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The salamander plague in Europe – a German perspective

The devastating effects of the 'salamander plague', caused by the invasive fungal pathogen *Batrachochytrium salamandrivorans* (*Bsal*) on native caudate amphibians in Europe, have been intensively documented in the Netherlands (Spitzen-van der Sluijs et al. 2013). The decline of a Dutch population of the European fire salamander, *Salamandra salamandra,* indeed led to the discovery and taxonomic description of this fungus (Martel et al. 2013). Despite an enormous global concern about the emergence of this new pathogen (e.g. Yap et al. 2015) and intensive research on its origins and impact on European salamanders and newts (e.g. Martel et al. 2014, Stegen et al. 2017, Beukema et al. 2018, Canessa et al. 2018, O'Hanlon et al. 2018), there is only limited awareness of the catastrophic salamander declines that the pathogen is currently causing in Germany – a country that we can consider, without exaggerating, as the current *Bsal* 'hotspot' in Europe.

The presence of *Bsal* in the wild in Germany was first detected by Spitzen-van der Sluijs et al. (2016), while Sabino-Pinto et al. (2015) provided evidence for the presence of the pathogen in captive salamander collections in the country. This triggered an intensification of survey and monitoring activities, funded primarily by the Bundesamt für Naturschutz (BfN) and the Deutsche Bundesstiftung Umwelt (DBU), involving massive fieldwork efforts and the analysis, overall, of more than 8,000 swabs of wild amphibians and more than 1,000 swabs of captive specimens via quantitative PCR, in a comprehensive and collaborative approach led by a team of university researchers and professional conservation biologists. Updates of this research activity were released mostly in German language by Dalbeck et al. (2018), Schulz et al. (2018) and Wagner et al. (2019), and the captive collection results were published by Sabino-Pinto et al. (2018). Given the many affected salamander populations in Germany, our observation of declines in real time, and indications for prolonged presence of the pathogen for at least 16 years in the country, the assembled data give important insights into the impact of this novel pathogen. We therefore aimed at making the entire knowledge available to the international scientific and conservation community without further delay.

No journal could be better suited than SALAMANDRA, published by the German Herpetological Society, DGHT, when it comes to documenting these dramatic disease-related population declines in German populations of *S. salamandra*. The collection of articles in this issue of the journal provides a detailed summary of our knowledge on the impact of *Bsal* in the epicentre of its invasive range that Germany sadly has become. This includes accounts on the known distribution of the pathogen across geography and hosts, observed mass mortality and hypothesized population collapses, documentation of externally visible symptoms, co-infection with *Batrachochytrium dendrobatidis* (*Bd*) and presence of other pathogens at some sites, methodological development as well as species distribution models.

The collection of articles in this issue first presents an overview of the occurrence and impact of *Bsal* in wild amphibian populations in Germany (Lötters et al. 2020a), followed by more detailed accounts on the situation in the Ruhr District (Schulz et al. 2020) and the southern Eifel region (Sandvoß et al. 2020). Schmeller et al. (2020) and Thein et al. (2020) report two very recent *Bsal* outbreaks from southern Germany. Wagner et al. (2020a, b) report on conclusions on European fire salamander habitat requirements and hypothesized extinctions derived from in-depth surveys of their larvae. Jung et al. (2020) add further information on the (non-)occurrence of *Bsal* in several captive collections. Lötters et al. (2020b) provide evidence for the earliest occurrence of *Bsal* in Europe from histopathological evidence, and Sachs et al. (2020) summarize the results of a pathogen screening on amphibians in the city of Cologne, not far from the known *Bsal* outbreaks, where widespread *Bd* infection as well as other potentially harmful microorganisms were detected. Finally, Wagner et al. (2020c) contribute to methodological improvements of salamander monitoring at the *Bsal* expansion front by providing comparative data on different methods that are available to estimate larval population sizes of European fire salamanders.

Many of the papers in this issue include, on purpose, a large amount of 'anecdotal' information which will require additional scrutiny from future studies, but may help to inform and guide these. This applies to the apparent disappearance of European fire salamanders in the southern Eifel region – we are aware that absence of a species is always hard to demonstrate, and even more so in elusive salamanders. It also includes the apparent infection of an anuran host, *Rana temporaria*, with *Bsal* – although confirmed by independent analyses in two laboratories, this single case will require confirmation from additional research. We also find that *Bsal* has been present in Germany since at least 2004: confirmed for the Eifel by histopathology, and possibly – and thus in need of confirmation – also in the Ruhr District as indicated by photos.

By making all these data and results available, we hope to draw the attention to the threats that salamander and newt populations are facing in Germany by the

salamander plague, and we are confident that having all this information available will stimulate future research and proactive conservation management. In the next future our goal must go beyond documenting declines towards understanding spatio-temporal disease dynamics and the factors influencing the spread and impact of *Bsal* in different situations. The data we assembled over the past years and which we summarized in this issue of SALAMANDRA are reason for both despair and hope. On one hand, drastic and extremely fast population declines of European fire salamanders caused by *Bsal* are a reality, and probably the pathogen has led to the regional extinction of the species in large parts of the southern Eifel region. On the other hand, even in the strongly affected European fire salamander sites in the Ruhr District, a few salamanders can still be seen 2–3 years after the disease struck, and in the northern Eifel, populations where the pathogen was detected still thrive – although often at low numbers – several years later. And, apparently, at least some Central European species of newts can survive in considerable population sizes despite the presence of the pathogen, suggesting that not all European caudate species will be fatally affected by *Bsal*. However, there is reason to be seriously concerned about the northern crested newt (*Triturus cristatus*) which appears to be affected by population declines when *Bsal* appears.

Ultimately, we need to scientifically inform conservation managers on habitat management strategies advisable to ensure survival of European fire salamander and other caudate populations in face of *Bsal*. Should we embrace – in the short term – the isolation of small salamander populations to avoid the spread of the pathogen into them? Or do metapopulations offer better opportunities for decline-recovery dynamics allowing for coexistence of pathogen and host? Will increased temperature and drought – in the context of climate change, or from active measures such as partial forest clearance – affect the pathogen's long-term survival, or rather be an additional threat for the salamander populations? Which management units are worthy of ex situ preservation, and which re-introduction strategies should be followed after ex situ breeding?

As claimed by Lötters et al. (2020a) in this issue, a national *Bsal* Action Plan is needed to coordinate and prioritize the next steps in research, but especially in conservation of salamanders and newts in Germany. A long-term monitoring plan is necessary to understand not only the spread of the pathogen but also possible recovery of populations that have been affected by declines. An ex situ emergency strategy is needed to preserve genetic Management Units of especially the European fire salamander if local extinctions cannot be halted. And for all this, large-scale diagnostic capacities are necessary to allow for quick testing of suspicious cases of salamander mortality, as well as for continued testing of long-term monitored populations. We hope this collection of articles constitutes a first step towards such a German *Bsal* Action Plan.

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