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RESEARCH NOTE

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Distant but similar: Simultaneous drop in the abundance of three independent amphibian communities

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Abstract

Amphibian species are declining worldwide, with a negative trend affecting both rare and widespread species. There is increasing evidence that resources must be allocated not only toward the monitoring of rare and charismatic species; however, the attention toward abundant species has often been minimal. Here, we describe the strong reduction in the numbers of several widespread amphibian species over the last 3 years observed in three independent amphibian monitoring studies conducted in an alpine, floodplain, and urban landscape in Italy, Germany, and Russia, respectively. The decline was particularly strong in juveniles, but adults and egg clutches were also affected. Such declining rates, if prolonged in the future years, will likely pose a serious threat to the populations' ability to recover and might increase extinction risk also in abundant and widespread species.

KEYWORDS

extinction, floodplains, juveniles, monitoring, mountains, recruitment

1 | INTRODUCTION

Over the last 30 years, the worldwide decline of amphibian populations has become a major concern of researchers and conservationists (Blaustein & Wake, 1990; Houlahan et al., 2000; Stuart et al., 2004). Recent trajectories forecast that this decline is likely to accelerate by the end of the century (Hof et al., 2011) and there are increasing indications of an acceleration already happening over the last few years (Laufer, 2021; Zahn et al., 2021).

A wide series of anthropogenic stressors, in adjunct with natural fluctuations (Pechmann et al., 1991), is the cause of this trend (Blaustein et al., 2011). These include global warming (Pounds, 2001), pathogen infections (Voyles et al., 2009), habitat loss (Cushman, 2006), and exposure to agro-industrial chemicals (Rohr et al., 2008).

Regardless of what the causes might be, intense fluctuations in the demographic characteristics of a population might increase its extinction risk even in widespread and abundant species (Green, 2003; Hung et al., 2014; Inchausti & Halley, 2003).

There is increasing evidence of the importance of monitoring and protecting common species and that their conservation can have indirect beneficial impacts also on other ones (Gaston, 2008, 2010). Moreover, their decline might be more easily noticed than that of rarer or cryptic species (Jeliazkov et al., 2022) and thus halted more promptly, with beneficial cascading effects on the whole ecosystem (Koch et al., 2011).

Here, we report the results of three independent but simultaneous amphibian monitoring projects conducted in different sites of Eurasia between 2018 and 2020. By describing similar declines in the relative abundance of rather widespread species, we highlight the potential causes that might trigger similar results over such a vast scale and stress the need of investigating changes in widespread species' abundance.

2 | METHODS

2.1 | Italy

The study was conducted in northeast Italy, in Paneveggio-Pale di San Martino Nature Park (46°17′54″ N, 11°47′20″ E). We surveyed 16 different terrestrial plots in an altitudinal belt spanning from 1890 to 2100 m above sea level (asl), from June to August between 2018 and 2020. Each year, we rotated the survey order to avoid any possible bias caused by the season. Each plot consisted of two 100-m transects that were daily walked for nine consecutive days by the same observer at regular speed while searching for amphibians in the suitable microhabitats.

All individuals of *Rana temporaria* encountered were captured and processed for the collection of biometric data. To discern different rates of decline among age classes, we divided the captured individuals into three age groups, namely: juveniles (snout-vent length; SVL $\leq$ 3.5 cm, 12 months from metamorphosis), sub-adults (3.5 cm < SVL $\leq$ 5 cm, 24 months from metamorphosis), and adults (SVL > 5 cm; Miaud et al., 1999).

In addition, a different team sampled two spawning ponds of *R. temporaria* that were found in the southeastern area of the Park (Val Canali, 1000 m asl). There, we conducted count surveys of egg clutches every day following a rain or 3–4 days in case of good weather for the whole spring.

2.2 | Germany

The study took place in the "Papitzer Lehmlachen" (51°22′49″ N, 12°14′33″ E), a part of the flora–fauna–habitat area "Leipziger Auensystem" (floodplain system of Leipzig). An annual aquatic amphibian monitoring by means of minnow traps took place, which aimed at catching amphibians during their reproductive period for population viability analyses (Mazoschek, 2018). Due to logistic and license restrictions, trapping took place in June 2018, May and June 2019, and May 2020. To consider seasonal differences, we divided trapping data by month.

We restricted our dataset to the eight ponds that have been surveyed every year and standardized our data to six traps, although we placed between 4 and 10 traps per pond. Traps were placed for 3–5 days in 2018, for 6–8 in 2019, and for 3 days in 2020. Only two ponds were surveyed for 26 days in 2019 but, for having a comparable time frame, we used only the captures from the central 8 days of trapping.

2.3 | Russia

The study was conducted in Yekaterinburg urban agglomeration and its vicinity (56°51′06″ N, 60°36′43″ E). The area is a strongly anthropized landscape, consisting of a mixture of urban and industrial infrastructures, city parks, gardens, and native forested remnants. We sampled a total of 23 spawning ponds.

We conducted annual counts of amphibian egg clutches and metamorphosed juveniles every summer between 2018 and 2020, as part of a long-lasting monitoring program (Vershinin et al., 2015). Direct counts of egg clutches started at the end of April and were implemented for the following 2 weeks. To determine average density of metamorphosed juveniles per square meter, we used quadrat sampling (1 × 1 m) at randomly selected sites (Jaeger & Inger, 1994). Sampling started from the end of June, when metamorphosis begins, until the end of the season. These counts were conducted four times per pond in the immediate proximities of the water area.

2.4 | Statistical analysis

All analyses have been conducted in R 4.0.3. (R Development Core Team, 2020). We compared the numbers of individuals or clutches observed between the 3 years by means of one-way analysis of variance. In all three study sites, we used the different days as replicates with the exception of the egg clutch counts for which we used ponds as replicates and the yearly sum of clutches as response variable. We could not perform a statistical comparison between the clutches counted in Italy because of the extremely limited sample size.

3 | RESULTS

3.1 | Italy

Across the 3 years, we had 141 encounters with *R. temporaria*. Of these, we managed to distinguish 96 different individuals based on their dorsal pattern. The total numbers have been declining steadily, with a 40% reduction from 2018 to 2019 and of 46.7% between 2019 and 2020. The proportion of individuals captured to those observed only remained constant throughout the whole study period.

The numbers of individuals were not evenly distributed among age classes, with the adults remaining constant throughout the study period (Figure S1). On the other hand, we recorded a significant reduction in the number of juveniles and sub-adults (Table 1), with sub-adults declining from 15 individuals captured in 2018 to

TABLE 1 Analysis of variance summary for the differences in the number of amphibians caught in the three study sites between 2018 and 2020

Species	Age class	df	*F*	*p*
A. Paneveggio-Pale di San Martino Nature Park (Italy)				
Rana temporaria	Adults	2, 24	0.403	.673
	Sub-adults	2, 24	9.484	.0009*
	Juveniles	2, 24	5.925	.008*
B. Papitzer Lehmlachen (Germany)				
Bombina bombina	Adults	3, 17	1.315	.302
	Tadpoles	3, 17	4.807	.013*
Bufo bufo	Adults	3, 17	0.877	.472
	Tadpoles	3, 17	12.26	.0001*
Hyla arborea	Adults	3, 17	NA	NA
	Tadpoles	3, 17	4.934	.012*
Pelobates fuscus	Adults	3, 17	NA	NA
	Tadpoles	3, 17	4.115	.023*
Pelophylax spp.	Adults	3, 17	5.049	.011*
	Tadpoles	3, 17	16.45	2.84e−05*
Rana spp.	Adults	3, 17	0.339	.797
	Tadpoles	3, 17	1.13	.365
Lissotriton vulgaris	Adults	3, 17	8.218	.001*
	Larvae	3, 17	6.114	.005*
Triturus cristatus	Adults	3, 17	2.575	.087
	Larvae	3, 17	23.33	2.94e−06*
C. Yekaterinburg (Russia)				
Rana arvalis	Juveniles	2, 6	0.236	.797
	Clutches	2, 65	0.689	.506
Rana temporaria	Juveniles	2, 6	0.185	.836
	Clutches	2, 65	0.303	.739
Pelophylax cf. *bedriagae*	Juveniles	2, 6	0.335	.728
	Clutches	-	-	-
Lissotrito vulgaris	Juveniles	2, 6	0.47	.646
	Clutches	-	-	-
Salamandrella keyserlingii	Juveniles	2, 6	0.778	.501
	Clutches	2, 65	0.536	.588

*indicates a significant difference between years.

4 in 2019. Juveniles showed a drop especially between 2019 and 2020, with 18 versus only 6 individuals caught, respectively.

In addition, we observed a severe reduction in the number of clutches produced between 2019 and 2020 in the two spawning ponds that were monitored (Figure S1). Moreover, already in 2019 we started observing an increased percentage of eggs not reaching full development. Such high mortality affected also the few clutches found in 2020, resulting in an uncommonly low number of tadpoles.

3.2 | Germany

In the eight ponds surveyed, we caught 2304 individuals belonging to eight species of anurans and two caudates (Table 1). After standardization, it remained 1483 individuals, consisting of 1065 adults and 418 tadpoles or larvae.

We generally observed much more variability among tadpoles and larvae than adults, but there were species-specific differences (Figure S2). With the exception of *Rana* spp., all species showed significant differences in the number of juveniles captured across years (Table 1). In particular, post hoc Tukey test revealed significant pairwise difference existing between June 2018 and 2019 for *Hyla arborea* ($p = .028$), *Pelophylax* spp. ($p = .0003$), and the two newt species (*Lissotriton vulgaris*: $p = .017$; *Triturus cristatus*: $p = .00002$), as well as between May 2019 and 2020 in the case of *Bufo bufo* ($p = .023$). For the adult specimens, the only significant difference was found for *Pelophylax* spp. ($F_{3,17} = 5.04$, $p = .011$), particularly between June 2018 and 2019 ($p = .016$; Figure S3).

Rana spp. was the only species not showing any signs of decline: neither for adults nor juveniles. However, since they are early and explosive spawning species (Petrovan & Schmidt, 2019), they may have mated already in April or May and thus a larger number of adults might have been overlooked. Interestingly, we observed a slight increase in the number of tadpoles caught by trapping in 2020, possibly because the two brown frog species showed an earlier activity in 2020 than in the other 2 years with tadpoles already peaking in May.

3.3 | Russia

We evaluated the reproductive output through egg clutch counts in *Salamandrella keyserlingii*, *Rana arvalis*, and *R. temporaria*. Juvenile counts also included *L. vulgaris* and *Pelophylax* cf. *bedriagae*.

Overall, although for none of the species this was significant (Table 1), the number of juveniles decreased by 31.7% between 2018 and 2020, accentuating an ongoing negative trend that started decades ago (Vershinin et al., 2015). This was particularly evident with the urodeles *L. vulgaris* and *S. keyserlingii* that decreased by 38.2% and 84.2%, respectively. However, similarly to what happened in the Papitzer Lehmlachen to newts, the lowest level was reached in 2019 (Figure S4).

The reduction was more subtle (26.2%) for froglets of Ranidae, with *P.* cf *bedriagae* declining constantly since 2018 but the other species showing a more alternating trend and *R. temporaria* even slightly increasing over the 3 years (Figure S4). Also egg clutches production showed species-specific trends; although again none of these changes proved to be statistically significant (Table 1).

4 | DISCUSSION

The long-term crisis that amphibians are facing both worldwide and in Europe is a major concern of conservationists (Stuart et al., 2004); yet, far from being halted. With this study, we provide evidence of a drop in amphibian abundance over the triennium 2018–2020 in three different areas of Eurasia where we witnessed a particularly strong reduction in the number of juveniles. Although limited both in space and time, these results support the growing concern about a possible acceleration in the decline of European amphibians over the last few years (Laufer, 2021; Zahn et al., 2021) and expand it further than previously imagined.

Different hypotheses could explain these drops. The infections caused by pathogens, such as *Batrachochytrium* spp., have been reported to wipe out entire populations (Skerratt et al., 2007). Similarly, substantial landscape changes have also been shown to be responsible for the collapse of amphibian communities (Arntzen et al., 2017; Windmiller et al., 2008). However, none of the three areas underwent main landscape modification during the study period, nor were signs associated to *Batrachochytrium* spp. or other known pathogens outburst (e.g., adult mass mortality; Lips et al., 2005; Schulz et al., 2020) ever detected.

A more likely explanation can be found in the extreme meteorological events registered in Europe during the same years. Between 2018 and 2020, Europe experienced what is considered the most severe drought event of the last 250 years (Boergens et al., 2020; Schuldt et al., 2020), with the reduction in precipitation leading to a water deficit of about 112 Gt in 2018 and 145 Gt in 2019 (Boergens et al., 2020).

Due to their physiological and phenological needs, amphibians are particularly threatened by such extreme events (Blaustein et al., 2001; Carey & Alexander, 2003). Dry years have been shown to affect particularly strongly juveniles' survival when compared to periods with average precipitations (Cayuela et al., 2016), and the warmer temperature associated with a decrease in the ponds' water level is one of the main limiting factors affecting tadpoles and larval development (Enriquez-Urzelai et al., 2019).

Naturally, we cannot exclude the possibility for these trends to be simply natural fluctuations in otherwise rather stable populations and that these do not represent an immediate threat to the survival of the species. However, even if these drops were stochastic, excessive and repeated fluctuations can undermine population stability and increase extinction risks (Greenberg et al., 2017) and if, as forecasted (Hari et al., 2020), extreme weather events are going to increase in frequency, we argue that their magnitude and repetition could undermine population stability and jeopardize recovery of affected species. Moreover, since juveniles are the key determinants of the long-term population dynamics of *r*-selected species (Cole et al., 2016; Di Minin & Griffiths, 2011), the extinction risk increases strongly if such fluctuations affect the juvenile sub-fraction of the population (Cole et al., 2016; Schmidt, 2011).

Although long-term monitoring studies are fundamental, conservation practice cannot wait for the accumulation of long time series but should rather act rapidly. Therefore, even if limited to only 3 years and few sites, we believe that these results can work as an early alarm bell for conservationists in order to develop intervention strategies aiming at identifying and halting population fluctuations.

AUTHOR CONTRIBUTIONS

Michele Chiacchio, Annegret Grimm-Seyfarth, and Klaus Henle conceived the study; all authors contributed to datasets; Michele Chiacchio performed the analysis and wrote the manuscript; all authors reviewed, edited, and accepted the final version of the manuscript.

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CONFLICT OF INTEREST

The authors have no conflicts of interests to be disclosed.

DATA AVAILABILITY STATEMENT

Data supporting the results of the study can be accessed upon reasonable request from the corresponding author.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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