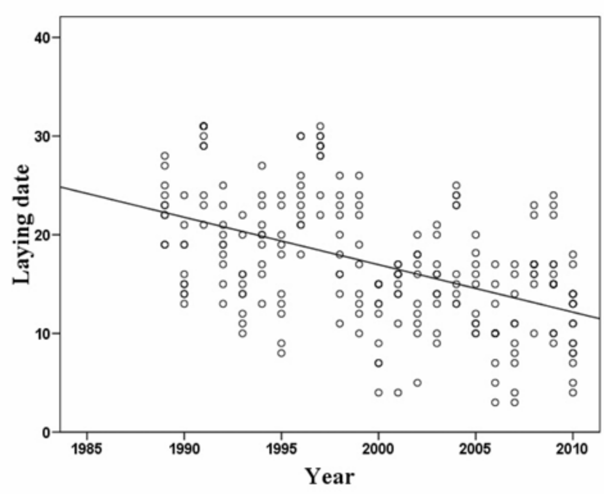

Figure 1. Long-term trends in laying date of the black redstart (*Phoenicuros ochruros*) in northwestern Croatia, 1989–2010 (where 1 indicates 1 April). The linear regression line is also shown.

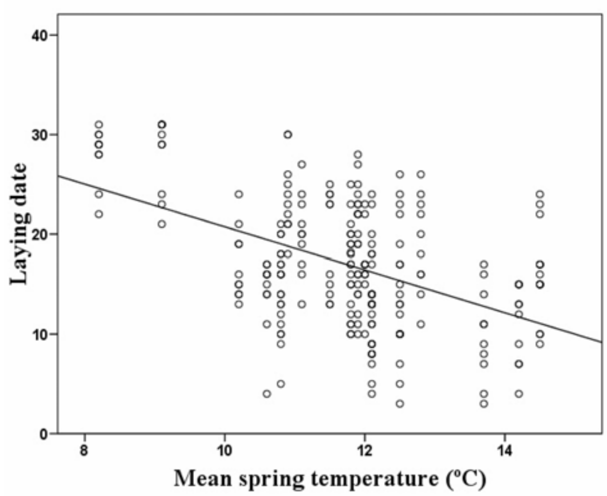

Figure 2. Relationship between laying date and mean spring (April) temperature of the black redstart (*P. ochruros*) in northwestern Croatia, 1989–2010 (where 1 indicates 1 April). The linear regression line is also shown.

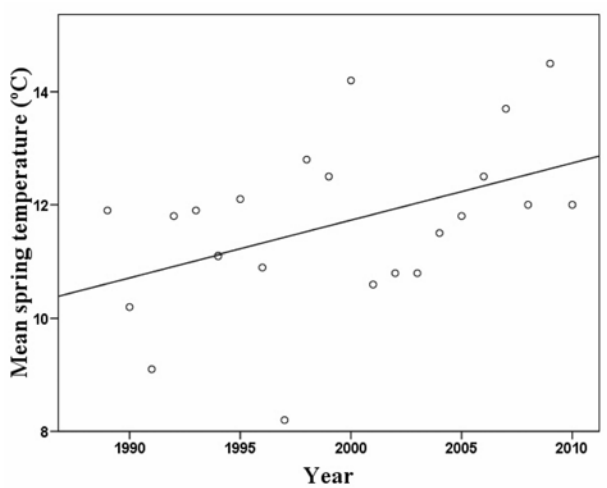

Figure 3. Mean spring (April) temperature from 1989 to 2010 at Maksimir, northwestern Croatia. The linear regression line is also shown.

laying date in black redstart in northwestern Croatia has advanced by 10.6 days (0.48 days/year) over the past 22 years (range: 3 April–1 May), trend over time: r (Pearson's coefficient) = –0.49, slope (linear regression) = –0.48, $n = 230$, $P < 0.001$ (Figure 1). Variation in laying date was significantly associated with mean spring temperature, warm spring being associated with earlier laying ($r = -0.48$, slope = –2.15, $n = 230$, $P < 0.001$; Figure 2). Mean air temperatures in April have increased by 2.2°C in the laying period (1989–2010; $r = 0.44$, slope = 0.10, $n = 22$, $P = 0.039$; Figure 3). Our results suggest that black redstart has responded to increasing air spring temperatures.

The main aim of this correspondence is to describe the change in the date of the black redstart clutch initiation and identify relationship between timing of breeding and local spring temperatures. Our results suggest that the studied bird species responds to temperature fluctuations by shifting the laying date in the study area. This earlier breeding can be explained by an increase in mean monthly temperature of 2.2°C in April over the study period. Results from our site in northwestern Croatia are in similar with those from other studies, where a significant relationship between date of breeding and local spring temperatures was found in many passerine populations[13,17]. The ready response of numerous species to recent climate change indicates that most of them have the phenotype to cope with such a change[18].

Several studies at single locations have reported shifts towards earlier laying in response to warming local spring temperature in the recent few decades. In the Czech Republic, Hušek and Adamík[8] showed that changes in the average laying date of a population of red-backed shrike (*Lanius collurio*) between 1964 and 2004 are linked to a shift in local spring temperature. In Croatia, Dolenec *et al.*[19] showed changes in the clutch initiation of tree sparrow (*Passer montanus*) between 1980 and 2009. Furthermore, McCleery and Perrins[20] also found that breeding dates for the great tit (*Parus major*) had advanced between 1947 and 1997 in the United Kingdom, in response to warmer springs. In general, this trend indicates that spring activities such a first laying dates have occurred progressively earlier since the mid-1970s in response to increasing temperatures. According to Crick *et al.*[13], spring warming is likely to have increased the availability of food supplies, resulting in earlier laying dates. However, there is documented evidence that several species may find it difficult to adapt to climate change[21]. The possible explanation might be, for instance, that different parts of a food chain may respond differently to climate change[21].

If climate change is the only new challenge that birds have to face, then one might imagine that many species could become adapted to the new conditions and survive with existing population variability and genetic information that their ancestors used to survive the past climate changes[22]. According to the author[22], other man-made challenges, such as habitat disruption, release of toxic chemicals into the environment, and other existing factors can interfere singly or synergistically with the lives of birds. Ornithology has provided some of the best examples of the impacts of recent climate change on wildlife from around the world. However, we have only begun to scratch the surface[18] and the future will show how the various bird species are able to cope with climate change and adapt to it[23].

1. Solomon, S. *et al.* (eds), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, 2007.
2. Parmesan, C. and Yohe, G. A., *Nature*, 2003, **421**, 37–42.
3. Rosenzweig, C. *et al.*, *Nature*, 2008, **453**, 353–357.
4. Parmesan, C., *Annu. Rev. Ecol. Evol. Syst.*, 2006, **37**, 637–669.
5. Beebee, T. J. C., *Nature*, 1995, **374**, 219–220.
6. Najmanova, L. and Adamík, P., *Bird Study*, 2009, **56**, 349–356.
7. D'Alba, L., Monagham, P. and Nager, R. G., *Ibis*, 2010, **152**, 19–28.
8. Hušek, J. and Adamík, P., *J. Ornithol.*, 2008, **149**, 97–103.
9. Dolenec, Z., *Pol. J. Ecol.*, 2009, **57**, 817–820.
10. Potti, J., *Acta Oecol.*, 2008, **33**, 387–393.
11. Tryjanowski, P., Kuźniak, S. and Sparks, T., *Ibis*, 2002, **144**, 62–68.
12. Dolenec, Z. and Dolenec, P., *Pol. J. Ecol.*, 2010, **58**, 605–608.
13. Crick, H. Q. P., Dudle, P. C., Glue, D. E. and Thompson, D. L., *Nature*, 1997, **388**, 526.
14. Dolenec, Z. and Dolenec, P., *J. Environ. Biol.*, 2011, **32**, 625–627.
15. Cramp, S., *Complete Birds of Western Palaearctic on CD–ROM*, Oxford University Press, Oxford, 1998.
16. Vaurie, C., *The Birds of Palaearctic Fauna: Passeriformes*, Witherby, London, 1959.
17. Dolenec, Z., Dolenec, P., Kralj, J. and Novak, D. K., *Pol. J. Ecol.*, 2009, **57**, 611–614.
18. Crick, H. Q. P., *Ibis* (*Suppl. 1*), 2004, **146**, 48–56.
19. Dolenec, Z., Dolenec, P. and Møller, A. P., *Curr. Zool.*, 2011, **57**, 414–418.
20. McCleery, R. H. and Perrins, C. M., *Nature*, 1998, **391**, 30–31.
21. Harington, R., Woiwod, I. and Sparks, T., *Trends Ecol. Evol.*, 1999, **14**, 146–150.
22. Carey, C., *Philos. Trans. R. Soc. London, Ser. B*, 2008, **364**, 3321–3330.
23. Schneider, N. A., *Introd. Res. Essay SLU*, 2008, **4**, 1–7.

ACKNOWLEDGEMENTS. We thank the Meteorological Office in Zagreb for providing temperature data. This study was supported by the Croatian Ministry of Science, Education and Sport (grant 119–1012682–1221).

Received 14 December 2011; revised accepted 2 March 2012

ZDRAVKO DOLENEC[1,*]
PETRA DOLENEC[2]
JELENA KRALJ[3]

[1]*Department of Zoology,*
Faculty of Science, University of Zagreb,
Rooseveltov trg 6,
HR-10000 Zagreb, Croatia
[2]*Department of Pharmacology,*
School of Medicine, University of Rijeka,
Braće Branchetta 20,
HR-51000, Rijeka, Croatia
[3]*Institute of Ornithology,*
Croatian Academy of Sciences and Arts,
HR-10000, Zagreb, Croatia
**For correspondence.*
e-mail: dolenec@zg.biol.pmf.hr