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PERSPECTIVES AND NOTES

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Conservation decisions under pressure: Lessons from an exercise in rapid response to wildlife disease

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Target audience: Managers and scientists seeking to mitigate impacts of emerging wildlife diseases, particularly those facing a novel pathogen invasion to which they wish to respond quickly.

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Abstract

Novel outbreaks of emerging pathogens require rapid responses to enable successful mitigation. We simulated a 1-day emergency meeting where experts were engaged to recommend mitigation strategies for a new outbreak of the amphibian fungal pathogen *Batrachochytrium salamandrivorans*. Despite the inevitable uncertainty, experts suggested and discussed several possible strategies. However, their recommendations were undermined by imperfect initial definitions of the objectives and scope of management. This problem is likely to arise in most real-world emergency situations. The exercise thus highlighted the importance of clearly defining the context, objectives, and spatial–temporal scale of mitigation decisions. Managers are commonly under pressure to act immediately. However, an iterative process in which experts and managers cooperate to clarify objectives and uncertainties, while collecting more information and devising mitigation strategies, may be slightly more time consuming but ultimately lead to better outcomes.

KEYWORDS

amphibians, chytridiomycosis, containment, detection, early warning, epizootic, expert elicitation, mitigation, objectives, workshop

1 | INTRODUCTION

Of all major causes of biodiversity loss, emerging infectious diseases of wildlife remain one of the most challenging to address. Once a pathogen invades a new area, eradication is typically impossible (e.g., Canessa et al., 2018; Carter et al., 2009; Hallam & McCracken, 2011). However, greater awareness of disease impacts is opening new possibilities for rapid response. For example, when the fungus *Batrachochytrium dendrobatidis* (Bd) was described in 1998 as causing amphibian chytridiomycosis, it had already been driving widespread species losses since the 1970s (Scheele et al., 2019). When a second related pathogen emerged in the early 2010s (*B. salamandrivorans*, Bsal; Martel et al., 2013), its threat was recognized more quickly than for Bd, prompting the development of strategic plans for prevention and reaction in Europe (www.bsaleurope.com) and North America (www.salamanderfungus.org/resources/). Framing such strategic plans as decision problems can assist their development and implementation (Bernard & Grant, 2019). Grant et al. (2017) developed a decision-support analysis for proactive Bsal management, and Hopkins et al. (2018) used scenario-building to prepare response frameworks for Bsal detection on public lands in the United States. However, these general plans and frameworks remain to be tested and a true emergency response has rarely been implemented for a wildlife disease (Mysterud & Rolandsen, 2018). For chytridiomycosis, several Panamanian species were brought into captivity ahead of the expected wave of Bd invasion (Gratwicke et al., 2016). Yet even this action did not seek to actively respond to the pathogen's arrival, instead aiming to mitigate its long-term impacts through development of assurance colonies and reintroductions.

2 | CASE STUDY: A SIMULATED EMERGENCY MEETING TO INFORM RESPONSE TO DISEASE DETECTION

In April 2019, we simulated an emergency meeting in which a panel of experts was asked to recommend a rapid response to Bsal detection. The 1-day workshop was organized jointly with the international symposium “Mitigating single pathogen and co-infections threatening amphibian biodiversity” hosted by the Zoological Society London (UK). Attendees signed up voluntarily for the workshop, without prior knowledge of the specific topic or structure, although a focus on mitigating chytridiomycosis was anticipated. To give experts a practical context for the exercise, organizers presented a realistic case study, based on a real case of Bsal detection in 2018 in the Netherlands, 200 km from the closest known Bsal location in Europe. Two professionals from

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RAVON (Reptile, Amphibian, and Fish Conservation the Netherlands), a nongovernmental organization that routinely advises Dutch authorities on herpetological conservation planning, attended the workshop and acted as decision-makers in the simulation (A.S. and T. S; S.C. facilitated). All other 24 attendees were scientists with expertise in amphibian diseases or conservation attending the above-mentioned international symposium (hereafter "the experts").

For realism, experts were given no case-specific information before the workshop. At the beginning of the exercise, they were provided limited information available about the hypothetical Bsal detection: a brief summary of species, focal area, and Bsal detection history at the site. The detection site was a single 235-m^2 pond in a multiple-pond system within the agricultural landscape (Figure 1), where two dead crested newts (*Triturus cristatus*) were found by volunteers during routine monitoring and subsequently confirmed as Bsal-positive by laboratory testing (personal communication by co-authors A.S. and T.S.).

Experts were given three management objectives, agreed upon the previous day by the acting decision-makers and facilitator: (a) minimize the probability of Bsal spread from the detection site to neighboring sites, (b) minimize collateral damage to the amphibian community, and (c) minimize collateral damage to nontarget species and the environment.

Participants then articulated the uncertainty that influenced their recommendations about mitigation actions. The question of whether Bsal was present, but undetected, at sites adjacent to the detection site was perceived as particularly important for recommending management actions. The only relevant information available was that a limited number of newts sampled across the neighboring ponds shortly after the initial diagnosis ($n = 37$) all tested negative for Bsal. This information was considered insufficient to infer Bsal presence or absence (results of additional surveys in spring 2019 were not yet available at the time of our workshop). Uncertainty was therefore further articulated into three hypotheses: (a) Bsal is currently present only at the detection site; (b) Bsal is present at neighboring ponds (i.e., within amphibian dispersal distance from the detection site—hundreds of meters); and (c) Bsal is present in the surrounding landscape (>1 km from the detection site).

Participants then developed a set of mitigation actions of different intensity. The group agreed upon five alternative actions: (a) implement basic biosecurity (Phillott et al., 2010) when entering or leaving the detection site; (b) prevent amphibian movement into or out of the site by fencing and limit other wildlife movements into the detection site (e.g., overhead netting to prevent bird entry), and capture amphibians around the fence and release them inside to reduce pathogen spread; (c) in addition to the actions in 2, treat captured amphibians with heat to clear putative Bsal infection (Blooi et al., 2015) before release inside the fence; (d) install a fence impermeable to most potential Bsal hosts and vectors at the detection site, remove all animals from the detection site and treat the site with chemicals using Virkon Aquatic® (sensu Bosch et al., 2015)—the captured individuals could be euthanized, or quarantined and tested

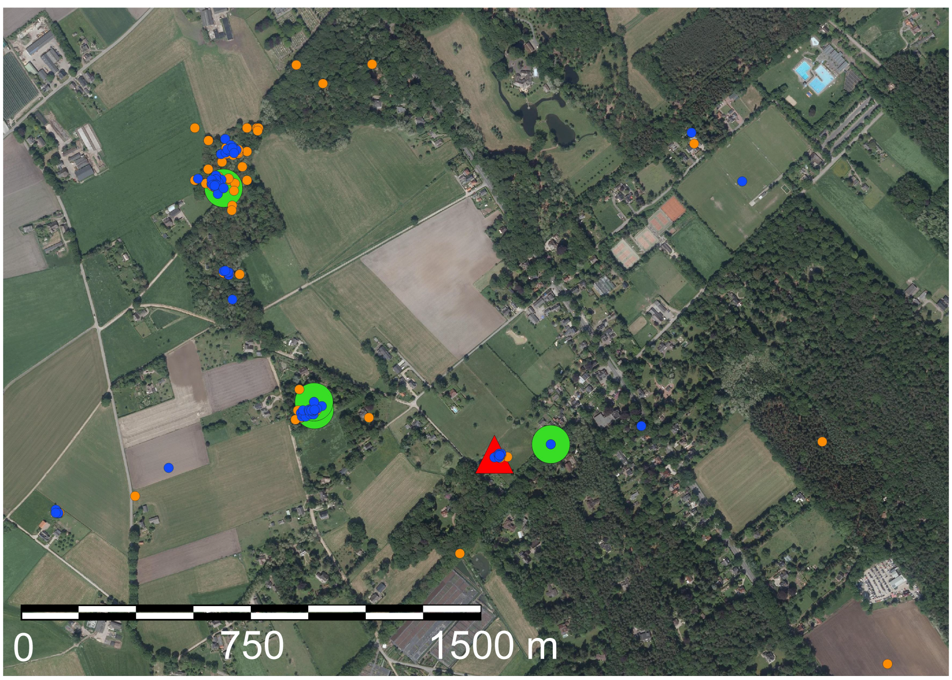

FIGURE 1 Aerial image of the case study landscape where Bsal was detected. The green circles are locations where newts were tested for Bsal in 2018 (light green; $n = 37$ all negative). The red triangle is the confirmed Bsal positive site in 2019. Small circles indicate known presence of *Triturus cristatus* (orange) and *Lissotriton vulgaris* (blue) at ponds between 2009 and 2019. Map orientation and coordinates not provided

for Bsal then disinfected; and (e) in addition to the actions in (d), completely dry the waterbody at the detection site and return the captured and treated amphibians to the site after water was again present.

We then used a modified Delphi process with four-point elicitation (Hemming, Burgman, Hanea, McBride, & Wintle, 2018) to obtain quantitative estimates of the expected outcomes of actions under the different hypotheses. In other words, experts were asked to estimate the probability that each action would succeed in containing Bsal spread if Bsal were present only at the detection site *or* if it were present in neighboring water bodies *or* if it were present across the adjacent landscape (three estimates per action, each with the associated uncertainty). Experts provided initial estimates individually; these were summarized and displayed to the group using bar plots, to allow opinions and information to be shared among experts.

The ensuing discussion soon highlighted discrepancies among experts about the decision context, particularly about whether eradication or containment were sought only from the detection site, from the broader landscape, or from the province/region/country, and about the size of the area that could be directly managed. There was a wide array of implicit assumptions among experts, fueled in part by the imprecise definition of objectives against the three hypotheses about the current spread of the Bsal outbreak. For example, if Bsal were already present across the landscape, would action focusing at one pond contribute at all to preventing its spread? Would uncertainty about the broader presence of Bsal in the surrounding landscape truly affect the decision to manage the focal pond, or would pond-level actions be undertaken regardless? These and other components of the problem had been, to this point, interpreted in substantially different ways by different experts, which meant that a comparison of individual estimates was not meaningful. Further discussion failed to resolve these issues, and the acting decision-makers were unable to provide definitive responses about the objectives. A complete revision of the decision problem appeared necessary, but time did not allow it. Rather than pushing through an artificially simplified solution, we chose to terminate the exercise and focus the final discussion on the difficulties encountered and lessons learned.

3 | DISCUSSION

Our workshop failed to solve our simulated decision problem, but it succeeded in its primary aim of highlighting some key challenges likely to arise in emergency responses to pathogen detection. Here we convert these challenges into lessons learned. We identify stall-points that could easily arise in a real emergency wildlife-disease event with elevated emotions and a broader set of stakeholders. Resolving known stall-points ahead of a crisis can facilitate and accelerate rapid responses when it really matters.

3.1 | Poorly defined objectives make decisions difficult

Our workshop focused exclusively on engaging experts to provide recommendations about which actions to implement. The workshop was free from many complexities that are likely to arise in real emergency situations: Experts had engaged voluntarily in the exercise, had no personal stakes in its outcome, and there were no obvious conflicts among scientists. Potentially challenging interactions among decision makers and stakeholders, such as obtaining access to private properties, were also not represented in the exercise. Experts generally felt comfortable discussing actions and providing scores, even without elicitation training or experience, and interacted well in small and large groups. While knowledge of chytridiomycosis is still incomplete, it is probably sufficient to devise an emergency mitigation plan. Despite these favorable conditions, issues emerged that proved insurmountable within the time available. Those problems did not arise from scientific disagreements about disease dynamics and management actions but from the unclear definition of the initial decision context (the objectives, scope, and spatial scale of mitigation). The importance of context and objectives is a central principle of decision-making theory (Gregory et al., 2012) and a recognized challenge to Bsal mitigation (Bernard & Grant, 2019). We observed this challenge develop first-hand, which could severely impede a real emergency response where there is little room for error and delay. Decision-makers should prepare for such an emergency by clarifying the decision context as much as possible before a real crisis occurs. A clear context, including objectives, scale, and scope of the decision, will allow experts to be more efficient and provide more informed advice.

In the absence of clearly stated objectives and context, experts will use their own experience to construct the context from which they then advise decisions. During our workshop, uncertainty about Bsal epidemiology and the state of the outbreak in the wild highlighted our lack of clarity in defining objectives. For example, the optimal spatial scale at which to manage an outbreak is related to its rate of spread across a landscape, but the scope of our decision (whether objectives were at the local, regional, or national level, and what time frame was being considered) was unclear, so experts struggled to provide their estimates or based them on their own assumptions about the spatial scale.

Objectives may need to be updated quickly to reflect the current state of knowledge. In some cases, local information may be accessed for additional information and surveillance could be initiated that might yield results in time for incorporation into the decision-making process. In our case, if new monitoring confirmed Bsal presence beyond the focal pond, the objective of minimizing spread might change to large-scale eradication, and some actions such as fencing would be inappropriate. If data collection cannot be incorporated into the initial decision, managers might decide to precautionarily implement mitigation over a larger area. Data collection and broader precautionary actions might also be combined, to the extent allowed by the resources available.

3.2 | Ask quantitative questions of the right experts

There is still much to be learned about wildlife diseases. Many management decisions will depend on expert opinion, especially in a crisis. Formal methods for expert elicitation may be perceived as time-consuming (even our incomplete Delphi process took over a third of the 1 day workshop). However, the problems in our scenario emerged only when quantitative individual estimates were shared and discussed with the group and divergent assumptions became apparent. More informal, purely verbal assessments might have failed to uncover different personal interpretations, leading to a flawed recommendation and a poor decision. Simply asking experts, or even worse a single expert, for their intuition rather than engaging them formally is likely to exacerbate such problems (Sutherland & Burgman, 2015). We recommend eliciting written quantitative estimates, to facilitate discussion, analysis and reporting.

The composition of the expert panel is also important. Discussions rapidly expanded our decision to include impacts on nonamphibian species and the environment; such multiple objectives are common and should be considered when assembling an expert panel. Our workshop was planned around amphibians and the panel assembled opportunistically, but an ecotoxicologist or a restoration ecologist likely would have contributed to the discussion about the collateral damage of mitigation treatments, improving both the definition of objectives and the elicitation of consequences (Game, Kareiva, & Possingham, 2013). Other types of experts may also be required (e.g., for legal advice); again, decision-makers should anticipate these needs and prepare as much as possible before the emergency occurs. Finally, cultural and disciplinary diversity is generally advantageous when assembling expert panels (Sutherland & Burgman, 2015). Our exercise involved scientists from Europe, the Americas, and Oceania, allowing us to hear a wide range of views and experiences. However, this also meant there was little time to establish a common knowledge base of the decision context, for example, by clarifying the relevant European, Dutch and local authorities and legislation (such as regulations for accessing private sites, releasing chemicals into the environment or killing nontarget species), or addressing implicit assumptions about resource availability, willingness to act, or species ecology. Preplanning, including a list of experts, their areas of knowledge and contact details is advantageous in reacting to an emergency.

3.3 | Iterative processes are necessary but time-consuming

Facilitators of decision-making workshops often repeat the process several times. This approach, known as "rapid prototyping," initially requires heavy simplification but quickly highlights key problems on which a second iteration can then focus (Gregory et al., 2012). In our workshop, a second iteration might have sought a shared definition of "spread" and "landscape" that satisfied the decision-maker and gave experts a clear scenario for elicitation. This second iteration would have probably been more efficient, as common language and objectives had been developed and clarified in the first one. However, we ran out of time for a second iteration. In comparison, a 3-day scenario planning exercise for Bsal response in the United States provided more information for policymakers, but it did not include an explicit quantitative assessment of detailed actions (Hopkins et al., 2018). A 4-day workshop in Europe produced a complete quantitative assessment of several Bsal mitigation actions but did not involve a real decision-making context (Canessa et al., 2018). Gerber et al. (2018) developed a full mathematical model and decision process for landscape-scale management of enzootic chytridiomycosis in boreal toads (*Anaxyrus boreas*) over several months, including two multiday workshops and iterated remote elicitation. Such complex tools are obviously difficult to develop in emergency situations; if possible, they should be prepared in advance.

Disease outbreaks typically leave little time for response, but also little room for error. Even 1–2 extra days might allow a more informed decision, although longer delays are obviously riskier (Scudamore & Harris, 2002). How long is too long depends on the local policy context and on the characteristics of the disease: for example, Bsal might disperse slowly (Spitzen-van der Sluijs et al., 2018), allowing managers more time—possibly weeks—than in the case of pathogens spread by more mobile hosts (e.g., *Pseudogymnoascus destructans* causing white-nose syndrome in bats; Foley, Clifford, Castle, Cryan, & Ostfeld, 2011). Again, such characteristics may be unknown in the case of novel emerging pathogens and diseases, forcing decision-makers to rely on expert elicitation and making uncertainty inevitable.

3.4 | Drills are not reality, for better or worse

In a real emergency, urgency could give the decision-maker a stronger resolve to act, but might also rush decisions. For simplicity, we did not explicitly represent such time and social pressures in our 1-day workshop. For *P. destructans*, a similar recent workshop was successful in reaching a decision for pathogen control (Bernard et al., 2019). We did not provide information to experts before the workshop, but the logistics of larger, international meetings might allow some time for preparation. Preselecting panels could make emergency meetings more efficient when they are eventually called.

3.5 | Policy directions

Based on our experience, we suggest the following for engaging scientists to define a rapid response plan for pathogen invasions.

- Clarify the decision context as much as possible: identify the decision-maker and the spatial and temporal scope.
- Assemble a mid-sized group (10–15) including managers and experts, not limited to specialists of the focal hosts and pathogen.
- Engage experts with clear questions but be prepared to incorporate feedback and go back to clarify policy aspects as needed. Presence of decision-makers at the meeting should facilitate this process.
- Formal expert elicitation requires more preparation than informal discussions, but is more effective and transparent for identifying misunderstandings and presenting results. Trained facilitators can assist.
- Take extra time as necessary without rushing to action. Plan for multiple iterations of the decision-making process, even if it means simplifying at the beginning.

Decisions made in the first days after disease detection can be crucial for mitigation success (Keeling & Rohani, 2008). Effective collaboration between managers and scientists before and after detection is the key to that success.

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CONFLICT OF INTEREST

The authors declare there are no conflicts of interest associated with this publication.

AUTHOR CONTRIBUTIONS

S.C., A.S., T.S. and T.W.J.G. conceived the idea and organized the workshop; all authors attended the workshop and contributed to the elicitation and discussions; S.C. wrote the manuscript with input from all other authors.

ETHICS STATEMENT

The research did not require ethics approval.

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