BSAL GUIDANCE FOR STATE WILDLIFE ACTION PLANS 2024

ASSOCIATION of FISH & WILDLIFE AGENCIES

What is Bsal?

The United States has the largest diversity of salamanders in the world, particularly in the Appalachian, Pacific Northwest, and Sierra Nevada regions, but disease is a major threat to these populations. *Batrachochytrium salamandrivorans* (Bsal) is a pathogenic chytrid fungus known for infecting various amphibian species. Many species of salamanders and newts are susceptible, but certain anuran species are also vulnerable to the fungus (Towe et al. 2021; Gray et al. 2023). *Batrachochytrium salamandrivorans* is closely related to the amphibian pathogen *Batrachochytrium dendrobatidis* (Bd), which has been implicated in the extinction of several dozen amphibian species throughout the world and tied to the decline of many other species.

Research suggests that Bsal originated in Asia and was likely spread to Europe via the pet trade. Due to the international trade of amphibians, both legal and illegal, the probability of Bsal introduction into North America is high. While the U.S. Fish and Wildlife Service listed 201 species of salamander as injurious wildlife under the Lacey Act due to being potential carriers of Bsal, other susceptible species like fire-bellied toads (*Bombina spp.)* remain in trade (Grear et al., 2021; Connelly et al., 2023).

Why is Bsal a concern?

After introduction into Europe, Bsal extirpated fire salamander populations in multiple countries, across much of middle Europe. Based on lab studies, Bsal caused infection in 74%, and mortality in 35% of North American species tested (Gray et al. 2023). Models predict that biodiversity loss is expected to be greatest in the Appalachian Region and along the west coast of the United States. It is believed that Bsal may be actively spread by carriers (e.g. salamanders, anurans) and passively spread by birds and other species, and by humans via things like water, waders, and equipment.

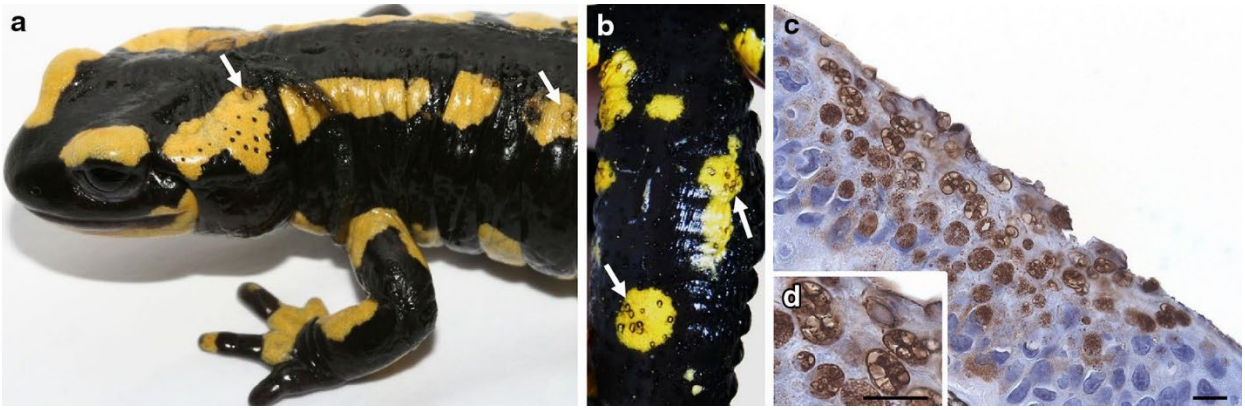
Prevention versus response

Measures to prevent introduction and spread of Bsal will be more effective at minimizing the catastrophic effects of the fungus on susceptible native amphibian populations than will attempts to control the fungus after its detection. Suggested measures to prevent the introduction of Bsal encompass reaching out to diverse audiences such as retail pet stores, pet owners, and outdoor enthusiasts. This involves communicating the potential threat that Bsal poses to native amphibians and actively involving these audiences to

mitigate the risk of introduction. Additionally, the implementation of rules or regulations is recommended to prohibit the import of potential carriers with a high risk of transmitting the pathogen. Proactive management, in advance of detection of Bsal at a site, may be the best option to reduce the risk of catastrophic declines.

What species are at risk?

Recent research has indicated a number of amphibian species are vulnerable to Bsal infection in laboratory settings (Gray et al. 2023). Table 1 below depicts species, life stages, and responses to experimental infection. Some of the species tested are Species of Greatest Conservation Need (SGCN) while others, like the American bullfrog (*Rana catesbeiana*) and Cuban treefrog (*Osteopilus septentrionalis*) are invasive in some parts of the United States.



Clinical signs and pathology associated with infection due to Batrachochytrium salamandrivorans.

a) A naturally infected fire salamander (Salamandra salamandra) found during a B. salamandrivorans-outbreak (Robertville, Belgium) showing several ulcers (white arrows) and excessive skin shedding;

b) extensive ulceration (white arrows) at the ventral side of an infected fire salamander;

c) skin section through an ulcer evidences abundant intracellular colonial thalli in all epidermal skin layers; immunohistochemical stain with polyclonal antibodies to B. dendrobatidis; scale bar 10 µm;

d) magnification of the intracellular colonial thalli from micrograph c; immunohistochemical stain; scale bar 10 µm.

Pascale van Rooij et al.: Amphibian chytridiomycosis: a review with focus on fungus-host interactions. In: Veterinary Research 2015; vol. 46, nr. 137, doi:10.1186/s13567-015-0266-0

Table 1. Host susceptibility and conservation risk for Moderate to High-Risk North American amphibian species exposed to *Batrachochytrium salamandrivorans* (Bsal) at 15°C**

Species	Family	Life-stage	% Infection (n)[a]	% Mortality[a]	Conservation Risk[b]
Aneides aeneus	Plethodontidae	Adult	100 (10)	50	Moderate
Ensatina eschscholtzii klauberi	Plethodontidae	Adult	100 (4)	75	Moderate
Eurycea bislineata	Plethodontidae	Adult	100 (9)	66.67	High
Notophthalmus meridionalis	Salamandridae	Adult	100 (9)	100	Very High
Notophthalmus perstriatus	Salamandridae	Adult	100 (10)	100	Very High
Notophthalmus viridescens	Salamandridae	Adult	100 (10)	100	Very High
Notophthalmus viridescens	Salamandridae	Juvenile	100(10)	100	Very High
Osteopilus septentrionalis	Hylidae	Adult	100 (4)	100	High
Pseudotriton ruber	Plethodontidae	Adult	100 (5)	100	Moderate

***The full table of species tested in the experiment can be found at Gray et al. (2023).*

In addition to examining risks to species, researchers also conducted geographic risk analyses based on environmental suitability and presence of host species. Figure 1 below is from Gray et. al (2023) and show the risk predictions. As a note, Dr. Matthew Gray and his team are able to create State-Level Risk maps for interested states.

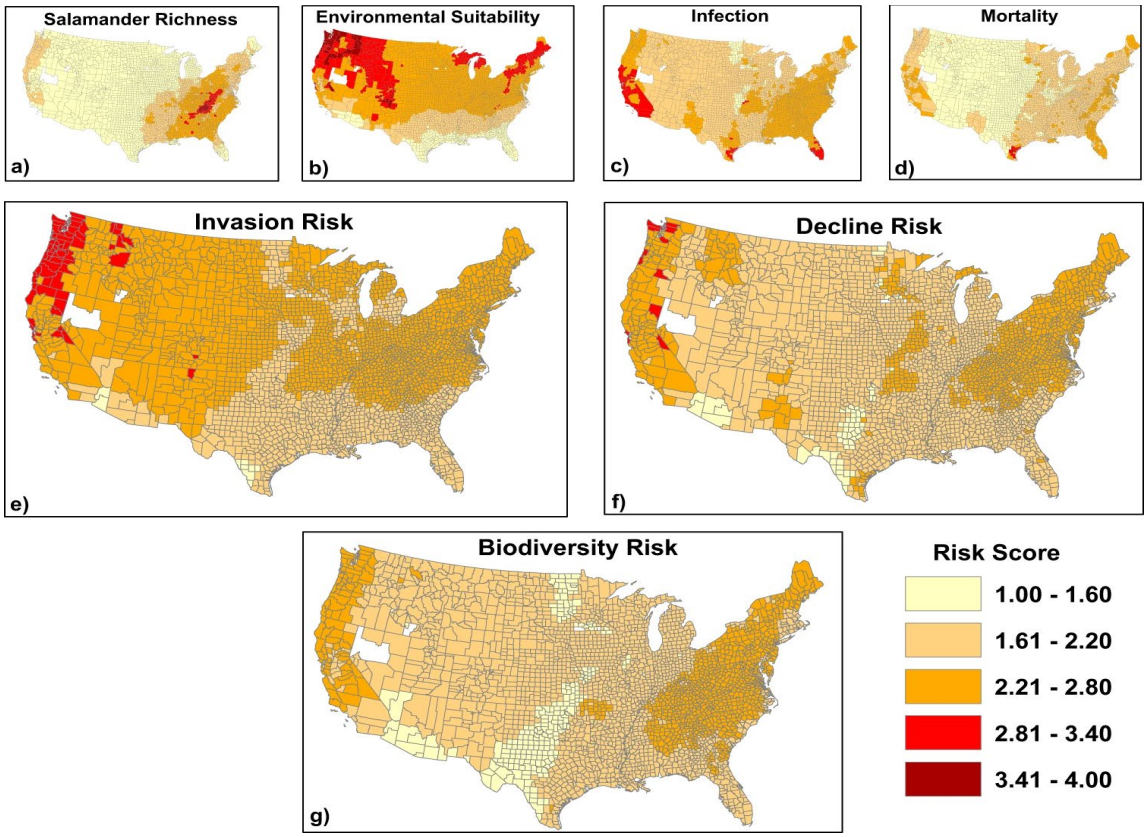


Figure 1: *The top row shows salamander species richness (a), environmental suitability for Bsal (b) and mean predicted infection and mortality across host species at the county level (c, d). Invasion risk (e) was created by averaging environmental suitability (b) and mean predicted infection (c). Decline risk (f) is the average of b, c, and d; high scores indicate environmentally suitable areas where the host community includes species that are readily infected and experience Bsal-related mortality. Biodiversity risk (g) due to Bsal also takes species richness into consideration (i.e., is the average of a–d), and indicates where salamander diversity will be impacted most. Darker shades indicate greater risk.*

Pre-Detection Strategies to Include in SWAPs

1. Establish and implement prevention protocols.

a. Establish standard biosecurity protocol for work in wetlands and aquatic habitats. As a note, the use of a stronger bleach concentration (ca. 10× stronger) is needed for effectiveness against Bsal (Van Rooij et al. 2017).
   i. Disinfection protocols for herpetofaunal pathogens (2023)
   ii. Simple disinfection protocol

b. Reduce the risk of spillover from captive to wild amphibians.
   i. Consider prohibitions on import of certain high-risk species.
   ii. Establish communications with pet stores and captive amphibian breeders to provide information about Bsal and how to test captive amphibians for pathogens. Consult the Healthy Amphibian Trade Project for resources.

c. Create a communication plan that includes messages on the importance and value of amphibians, the risks Bsal poses, and how target audiences (researchers, captive amphibian owners/breeders, hikers, and others) can prevent introduction and spread of Bsal.

2. Establish surveillance efforts.

a. Identify high-risk species and areas in your state.

b. Develop a surveillance plan to test for occurrence of Bsal in the field and in captivity.
   i. Consult the Pathogen Surveillance in Herpetofaunal Populations: Guidance on Study Design, Sample Collection, Biosecurity, and Intervention Strategies for field sampling protocol and other strategies.
   ii. Partner with other organizations and academic institutions to assist with surveillance. For example, Student Network for Amphibian Pathogen Surveillance (SNAPS) leverages student-power to conduct ongoing and cost-effective Bsal surveillance.

3. Engage in proactive management.

a. For high-priority populations or habitats, determine the kinds of actions possible and potential tradeoffs (Note: *a research paper listing management actions will be published in late Summer 2024 and will be added to this document*). Actions that may be useful for preventing the introduction and establishment of Bsal include:
   a. Decontamination protocols
   b. Access limitations/closures

c. Habitat management
d. Education and outreach

b. Consider other important resources that exist in high priority habitats (e.g., other rare, threatened & endangered species, the public use of an area).
c. Work with a decision analyst (example: the Decision Science Working Group of the Bsal Technical Advisory Committee) to help understand what tradeoffs may occur with proactive management.
d. Develop and implement a management plan.

4. Establish a rapid response and management plan.

a. Create a rapid response plan for your agency or state. Consider:
    i. Who will need to be contacted such as agencies, wildlife health staff, etc, that should be notified during emergency events.
    ii. How rapid response may be funded.
    iii. How to delineate outbreak area.
    iv. How to manage amphibian hosts.
    v. How to manage the site.
        1. Determine containment considerations such as: when to restrict public access to exposed area(s), signage, and local personnel notification and access restrictions to the exposed area(s).
        2. Determine how mitigation may occur at different sites based on current management research.
    vi. Post-detection surveillance protocol actions
b. A Bsal Rapid Response Template is available and is in the process of being updated to reflect new data regarding Bsal.

Additional Resources

- **North American Bsal Task Force** https://www.salamanderfungus.org/
    - Diagnostic resources, including laboratories: https://www.diagnostics.salamanderfungus.org/
- **Amphibian Disease Portal** https://amphibiandisease.org/
- **Bsal Basics: Better Together Webinar (Dec 2022)** https://youtu.be/ahXtnr0KIzE?si=wsEtV4yF353lpPp8
- **Factsheets and Flyers** https://www.salamanderfungus.org/resources/fact-sheets/

References

Bernard, R.F., & Grant, E.H. (2019). Identifying common decision problem elements for the management of emerging fungal diseases of wildlife. Society & Natural Resources, 32(9), 1040–1055. https://doi.org/10.1080/08941920.2019.1610820

Connelly, P.J., Ross, N., Stringham, O.C., et al. (2023). United States amphibian imports pose a disease risk to salamanders despite Lacey Act regulations. Communications Earth & Environment, 4, 351. https://doi.org/10.1038/s43247-023-01004-z

Gray, M.J., Carter, E.D., Piovia-Scott, J., et al. (2023). Broad host susceptibility of North American amphibian species to *Batrachochytrium salamandrivorans* suggests high invasion potential and biodiversity risk. Nature Communications, 14, 3270. https://doi.org/10.1038/s41467-023-38979-4

Grear, D.A., Mosher, B.A., Richgels, K.L.D., & Grant, E.H. (2021). Evaluation of regulatory action and surveillance as preventive risk-mitigation to an emerging global amphibian pathogen *Batrachochytrium salamandrivorans* (Bsal). Biological Conservation, 260, 109222. https://doi.org/10.1016/j.biocon.2021.109222

Towe, A.E., Gray, M.J., Carter, E.D., Wilber, M.Q., Ossiboff, R.J., Ash, K., et al. (2021). *Batrachochytrium salamandrivorans* can devour more than salamanders. Journal of Wildlife Diseases, 57, 942–948. https://doi.org/10.7589/JWD-D-20-00214

Van Rooij, P., Pasmans, F., Coen, Y., & Martel, A. (2017). Efficacy of chemical disinfectants for the containment of the salamander chytrid fungus *Batrachochytrium salamandrivorans*. PLoS ONE, 12(10), e0186269. https://doi.org/10.1371/journal.pone.0186269