ÖGH Herpetozoa
Austrian Herpetological Society

Herpetozoa 32: 109–112 (2019)
DOI 10.3897/herpetozoa.32.e35825

Early onset of breeding season in the green toad *Bufotes viridis* in Western Poland

Mikołaj Kaczmarski[1], Klaudia Szala[1], Janusz Kloskowski[1]

1 *Poznan University of Life Sciences, Institute of Zoology, Wojska Polskiego 71c, 60-625, Poznań, Poland*

http://zoobank.org/083A67C2-D89B-4631-BFEC-D610D396E68F

Corresponding author: *Mikołaj Kaczmarski* (traszka.com@gmail.com)

Academic editor: *Andreas Maletzky* ♦ **Received** 29 July 2018 ♦ **Accepted** 9 January 2019 ♦ **Published** 22 May 2019

Abstract

Amphibians are highly sensitive to environmental changes such as climate warming. Here, we report unusually early oviposition in two spatially isolated urban subpopulations of the green toad *Bufotes viridis* Laurenti, 1768, in Poznań, Western Poland. To our knowledge, we report the earliest breeding date for Central and Eastern Europe, for areas of similar latitude. We ascribe the early onset of *B. viridis* reproduction to an exceptionally warm spring in Western Poland in 2017. *B. viridis* shows flexibility in the timing of reproductive activity, however, shifts in breeding phenology may have both beneficial and detrimental population consequences.

Key Words

Amphibia, Anura, climate change, global warming, phenology, Poznań

Global warming affects the phenology of amphibians (e.g. Beebee 1995; Muths et al. 2017), inducing shifts in reproductive periods that may influence amphibian populations both directly (e.g. mortality rates) and indirectly (e.g. impacts on terrestrial and aquatic habitats, changes in food webs or the spread of diseases) (Blaustein et al. 2010; Li et al. 2013). Amphibians, as a group, are highly sensitive to changes in their environment (Wake and Vredenburg 2008; but see: Kerby et al. 2009). Shifts towards earlier reproduction as an effect of climate changes progress twice as quickly amongst amphibians as in any other taxonomic group (Parmesan 2007). Here, we report unusually early reproductive activity and spawning events in the green toad *Bufotes viridis* Laurenti, 1768 in Western Poland. *Bufotes viridis* has a prolonged breeding season beginning in April in Central Europe (Table 1). This species readily inhabits human settlements (Stöck et al. 2008).

In 2017, we monitored the occurrence of *B. viridis* in the two largest known breeding sites in downtown Poznań (area: 262 km^2, total human population: about 540,000 according to the Polish Central Statistical Office, 2017): Park Cytadela [52°25'26"N, 16°55'56"E], a stone garden/amphitheatre with a permanent shallow concrete pond (area: ca. 5,150 m^2) and Park Rataje [52°23'9"N, 16°57'20"E], a post-industrial area containing debris and concrete waste, where, due to a non-permeable clay substratum, water from precipitation forms irregular ephemeral pools and habitats (Fig.1).

Evening counts were conducted twice a week with additional visits after intensive rainfalls, from mid-March to June in Park Cytadela and from the end of March to July 2017 in Park Rataje. We recorded mating calls, numbers of adults, including amplexed individuals and the presence of eggs and tadpoles. We used meteorological data from Weatherbase (http://www.weatherbase.com/, accessed 13 April 2018) and Weather Underground (https://www.wunderground.com, accessed 25 April 2018).

On 20 March 2017 in Park Cytadela, we observed 10 calling males in the pond; the number of mating individuals increased progressively, with the first two females being observed on 24 March 2017. On 31 March 2017, we counted 105 mating individuals (85 males, 20 females);

PENSOFT.

Table 1. Phenology of green toad (*Bufotes viridis*) reproduction in Central and Eastern Europe countries.

Country (region/part)	First calling/start of breeding	Oviposition	Metamorphosis
S Belarus[†]	10 –15 April	first two weeks of May	end of June – beginning of July
Czechia[‡]	April	April – August	June – July (permanent bodies) June – October (ephemeral bodies)
Germany (Berlin)[§]	6 April	from mid-April to the end of April	
SW Germany (Rhineland-Palatinate)[|]	24 March (the earliest)	28 March – 11 May	July
SE Germany (Saxony)[¶]	mid-April (often)	from the end of April to mid-June	ca. the beginning of July
Poland[#,††]	16 – 30 April	25 April – June (exceptionally from early April)	June – early August
Poznań, Poland (our study)	20 March	31 March	23 August

[†] Drobenkov et al. 2005; [‡] Zavadil et al. 2011; [§] Kühnel and Krone 2003; [|] Sinsch et al. 1999; [¶] Stöck et al. 2008; [#] Juszczyk 1987; [††] Kowalewski 1974

Figure 1. The breeding sites of Bufotes viridis in Park Cytadela (upper), and in and in Park Rataje (lower).

the next day, we found a number of egg strings, we also observed interspecific amplexus between the common toad *Bufo bufo* (male) and *B. viridis* (female). However, electrofishing, performed in April 2017, revealed the presence of abundant fish in the pond, mainly *Carassius auratus* Linnaeus, 1758 and *Tinca tinca* Linnaeus, 1758; hence, apparently no tadpole survived to metamorphosis. In the second breeding site, Park Rataje, on 31 March 2017, we observed 71 mating individuals of *B. viridis* and the first three strings of eggs. The next day, there were several dozen strings of eggs, as well as the first developing embryos. However, the tadpoles did not survive, most probably as a result of pool desiccation in mid-May. On 7 June 2017, we observed 57 breeding individuals, including four amplexed pairs, as well as, two days later, abundant spawn; however, by the end of June, the tadpoles had perished once again due to pool desiccation. Nevertheless, on 23 August 2017, we found a number of toadlets at Gosner stage 45 and 46 (Gosner 1960), indicating that toads had reproduced after our last field visit (4 July 2017); thus, the breeding season of *B. viridis* in Park Rataje spanned about 3.5 months.

We suggest that the early spawning date of *B. viridis* was related to the exceptionally warm period in late March. According to the Köppen climate classification system, the city of Poznań is characterised by a maritime temperate climate (Cfb), with mean annual precipitation of approximately 513 mm. The mean monthly air temperature for March over the previous 10 years (2007–16) had been 4.1°C, with 5.4°C in the last decade of March. In March 2017, the mean air temperature was 6.5°C, with recorded daily mean temperatures in the last decade of March varying between 5.0°C and 16.0°C with a mean of 9.3°C. The days 31 March and 1 April 2017 were exceptionally warm: the mean daily temperature reached 17.3°C and 17.8°C, respectively. The effect of the urban heat island, with a mean annual temperature higher by 1°C in Poznań than in the surrounding non-urban areas (Majkowska et al. 2017), may have additionally accelerated the mating period. In addition, in Park Rataje, intense rainfalls exceeding 11.1 mm from 18 to 19 March 2017 created numerous pools providing reproductive sites.

The above observations of breeding *B. viridis* specimens are, to our knowledge, the earliest in the year amongst published data from Central and Eastern Europe sites with similar climates and at similar latitudes (see Table 1 for details). Reports on similar early breeding events originate from regions further to the south of the continent or simply characterised by warmer climates, such as Polish Jura, southern Poland (Kowalewski 1974), Rhineland-Palatinate, south-western Germany (Sinsch et al. 1999) or Lower Austria (Cabela et al. 2001). Notably, our observations do not concern single individuals, but apparently whole local subpopulations in two spatially isolated parts of the city (separated by an approximate distance of 4.5 km).

As a species adapted to climatic variability, *B. viridis* may show flexibility in the timing of its reproductive activity (Kyriakopoulou-Sklavounou 2000; Sicilia et al. 2006). Although the reproductive period of *B. viridis* in Central Europe usually spans three consecutive months (April–June) (Juszczyk 1987), in Park Rataje, Poznań, in 2017, this period lasted presumably until July, with metamorphosis recorded in the third decade of August. However, according to Zavadil et al. (2011), in ephemeral water bodies in Czechia, metamorphosing individuals can be observed as late as October.

In conclusion, we would like to highlight that shifts in phenology may be both advantageous and unfavourable. Earlier spawning gives juveniles more time to develop and accumulate energy reserves before winter hibernation (Reading and Clarke 1999; Tryjanowski et al. 2003). On the other hand, earlier breeding may imply the development of tadpoles in a colder environment, which may contribute to increased mortality of larvae. *B. viridis* tadpoles that develop later, in warmer water, have a higher survival rate, but at metamorphosis are smaller than tadpoles developing in colder water (Dastansara et al. 2017). Typically, in anurans, larger metamorphs have higher survival rates (Reques and Tejedo 1997), while smaller individuals are more threatened by predation (John-Alder and Morin 1990) and desiccation (Child et al. 2008). Earlier spawning may contribute to a mismatch between tadpole food demands and the availability of algae, resulting in reduced tadpole growth (Reading and Clarke 1999). In human-dominated landscapes, preterm spawning may also locally prolong the exposure of adult *B. viridis* to glyphosate-based herbicides during their spring migration to breeding ponds, while reducing the exposure of eggs, larvae and juveniles following their emergence from the water (Lötters et al. 2014). Furthermore, a tendency to early onset of reproduction in *B. viridis* may increase the risk of hybridisation with *B. bufo* due to the overlap of breeding periods (Stöck et al. 2008; Canestrelli et al. 2017).

Acknowledgements:

We are grateful to Wiktor Grenas and Łukasz Dylewski for help in the field. All research activities were approved by the Regional Directorate for Environmental Protection (permission no. WPN-II.6401.190.2016.AC.2).

References

Beebee TJC (1995) Amphibian breeding and climate. Nature 374: 219–220. https://doi.org/10.1038/374219a0

Blaustein AR, Walls SC, Bancroft BA, Lawler JJ, Searle CL, Gervasi SS (2010) Direct and indirect effects of climate change on amphibian populations. Diversity 2: 281–313. https://doi.org/10.3390/d2020281

Cabela A, Grillitsch H, Tiedemann F (2001) Atlas zur Verbreitung und Ökologie der Amphibien und Reptilien in Österreich: Auswertung der Herpetofaunistischen Datenbank der Herpetologischen Sammlung des Naturhistorischen Museums in Wien. Umweltbundesamt, Wien, 880 pp.

Canestrelli D, Bisconti R, Chiocchio A, Maiorano L, Zampiglia M, Nascetti G (2017) Climate change promotes hybridisation between deeply divergent species. PeerJ 5: e3072. https://doi.org/10.7717/peerj.3072.

Child T, Phillips BL, Shine R (2008) Abiotic and biotic influences on the dispersal behavior of metamorph cane toads (*Bufo marinus*) in tropical Australia. Journal of Experimental Zoology 309A: 215–224. https://doi.org/10.1002/jez.450

Central Statistical Office (2017) Area and population in the territorial profile in 2017. GUS, Warszawa, 189 pp.

Dastansara N, Vaissi S, Mosavi J, Sharifi M (2017) Impacts of temperature on growth, development and survival of larval *Bufo* (*Pseudepidalea*) *viridis* (Amphibia: Anura): implications of climate change. Zoology and Ecology 27: 228–234. https://doi.org/10.1080/21658005.2017.1360037

Gosner KL (1960) A simplified table for staging anuran embryos larvae with notes on identification. Herpetologica 16: 183–190. https://www.jstor.org/stable/3890061

John-Alder HB, Morin PJ (1990) Effects of larval density on jumping ability and stamina in newly metamorphosed *Bufo woodhousii fowleri*. Copeia 1990: 856–860. https://www.jstor.org/stable/1446453

Juszczyk W (1987) Płazy i gady krajowe. Wydawnictwo Naukowe PWN, Warszawa, 836 pp.

Kerby JL, Richards-Hrdlicka KL, Storfer A, Skelly DK (2009) An examination of amphibian sensitivity to environmental contaminants: are amphibians poor canaries? Ecology letters 13: 60–67. https://doi.org/10.1111/j.1461-0248.2009.01399.x

Kowalewski L (1974) Observations on the phenology and ecology of amphibia in the region of Częstochowa. Acta Zoologica Cracoviensia 19: 391–460. http://www.isez.pan.krakow.pl/journals/azc/pdf/19/19_18.pdf

Kühnel K-D, Krone A (2003) Bestandssituation, Habitatwahl und Schutz der Wechselkröte (*Bufo viridis*) in Berlin – Grundlagenuntersuchungen für ein Artenhilfsprogramm in der Großstadt. Mertensiella 14: 299–315. https://www.diveand.travel/pdf/nea000221_wechselkr_te_pdf_427.pdf

Kyriakopoulou-Sklavounou P (2000) Adaptations of some amphibian species to Mediterranean environmental conditions. Belgian Journal of Zoology 130: 109–113. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.619.3614&rep=rep1&type=pdf

Li Y, Cohen JM, Rohr JR (2013) Review and synthesis of the effects of climate change on amphibians. Integrative Zoology 8: 145–161. https://doi.org/10.1111/1749-4877.12001

Lötters S, Filz KJ, Wagner N, Schmidt BR, Emmerling C, Veith M (2014) Hypothesizing if responses to climate change affect herbicide exposure risk for amphibians. Environmental Sciences Europe 26: 1–5. https://doi.org/10.1186/s12302-014-0031-4

Majkowska A, Kolendowicz L, Półrolniczak M, Hauke J, Czernecki B (2017) The urban heat island in the city of Poznań as derived from Landsat 5 TM. Theoretical and Applied Climatology 128: 769–783. https://doi.org/10.1007/s00704-016-1737-6

Muths E, Chambert T, Schmidt BR, Miller DAW, Hossack BR, Joly P, Grolet O, Green DM, Pilliod DS, Cheylan M, Fisher RN, McCaffery RM, Adams MJ, Palen WJ, Arntzen JW, Garwood J, Fellers G, Thirion J-M, Besnard A, Campbell Grant EH (2017) Heterogeneous responses of temperate-zone amphibian populations to climate change complicates conservation planning. Scientific Reports 7: 17102. https://doi.org/10.1038/s41598-017-17105-7

Parmesan C (2007) Influences of species, latitudes and methodologies on estimates of phenological response to global warming. Global Change Biology 13: 1860–1872. https://doi.org/10.1111/j.1365-2486.2007.01404.x

Reading CJ, Clarke RT (1999) Impacts of climate and density on the duration of the tadpole stage of the common toad *Bufo bufo*. Oecologia 121: 310–315. https://doi.org/10.1007/s004420050933

Reques R, Tejedo M (1997) Reaction norms for metamorphic traits in natterjack toads to larval density and pond duration. Journal of Evolutionary Biology 10: 829–851. https://doi.org/10.1111/j.1420-9101.1997.tb00001.x

Sicilia A, Lillo F, Zava B, Bernini F (2006) Breeding phenology of *Bufo viridis* Laurenti, 1768 in Sicily. Acta Herpetologica 1: 107–117. https://doi.org/10.13128/Acta_Herpetol-1291

Sinsch U, Höfer S, Keltsch M (1999) Syntope Habitatnutzung von *B. calamita*, *B. viridis* und *Bufo bufo* in einem rheinischen Auskiesungsgebiet. Zeitschrift für Feldherpetologie 6: 43–64.

Stöck M, Roth P, Podloucky R, Grossenbacher K (2008) Wechselkröten. In Grossenbacher K (ed.). Handbuch der Amphibien und Reptilien Europas. Vol. 5. Froschlurche II. Akademische Verlagsgesellschaft, Wiesbaden, 413–498.

Tryjanowski P, Rybacki M, Sparks T (2003) Changes in the first spawning dates of common frogs and common toads in western Poland in 1978–2002. Annales Zoologici Fennici 40: 459–464. https://www.jstor.org/stable/23735858

Wake D, Vredenburg V (2008) Are we in the midst of the sixth mass extinction? A view from the world of amphibians. Proceedings of the National Academy of Sciences of the United States of America 105: 11466. https://doi.org/10.1073/pnas.0801921105

Zavadil V, Sádlo J, Vojar J (2011) Biotopy našich obojživelníků a jejich management. AOPK ČR, Praha, 178 pp.