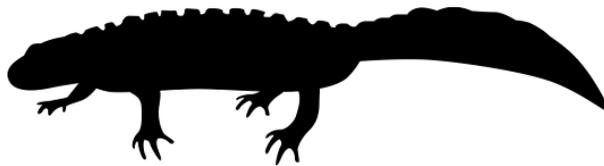


Background

Batrachochytrium salamandrivorans (Bsal) is a fungal pathogen of amphibians associated with the emerging infectious disease Bsal chytridiomycosis. Bsal was discovered in 2013 in Europe, following the discovery of ongoing mortality in Fire Salamanders (Martel et al. 2013). Bsal appears to be expanding in distribution (Spitzen-van der Sluijs et al. 2016). A 2014 experiment (Martel et al. 2014) revealed susceptibility of salamanders from around the world to Bsal chytridiomycosis, including some North American species. At a 2015 workshop in Colorado, researchers and managers discussed approaches to learn more about Bsal and the related emerging infectious disease caused by it and to forestall potential biodiversity losses in the Americas where it was not known to occur (Grant et al. 2016).

The North American Bsal Task Force was initiated in June 2015 and continues to meet in specialized working groups. Updates from each of the following Working Groups are highlighted below: 1) Data Management, 2) Decision Science, 3) Diagnostics, 4) Research, 5) Surveillance and Monitoring, 6) Clean Trade, 7) Response and Control, and 8) Communications and Outreach.

Working Group leads serve on the Technical Advisory Committee, which also includes representatives from concerned partner groups such as the Pet Advocacy Network (PAN), Amphibian Survival Alliance, and US federal agencies. An Executive Oversight Group was envisioned for consultation. Related tasks have been taken up by the Disease Task Team founded by Partners in Amphibian and Reptile Conservation (PARC), and an independent working group in Canada, the Canadian Herpetological Health Working Group. National amphibian disease contacts in Mexico have been identified. An update from PARC is also provided below.



The PARC Disease Task Team expands the scope and capacity of the Bsal Task Force by supporting the development of disease biosecurity guidance both nationally and within regional PARC working groups (including an email disease alert system to aid rapid responses to potential Bsal chytridiomycosis in North America), and developing complementary outreach materials to the Bsal Task Force such as magazine articles, and web-posted Factsheets and Webinars.

Actions to forestall Bsal transmission have been undertaken by three key partners. In 2015, the PIJAC instituted a moratorium on Asian salamander imports. In early 2016, the US Fish and Wildlife Service implemented an Interim Rule of the Lacey Act, naming 201 salamanders as injurious. They used an evidence-based approach prohibiting importation of any salamander genus whose members were shown to be carriers or to be lethally affected by Bsal in published papers. In the summer of 2017, Canada implemented import restrictions on all salamanders (Customs Notice 17-17; [http:// www.cbsa-asfc.gc.ca/ publications/cn-ad/cn17-17-eng.html](http://www.cbsa-asfc.gc.ca/publications/cn-ad/cn17-17-eng.html)).

This report compiles activities conducted by the Bsal Task Force and their partners from January 2023 to December 2023. The continuing global SARS-CoV-2 pandemic in 2023 and changes to standard practices slowed progress from the Bsal Task Force, but group members continued to meet and contribute when possible.

Key Accomplishments in 2023

- SNAPS (Surveillance and Monitoring WG) has established itself as a working model for Bsal surveillance and was implemented at 50+ institutions
- SNAPS participants sampled over 1300 animals representing 40+ species across North America
- Decision Science WG collaborating with USFWS and USFS to structure decision-making processes
- Data Management WG developed a factsheet for proper usage of the AmphibianDisease portal

Bsal Task Force Organization

The Bsal Task Force is an ad hoc group of scientists, managers, and citizens who are helping to understand and forestall the threat of Bsal in North America. Although a central focus is to coordinate strategic planning and efforts in the USA, there is participation from both Canada and Mexico, and also in partnership with European and Australian scientists. Below is a brief summary, please consult the Bsal Strategic Plan for a more detailed description of the organization (found at www.salamanderfungus.org).

Organizational Progress

Working Groups were initially formed in June 2015. Since then, they have met via conference calls on a regular basis to outline new tasks and discuss progress on existing efforts. Group membership is open and inclusive, but was initially founded with persons involved with disease research, natural resource management in state and federal agencies, environmental or conservation groups, nongovernmental organizations, and the pet industry. Each group has one to three leads, who help to coordinate personnel, manage the workload, and report to the Technical Advisory Committee. The Technical Advisory Committee (TAC) is populated by the Working Group leads and representatives from selected partner groups including federal agencies, the IUCN Amphibian Survival Alliance (ASA), and the Pet Industry Joint Advisory Council (PIJAC). The TAC meets by conference call monthly, with a focus on new items and round-robin reporting by participants. New items have included tasks to be assigned or delegated to others, opportunities for products and grant proposals, and communication-outreach and networking needs. Monthly meeting notes are routed to TAC members, then to their working group members, to ensure communication. A lead for the TAC is determined by the TAC and is rotated each year. The incoming and outgoing leads serve as co-leads. Decisions of the TAC are made by consensus.



Data Management Working Group Report

Lead(s)

Michelle Koo (UC Berkeley and AmphibiaWeb)

Deanna Olson (USDA Forest Service, Pacific Northwest Research Station)

Members

John Deck (developer, UC Berkeley)

Diana Lovette (website developer, UC Berkeley)

Kathryn Ronnenberg (US Forest Service, Bd-maps Data Manager)

Vance Vredenburg (AmphibiaWeb steering committee, San Francisco State University)

Background

The Data Management Working Group is focused on the archiving and sharing of aggregated Bd and Bsal data to facilitate research. The primary product is the Amphibian Disease web portal (amphibiandisease.org) for aggregated Bd and Bsal data inclusive of surveillance with pathogen detections and no-detections from worldwide published-and-unpublished sources. The portal also communicates project plans as well as results of Bd and Bsal surveillance and research, enhancing survey efficiencies across the science-management community.

Key Accomplishments

Manuscript written, prepared and submitted for publication about the Bsal Task Force, spearheaded by Dede Olson entitled “Preparing for a Bsal invasion into North America has improved multi-sector readiness”

PARC Factsheet on the Amphibian Disease portal, a one-page snapshot of relevant information for researchers needing to use or archive Bsal data.

Summary

In 2023 the Amphibian Disease portal use continues to grow, supporting a global footprint of active work and diversity of sampling data including from the pet industry/captive populations and eDNA samples. Coordination with the Bsal Task Force Surveillance and Monitoring Working Group’s Student Network of Amphibian Population Surveillance (SNAPS) has been a particular emphasis area in 2023, and the SNAPS dataset has grown the most. In addition, we have developed a Factsheet for posting at the Partners in Amphibian and Reptile Conservation Disease (PARC) Task Team webpage to expand outreach and communication of our world Bd and Bsal data management system. The system is a broad community resource available online for land managers, research scientists, and students. Preliminary discussions have started with PI’s at Purdue University, UC Berkeley, and Skidmore College to collaborate on a grant to

facilitate disease data and research networks, including support for the portal. Lastly, the Amphibian Survival Alliance (ASA) no longer has the capacity to host and update the Bsal Task Force website (salamanderfungus.org) so we are migrating the site to the same WordPress platform as the SNAPS website to streamline maintenance (hosted on a UC Berkeley server). We plan to make the site's maintenance available to members of the Bsal Task Force (previously any updates had to be made by ASA staff). This will be conducted in late 2023 and early 2024 by Koo, and the Communications Working Group (Megan Serr and Alex Shepack).

Key Points

We continue to expand the capacity of the Amphibian Disease Portal, amphibiandisease.org, which is a world Bd and Bsal data management system.

The new site location and developing Factsheet are expanding outreach and use of the portal. We will be taking over the hosting, new updates, and regular maintenance of the Bsal Task Force website.

Outcomes, Impacts, Products, and Manuscripts

- The online global Bd and Bsal data management system, amphibiandisease.org, is embedded within amphibiaweb.org by displaying data on species account pages for expanded outreach and use.
- A new Amphibian Disease Portal Factsheet is in development for posting at the PARC Disease Task Team resources web page, <https://parcplace.org/species/herpetofaunal-disease-resources/>

Challenges

Outreach and communication is a constant need as new generations of disease ecologists, epidemiologists, and natural resource managers may not be aware of the world Bd and Bsal detection and no-detection databases that we have compiled and maintain for community visualization and download, inclusive of planned and ongoing projects. One avenue of outreach may be to contact and educate journals which publish Bd and Bsal occurrence papers (e.g., *Herpetological Review*, etc.) about the Amphibian Disease Portal as a data repository. Maintenance and expansion of the Amphibian Disease Portal is unfunded, resulting in only periodic database updates of constantly accruing Bd and Bsal data.

Interactions with other Working Groups

The Data Management Working Group works closely with the Surveillance and Monitoring Working Group, and will start to collaborate with the Communications Working Group to migrate and update the Bsal Task Force website.

Decision Science Working Group Report

Lead(s)

Molly Bletz (Penn State University)

Members

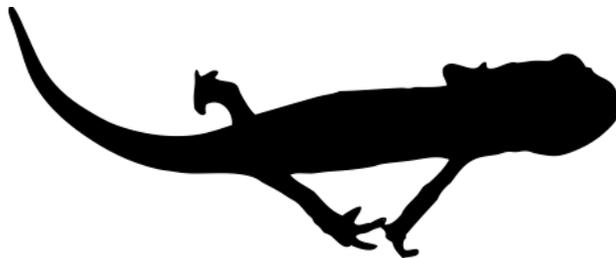
Robin Russell (USGS)
Riley Bernard (USGS/Penn State University)
Brittany Mosher (University of Vermont)
Alex Wright (Michigan State University)
Evan Grant (USGS-EESC)
Graziella DiRenzo (UMass Amherst USGS Coop Unit)

Summary

The goal of the Decision Science Working Group (DSWG) of the North American Bsal Task Force is to support management decisions regarding Bsal through (1) facilitation of decision-making processes, (2) identification and collation of information needed to make decisions, (3) development of models to predict the outcomes of different management options, and (3) evaluation of trade-offs and risk to overcome impediments to optimal decision-making.

Key Points

- Working with multiple resource managers, including, USFWS at multiple NE Refuges, New Mexico State, and US Forest Service to structure their decision-making and resolve uncertainties.
- A large effort has been made to build models and parameterize them through expert elicitation to aid in the evaluation of management actions. This work is in revision with Conservation Biology.



Outcomes, Impacts, Products, and Manuscripts

- Grant et al. in press. Matching decision support modeling frameworks to disease emergence stages and associated objectives. Conservation Science and Practice
- Bletz, MC & Grant, EHC and DiRenzo G. Start early and stay the course: Proactive management outperforms reactive actions for wildlife disease control. TWS, Louisville, KY
- Co-organized TWS symposium. Advancing wildlife disease decision-making and research with cross-sector collaborations
- Bletz, MC & Grant, EHC and DiRenzo G. Proactive disease management outperforms reactive action, regardless of the action chosen. ESA, Portland, OR.

Challenges

Engaging managers when the immediate risk of Bsal infection is low (i.e., as Bsal has not been detected in the US) can be a major challenge. This limits the ability to identify and implement proactive management – representing a major challenge for developing management strategies for Bsal and other emerging infectious diseases. Engagement from managers at the Bsal Basics webinar which focused on the advantages of proactive management may help with this which is encouraging.

Improving integration among working groups can allow for synergies and advancement of Bsal management. For example, applied research guided by decision-making processes with managers has a better utility to address needed and critical knowledge gaps.

Interactions with other Working Groups

The decision science group interacts most closely with the response and control working group and the research group.

Diagnostics Working Group Report

Lead(s)

Jake Kerby (University of South Dakota)

Maria Forzan (Long Island University)

Members

Julie Ellis (University of Pennsylvania)

Dan Grear (U.S. Geological Survey)

Jeff Lorch (U.S. Geological Survey)

Robert Ossiboff (University of Florida)

Kim Hamad-Schifferli (University of Massachusetts)

Carly Muletz Wolz (Smithsonian National Zoo & Conservation Biology Institute)

Matt Allender (University of Illinois)

Heather Fenton (Northwest Territories, Canada)

An Martel (Ghent University)

Frank Passmans (Ghent University)

Laura Sprague (US Fish and Wildlife Service)

John Wood (Pisces Molecular)

Cherie Briggs (University of California)

Leon Grayfer (George Washington University)

Steven Lloyd (Zoologix, Inc.)

Deb Miller (University of Tennessee, Knoxville)

Allan Pessier (Washington State University)

LeAnn White (National Wildlife Health Center)

Summary

The Diagnostics Working Group (DxWG) promotes the development of standards for diagnosis and reporting of amphibian emerging infectious diseases (EIDs) among the wildlife health community, with the salamander chytrid fungus, *Batrachochytrium salamandrivorans* (Bsal) as the primary focus. We serve as a forum to exchange ideas and work out the challenges involved in Bsal detection. We advise the rest of the Bsal Task Force on the viability and pitfalls of traditional and new tools for Bsal detection and diagnosis.

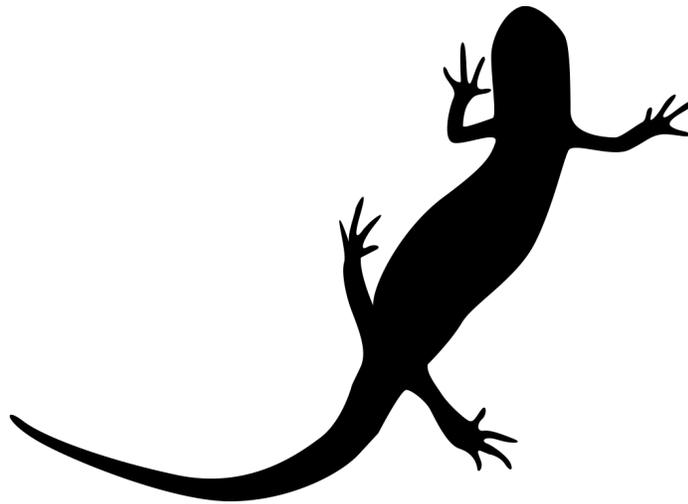
The Diagnostics Working Group (DxWG) is composed of professionals with expertise in the application and interpretation of an array of diagnostic tools. Our members work in academia, diagnostic laboratories, and government agencies throughout North America and are involved in the detection and reporting of amphibian diseases, including Bsal.

Key Points

- This group has served as a consultant throughout the past year to answer questions.
- The group has been mostly dormant in terms of meetings this past year.
- We served primarily as a consultant to the other groups on various projects.

Interactions with other Working Groups

The group primarily has consulted on technical questions for other groups.



Research Working Group Report

Lead(s)

Louise Rollins-Smith (Vanderbilt University)

David Lesbarrères (Environment and Climate Change Canada, Canada),

Members*

Molly Bletz (University of Massachusetts)

Alex Boren (University of California, Berkeley)

Jesse Brunner (Washington State University)

Allie Byrne (University of California, Berkeley)

Davis Carter (University of Tennessee)

Léa Fieschi-Méric (Laurentian University, Canada)

Maria Forzan (Long Island University)

Matt Gray (University of Tennessee)

Brady Inman (University of Massachusetts-Boston)

Susan Jewell (US Fish and Wildlife Service)

Jake Kerby (University of South Dakota)

Alexis Korotasz (Notre Dame University)

Mitch Le Sage (Vanderbilt University)

Stefan Lötters (Tier University, Germany)

An Martel (Ghent University, Belgium)

Julia McCartney (University of Massachusetts-Boston)

Cynthia Pekarik (Environment and Climate Change Canada, Canada)

Jonah Piovia-Scott (Washington State University, Vancouver)

Neelam Poudyal (University of Tennessee)

Kristyn Robinson (University of Massachusetts)

Wesley Sheley (University of Tennessee)

Laura Sprague (US Fish and Wildlife Service)

Alexa Warwick (Michigan State University)

Doug Woodhams (University of Massachusetts-Boston)

**Includes every person who attended a Research Working Group meeting in 2023*

Summary

The Research Working Group has made substantial progress in understanding the drivers of Bsal arrival in North America, be it the pet trade or the landscape and species in which it will thrive. After 10 years of absence in North America, intensive research has been carried out and many species have been tested for their susceptibility. This compares with research in Europe where the work is more applied to surveillance and potential mitigation of Bsal. To better understand Bsal in Europe, the working group invited speakers from Europe to learn from areas where Bsal is present (Belgium, Germany) or absent (Italy), to increase the North American

preparedness and to enhance transatlantic collaborations. At least 30 scientists, representing >20 organizations from the United States, Canada, Germany, and Belgium attended our monthly meetings, representing a broad array of scientific expertise, including molecular and cellular biology, immunology, ecology, mathematics, pathology, and social sciences.

Key Points

- The pet-trade is a major vector in the potential introduction of Bsal in North America.
- Salamanders, but also frogs and toads, are at risk for infection and disease development, with Bsal causing infection in 74% and mortality in 35% of 35 North American species tested.
- Research on translocation and repeated exposure to Bsal are showing promising outcomes.
- Modeling efforts have determined environmental conditions underlying Bsal epizootics.

2023 outcomes and impacts in the context of the Strategic Plan

Goal B.3.1 Understand the role of human behavior and the pet trade in the spread and spillover of Bsal.

Priority B.3.1.3: Characterize human behaviors for amphibian hobbyist and specialist groups to estimate the likelihood of Bsal spillover from consumers to wild populations and the acceptance of public outreach strategies designed to limit the anthropogenic spread of Bsal.

A majority of pet amphibian owners are aware of the threat of emerging pathogens, concerned about potential spillover of pathogens from captive to wild populations and willing to adopt biosecurity practices to mitigate pathogen threats.

Goal B.3.3: Produce more informed Bsal risk models for North America through improved, objective classification of species susceptibility and tolerance to Bsal infection (e.g., integral projection models).

Priority B.3.3.1: Estimate the susceptibility (i.e., tolerance) of North American amphibians to Bsal infection and chytridiomycosis using standardized, dose-dependent experiments (suggestions for targeted taxa can be provided by the lead of the Research Working Group).

Priority B.3.3.2: Estimate the impact of habitat characteristics (temperature, pH, salinity, zooplankton abundance, etc.) on Bsal infection risk.

Priority B.3.3.3: Develop integral projection models (IPMs) that predict tolerance using temporal estimates of Bsal infection load and host fitness metrics (e.g., survival, disease ranking based on microscopic and gross lesions).

Priority B.3.3.4: Use information developed in Priorities B.3.3.1–B.3.3.3 to map susceptibility indices on the geographic distributions of hosts and environmental suitability niches for Bsal to produce robust spatial predictions of Bsal risk in North America.

Multiple projects are underway or recently completed; manuscripts in preparation.

Goal 5: Quantify innate and adaptive immune responses to Bsal across species and environmental conditions.

Priority B.3.5.1: Determine whether amphibians are able to develop a lymphocyte-mediated immune response to Bsal and how this and other responses compare among species, populations, and life stages and across environmental conditions.

Priority B.3.5.2: Determine whether salamanders produce antimicrobial skin peptides or other antimicrobial compounds and if skin toxins used for defense (e.g., tetrodotoxin, TTX) influence antimicrobial product production.

Goal B.3.8: Estimate the interactive effects of Bsal with natural and anthropogenic stressors.

Priority B.3.8.1: Conduct susceptibility trials that include common natural and anthropogenic stressors (e.g., hydration, salinity, pesticides) to determine if outcomes following Bsal exposure are altered.

Priority B.3.8.2: Conduct susceptibility trials in complex settings that include community features such as predation and trophic interactions and changing habitat quality.

Results on a translocation experiment of yellow spotted salamanders (*Ambystoma maculatum*) indicated an important reorganization of bacterial assemblages throughout ontogeny but not due to the translocation itself, with strong changes in composition, diversity and structure of the skin microbiota in both control and translocated individuals over the 15 days of monitoring (Fieschi-Méric et al. 2023b). However, the translocation of two European newt species ex-situ was associated with rapid impoverishment, decrease in alpha diversity and strong species turnover of bacterial communities. Shifts between active and overwintering phases also caused changes in the diversity and composition of the microbiota, and on the prevalence of Bd-inhibitory phylotypes (Fieschi-Méric et al. 2023c).

List of monthly seminars

Meeting Dates	Speakers
January 9	Matt Gray, University of Tennessee Amphibian trade: a socioeconomic survey pilot.
February 6	Léa Fieschi-Méric*, Laurentian University Effect of captivity and translocation on <i>Bd</i> -related bacteria.
March 6	Louise Rollins-Smith & Mitch Le Sage*, Vanderbilt University Enhanced Bsal survival of newts after 1 st and 2 nd exposures.
April 3	Molly Bletz*, University of Massachusetts Results of expert elicitation regarding possible Bsal arrival.
May 1	Davis Carter*, University of Tennessee Bsal devours more than salamanders.
June 5	Wouter Beukema, RAVON and Ghent University Landscape epidemiology of <i>Batrachochytrium salamandrivorans</i> .
September 11	Alex Boren**, UC Berkeley A Decade of Bsal Research: Trends and Perspectives.
November 6	Stefan Lötters, Tier University The salamander plague (Bsal), an EID in Europe - A Germany perspective.
December 4	Sebastiano Salvidio and Elena Grasselli, Università di Genova <i>Bsal in Europe: a perspective from Italy.</i>

*postdoctoral researcher

**undergraduate student

Products and Manuscripts

Peer-reviewed publications (18)

- Bletz, M.C., Julian, J.T., Kirchgessner, M., Drasher, J.M., Henry, P.F.P., Jewell, S.D., et al. (2023a). Disinfection protocols for herpetofaunal pathogens. *Herpetological Review* 54(2), 200–203.
- Bletz, M.C., Palmisano, J., Julian, J.T., Shender, L., Olson, D.H. (2023b). Amping up biosecurity for herps: simpler, stricter practices can help protect reptiles and amphibians from disease. *The Wildlife Professional*. 17(6), 46–49.
- Bletz, M.C., Gratwicke, B., Belasen, A.M., Catenazzi, A., Duffus, A.L.J., Lampo, M., et al. (2024 in press). “Infectious diseases”, Chapter 6 in *The Amphibian Conservation Action Plan (ACAP): A Status Review and Roadmap for Global Amphibian Conservation*, eds. S. Wren, A. Angulo, H. Meredith, J. Kielgast, M. Dos Santos and P. Bishop. (IUCN SSC Amphibian Specialist Group [2022]).
- Böning, P., J. Virgo, S. Bleidißel, N. Dabbagh, L. Dalbeck, S. Ellwart, L. Feiler, V. Ferner, T. Fleck, L. Gemeinhardt, M. Guschal, G. Hansbauer, K. Kirst, T. Kordges, L. Kühnle, S. Neumann, A. Plewnia, K. Preissler, M. Schlüpmann, M. Schneider, R.

Schreiber, J. Thein, R. Thielen, S. Twietmeyer, M. Veith, S. Lötters & M. Schweinsberg (2023): Key questions about the impact of the salamander plague on the Northern crested newt, *Triturus cristatus* – a German perspective. *Salamandra*, 59: 107-116.

- Cavasos, K., Adhikari, R., Poudyal, N.C., Brunner, J.L., Warwick, A., Gray M.J. (2023a). Understanding the demand for and value of pathogen-free amphibians to US pet owners. *Conservation Science and Practice* 5(9), e12995.
- Cavasos, K., Adhikari, R.K., Poudyal, N.C., Warwick, A.R., Gray, M.J. (2023d). Natural area visitors' potential role in preventing pathogen threats to amphibian biodiversity. *Environmental Conservation* 50, 142–147.
- Cavasos, K., Poudyal, N.C, Brunner, J.L., Warwick, A.R., Jones, J., Moherman, N., et al. (2023b). Attitudes and behavioral intentions of pet amphibian owners about biosecurity practices. *EcoHealth* 20, 194-207. <https://doi.org/10.1007/s10393-023-01645-8>.
- Cavasos, K., Poudyal, N.C, Brunner, J.L., Warwick, A.R., Jones, J., Moherman, N., et al. (2023c). Exploring business stakeholder engagement in sustainable business practices: evidence from the US pet amphibian industry [Early View]. *Business Strategy and the Environment* Available at: <https://doi.org/10.1002/bse.3455>
- Fieschi-Méric, L., Denoël, M., Lesbarrères, D. (2023a). No detection of Ranaviruses nor Chytrids among salamanders and newts in Algonquin Provincial Park, Ontario, Canada. *Herpetological Review* 54 (2), 204–207.
- Fieschi-Méric L., Van Leeuwen P., Denoël M. & Lesbarrères, D. (2023b) Encouraging news for in-situ conservation: translocation of salamander larvae has limited impacts on their skin microbiota. *Mol. Ecol.* <http://doi.org/10.1111/mec.16914>
- Fieschi-Méric L., Van Leeuwen P., Hopkins K., Bournonville M., Denoël M. & Lesbarrères, D. (2023c) Strong restructuring of skin microbiota during captivity challenges ex-situ conservation of amphibians. *Front. Microbiol.* <https://doi.org/10.3389/fmicb.2023.1111018>.
- Gray, M.J., Carter, E.D., Piovita-Scott, J., Cusaac, J.P.W., Peterson, A.C., Whetstone, R.D., et al. (2023b). Broad host susceptibility of North American amphibian species to *Batrachochytrium salamandrivorans* suggests high invasion potential and biodiversity risk. *Nature Communications* 14, 3270.
- Gray, M.J., Ossiboff, R.J., Berger, L., Bletz, M.C., Carter, E.D., DeMarchi, J.A., et al. (2023a). One Health approach to globalizing, accelerating, and focusing amphibian and reptile disease research – Reflections and opinions from the First Global Amphibian and Reptile Disease Conference. *Emerging Infectious Diseases* 29, e1-e7.

- Grisnik, M., Gray, M.J., Piovia-Scott, J., Carter, E.D., Sutton, W.B. (2023). Incorporating caudate species susceptibilities and climate change into models of *Batrachochytrium salamandrivorans* risk in the United States of America. *Biological Conservation* 284, 110181.
- Hardman, R.H., Reinert, L.K., Irwin, K.J., Oziminski, K., Rollins-Smith, L., Miller, D.L. (2023). Disease state associated with chronic toe lesions in hellbenders may alter anti-chytrid skin defenses. *Scientific Reports* 13, 1982.
- Plewnia, A., S. Lötters, M. Veith, M. Peters & P. Böning (2023): Successful drug-mediated host clearance of *Batrachochytrium salamandrivorans*. *Emerging Infectious Diseases*, 29: 411-414.
- Sheley, W.C., Gray, M.J., Wilber, J.G., Cray, C., Carter, E.D., Miller D.L. (2023). Electrolyte imbalances and dehydration play a key role in *Batrachochytrium salamandrivorans* chytridiomycosis. *Front. Vet. Sci.* 9, 1055153.
- Woodhams DC, McCartney J, Walke JB, Whetstone R. 2023. The Adaptive Microbiome Hypothesis and Immune Interactions in Amphibian Mucus. *Developmental and Comparative Immunology*, 145:104690. doi: 10.1016/j.dci.2023.104690..

Conference Presentations (3, not exhaustive)

- Boren A., Byrne A. & Lesbarrères D. A decade of Bsal research: Trends and perspectives. November, 2023. Amphibian Disease Conference. Vanderbilt University.
- Piovia-Scott, J. 2023. Preparing for amphibian pathogen introductions: Evaluating Bsal risk in the Pacific Northwest. Northwest Regional Invasive Species and Climate Change Symposium. 8 September 2023 (Virtual).
- Woodhams DC. Bsal has a sweet tooth. November, 2023. Amphibian Disease Conference. Vanderbilt University.

Challenges & Future Steps

Translate science into management

- Integrate with Decision Support, Response, and Communication WGs
- Bring government agencies to the table
- Mitigation work in progress

Learn from studies of Bsal in its native range

Learn from efforts to understand spread in Europe



Surveillance and Monitoring Working Group Report

Lead(s)

Oliver Hyman (James Madison University)

Aubree Hill (Tennessee Tech University)

Members

Michael J. Adams (U.S. Geological Survey)

Flor Breitman (Auburn University at Montgomery)

Kayla Buck (SCWDS)

Daniel A. Grear (U.S. Geological Survey)

Sasha E. Greenspan (The University of Alabama)

Olya Milenkaya (Warren Wilson College)

Brittany A. Mosher (University of Vermont)

Eria Rebollar (Universidad Nacional Autónoma de México)

Lenny Shirose (Canadian Wildlife Health Cooperative)

Jenifer B. Walke (Eastern Washington University)

Megan Winzeler (U.S. Geological Survey)

Michael Yabsley (SCWDS)

Background

The mission of the *Bsal* Surveillance and Monitoring Working Group is to facilitate and coordinate the surveillance and monitoring of *Bsal* in North America. The Working Group's primary focus for ongoing and coordinated *Bsal* surveillance continues to be the development of the Student Network for Amphibian Pathogen Surveillance (SNAPS) - a student-powered *Bsal* surveillance network that includes members in the United States, Canada, and Mexico. Here we describe the progress and plans for SNAPS expansion and assessment.

Key Accomplishments

- SNAPS has established itself as a working model for *Bsal* surveillance and is facing the financial and logistical burden that comes with a growing membership.
- In 2023, SNAPS was implemented at 50+ institutions from the US, Canada, and Mexico, and plans to maintain this same level of participation in 2024.
- SNAPS participants have sampled over 1300 animals (40+ species across North America).
- We have developed free educational and training resources for SNAPS participants including a formal lesson plan, orientation handbook, and training videos.
- A formal assessment of SNAPS participants was completed, and results indicated SNAPS is an effective way for students to learn about amphibian pathogens.

Key Points

- SNAPS has established itself as a working model for *Bsal* surveillance and is facing the financial and logistical burden that comes with a growing membership.
- In 2023, SNAPS was implemented at 50+ institutions from the US, Canada, and Mexico, and plans to maintain this same level of participation in 2024.
- SNAPS participants have sampled over 1300 animals (40+ species across North America).
- We have developed free educational and training resources for SNAPS participants including a formal lesson plan, orientation handbook, and training videos.
- A formal assessment of SNAPS student participants from 10 institutions indicated.
 - SNAPS is an effective way for students to learn about amphibian pathogens.
 - A lack of student participant diversity (~75% white).
- Preliminary assessment of SNAPS partners indicated high levels of instructor satisfaction.

Outcomes, Impacts, Products, and Manuscripts

SNAPS has successfully undergone its second stage of growth. Five universities participated in SNAPS at its inception in 2021, we expanded to 23 participating institutions in 2022, and reached 54 this past calendar year (2023; Fig. 1). We plan to enroll ~60 institutions in 2024 (assuming historical attrition rates of ~10-20%, resulting in sample collection from ~50

institutions). Surveys of instructors continue to indicate high levels of satisfaction with the program and protocols. Participants include institutions in the US, Mexico, and Canada which have sampled over 1300 animals representing 40+ species from across North America; openly accessible at <https://amphibiandisease.org/projects/?id=284>

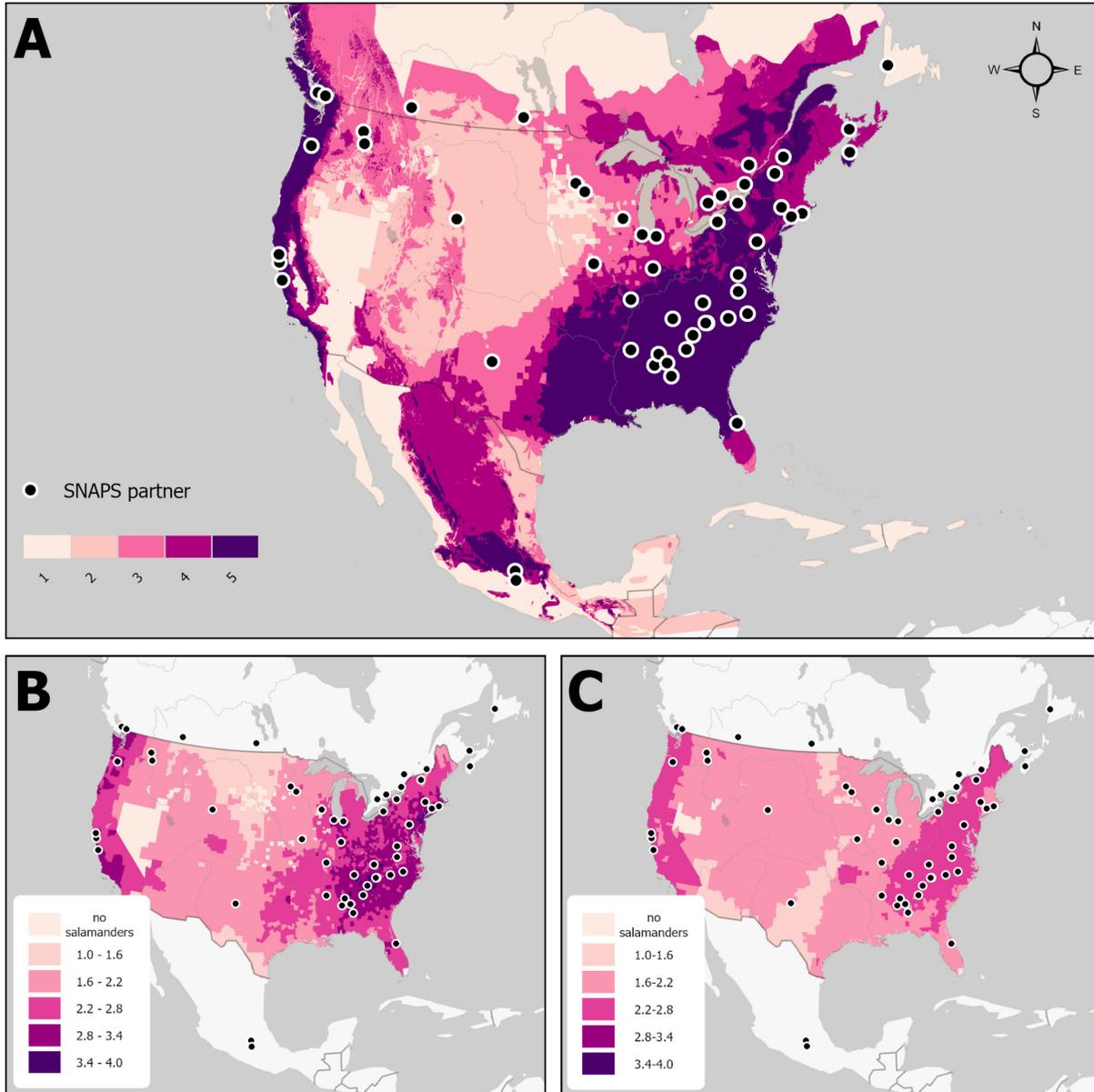


Fig. 1. Locations of 54 SNAPS (Student Network for Amphibian Population Surveillance, Surveillance and Monitoring Working Group, North American *Bsal* Task Force) partnering institutions (2 in Mexico, 10 in Canada, 40 in USA) overlaying maps showing three predictive risk models of relative host susceptibility to *Batrachochytrium salamandrivorans* (Bsal; darker shades denote higher risk): A) before implementation of import restrictions (from Yap et al., 2015); B) after implementation of import restrictions (Gear et al., 2021); C) with updated *Bsal* host susceptibility data (Gray et al., 2023b). The lightest shade on the maps denotes that no salamanders are at risk in that geographic area.

SNAPS has enlisted one additional research lab, Southeastern Cooperative Wildlife Disease Study (SCWDS), which fully funded and processed samples from a pilot set of 3 SNAPS

institutions in 2023, and which will increase support to 10 institutions in 2024. We are hopeful that the number of partnering institutions handled by SCWDS will increase to 20 over the next year.

Since its inception, several hundred students have participated in SNAPS. This past year students were invited to voluntarily complete pre- and post-SNAPS surveys from all of our participating institutions to assess SNAPS effectiveness in affecting students' (1) knowledge of amphibian disease, (2) interest in the environment, and (3) self-efficacy towards conservation. Viable student assessment data collected from 10 institutions revealed that participation in SNAPS significantly increased students' knowledge and understanding of amphibian fungal pathogens (unpublished data, Jennifer Perez, Master's thesis, Eastern Washington University). However, SNAPS participation did not lead to an increase in students' interest in the environment or their self-efficacy in contributing to conservation efforts, likely because students' scores on these elements were already quite high, nearly at the top of the 5-point scale. Survey results also indicated SNAPS lacks student participant diversity (~75% white). These results underscore the need to expand SNAPS into a broader range of course types (Ex. introductory) and institutions (Ex. CC, HBCU).

Upon analysis of 70 students' pre- and post-SNAPS survey data across 10 institutions, we found that participating in SNAPS significantly increased both affective and cognitive learning outcomes (unpublished data, Jennifer Perez, Master's thesis, Eastern Washington University). Affective outcomes included students' self-efficacy towards the environment, enjoyment of nature, and interest in STEM careers, while cognitive outcomes included content knowledge and self-reported content knowledge about amphibians, their pathogens, and sampling methods. SNAPS enhanced students' self-efficacy towards environmental conservation efforts ($t(68) = 2.062, p = 0.04$). However, since students' enjoyment of nature and their interest in STEM careers was already high and at the top of the Likert scale in the pre-surveys, participation in SNAPS did not further increase these measures ($t(67) = 0.242, p = 0.8$; $t(69) = -0.071, p = 0.9$). SNAPS is an effective way for students to learn about amphibians, their pathogens, and how to conduct field sampling (Fig. 2; content knowledge: $t(68) = 11.119, p < .001$; sampling method knowledge: $t(68) = 4.323, p < .001$). In addition, students' self-reported knowledge indicated that students were confident about their newly acquired knowledge (content knowledge: $t(69) = 11.207, p < .001$; sampling method knowledge: $t(68) = 16.092, p < .001$).

We also evaluated the equity of outcomes for SNAPS by analyzing the effects of institution, student demography, and class standing. The results were consistent across institutions for the majority of objectives evaluated, suggesting that the implementation of SNAPS across multiple universities yields consistent outcomes, regardless of the teaching implementation, course subject, and location. The onboarding process and materials likely contribute to this consistency across institutions. While changes in students' content knowledge varied based on demographics and class standing, all other measured outcomes were consistent demonstrating that SNAPS provides a generally equitable educational experience. Underclassmen had greater gains in content knowledge from participating in SNAPS than upperclassmen ($F(1) = 4.896, p =$

0.030), and first-generation students had greater gains than non-first-gen students ($F(1, 51) = 7.552, p = 0.008$). Student gender and ethnicity did not have an impact alone on content knowledge (ethnicity: $F(1, 51) = 0.563, p = 0.46$; gender: $F(2, 51) = 2.185, p = 0.123$); however, the interaction between student ethnicity and gender did influence content knowledge gains ($F(2, 51) = 3.818, p = 0.028$), but sample sizes were low per category since ~75% of participants were white.

Based on the analysis of the spring 2022 assessment data, we have made improvements to the survey questions and design to streamline the analysis of the 2023 data consisting of ~350 students across 34 institutions. We plan on publishing these assessment results in a peer-reviewed journal.

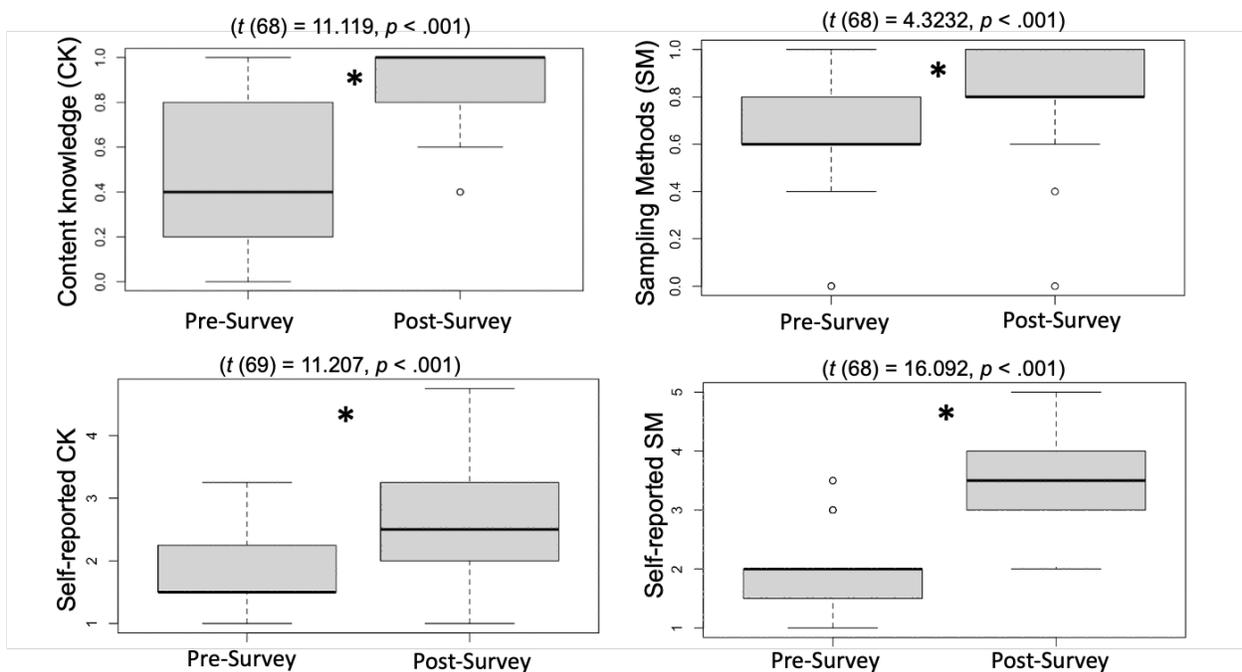


Fig. 2. Cognitive Outcomes for 70 Undergraduate Students After Participation in 2022 SNAPS (unpublished data, Jennifer Perez, Master’s thesis, Eastern Washington University). * Indicates significant difference between the pre- and post-SNAPS survey scores.

Products, Presentations, and Manuscripts

- SNAPS website (<https://snaps.amphibiandisease.org>)
- SNAPS database (<https://amphibiandisease.org/projects/?id=284>)
- SNAPS resources have been updated to include a formal lesson plan, orientation handbook, and training video (Ex. <https://youtu.be/IBgkvjcxQ>)

- Manuscript (in review, *Frontiers in Amphibian and Reptile Science*): “Preparing for a Bsal invasion into North America has improved multi-sector readiness,” Olson et al.
- Master’s thesis (Jennifer Perez, Eastern Washington University): “Surveillance and monitoring of amphibian pathogens and evaluating the impacts of an associated Course-based Undergraduate Research Experience (CURE)”

Challenges

Funding and Sustainability: SNAPS has proven to be a viable model for sustainably sampling Bsal across North America. In 4 years we have expanded to ~50 institutions including key locations across the United, Mexico, and Canada, with more institutions/instructors expressing interest in joining our program than we can currently support. Funding and core-member burn-out are the major factors limiting our growth and success. We currently rely on volunteers from our Working Group to develop and administer the program. This has included the development of a website, protocols, lesson plans, learning outcome assessment tools and analysis, onboarding, and data management. The growth of SNAPS means that this program will soon require dedicated (paid) personnel to manage and administer the program. The program will need to improve and professionalize various systems, including updating and maintaining the website, developing right-to-know (RTK) fieldwork training/orientation materials, procuring grants and regular funding, the onboarding of new participants, accountability, data management, coordination with multiple labs, assessment of student learning outcomes, and reporting.

SNAPS website development and upkeep: Our WordPress based website (<https://snaps.amphibiandisease.org>) serves a hub for advertisement, recruitment, participant and sponsor recognition, as well as sharing lesson plans, participant data, and training materials. The website needs to be restructured to enhance sponsorship visibility, enable participant data (Ex. participant locations, # of institutions, # of students, # of samples, etc.) to update in real-time. We also need a better structure for sharing lesson plans/instructor materials and formally recruiting new participants. We currently lack a member with extensive website development experience and no members have stepped up to take the lead on this role. We need funding to pay for a web developer or identify a person to take the lead on this on a voluntary basis.

Core membership—structure, recruitment & retention: Our group currently has ~10 “core” members who semi-regularly attend 1-hour meetings each month to discuss major needs of the group. All of these members have been participating for several years now on a voluntary basis. It may be time to explore new strategies to recruit and retain new members to participate in the core steering group. New members can bring fresh energy and ideas to contribute to funding, assessment, and website initiatives. We also need to identify the key needs of our group and perhaps restructure our meetings and member activities to best meet these objectives.

Assessment & Diversifying SNAPS participants: Our formal assessment results revealed that SNAPS is currently lacking in diversity of student race and ethnicity (77% white, and only 19% of participants known to be underrepresented in STEM), grade level (64% in 3rd or higher year of undergraduate), fields of interest (already enrolled in ecology-type elective courses), and institution type. Our goals include strategically expanding and diversifying the SNAPS network to include identities that are underrepresented in STEM, lower-level students, students with broad interests (not already inclined to take conservation/ecology/ field-based courses), and a variety and larger number of institution types (including field stations, Historically Black Colleges and Universities, and Hispanic-Serving Institutions). Ideally, this expansion should also overlap with key gaps in our Bsal risk/geographic coverage and SCWDS member states.

Past and Future Objectives

The objectives of this Working Group are to facilitate and coordinate (1) the surveillance of Bsal in North America, and (2) the monitoring of Bsal in the event of its detection in North America.

Our goals from the previous year ('22) were:

Goal 1: Facilitate and support a wide-reaching, ongoing, coordinated, and sustainable Bsal surveillance program in Canada, Mexico, and the United States.

Objective 1: Secure SNAPS funding for the upcoming spring and fall 2023 semesters

Objective 2: Secure longer-term SNAPS funding to sustain the program

Objective 3: Publish, update, and overhaul the SNAPS website

Objective 4: Recruit and onboard new participants for SNAPS, including supporting new participants and infrastructure in Mexico and Canada

Objective 5: Implement SNAPS across North America during the upcoming spring and fall semesters

Objective 6: Assess student learning outcomes and SNAPS participant demographics

Objective 7: Streamline data processing and management to allow for additional diagnostic labs to participate

Goal 2: Identify Bsal sampling efforts that are occurring outside of efforts coordinated by the Bsal Surveillance & Monitoring Working Group.

Objective 1: Identify a new point-person to implement this goal

Goal 3: Support and facilitate sampling of amphibians in the pet trade.

Objective 1: Coordinate with the Bsal Research Working Group regarding current efforts to do pathogen surveillance and monitoring of amphibians in the pet trade

Goal 4: Develop initial plans for post-detection monitoring if Bsal were to be detected at a field or captive site in North America.

Objective 1: Identify a new point-person to implement this goal

In the timespan of this Annual Report (Jan 2023 - Dec 2023), we have continued to address all of the above goals. Goal #1 was our priority as we continued to develop our surveillance centerpiece, SNAPS. For an update on this program, see “Outcomes and Impacts” above. We also initiated implementation of Goal #2, but faced a setback when we lost the personnel needed to coordinate this effort. We made initial but limited efforts for Goals #3 and #4.

Our goals for the coming year continue to be those listed above, with our primary focus remaining the successful development, implementation, growth and maintenance of SNAPS (Goal #1). For the coming year, we have the following new objectives for each goal:

Goal 1: Facilitate and support a wide-reaching, ongoing, coordinated, and sustainable Bsal surveillance program in Canada, Mexico, and the United States.

Objective 1: Secure SNAPS funding for the upcoming spring and fall 2024 semesters

Objective 2: Secure longer-term SNAPS funding to sustain the program and fund a full/part-time administrator

Objective 3: Update and overhaul the SNAPS website

Objective 4: Recruit and onboard new participants for SNAPS, including supporting new participants and infrastructure in Mexico and Canada

Objective 5: Implement SNAPS across North America during the upcoming spring and fall 2024 semesters

Objective 6: Assess student learning outcomes and participant demographics from SNAPS following the spring and fall 2023 implementation, and publish these results

Objective 7: Streamline data processing and management to allow for additional diagnostic labs to participate

Goal 2: Identify Bsal sampling efforts that are occurring outside of efforts coordinated by the Bsal Surveillance & Monitoring Working Group.

Objective 1: Identify a new point-person to implement this goal

Goal 3: Support and facilitate sampling of amphibians in the pet trade.

Objective 1: Coordinate with the Trade subgroup of the Bsal Research Working Group regarding current efforts to do pathogen surveillance and monitoring of amphibians in the pet trade

Goal 4: Develop initial plans for post-detection monitoring if Bsal were to be detected at a field or captive site in North America.

Objective 1: Coordinate with the Bsal Research Working Group regarding current strategies and recommendations for post Bsal-detection monitoring

[Interactions with other Working Groups](#)

Co-leads attended monthly Bsal Technical Advisory Committee meetings, where we shared regular updates on SNAPS growth and accomplishments. We also discussed funding, recruitment, and staffing challenges our group is facing. In a collaborative effort with the rest of the North American Bsal Task Force, we wrote a manuscript entitled “Preparing for a Bsal invasion into North America has improved multi-sector readiness,” which highlighted the above information (i.e., SNAPS growth, working group accomplishments, challenges, etc.). We submitted it to the journal *Frontiers in Amphibian and Reptile Science* in December 2023. Working group members who co-authored the manuscript included Brittany Mosher, Michael Adams, Daniel Grear, Aubree Hill, Lenny Shirose, Olya Milenkaya, Jenifer Walke, Eria Rebollar, and Maria Florencia (Flor) Breitman.



Healthy Trade Working Group Report

Lead(s)

Alexa Warwick (Michigan State University)

Matt Gray (University Tennessee Knoxville)

**Includes all 2023 members of the NSF EEID grant team (faculty, staff, postdocs, graduate students), Pet Advocacy Network staff, and pet trade industry partners.*

Summary

With the growing concern that Bsal could be translocated to North America via trade, the Healthy Trade WG was created in 2020. This working group includes members from the Pet Advocacy Network, US pet amphibian businesses, and academia. Originally called the Clean Trade WG, the working group was renamed because the intent of the group is not to promote clean/sterile trade, but rather pathogen-free/healthy trade. By pathogen-free, this group is most concerned with Bsal, but there is also plenty of evidence that Bd and ranaviruses are being translocated globally through amphibian trade.

A major concern with domestic and international trading of amphibians infected with novel pathogens or variants is spillover to wild populations and biodiversity loss. Pathogens in trade also cause major losses to industry. It is estimated that pathogens contribute \$140M in losses each year to US pet-amphibian businesses. As such, it is not surprising that most US businesses and consumers are in support of acquiring pathogen-free amphibians (Cavasos et al., 2023a,b). In fact, US pet-amphibian consumers are willing to pay up to 75% more for certified pathogen-free amphibians compared to amphibians with unknown health status (Cavasos et al., 2023c). Thus, in 2022, the Healthy Trade Working Group began discussions with 22 stakeholders on possible components of a healthy trade certification program for US businesses. Four components were identified: online training; use of certain biosecurity practices; animal testing for Bd, Bsal and ranavirus; and response if a detection of these pathogens occur. Working groups were subsequently created for each of the plan components to draft details, and a follow-up survey is ongoing to receive feedback from US businesses and consumers on the draft plan (<https://www.healthyamphibiantrade.org>). The Healthy Trade WG is working with Pet Advocacy Network, industry, and academic partners to hopefully launch a market-driven US healthy trade certification program for pet amphibians in the near future. Through socioeconomic surveys (Cavasos et al., 2023a,b,c) and over two years of discussions with industry stakeholders, the Healthy Trade Working Group has learned that US pet amphibian businesses are supportive of healthy trade practices, especially in comparison to trade bans, which the federal government has used in the past (US Fish and Wildlife Service 2016).

Key Points

- NSF EEID grant activities
- Quarterly grant meetings to share work in progress
- At least monthly meetings with grant team and industry partners to share updates and discuss next steps or resolve challenges
- Progress made in four areas of project: socioeconomic surveys of businesses and pet amphibian owners
- Launched second soci
- Collecting data about socioeconomic

Interactions with other Working Groups

Most of the NSF EEID grant team Principal Investigators are also Research Working Group members.



Response and Control Working Group Report

Lead(s)

Laura Sprague (US Fish and Wildlife)

Members

Molly Bletz (Umass Amherst)

Blake Hossack (USGS)

Evan Grant (USGS)

Su Jewell (USFWS)

Michael Adams (USGS)

Matthew Gray (University Tennessee Knoxville)

Summary

The purpose of the Response and Control Group is to facilitate efficient and rapid response for managers in the event of an amphibian die-off and/or if Bsal is detected. This group aims to synergize with other working groups like the Research and Decision Science Working group to allow for effective planning for and management of Bsal.

Key Points

- Rapid Response Template: Began work to revise and streamline this document by eliciting feedback from other groups, such as Decision Science and AFWA Managers interested in Rapid Response in the event Bsal is detected.
- DOI-Wide Categorical Exclusion (CatEx) for management of invasive species, including pathogens has been on CEQ's Desk, and may not be completed before 2025.
- We have low membership and a lack of state representation which is challenging.

Outcomes, Impacts, Products, and Manuscripts

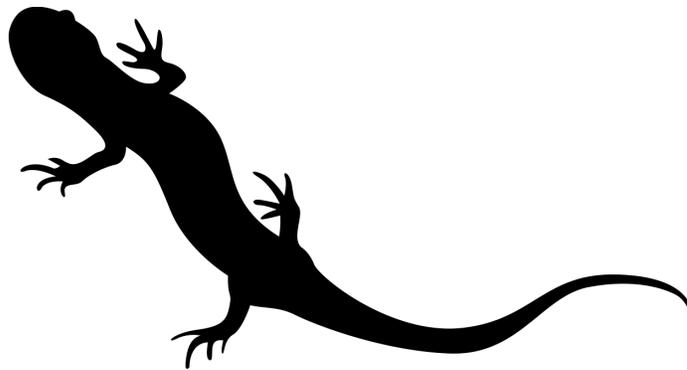
- Rapid Response Template: Began work to revise and streamline this document by eliciting feedback from other groups, such as state and federal managers that would potentially use this, as well as people who work on rapid response exercises for the control of aquatic invasive species.
- Members of the group attended AIS Rapid Response benchtop exercises to help understand the shortfalls and processes.

Challenges

This group is a small cohort of busy people and lacks representation for state-level managers. Due to the time and day of the Bsal Task Force monthly call, it is difficult to attend and be present.

Interactions with other Working Groups

Members from the Research Group and Decisions Group participate in the Response and Control Group calls and give updates on what the other groups are doing and how we can collaborate.



Communications and Outreach Working Group Report

Lead(s)

Alex Shepack (Florida International University)

Megan Serr (Meredith College)

Members

Mark Mandica (Amphibian Foundation)

Nina McDonnell (UMass Boston)

Summary

The Communications Task Force is co-led by Alex Shepack and Megan Serr. Alex and Megan had a summer meeting to discuss potential engagement ideas. Engagement ideas that are at the formative stages include:

- Updating the Task Force Website in collaboration with the Data Management Working Group.
- Engaging in PARC's Amphibian Week.
- Updating Museum and Zoo Exhibits to include Bsal with Bd.
- Collaborating with TAC members on the Herpetological Review Summary of the Bsal Task Force.

Key Points

- Compiled, formatted, designed, and published the 2022 Annual Report
- Social Media: We continue to maintain and utilize Twitter (@salamanderfungi) and Facebook (www.facebook.com/salamanderfungus/). As of December 2023 we have 946 followers on Twitter and 460 on Facebook. Twitter followers have decreased slightly since last year, while the Facebook page has increased by 33.

Outcomes, Impacts, Products, and Manuscripts

Nina McDonnell spearheaded the creation of promotional and educational materials that were displayed at the inaugural 2022 GARD Conference and other wildlife related meetings this year.

Challenges

Interest in WG participation has flagged over the years but we hope for renewed involvement with the new manuscript and an updated website.

Interactions with other Working Groups

The working group continues to interface with members of other groups to work on specific projects, including:

- Dede Olson; Data Management
- Maria Forzan; Research
- Molly Bletz; Decision Science, Response and Management, Research
- Michelle Koo; Data Management

