Bsal Task Force

2021 Annual Report

March 2022

salamander fungus .org

2021 Bsal TAC Annual Report

Ambystoma cingulatum. © Mark Mandica

Background

Batrachochytrium salamandrivorans (Bsal) is an emerging fungal pathogen that infects amphibian skin. It was discovered in 2013 in Europe, following the discovery of ongoing mortality of Fire Salamanders (Martel et al. 2013). It 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 the pathogen, including some North American species. At a 2015 workshop in Colorado, researchers and managers discussed approaches to learn more about the 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 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 Industry Joint Advisory Council (PIJAC), 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.

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).

This report compiles activities conducted by the Bsal Task Force and their partners from January 2020 to December 2020. The global SARS-CoV-2 pandemic in 2020 slowed progress from the Bsal Task Force, but group members continued to meet and contribute when possible.

Key Accomplishments in 2021

- Amphibian disease repository and website (amphibiandisease.org) is now fully operational
- Continued working with National Wildlife Managers to create Bsal specific management plans
- Secured funding for a second ring test of Bsal diagnostic laboratories
- Continued ongoing research into transmission pathways and susceptible species
- Began trial runs of the Student Network for Amphibian Pathogen Surveillance (SNAPS)
- Assembled a Clean Trade Working Group of researchers and industry professionals
- Continued working towards Categorical Exclusion for Bsal
- Redesigned salamanderfungus.org

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 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.

Ambystoma maculatum. © Twan Leenders

Data Management Working Group

Leads

Michelle Koo (UC Berkeley and AmphibiaWeb)
Deanna Olson (US Forest Service, Pacific Northwest Research Station)

Members

Diana Lovette (website developer, UC Berkeley); Vance Vredenburg (AmphibiaWeb steering committee, San Francisco State University); David Wake (AmphibiaWeb director, UC Berkeley); Kathryn Ronnenberg (US Forest Service, Bd-maps data manager); John Deck (developer, UC Berkeley).

Summary Statement

The Amphibian Disease web portal (amphibiandisease.org) archives and shares aggregated Bd and Bsal data from published-and-unpublished sources. It can communicate project plans for Bd and Bsal surveillance, enhancing survey efficiencies across the science-management community. In 2021, two key products were completed: 1) a journal publication describing the structural underpinnings of the web portal and providing an important roadmap for the incorporation of the legacy Bd-maps.net dataset (Koo et al. 2021); and 2) a global Bd update (Olson et al. 2021) with transference of the Bd-maps.net database updated through 2019 to the new web portal. The website is poised for its next phase to expand data visualizations, 2020-2021 data updates, and outreach. Currently, the database has dynamic links to AmphibiaWeb to show species-specific data summaries and projects, which can be similarly used other external websites. Ongoing maintenance and web programming tasks include working to expand data visualizations of the Bd and Bsal data such as country- and species-summary charts and custom query interfaces. The Working Group leads are focusing on outreach to the research, management, and public communities to expand use by researchers and managers. One aspect of outreach may be to contact journals directly so that the Amphibian Disease Portal may serve as a repository for open-access data.

Key Points

- Bsal and Bd data are accessible for queries to inform science and management decisions and for metadata analyses of host-pathogen-geographic dynamics.
- Koo et al. (2021) describe the web portal structure and use.
- Olson et al. (2021) provide a global update of Bd detections/no-detections and climate associations.
- Bd-maps.net data are available now in the Amphibian Disease Portal. DOI numbers for the global Bd dataset (2007-2014; 2015-2019) within amphibiandisease.org are referenced in Olson et al. 2021.

Outcomes or impacts (including products and contribution to Strategic Plan) from workgroup activities

The Data Management Working Group has developed an operational amphibian chytrid web portal for both Bsal and Bd data from research and monitoring efforts worldwide, with greater user query capacities and data visualizations. The Amphibian Disease portal (https://amphibiandisease.org) includes data from captive and wild field settings, and capacity to report results of sample analyses from hosts and environments (eDNA), infection intensity such as zoospore loads, genetic strain, and disease symptoms in addition to pathogen occurrences. The portal is aligned with the GEOME platform (https://geome-db.org; Genomic Observatories Meta-Database) which captures biological samples and associated genetic sequences. The portal houses several important large survey efforts and many datasets from publications, including data from the legacy Bd-Maps.net, USGS survey results for Bsal in 2014-2017 (Waddle et al 2020), results from the Bsal Consortium of Germany (see special edition of Salamandra 56).

Products and Manuscripts

Papers:

Koo, M.S., V.T. Vredenburg, J.B. Deck, D.H. Olson, K.L. Ronnenberg, and D.B. Wake. Tracking, synthesizing and sharing global Batrachochytrium data at AmphibianDisease.org. Front. Vet. Sci. 8:728232. Doi: 10.3389/fvets.2021.728232.

Olson, D.H., K.L Ronnenberg, C.K. Glidden, K.R. Christiansen, and A.R. Blaustein. 2021. Global patterns of the fungal pathogen Batrachochytrium dendrobatidis support conservation urgency. Front. Vet. Sci. 8:685877. doi: 10.3389/fvets.2021.685877

Olson, D.H., K.L Ronnenberg, C.K. Glidden, K.R. Christiansen, and A.R. Blaustein. 2021. Global Bd mapping project: 2021 Update. Northwestern Naturalist 102(2):172. [published abstract]

Talks:

Olson, D.H. 2021. How government science informs government policies: Climate change and disease threats to amphibians and Reptiles. Oregon State Univ., Dept. Integrative Biol., Science and Policy graduate student webinar course, 20 students (2 universities and 7 OSU colleges). Honorable Jane Lubchenco, Professor. February 11, 2021.

Olson, D.H. 2021. Biosecurity priorities to forestall amphibian chytrid transmission. Invasive Species Week. SCIENCEx Webinar series. USDA Forest Service, Becky Gravenmeier, organizer. February 24, 2021.

Olson, D.H., K.L. Ronnenberg, K.R. Christiansen, C.K. Glidden, and A.R. Blaustein. 2021. Global Bd Mapping Project: 2021 Update. Joint Annual Meeting Northwest PARC and Assoc. Prof. Biologists, virtual, lightning talk. May 7-8, 2021 [end of Amphibian Week]. 50 participants.

Olson, D.H. 2021. Biosecurity Priorities to Forestall Amphibian Chytrid Transmission. New York Invasive Species Research Institute, Cornell Univ. October 27, 2021. ~50 participants. YouTube recording.

Olson, D.H., K.L. Ronnenberg, K.R. Christiansen, C.K. Glidden, and A.R. Blaustein. 2021. Climate-niche space associations of global detections of the amphibian chytrid fungus Batrachochytrium dendrobatidis support conservation urgency. Invited speaker, Symposium: Climate Change in the USDA Forest Service – Using a Scorecard Approach to Vulnerabilities, Adaptation, and Watersheds and collaborating with USDA Climate Hubs Part 1. TWS2021 Virtual. November 1-5, 2021.

Awards/Recognitions:

Top 10% most cited PLoS ONE papers published in 2017; this article uses the global Bd database in a meta-analysis:
Gervasi, S.S., P.R. Stephens, J. Hua, C.L. Searle, J. Urbina, D.H. Olson, B.A. Bancroft, V. Weis, J.I. Hammond, and R.A. Relyea. 2017. Linking ecology and epidemiology to understand predictors of multi-host responses to an emerging pathogen, the amphibian chytrid fungus. PLoS ONE 12(1):e0167882.

Challenges & Future Steps (Bulleted List)

- Funding for web portal maintenance and development is needed; funding for personnel to help address goals listed below is needed.
- Database contributions are open to the global research community. We realize that we also need in-house updates by tracking the recent literature, not all of which is open access and attainable by web search engines. A two-step process is envisioned to conduct web searches, augmented by annual updates of known publication outlets not obtainable online.
- Tying database updates to project and permit reporting can facilitate more comprehensive understandings of amphibian chytrid data. This may also facilitate reporting of negative data.
- Improved classification of disease occurrences in past and future data is needed.
- Improved dynamic data summaries and mapping is needed.
- Expanded outreach and education to surveillance communities to report disease symptoms, strains, and zoospore loads is needed.

Implementation Plan Updates

New Goal 3: Establish the Amphibian Disease portal as a recommended data repository

Task: engagement with potential researchers with better user guidelines, templates and tutorials (in progress but ideas how to do this better is welcomed. Maybe workshop outreach at conferences, maybe more information flyers?)
Task: outreach to journals and editors to have as a recommended repository.

Interactions with other Working Groups

We are working with the Surveillance and Monitoring WG to help implement the technical requirements of the SNAPS (Student Network of Amphibian Pathogen Surveillance), including creating a dedicated portal page (https://amphibiandisease.org/projects/?id=284), project website (https://snaps.amphibiandisease.org/), and other data and training needs. We will work with the PIs on an NSF RCN-UBE grant proposal this coming year.

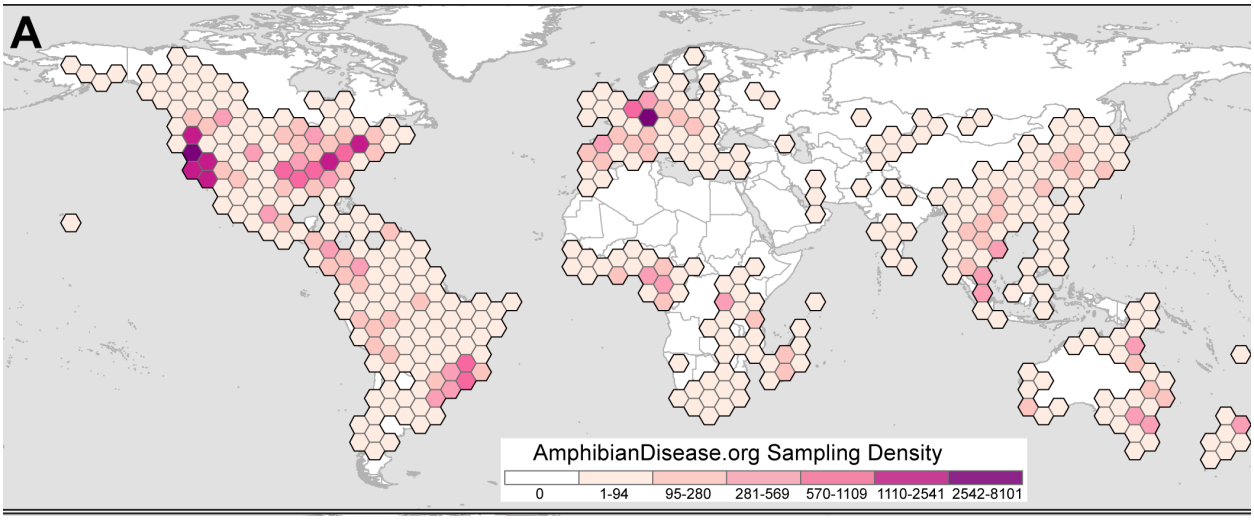

Figure 3A from Koo et al 2021.

Amphibian Disease portal sampling data for the chytrid fungal pathogens *Batrachochytrium dendrobatidis* (Bd) and *B. salamandrivorans* (Bsal). Bd and Bsal sampling is worldwide and reflects prominent sampling efforts for Bsal in the USA by the US Geological Survey (Waddle et al. 2020) and in Germany by the Bsal Consortium Germany (Vences and Lötters 2020). Gradient summarizes number of sample points per 5-degree latitude and longitude bins as of June 2021. Sampling strength is classified using natural breaks with Jenks optimization where darker colors denote greater numbers of samples per bin.

Decision Science Working Group

Lead

Evan Grant (USGS)

Members

Robin Russell (USGS), Riley Bernard (USGS/Penn State University), Brittany Mosher (University of Vermont), Alex Wright (Michigan State University)

Summary

The Decision Science Working Group provides problem framing, models, and analyses to support management decisions regarding *Bsal*.

Key Points

This group evaluated problems facing US protected area managers in responding to the threat of Bsal and identified the decisions that can be solved via research (reduction of uncertainties) and decision analysis (e.g., trade-off with other non-amphibian objectives). The group has been asked by resource managers to help further refine their decision problem, to help identify possible proactive management solutions that can be implemented immediately to reduce the threat of Bsal invasion. This group completed a model to assess the effectiveness of importation bans of salamanders as a management strategy for Bsal, given the deep uncertainty in the processes leading to introduction of Bsal to wild and susceptible populations. The group began work with international collaboration to develop a complete system diagram that may be used for modeling, research prioritization, and decision-making.

Products & Manuscripts

- Grear, Daniel A., Brittany A. Mosher, Katherine LD Richgels, and Evan HC Grant. "Evaluation of regulatory action and surveillance as preventive risk-mitigation to an emerging global amphibian pathogen Batrachochytrium salamandrivorans (Bsal)." Biological Conservation 260 (2021): 109222.
- Mosher BA, Grant EHC, Russell RE. August 2021. “Translating wildlife disease models into viable information for managers.” Oral presentation, held virtually. Annual conference of The Wildlife Society.
- Alger, KE and Mosher, BA. August 2021. Difficult Disease Decisions: The Role of Value-Focused Thinking and Decision Analysis in Wildlife Disease Management. Organized symposium at the annual conference of The Wildlife Society.

Challenges & Future Steps

Challenges remain, including engaging managers when immediate risk of Bsal infection is low (i.e., as Bsal has not been detected in the US). This effectively limits the ability to identify and implement proactive management – representing a major challenge for developing management strategies for Bsal and other emerging infectious diseases. Specific and measurable amphibian management objectives are not common among natural resource agencies and we are working with several agencies to set objectives for amphibians in communities vulnerable to Bsal. In addition, there have been not treatment options identified for Bsal (and limited options for other fungal diseases of wildlife), which limits the alternatives available to managers.

Better coordination among the Bsal working groups could improve the use of skills among groups. For example, models for population outcomes may be informed by both the available treatment options and the ability of managers to implement a treatment, which can be considered by merging knowledge and skills between the Research and Decision Science working groups.

Interactions with Other Working Groups

Ongoing work includes collaboration with the USFWS to frame emerging disease problems for WNS local management and treatment decisions, with the intention to use insights to inform Bsal decision problems. We are working with the Research and Management working groups to detail a model of the Bsal system so that management actions may be identified and evaluated using a shared system model (SESYNC funded workshop). We continue to work with the Research working group and outside experts in amphibian disease ecology to populate a disease treatment table, which will provide options to resource managers considering actions, help to guide research priorities, and identify tradeoffs in other important objectives for resource management..

Diagnostics Working Group

Leads

Jake Kerby (University of South Dakota)
Maria Forzan (Long Island University)

Members

Julie Ellis, Dan Grear, Jeff Lorch, Robert Ossiboff, Kim Hamad-Schifferli, Carly Muletz Wolz, Matt Allender, Heather Fenton, Jacob Kerby, An Martel, Frank Passmans, Laura Sprague, John Wood, Cherie Briggs, Leon Grayfer, Steven Lloyd, Deb Miller, Allan Pessier, LeAnn White

Summary

The Diagnostics Working Group (DxWG) promotes the development of standards for diagnosis and reporting of amphibian 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 and to provide expert advice to the rest of the Bsal Task Force regarding 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 detection and reporting of amphibian diseases, including BSal.

Phase 1 of a laboratory round robin proficiency test (ring test) for the detection of *Batrachochytrium dendrobatidis* (Bd), *B. salamandrivorans*(Bsal) and ranaviruses in amphibian species to ensure the validity and comparability of results across labs was conducted between the end of 2020 and early 2021. A matrix of 16 sample-compositions was prepared, and included samples with one, two or three of the pathogens at various concentrations, as well as some samples free of any pathogen (blanks). A call for participation went out middle of August 2020, and disseminated by various media. When possible, the postings and emails were done in English and Spanish. Participants who received the blind samples reported results by logging in to the diagnostics.salamanderfungus.org website, to upload their results via an online form. Once the results were collated, our Access database was used to provide a summary of the overall agreement between labs, and produce a general summary and individual lab reports, organized by Run (samples ran together) and Pathogen

(Bd, Bsal or FV3). A total of 41 of the 43 labs worldwide that received blind sample sets had reported results back by March 26th, 2021. This high level of participation (95%) at a time of a pandemic that has disturbed working and private lives, is astounding.

Key points

- This group has primarily served as a consultant throughout the past year to answer questions.
- Several members are working on a manuscript to highlight key issues in understanding diagnostic tools and highlighting the need to understand uncertainty at many scales.

Implementation Plan Updates

The second 'ring test' has been completed and results have been distributed to participating laboratories. Efforts are underway to complete a manuscript describing these results.

Interactions with other Working Groups

Continued collaboration with relevant working groups is planned. The group primarily has acted as a consultant on technical questions for other groups.

Research Working Group

Leads

Jonah Piovia-Scott (Washington State University, Vancouver)
Molly Bletz (University of Massachusetts, Boston)

Members

Alexa Warwick (Michigan State University), Alexis Korotasz (Notre Dame University), Alysha Henderson (Washington State University), Léa Fieschi-Méric (Laurentian University, Canada), William Sutton (Tennessee State University), Brandon LaBumbard (University of Massachusetts-Boston), Jesse Brunner (Washington State University), David Lesbarres (Laurentian University, Canada), Davis Carter (University of Tennessee), Doug Woodhams (University of Massachusetts-Boston), Evan Grant (United States Geological Survey), Jake Kerby (University of South Dakota), Kenzie Pereira (Duquesne University), Kristyn Robinson (University of Massachusetts), Louise Rollins-Smith (Vanderbilt University), Maria Forzan (Long Island University), Matt Gray (University of Tennessee), Mitch Le Sage (Vanderbilt University), Gia Haddock (Michigan State University), Julia McCartney (University of Massachusetts-Boston) ,Wesley Siniard (University of Tennessee), Brady Inman (University of Massachusetts-Boston), Sarah Woodley (Duquesne University), Deb Miller (University of Tennessee), Mark Wilber (University of Tennessee), Gwyneth Daunton (Columbus State University), Jakobi Deslouches (University of Maryland), Madison Uhrin (Duquesne University), Skylar Hopkins (North Carolina State University), Kyle Emerson (Duquesne University), Patrice Klein (United States Forest Service), Tasia Slater, Zoey Brown

Summary

The Research Working Group has advanced understanding of the threat posed by Bsal to North American amphibians and the transmission dynamics of Bsal in susceptible North American host species. Ongoing research focuses on understanding the potential for the introduction of Bsal through the pet trade, identifying effective methods for managing Bsal in captive and field settings, and investigating how interactions between Bsal and host immune systems influence host susceptibility and disease progression. At least 35 scientists from the United States and Canada 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

- North American amphibians are broadly susceptible to Bsal, and there is great potential for biodiversity loss if Bsal is introduced
- Susceptible species include frogs and toads, which are not currently covered by Bsal-related regulations on import and trade
- Bsal is highly transmissible, and has the potential to spread rapidly in populations of susceptible North American host species, even at relatively low densities

Outcomes and Impacts

The research working group has made substantial progress in understanding Bsal transmission and disease progression in susceptible North American salamanders such as the eastern newt (*Notophthalmus viridescens*). In addition, susceptibility trials conducted on >50 North American species have confirmed the vulnerability of many North American species to Bsal and allowed for a clearer picture of regions with the greatest potential for biodiversity loss, which include Appalachia and the West Coast in the United States. Furthermore, these trials have identified frog and toad species that can become infected with Bsal and develop chytridiomycosis, which was not previously known to occur. Disease mitigation trials testing probiotics, vaccination, and micropredator augmentation and these strategies in combination are also underway using the larval and adult eastern newt as a focal species.

Products and Manuscripts

Peer-reviewed publications

Bienentreu J. & Lesbarrères D. (2020) Amphibian disease ecology: are we just scratching the surface? Herpetologica 76: 153-166.

Bletz, M. C., LaBumbard, B. C., Le Sage, E. H., & Woodhams, D. C. (2021). Extraction-free detection of amphibian pathogens from water baths. Diseases of Aquatic Organisms, 146, 81-89.

Carter, E. D., Bletz, M. C., Le Sage, M., LaBumbard, B., Rollins-Smith, L. A., Woodhams, D. C., ... & Gray, M. J. (2021). Winter is coming–Temperature affects immune defenses and susceptibility to Batrachochytrium salamandrivorans. PLoS pathogens, 17(2), e1009234.

DiRenzo, G. V., Longo, A. V., Muletz-Wolz, C. R., Pessier, A. P., Goodheart, J. A., & Lips, K. R. (2021). Plethodontid salamanders show variable disease dynamics in response to Batrachochytrium salamandrivorans chytridiomycosis. Biological Invasions, 1-19.

Islam, M. R., Gray, M. J., & Peace, A. (2021). Identifying the dominant transmission pathway in a multi-stage infection model of the emerging fungal pathogen Batrachochytrium Salamandrivorans on the Eastern Newt. In Infectious Diseases and Our Planet (pp. 193-216). Springer, Cham.

Le Sage, E. H., LaBumbard, B. C., Reinert, L. K., Miller, B. T., Richards–Zawacki, C. L., Woodhams, D. C., & Rollins–Smith, L. A. (2021). Preparatory immunity: Seasonality of mucosal skin defences and Batrachochytrium infections in Southern leopard frogs. Journal of Animal Ecology, 90(2), 542-554.

Lopes, P. C., French, S. S., Woodhams, D. C., & Binning, S. A. (2021). Sickness behaviors across vertebrate taxa: proximate and ultimate mechanisms. Journal of Experimental Biology, 224(9), jeb225847.

Olson, D., Haman, K. H., Gray, M., Harris, R., Thompson, T., Iredale, M., ... & Ballard, J. (2021). Enhanced between-site biosecurity to minimize herpetofaunal disease-causing pathogen transmission. Herpetological Review. 52 (1): 29-39., 52(1), 29-39.

Pereira, K. E., & Woodley, S. K. (2021). Skin defenses of North American salamanders against a deadly salamander fungus. Animal Conservation, 24(4), 552-567.

Prostak, S. M., Robinson, K. A., Titus, M. A., & Fritz-Laylin, L. K. (2021). The actin networks of chytrid fungi reveal evolutionary loss of cytoskeletal complexity in the fungal kingdom. Current Biology, 31(6), 1192-1205.

Robinson, K. A., Dunn, M., Hussey, S. P., & Fritz-Laylin, L. K. (2020). Identification of antibiotics for use in selection of the chytrid fungi Batrachochytrium dendrobatidis and Batrachochytrium salamandrivorans. Plos one, 15(10), e0240480.

Rollins-Smith, L. A. (2020). Global amphibian declines, disease, and the ongoing battle between Batrachochytrium fungi and the immune system. Herpetologica, 76(2), 178-188.

Rollins-Smith, L. A., & Le Sage, E. H. (2021). Batrachochytrium fungi: stealth invaders in amphibian skin. Current Opinion in Microbiology, 61, 124-132.

Tompros, A., Dean, A. D., Fenton, A., Wilber, M. Q., Carter, E. D., & Gray, M. J. (2021). Frequency–dependent transmission of Batrachochytrium salamandrivorans in eastern newts. Transboundary and emerging diseases.

Towe, A. E., Gray, M. J., Carter, E. D., Wilber, M. Q., Ossiboff, R. J., Ash, K., ... & Miller, D. L. (2021). Batrachochytrium salamandrivorans can Devour more than Salamanders. The Journal of Wildlife Diseases, 57(4), 942-948.

Wilber, M. Q., Carter, E. D., Gray, M. J., & Briggs, C. J. (2021). Putative resistance and tolerance mechanisms have little impact on disease progression for an emerging salamander pathogen. Functional Ecology, 35(4), 847-859.

Conference Presentations

Haddock, G., & Warwick, A. R. (2021) Amphibian Pet Trade Stakeholders' Opinions, Knowledge, and Behaviors Surrounding Disease Spread. Poster. The Wildlife Society.

Additional funding secured
Gray, M. J., N. Poudyal, and N. H. Fefferman. 2021. Socioeconomic epidemiology of disease risk in wildlife trade networks. University of Tennessee One Health Initiative, $125,291.
Piovia-Scott, J. 2021. Threat of Batrachochytrium salamandrivorans to native Oregon amphibians. Oregon Department of Fish and Wildlife. $10,000

Challenges & Future Steps

- Evaluate the potential for Bsal spillover from the pet trade
- Identify field-applicable methods for managing Bsal
- Investigate the pathways of regional spread for Bsal
- Determine mechanisms of disease resilience or evolutionary rescue from Bsal

Implementation Plan Updates

Goal B.3.2: Identify critical transmission pathways and conditions under which Bsal is likely to emerge in amphibian host populations in North America

Priority B.3.2.1: Estimate latency period of infection and recovery rate for pre- and postmetamorphic amphibian hosts at biologically relevant temperatures.

Mostly complete: Latency and recovery following contact with an infected individual estimated for Eastern newts by Malagon et al. (2020). Latency and recovery rates for other North American amphibian species can be estimated from the >50 controlled exposure experiments that have been conducted to date (e.g., Gray et al in revision), though these analyses have not yet been performed.

Priority B.3.2.2: Estimate daily shedding and encystment rate of Bsal zoospores and the infectious dose (ID)-50 for pre- and post-metamorphic amphibian hosts at biologically relevant temperatures.
Partly complete: ID-50 has been estimated for most of the >50 controlled exposure experiments that have been conducted to date (e.g., Gray et al in revision). It would be useful to relate shedding rates to Bsal load as measured by skin swabs, to see if load can be used as a proxy for shedding.

Priority B.3.2.3: Estimate daily contact rates of amphibian hosts at relevant temperatures and densities when exposed to different complexities of habitat structure.
Completed for Eastern newts (Malagon et al. 2020 Scientific Reports 10:1-11).

Priority B.3.2.4: Estimate probability of Bsal transmission between infected and uninfected amphibian hosts (within and between species) at different post-exposure durations and temperatures.
Completed for duration of exposure in eastern newts (Malagon et al. 2020).

Priority B.3.2.6: Estimate the influence of co-infection with other pathogens (e.g., Bd, ranavirus) on the likelihood of Bsal transmission and development of chytridiomycosis.
Partly complete: There is emerging evidence that Bd can increase Bsal susceptibility (e.g., Longo et al. 2019, Hardman et al. in prep).

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

Priority B.3.3.1:Estimate the susceptibility and tolerance of North American amphibians to Bsal infection and chytridiomycosis using standardized, dose-dependent experiments.
Completed: We have conducted controlled Bsal exposure experiments for more than 50 species of North American amphibians. Results for most of these species appear in Gray et al. (in revision); additional species will appear in subsequent papers that are in preparation. Towe et al. (2021) revealed that Bsal chytridiomycosis can occur in frogs.

Priority B.3.3.2:Estimate the impact of habitat characteristics (temperature, pH, salinity, zooplankton abundance, etc.) on Bsal infection risk.
Partly complete: The effects of temperature on Bsal infection and mortality are explored by Carter et al. (2021).

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).
Complete for four North American salamander species (Wilber et al. 2021).

Priority B.3.3.4: Use information developed in Priorities 1–3 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.
Partly complete: Initial spatial predictions of Bsal risk in the United States are in Gray et al. (in revision).

Goal B.3.4: Identify effective methods for managing Bsal-induced disease and clearing Bsal infections in captive and field settings.

Priority B.3.4.8: Determine the effectiveness of reducing host density or altering relative abundance of host species with different infection tolerances on the invasion potential of Bsal.
Partly complete: Evaluated the effect of host density on transmission in eastern newts (Wilber et al. 2021).

Goal B.3.5: 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.
Partly complete: LeSage et al. (2021) evaluated seasonal patterns in immunity and Pereira et al. (2021) investigated defenses.

Goal B.3.7: Establish effective methods for detecting Bsal infections.

Priority B.3.7.1: Develop new diagnostic tools and improve existing tools.
Partly complete: Bletz et al. (2021) developed a method for extraction free diagnostic testing using lyophilization.

Interactions with other Working Groups (Leave blank if not applicable)
Presentations to Research Working Group from Diagnostics Working Group (Jake Kerby, 11 January 2021), Decision Science Working Group (Evan Grant, 3 May

2021), Surveillance and Monitoring Working Group (Jenifer Walke, 13 September 2021).

Engagement of Research Working Group members with SNAPS program (Student Network for Amphibian Pathogen Surveillance), being developed by members of the Surveillance and Monitoring Working Group.

Engagement of Research Working Group with RIBBITR (ribbitr.com)

Surveillance and Monitoring Working Group

Leads

Jenifer B. Walke (Eastern Washington University)
Brittany A. Mosher (University of Vermont)
Olya Milenkaya (Warren Wilson College)

Members

Michael J. Adams (U.S. Geological Survey), Daniel A. Grear (U.S. Geological Survey), Sasha E. Greenspan (The University of Alabama), Oliver Hyman (James Madison University), Michelle S. Koo (Museum of Vertebrate Zoology, University of California), Eria Rebollar (Universidad Nacional Autónoma de México), Lenny Shirose (Canadian Wildlife Health Cooperative), Vance Vredenburg (San Francisco State University), Arlene Buchholz (USDA), Aubree Hill (Tennessee Tech University)

Summary

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 a student-powered surveillance network: Student Network for Amphibian Pathogen Surveillance (SNAPS). Here we describe the progress and future plans for SNAPS expansion and assessment. Beyond SNAPS, we are also coordinating with surveillance efforts outside of our Working Group, including sampling in the amphibian pet trade. Lastly, we continue to develop guidelines for Bsal monitoring in the event of a Bsal detection in North America.

Key Points

- We developed a visual identity for SNAPS, with both a logo and website being created this year.
- SNAPS was implemented at five institutions this year and will expand to 17 institutions in 2022.
- Initial educational assessments suggest that SNAPS is an effective way for students to learn about amphibian pathogens.
- The assessment also indicated a lack of diversity in the current students that SNAPS reaches, so the plans for expansion include diversifying our partner institutions.
- SNAPS is facing the financial and logistical burden that comes with a growing membership.

Outcomes and Impacts

After our initial trial of SNAPS was interrupted by the emergence of Covid-19 during the spring 2020 semester, our primary outcome during 2021 was our successful trial of SNAPS. Three participating institutions implemented SNAPS during spring 2021 (Warren Wilson College, Eastern Washington University, University of Vermont), and another two participated during fall 2021 (University of Notre Dame, Tennessee Tech University).

We completed preliminary analyses of SNAPS Learning Outcome Assessment data that we collected from student participants during the spring 2021 trial. Students were invited to voluntarily take pre- and post-SNAPS surveys (N=63 students total) from each of the three spring 2021 trial institutions. The surveys assessed SNAPS effectiveness in terms of students' (1) knowledge of amphibian disease, (2) interest in the environment, and (3) self-efficacy towards conservation. Assessment revealed that participation in SNAPS significantly increased students' knowledge and understanding of amphibian fungal pathogens. 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. These students were enrolled in upper division conservation biology, herpetology, and microbial ecology courses, thus already had an apparent interest in ecology and conservation. This result points to the need to expand SNAPS into a broader range of course-types, including introductory biology courses.

We developed a visual identity for SNAPS by creating both a logo (designed by Magritte Hyman, Oliver Hyman (JMU), and Craig Baugher (JMU)) and a website (https://snaps.amphibiandisease.org/), which will be helpful in upcoming recruiting efforts. We currently have seven institutions ready to participate in SNAPS during Spring 2022 and are in the process of recruiting another ten institutions. We also finalized our SNAPS mission and vision statements:

SNAPS Mission: Mobilizing students to lead the search for emerging amphibian pathogens.
SNAPS Vision: An experiential learning network driving early detection of emerging amphibian pathogens in North America.
Products and Manuscripts (List talks, papers, etc) [APA Format]
Milenkaya O, Mosher BA, Walke JB, Hyman O, Greenspan SE, Koo MS, Grear DA, MJ Adams. August 2021. "A Novel Approach to a Novel Pathogen: Student-Powered Surveillance of Batrachochytrium salamandrivorans." Oral presentation, held virtually. Joint Conference of the Wildlife Disease Association and the European Wildlife Disease Association.
Grear, Daniel A., Brittany A. Mosher, Katherine LD Richgels, and Evan HC Grant. "Evaluation of regulatory action and surveillance as preventive risk-mitigation to an emerging global amphibian pathogen Batrachochytrium salamandrivorans (Bsal)." Biological Conservation 260 (2021): 109222.
Mosher BA, Grant EHC, Russell RE. August 2021. "Translating wildlife disease models into viable information for managers." Oral presentation, held virtually. Annual conference of The Wildlife Society.

Challenges & Future Steps

Our primary challenges for the coming year stem from the success of SNAPS. With success comes growth, and this nascent program is growing with new participants in Mexico, USA, and Canada. We now have more prospective participants requesting the opportunity to engage in SNAPS for the coming year than we can currently support. We anticipate implementing SNAPS with 17 participating institutions during the coming year, spanning all North American countries. This growth is exciting and has been our goal. We always intended to scale-up SNAPS both geographically and numerically so that it can be an effective tool for the early detection of Bsal in North America. Therefore, our current success and growth is welcomed. However, it is also a challenge.

One challenge for the coming year is to secure sufficient funding to support this growing program. Another challenge is the administrative burden of a larger program. 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 the onboarding of new participants, accountability, data management, coordination with multiple labs, assessment of student learning outcomes, and reporting.

Our pilot assessment results revealed that SNAPS is currently lacking in diversity of student race and ethnicity (90% white), grade level (97% in 3rd or higher year of undergraduate), fields of interest (already enrolled in ecology-type elective courses), and institution type (only one representative institution from small liberal arts, medium regional comprehensive, and large research). 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).

Implementation Plan Updates (New Objectives/Goals, Completed 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 were:

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

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

Goal 3: Support and facilitate sampling 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.

In the timespan of this Annual Report (October 2020 - September 2021), 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, and growth 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 2022 semesters
Objective 2: Secure longer-term SNAPS funding to sustain the program
Objective 3: Publish 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 2022 semesters
Objective 6: Assess student learning outcomes from SNAPS following the spring and fall 2022 implementation
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

Interactions with other Working Groups

1.We participated in the Annual Meeting of the North American Bsal Task Force and Olya Milenkaya gave the following talk: Milenkaya O, Mosher BA, Walke JB, Hyman O, Greenspan SE, Koo MS, Grear DA, Vredenburg V, MJ Adams. October 2020. "Surveillance & Monitoring Working Group." Oral presentation live in Zoom, Annual Meeting of the North American Bsal Task Force.

2.Jenifer B. Walke participated in a meeting of the Research Working Group in September 2021 where she gave a talk about our Working Group efforts, including SNAPS. We shared preliminary data demonstrating the positive impact of SNAPS on students' knowledge of Bsal. We also discussed ideas for an analysis/synthesis product using SNAPS Bd and Bsal data (including negative results), along with potential to collaborate more on Bsal surveillance in the pet trade through their connections with PIJAC (Pet Industry Joint Advisory Council).

3.We hosted Alexa Warwick (Michigan State) from the Research Working Group at our Working Group meeting. We discussed the need for Bsal surveillance in the pet trade and the potential for incorporating Bsal surveillance into SPARCnet (Salamander Population & Adaptation Research Collaboration Network, http://sparcnet.org/) activities.

4.Brittany Mosher worked with the Decision Science Working Group to plan a symposium on Difficult Disease Decisions at the 2021 WIldlife Society annual conference. The session was well-attended and well-received.

Clean Trade Working Group

Lead

Joshua Jones

Members

Matthew Gray, Jesse Brunner, Jonah Piovia-Scott, Alex Shepack, Craig Watson, James Collins, Joe Hiduke, Josh Willard, Zach Brinks, Scott Hardin

Summary

This working group is comprised of experts in the care, husbandry, and/or disease research of amphibians. Our task is to explore and identify the potential components of a comprehensive, North American clean trade program to help prevent Bsal from entering North America while allowing for the legal and responsible importation of amphibians to be cared for as pets. Discussions on funding things like research that may be needed to test certain aspects of the program, as well as any discussions on realizing legislative/ regulatory changes necessary for implementing the program are outside the scope of this workgroup.

Key Points

- This working group's mission is to foster collaboration among participants to determine the potential components for a comprehensive North American clean trade program and report findings back to the Bsal Task Force Technical Advisory Committee.
- Individual stakeholder bandwidth impacted by supply chain disruption and the ever-evolving situation with COVID-19 to help stop the spread of the disease have been significant challenges for the group to overcome this year.
- Industry stakeholders have completed a description of the North American trade in pet amphibians using the best available data and information

Outcomes/impacts

The Clean Trade Working Group began organizing in the fall of 2019 with the drafting a framework for the group which included a mission, vision, purpose and structure best suited for achieving the goals outlined in the document. The working group then held its first call in March 2020 where it was agreed that

the first steps for the group would be for stakeholders to gather information on the current status of the amphibian pet trade across North America.

The initial description of the amphibian trade drafted by stakeholders was finalized in early 2021 and shared with the group. This allowed pet care community stakeholders to begin discussing with the full group what the components of a Bsal-specific clean trade program may include to help prevent the pet trade from becoming one of the many potential pathways for Bsal to enter North America.

Several external challenges including ongoing changes with COVID-19 protocols to stop the spread of the disease and supply chain disruptions, have made it difficult for stakeholders to devote the time, energy, and resources needed to work on next steps. It is important to note that several pet care community stakeholders involved in this workgroup have been actively participating with the University of Tennessee Institute of Agriculture on a pilot project to identify science-based solutions that promote and foster animal wellbeing and environmental stewardship, minimize revenue losses due to harmful microbes, examine potential benefits of beneficial microbes, and decrease opportunities for microbial spillover from captive to wild populations.

Challenges

Evolving situation with COVID-19: The ever-evolving impacts of COVID-19 has continued to impact the group. The workgroup's initial momentum from the beginning of March 2020 was slowed due to the need to address and ensure compliance with subsequent stay-at-home orders and rules from all levels of U.S. government being established to stop the spread of the virus.

Supply chain disruptions: Supply chain disruptions have created a challenge for pet care community stakeholders who provide animals and care items to make sure they are meeting the needs of the animals and are able to supply care items citizens need for their pets. The combination of impacts from COVID and from supply chain disruptions have left stakeholders with little time, energy, or resources to devote to the workgroup and this effort until later in 2022.

Response and Control Group

Leads

Laura Sprague, U.S. Fish and Wildlife Service

Members

Molly Bletz (Umass Amherst), Mike Adams (USGS), Evan Grant (USGS), Su Jewell (USFWS), Betsy Howell (Forest Service), Matthew Gray (University Tennessee Knoxville), Brittany Mosher (University of Vermont)

Bsal Response and Control Working Group 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.

Outcomes and Impacts

- Updated the response plan document in the strategic plan
- Continued to work on DOI-Wide Categorical Exclusion (CatEx) for management of invasive species, including pathogens

Products and Manuscripts

Presented at First Bsal Task Force Annual Meeting for external partners

Challenges & Future Steps

- Develop more user-friendly response plan template
- Match response plan template to changes made in strategic plan
- Develop white papers to inform management at all levels within different agencies and departments that will be used to inform them of Bsal; the Task Force; and the resources available for rapid response if Bsal is detected

Interactions with other Working Groups

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

Communications and Outreach Working Group

Leads

Alex Shepack, University of Notre Dame
Mark Mandica, Amphibian Foundation

Participants

Arlene Buchholz, Heather Fenton, Kenzie Pereira, Megan Serr

Summary

The Bsal Task Force Communications and Outreach Working Group manages Bsal-related communication and products for outreach, especially relative to providing informational materials for a myriad of interested groups and people with concern for salamander health and well-being.

Key Points

- Compiled, Formatted, Designed and Published the Bsal Task Force Annual Report
- Assisted with the redesign of the salamanderfungus.org website for the Bsal Task Force.
- Assisted with the revising, editing, and formatting of the Bsal Strategic and Implementation Plans.
- Social Media: We continue to maintain and utilize Twitter (@salamanderfungi) and Facebook (www.facebook.com/salamanderfungus/). As of Dec 17 we have 982 followers on Twitter and 299 on Facebook. Twitter followers have increased by almost 50 since last year, while the Facebook page has increased by 20.

Challenges

Maintaining active membership has been a challenge. The intermittent nature of the tasks of this working group make it hard to keep members involved. Additionally, increased communication is necessary between Task Force participants and the communication group so that media releases can be prepared in advance prior to the release of publications. Maintaining an active social media presence is necessary to continue growing our following on the platforms.

Outcomes

As we continue to post updates, articles, and information, we are increasing our chance of engaging with individuals, groups, and organizations to make them aware of what is occurring with Bsal. This gives us the opportunity to share what work the Bsal Task Force has accomplished, and what work is currently occurring.