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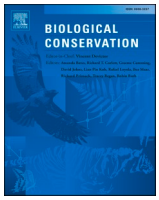

Short communication

Dealing with a *Batrachochytrium salamandrivorans* outbreak in Italy: Are conservationists prepared?

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ABSTRACT

The recently updated IUCN Red List assessment indicates endemic amphibians in southern Europe are threatened by imminent arrival of the invasive pathogen *Batrachochytrium salamandrivorans* (*Bsal*). Several efforts have aimed to raise awareness of this threat, set up early warning networks, and explore management strategies. Should a *Bsal* outbreak be detected, rapid and effective actions are necessary to ensure containment and eradication. We surveyed a sample of salamander specialist researchers and conservationists in Italy to gauge the level of preparedness. Out of 35 respondents, the majority expressed incomplete awareness of the *Bsal* threat and of what management actions might be available, and were unsure or pessimistic about available resources and the necessary decision processes. We recommend continuing efforts on raising awareness of the *Bsal* threat, adding more practical measures such as clarifying available actions and stakeholders, running local stress tests and facilitating communications and procedures to be followed in an emergency.

Emerging diseases are a well-known threat to amphibian diversity worldwide (Scheele et al., 2019). For areas with susceptible host species, the arrival and unchecked spread of novel pathogens can be disastrous. For example, *Batrachochytrium salamandrivorans* (*Bsal*) led to collapse of local fire salamander (*Salamandra salamandra*) populations in the Netherlands (Martel et al., 2014) and now threatens endemic salamanders in the Americas and southern Europe (Luedtke et al., 2023). Unfortunately, preventing and managing future *Bsal* outbreaks remains extremely difficult (Canessa et al., 2018).

Preparation for *Bsal* arrival includes establishing an early warning network (Gray et al., 2015; Thomas et al., 2019), but warning is only useful if it rapidly triggers an effective practical response (Gagliardo et al., 2008). For *Bsal*, the time window for intervention appears limited, possibly weeks (Stegen et al., 2017). Managers would have to quickly choose among prospective actions that range from doing nothing, to restricting access to site, to eradication of all possible amphibian hosts and even site destruction (Thomas et al., 2019). These diverse actions involve different biological, financial, practical and ethical implications, depending on the background context. To accelerate such emergency decisions, several problems should be clarified pre-emptively (Bozzuto et al., 2020). For example, what management options exist? What resources would be available? Are side effects of drastic actions, such as removing reservoir hosts, acceptable? Who is tasked with making these decisions?

We sought to gauge the level of preparedness to a hypothetical *Bsal* incursion in Italy, a country hosting 19 salamander species, many of which are endemic and have a restricted area of occurrence (Sindaco and Razzetti, 2021). The spread of *Bsal* could threaten this highly diverse amphibian fauna. During the 1st Italian National Congress on Urodelans held in Chiavari (Italy) on 26–27 October 2023 (Rosa, 2023), we administered an anonymous questionnaire addressing the why-when-how-who of a hypothetical *Bsal* outbreak response. Each respondent was asked to imagine that *Bsal* was detected in one of their focal study populations, and was then asked to answer the following questions with closed answers (administered in Italian – the following is a literal translation to English):

(1) Do I know the susceptibility to *Bsal* of all urodele species occurring within a 10-km range? (possible answers: Yes/No)
(2) How often is this population monitored? (less than once a month/at least once a month)
(3) Can I think of possible practical actions to manage a *Bsal* outbreak? (No, none/Yes, one/Yes, more than one)

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(4) Are economic and logistical resources available to implement such practical actions? (I don't know/No, not available/Yes, available on request/Yes, available immediately)
(5) Do I know who is tasked with deciding whether and how to implement actions? (Yes/No, it would take a few days to find out/No, it would take longer than a week to find out)

We formulated these questions to explore the space between the above-mentioned literature on *Bsal* outbreaks, including host susceptibility and prospective actions, and the implementation phase with its likely constraints in resources and control on decisions. We limited the questionnaire to five questions for practical reasons, providing pre-set answers for easer of comparison, while encompassing five recommended elements for rational decision making: triggers, decision-makers, objectives, alternatives and constraints/trade-offs (Gregory et al., 2012). Further, we deliberately chose non-specific wording because our purpose was not to recommend a given course of action (which for *Bsal* remains largely uncertain), but to gauge the extent of *Bsal*-related reflection and awareness among the respondents.

The online questionnaire was administered, using an anonymous Google Form, on-screen and via email to approximately 100 conference attendees: 35 responded within 48 h, after which the link was closed. Although the sample is small in absolute terms, we consider it highly representative of the small pool of specialist urodele researchers in Italy. These are presumably the people most aware of *Bsal*, most likely to detect it, and most likely to advise a response.

Out of 35 respondents, 13 (37 %) expressed confidence that they knew the susceptibility to *Bsal* of all species that occur within a 10-km range (Fig. 1). Thirteen (37 %) responded that their focal population was monitored more than once a month. Sixteen (46 %) could not immediately think of any action that could be applied in response to a *Bsal* outbreak, 12/35 (34 %) could think of one action, and 7/35 (20 %) of more than one available option. Six out of 35 (17 %) believed resources to implement actions would be available upon request, 11/35 (31 %) that resources would not be available, the majority (18/35, 51 %) did not know the answer, and no respondent believed resources would be available immediately. Finally, 11/35 (31 %) felt they knew who would be tasked with making decisions about implementing management, 16/35 (46 %) did not know but felt confident they could find out within a few days, and 8/35 (23 %) expected that identifying decision makers would take longer than a week.

The range of responses suggests that in some circumstances, a rapid response to a *Bsal* outbreak could be mounted, but in most cases effectiveness and speed would be limited by a lengthy decision process. The susceptibility of local species to *Bsal* was mostly unclear even to specialists, suggesting awareness is still insufficient despite the considerable efforts in research (Dondero et al., 2023) and communication (e.g. http://*Bsal*europe.com/).

First, respondents were unaware or unclear of the level of threat posed by *Bsal* to Italian urodelans, which would likely slow the pace of any response, particularly if action requires collecting evidence and conveying a sense of urgency to non-specialist decision makers. Further, if monitoring is infrequent, and unless samples are collected regularly for surveillance, detection will probably occur when the suitable window for intervention has passed (Bozzuto et al., 2020). The more communication steps are needed, the more time will elapse while understanding the threat, contacting specialists, collecting and analyzing more data, and confirming the presence and extent of the outbreak.

Upon detection, managers will likely seek expert guidance on whether to act and how. Actions should be chosen carefully but quickly. There are only few options available to manage emerging wildlife diseases, particularly *Bsal* (Thomas et al., 2019). To our knowledge, the only instance where drastic containment actions were taken during a *Bsal* outbreak, including site destruction and host culls, concerns a 2018 report from north-eastern Spain, where management appears to have at least contained the outbreak (Martel et al., 2020). Given this limited experience, the effectiveness of actions remains uncertain; regardless, judging from our results, prospective actions are largely unknown even to specialists. The literature on amphibian diseases does not yet fill this gap between scientific knowledge and evidence-based, tested recommendations (Canessa et al., 2019). Factsheets with multiple options for management might be a simple solution, including estimates of cost-effectiveness and uncertainty, possibly issued by herpetological societies and easily retrievable online. We emphasize that we do not

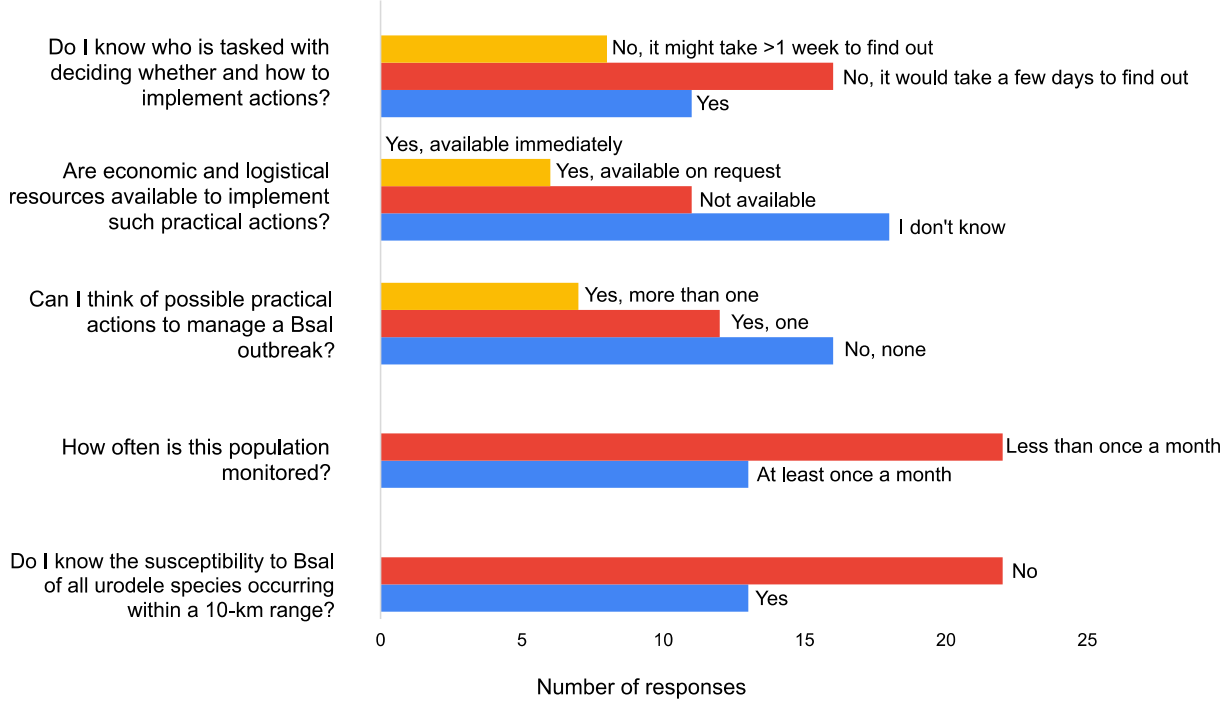

Fig. 1. Summary of questionnaire responses ($n = 35$). Note that for question 4 ("Are economic and logistical resources available") no respondent indicated "Yes, available immediately". All answers allowed in the questionnaire are represented.

recommend here a specific course of action over another, or even any reaction at all. Whether and how to react to an outbreak will largely depend on local management priorities and constraints, encompassing local regulations on nature conservation and animal welfare: in some cases, even not reacting at all could be the optimal action in the face of an outbreak (Bozzuto et al., 2020). Although careful choice of actions cannot ensure success, a more rushed and less informed decision is more likely to have worse outcomes.

Knowing what to do is irrelevant if one does not have the appropriate resources or is stopped by administrative complications. Decision makers can include local landowners, water/land agencies, ethics committees, local administration and subcontractors. Time needed to identify actors, obtain funds and legal authorizations, and follow administrative steps will further reduce the window for action. Decision structures are context-specific, so universal guidelines are unrealistic. However, at the national level at least, it should be possible to identify key competencies and administrative steps to take. Stress tests help highlight significant bottlenecks (Bernard and Grant, 2021; Canessa et al., 2020; Hopkins et al., 2018). For example, Canessa et al. (2020) tested the process of rapidly eliciting advice from experts in the event of a *Bsal* outbreak. They found that vaguely defined objectives and competencies created gaps which experts filled with their own interpretations, making it difficult to compare and aggregate different opinions, and likely disrupting rapid response. In the USA, Hopkins et al. (2018) explored several scenarios of *Bsal* detection in different circumstances, identified possible responses and key communication chains, and listed the steps to take before and after detection, including the relevant agencies to contact. This experience should be replicated as soon as possible in countries like Italy, ideally under the guidance of national herpetological societies, with the aim of providing a template for decision making and chain of contacts. Finally, concerning the issue of available resources, recognizing *Bsal* outbreaks as environmental disasters might facilitate mobilization and administrative processes, speeding up decision-making and reaction times.

Prevention remains the most plausible strategy against *Bsal* (Thomas et al., 2019; Yap et al., 2015). However, when that line of defense fails, time becomes the limiting factor. The experience in Spain shows there may still be a narrow window of opportunity in the early stages of a *Bsal* outbreak (Martel et al., 2020). Considering the potential consequences, it would be a pity to give up that opportunity because of unpreparedness.

CRediT authorship contribution statement

Stefano Canessa: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Data curation, Conceptualization. **Andrea Costa:** Writing – review & editing, Writing – original draft, Validation, Resources. **Giacomo Rosa:** Writing – review & editing, Writing – original draft, Validation, Resources. **Sebastiano Salvidio:** Writing – review & editing, Writing – original draft, Validation, Resources.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

Data availability

All data are included in the article

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Author statement

Stefano Canessa conceived the study, administered the questionnaire with help from all other authors, and analyzed results. All authors co-wrote the manuscript.

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