

Bsal Task Force

2019 Annual Report

Sept 2020



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2019 Bsal TAC Annual Report

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
- 6) Communication 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 2019 to December 2019.

Key Accomplishments in 2019

- Hosted the First North American Symposium on *Batrachochytrium salamandrivorans*, Reno, NV, USA.
- Produced multiple research deliverables, including >35 presentations and >10 articles, on the threat of *Bsal* to North American amphibians, possible mechanisms driving variation in susceptibility, including temperature, stress, host defenses and microbiomes, pathogen transmission, pathogenesis, and potential disease mitigation strategies.
- Members developed a new diagnostic tool: probe to detect and identify Bd and Bsal in tissue sections.
- Members formed the initial components of a surveillance network based on students called SNAPS: Student Network for Amphibian Pathogen Surveillance.
- PARC associated members participated in technical workshops with a Bsal focus, including: 1) Amphibian skin microbiomes as probiotics for disease management workshop, Zoological Society of London, April 2019; 2) Bsal field management responses workshop, Zoological Society of London, April 2019; and 3) Bsal scenarios and decision modes, Bsal Task Force, Reno, NV, September 2019.
- Continued to update online database for latest available information and analytics on Bsal and Bd tests.



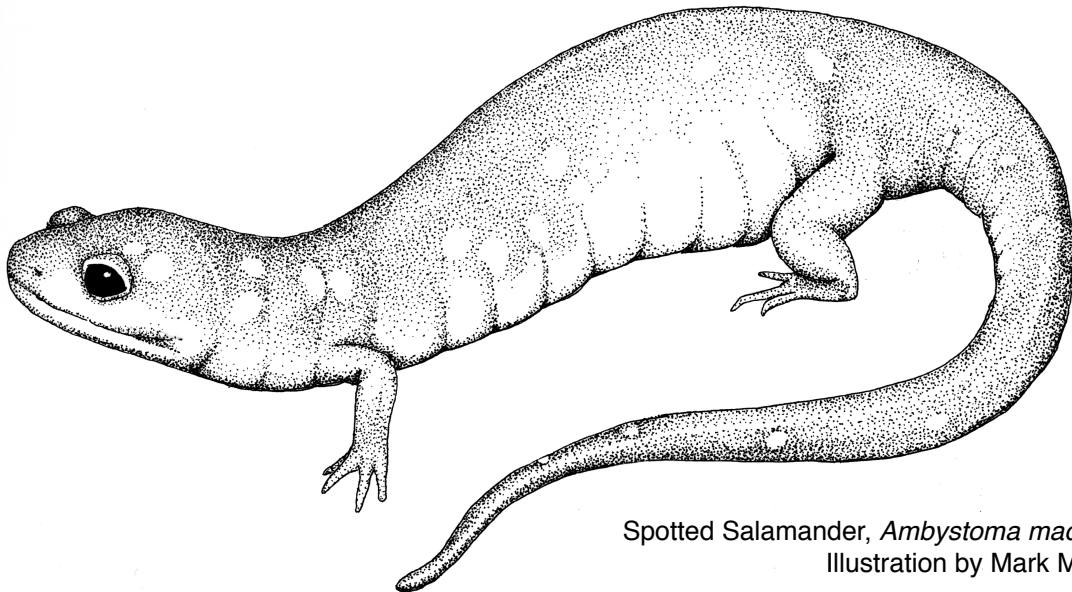
Marbled Salamander, *Ambystoma opacum*
Illustration by Mark Mandica

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



Spotted Salamander, *Ambystoma maculatum*
Illustration by Mark Mandica

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.

Working Group Reports

Data Management Working Group

Leads

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

Members

Philip Kahn (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 Chytrid Data Management Web Portal (amphibiandisease.org) continues to expand in scope, with ongoing Bsal and Bd data imports, and new data export applications, and initiation of substantial database work to strengthen its technical and intellectual ties to global bio-sampling efforts.

Key Points

- 1) Bsal data imports by registered users are ongoing. Currently there are 83 registered users from mainly academic institutions (as presumed from *.edu email addresses). Bsal data harvested from the literature is pending.
- 2) Bd data imports from registered users are ongoing. To date, these data include 23,548 *samples* analyzed for Bd from 518 species, of which 3,159 (13.4%) samples were Bd-positive.
- 3) Bd data from the Global Bd Mapping Project and Bd-maps.net database are in transition to amphibiandisease.org, with a comprehensive data update in progress before the world dataset is uploaded to the new portal. As a measure of where we stand, the last functional download from the online database in 2013 contained 11,305 records. Updates that had failed to upload, plus additional new data from papers published through the end of 2014 comprise an additional 8610 records. New data mostly published from 2014 through 2018 that have been compiled thus far add a further 6754 records, for a current total of 26,669 records (*record defined below).
To date, Bd has been detected in 84 of 105 countries sampled (80%).
The tables below show our current knowledge of Bd prevalence (detection rate) by species in the three amphibian orders (overall 53% prevalence) and by family (overall 88.6% prevalence). At this time about 25% of amphibian species and 91% of families have been tested for Bd, according to available reports.

Order	No. species w/ Bd detected	No. species tested	Spp. prev. (%)	Total species	% spp. tested
Anura	943	1732	56.0	6984	24.8
Caudata	121	241	51.0	718	33.6
Gymnophiona	8	34	25.0	205	16.6
Total	1072	2007	53.4	7907	25.4

Order	No. families w/ Bd detected	No. families tested	Family prev. (%)	Total families	% families tested
Anura	49	53	92.5	58	91.4
Caudata	8	8	100.0	9	88.9
Gymnophiona	5	9	55.6	10	90.0
Total	62	70	88.6	77	90.9

*A “record” falls under one of two headings: a location record (the majority of the legacy database harvested from the literature), or a species record. A *location record* comprises samples taken from the specified coordinates on a sampling occasion. Each location (site) may match up to one, several, or many records distinguished by sampling date(s), species, and/or life stage(s). A record may report results from the test on a single animal or results for all the animals of that species sampled on that occasion at that site (most of the records are of this latter type). In some cases, only detections/no detections of Bd are reported for a location, with no species information attached. In others, published studies report species test results separately from the results by location, and the two types of information cannot be connected. To account for this case, *species records* report detections/not detections by species, but associated with a more general coordinate/location not intended to be used for geographic modeling. Species records are always tied to a set of location records that document the locations sampled in the study, even if particular species cannot be tied to a specific location. In this way, the database can account for both all species sampled and all locations sampled, even if not always in the same line of data.

Reconciling these legacy BdMaps data with samples based records of the disease portal will require coordinated efforts and can be done once the infrastructure migration is complete. See below

- 4) Bsal data—there are 673 samples for Bsal, with no positive results.

- 5) Web portal applications continue to grow—we are initiating substantial infrastructure changes especially to enhance and strengthen our data validation process by collaborating and aligning the portal with the GEOME database (<https://geome-db.org>). Sharing the same validation process will allow a streamlined way to maintain security and share enhancements from the GEOME project. GEOME is the Genomic Observatories Meta-Database which is a web-based database that captures the who, what, where, and when of biological samples and associated genetic sequences. GEOME ensures the metadata from bio-samples are discoverable, accessible and useful in research by adhering to global metadata standards and provides API access. It is currently supported by the Berkeley Natural History Museums, Smithsonian National Museum of Natural History and NSF's iDigBio efforts. In addition, we will also update the public website for Amphibian Disease portal to provide a more uniform and robust user interface, which will also make the website easier to maintain.
- 6) Funding for ongoing website development and maintenance is a current need. The US Forest Service and AmphibiaWeb (Berkeley Natural History Museums, UC Berkeley) have cost-shared the disease portal, but both entities are facing future funding shortfalls or at least uncertainties. We have and need to continue discussing how to pursue grant opportunities for new and improved functionalities.
- 7) Preliminary discussions have been conducted about the utility of this web portal for data management additional diseases. We anticipate this discussion to continue over the next year, as the portal capacity for *Bsal* and *Bd* becomes more fully realized.

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

- a) Presentations and demonstrations of the Disease Portal:

Koo, M.S. July 2019 “New updates from AmphibiaWeb: All Amphibians, All the Time” presented at the Joint Meeting of Ichthyologists and Herpetologists, Snowbird, UT.

Olson, D.H. 2019. Amphibian pathogen web portals. International symposium, Mitigating single pathogen and co-infections that threaten amphibian biodiversity. Zoological Society of London, UK. April. ~100 participants.

- b) Interactions with Other Groups

The Data Management Working Group works closely with the Surveillance Working Group, the Communications and Outreach Working Group, and the PARC Disease Task Team. Specifically the combined efforts of the working groups are collaborating on a joint project called SNAPS: Student Network for Amphibian Pathogen Surveillance in which college courses will spearhead student efforts to sample from field or collections chytrid swabs to be tested by the National Lab for *Bd* and *Bsal* as part of a STEM-based curricula. These data in turn will be deposited in the Amphibian Disease portal and be available for student-led projects or other research.

Decision Science Working Group

Summary

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

Lead

Evan Grant (USGS)

Participants

Robin Russell (USGS), Katie Richgels (USGS), Riley Bernard (USGS/Penn State University), Brittany Mosher (University of Vermont), Katrina Alger (USGS)

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 three 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 initiated the development of 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 continued to work on this objective into 2020.

Manuscripts in preparation or review

*Author names in **bold** are members of the Decision Support Working Group.

Bernard, Riley F. and **Evan H. Campbell Grant.** *In Review*. Rapid assessment indicates context-dependent mitigation for amphibian disease risk. Wildlife Society Bulletin.

Wright, Alex D., **Riley F. Bernard**, **Brittany A. Mosher**, Katie M. O'Donnell, Taylor Braunagel, Grazella V. DiRenzo, Jillian E. Fleming, Charles Shafer, Adrienne B. Brand, Elise F. Zipkin, & **Evan H. Campbell Grant.** *Minor Revisions*. Moving from decision to action in conservation science. Biological Conservation.

Progress:

We are making efforts to extend the scope of the work to address emerging fungal diseases in general including white-nose syndrome (this is partially to attract greater funding sources and increase the level of interest in the project) and snake fungal disease (new project in Vermont led by Grant & Mosher). The aim is to learn from

WNS how to best prepare for proactive and preventative management for *Bsal* as well as for future wildlife diseases.

A set of questions was sent to Federal and State land managers, with the goal of helping to get a better sense of the management issues and information needs necessary to develop a response to the salamander chytrid fungus (*Bsal*), and to better understand the context in which these decisions take place. This survey of manager issues has been completed, with results published in Society and Natural Resources (see Bernard & Grant 2019).

Following the publication by Bernard & Grant (2019), we engaged with three USFWS National Wildlife Managers in Region 5 to work through their amphibian – *Bsal* decision problems. Using the refuges' most recent Comprehensive Conservation Plans and Habitat Conservation Plans, we identified refuge specific management objectives, including amphibian and disease-focused objectives and developed *Bsal*-specific means objectives. We are currently revising the decisions with each manager using a 'rapid prototyping' approach.

In May 2019, we submitted a workshop proposal to the National Socio-Environmental Synthesis Center (SESYNC) with the goal of creating a multi-disciplinary working group comprised of amphibian and disease experts from academia, governmental and non-governmental agencies, non-profit entities, and decision analysts. In order to gain traction in mitigating pervasive threats to amphibian populations, we propose to develop a co-generated system model, or influence diagram, to improve opportunities for proactive management of *Bsal*. Using tools from decision theory, we will create a model that will be used to (1) quantitatively evaluate potential effects of alternative management actions, (2) generate novel actions for mitigation and control, and (3) improve communication with stakeholders and the public regarding *Bsal* and amphibian management decisions. Relevant to the mission of SESYNC, our approach will identify both ecological and social factors that influence the susceptibility and control of *Bsal* in native US amphibian populations. This project has been funded and will take place Spring 2020.

Challenges

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.

Outcomes / Manuscripts

*Author names in **bold** are members of the Decision Support Working Group.

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

Grant, E. H. Campbell, M. J. Adams, R. N. Fisher, D. A. Gear, B. J. Halstead, B. R. Hossack, E. Muths, **K. L. D. Richgels, R. E. Russell,** K. L. Smalling, J. H. Waddle, S. C. Walls, & C. L. White. 2018. Identifying management-relevant research priorities for responding to disease-associated amphibian declines. *Global Ecology & Conservation*. 16: e00441. doi: 10.1016/j.gecco.2018.e00441

Mosher, Brittany A., Riley F. Bernard, Jeffrey M. Lorch, David A. W. Miller, **Katherine L. D. Richgels,** C. LeAnn White, and **Evan H. Campbell Grant.** 2020. Successful molecular detection studies require clear communication among diverse research partners. *Frontiers in Ecology and the Environment*. 18:1 43-51. doi: 10.1002/fee.2141

Waddle, Hardin J., Daniel A. Gear, **Brittany A. Mosher, Evan H. Campbell Grant,** Michael J. Adams, Adam R. Backlin, William J. Barichivich, Adrienne B. Brand, Gary M. Bucciarelli, Daniel L. Calhoun, Tara Chestnut, Jon M. Davenport, Andrew E. Dietrich, Robert N. Fisher, Brad M. Glorioso, Brian J. Halstead, Marc P. Hayes, R. Ken Honeycutt, Blake R. Hossack, Patrick M. Kleeman, Julio A. Lemos-Espinal, Jeffrey M. Lorch, Brome McCreary, Erin Muths, Christopher A. Pearl, **Katherine L. D. Richgels,** Charles W. Robinson, Jennifer C. Rowe, Brent H. Sigafus, Iga Stasiak, Samuel Sweet, Susan C. Walls, Gregory J. Watkins-Colwell, C. LeAnn White, Lori A. Williams, and Megan E. Winzeler. *In press. Batrachochytrium salamandrivorans (Bsal)* not detected in an intensive survey of North American amphibians. *Scientific Reports*.

Presentations

Grant, E. H. Campbell & R. F. Bernard. 2019. Disease decisions can be rational. 2019 Joint Annual Conference of The Wildlife Society and the American Fisheries Society

Grants

Bernard, R. F. & E. H. Campbell Grant. 2019. Co-generating a system model to improve opportunities for proactive management of the *Batrachochytrium salamandrivorans (Bsal)* threat in North America. National Socio-Environmental Synthesis Center (SESYNC).
Award amount: ~\$40,000.00 USD (Travel & reimbursement grant for 25 participants from around the world)

Workshops

Mini-workshop at The 2019 Joint Meeting of The Wildlife Society and American Fisheries Society

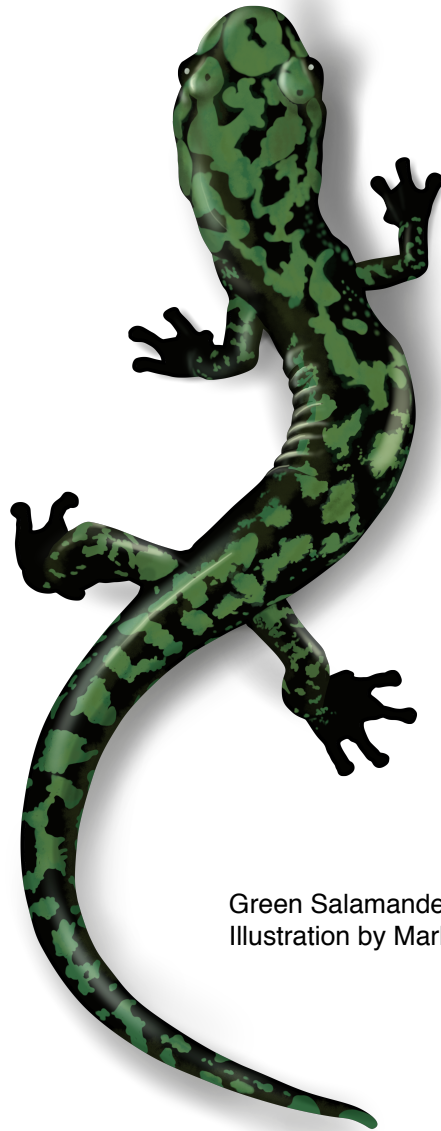
The workshop was conducted between the morning and afternoon sections of the “*Batrachochytrium salamandrivorans*: The next threat to North American biodiversity” special session. During the workshop, approximately 30 individuals (i.e., academic professors, graduate students, and postdocs, agency scientists and statisticians, and NGO scientists) divided into three groups (i.e., Pacific Northwest rough-skinned newt, Southeastern stream salamander, and Northeastern red-spotted newt community scenarios) to predict the magnitude (scale from 0 – 3) and effect (positive or negative) of 11 treatment or management actions (proactive, reactive and state-independent) on five distinct endpoints. The endpoints included host survival and reproduction, pathogen transmission and persistence, and non-target effects of an action during and after implementation. The Decision Support WG is currently writing up a formal workshop report and will be incorporating the results into a manuscript that will help scientists identify which endpoints are most critical in determining if a treatment will be implemented by a manager.

Rapid prototype conversations with R5 Refuge managers

We identified three R5 National Wildlife Refuge managers who have been engaged in long-term monitoring and surveillance efforts with the Northeast branch of the Amphibian Research and Monitoring Initiative (NEARMI). Since spring of 2018, we have reviewed the management objectives and goals identified in each of the Refuges’ Comprehensive Conservation Plan and Habitat Conservation Plan and developed a rapid prototype of a *Bsal*-focused management decision for each refuge. In lieu of three week-long Structured Decision Making workshops, we have been communicating with the managers regularly to ensure we are properly framing their decision problem and incorporating the correct management objectives. Currently, we are working with each manager to finalize the rapid prototypes and will be incorporating the various management objectives into a manuscript that will help scientists identify which objectives and endpoints are most critical in determining if a treatment will be implemented by a manager.

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 are continuing 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. We are working with the Research working group and outside experts in amphibian disease ecology to populate the disease treatment table as well as develop the amphibian host – *Bsal* system diagram.



Green Salamander, *Aneides aeneus*
Illustration by Mark Mandica

Diagnostics Working Group

Lead

María J. Forzán, Long Island University

Participants

Julie Ellis, Dan Grear, Jeff Lorch, Robert Ossiboff, Kim Hamad-Schifferli, Carly Muelzt 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 Statement

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.

Key Points

The main priorities of the group are:

- 1) Inter-laboratory quality control program (round robin) for 2020: currently looking for funding to perform the round robin planned with the funding from ECCC. Funding sources approached include ECCC (proposal submitted in early October 2019) and Morris Animal Foundation (MAF, proposal to be submitted Nov 15, 2019).
- 2) Develop a standardized and replicable method that will allow comparison across studies and a reliable estimation of presence and/or prevalence and Bd and Bsal. If obtained, funding from ECCC and/or MAF would allow us to perform the round robin and evaluate the performance of various protocols and standards.
- 3) Collaborate on a review manuscript, spearheaded by Kim Hamad-Schifferli, on diagnostics methods for infectious disease surveillance and monitoring in wildlife, pros and cons, as they are applied to Bsal detection. **NEW**

Outcomes or Impacts

Establish a long-term program for inter-laboratory quality control and evaluation of protocols for the detection of wildlife pathogens, particularly Bd and Bsal, Goal 1 of the Strategic Plan (2018): Partially accomplished

Jennifer Provencher, Environment and Climate Change Canada (ECCC), was able to secure funding so that María Forzán (MF), DxWG facilitator, and Nicholas Hollingshead (NH), Data Analyst, established the framework for a ring test, or round robin, designed

to test laboratory proficiency in PCR tests for Bd and Bsal. MF developed the logistical plan, contacted potential participants, sourced out the test material and secured the facilities to prepare the blind samples. Inactivated cultures of Bd and Bsal are to be provided by the laboratories of University of Tennessee (Deb Miller, Director of the Center for Wildlife Health) and Vanderbilt University (Louise Rollins-Smith, Professor), prepared and randomized by experienced technicians at Pisces Molecular (John Wood, Director) under MF's supervision. NH prepared a website (diagnostics.salamanderfungus.org/about) which is now linked to the Task Force's main site (salamanderfungus.org) that includes information about the DxWG, a summary of the finding from the 2016 round robin, and which will also serve as a portal for participating labs to upload their results and review the results of future round robins. Images of the website are provided at the end of this document.

Develop a standardized and replicable method that will allow comparison across studies and a reliable estimation of presence and/or prevalence and Bd and Bsal load in the wild, Goal 2 of the Strategic Plan (2018): Not accomplished

Funding to perform the round robin proficiency test could not be obtained, so there could be no evaluation of the efficacy of certain standards or protocols, so Goal 2 was not achieved.

Develop and validate a diagnostic assay to differentiate between Bsal and Bd in tissue section, Goal 3 of the Strategic Plan (2018): Accomplished

Robert Ossiboff (University of Florida) lead the effort and was successful in developing an *in situ* hybridization technique capable of detecting, and distinguishing between, Bd and Bsal zoosporegia and zoospores in formalin-fixed paraffin-embedded tissue sections. A manuscript on the application of the technique was published in *Frontiers in Veterinary Science* (10.3389/fvets.2019.00304).

Obstacles

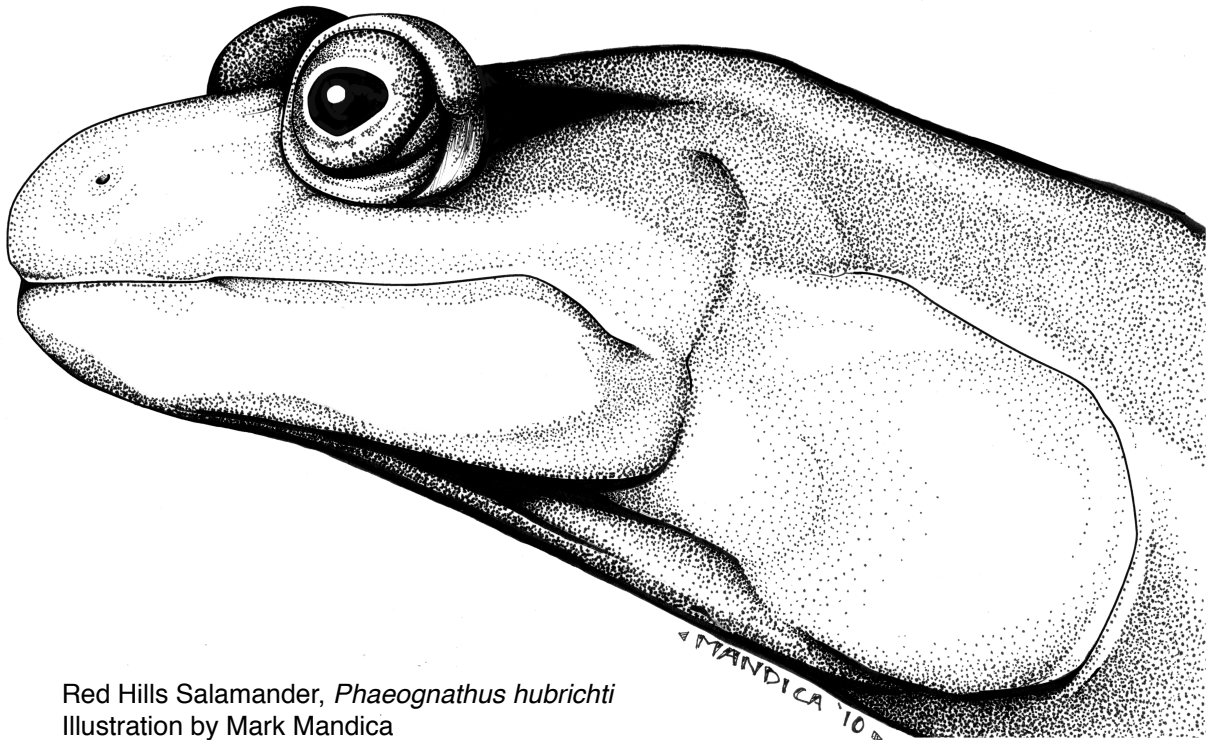
Inter-laboratory quality control program (round robin) and development of standardized methods to compare across studies and provide recommendations for Bd/Bsal detection: lack of funding.

An application was submitted by MF and collaborators to the National Geographic Society Species at Risk fund, with numerous letters of support from proposed participants and the leads of the IUCN's Amphibian Specialists Group. Unfortunately, the proposal was not successful. Reasons for rejection were not provided.

As all group members are fully employed at academic, private or governmental institutions, their professional commitments make it difficult to dedicate time to the collaborative effort to produce a review manuscript.

Interactions with other groups

Several members also serve in the Research, Management, Response and Data Management groups. The group's lead is the incoming chair of the Task Force.



Red Hills Salamander, *Phaeognathus hubrichti*
Illustration by Mark Mandica

Research Working Group

Leads

Douglas Woodhams, University of Massachusetts Boston
Molly Bletz, University of Massachusetts Boston

Members

Alessandro Catenazzi, Agata Grzelak, Alexis Korotas, An Martel, Anna Peterson, Andrianna Pompros, Alexa Warwick, Kenzie Pereira, Davis Carter, Debra Miller Evan Grant, Riley Bernard, Grace Direnzo, Jessie Brunner, Jonah Piovita-Scott, Kristyn Robinson, Matthew Gray, Maria Forzan, Lilian Fritz-Laylin, Sarah Woodley, Louise Rollins-Smith, Mitch LeSage, Obed Hernandez, Evan Eskew

Bsal Research Working Group Accomplishments

1. Extramural Funding Secured for Bsal Research
 - a. Secured
 - i. U.S. Fish and Wildlife Service, Competitive State Wildlife Grant (in collaboration with Tennessee Wildlife Resources Agency), The threat of *Batrachochytrium salamandrivorans* (Bsal) to species of greatest conservation need and proactive development of disease management strategies = \$499,167 (\$205,465 to UT).
 - ii. American Society for Ichthyologists and Herpetologists – Gaige Fund Award (\$900), May 2019
2. Research Activities
 - a. Completed susceptibility trials on nine additional species.
 - b. Completed experiments evaluating the influence of temperature on susceptibility to Bsal infection.
 - c. Completed experiment estimating contact rates of adult and juvenile eastern newts (*Notophthalmus viridescens*) at different host and plant densities, water volumes and temperatures.
 - d. Initiated experiments to identify the factors that contribute to Bsal pathogenesis in rough-skinned newts (*Taricha granulosa*).
 - e. Initiated efforts to model Bsal transmission and host tolerance to infection.
 - f. Completed experiments testing innate skin defenses (antimicrobial peptides) against *Bd* and *Bsal* for 4 North American salamander species.

- g. Initiated experiments for testing the effects of physiological stress on the development of chytridiomycosis in the Eastern Newt (*Notophthalmus viridescens*).
- h. Initiated Microbiome analysis evaluating the role of the microbiome on Bsal infection across temperatures.

3. Delivered Research Presentations on Bsal

- a. Antifungal properties of salamander skin secretions vary against chytrid pathogens & do not predict *in-vivo* susceptibility. American Fisheries Society and The Wildlife Society Joint Meeting, Reno, NV, September 2019.
- b. Antifungal properties of salamander skin secretions vary and may protect some species from chytrid pathogens linked to worldwide amphibian decline, Graduate Student Research Symposium, Duquesne University, Pittsburgh, PA, March 2019.
- c. Investigating anti-chytrid properties of salamander skin secretions using *in-vitro* assays, Data Blitz, Duquesne University, Pittsburgh, PA, February 2019.
- d. Rollins-Smith, L.A., Reinert, L.K., Le Sage, M., Umile, T., Minbiole, K.P.C., Carter, E.D., Miller, D.L., and Gray, M.J. 2019. Immune defenses against *Batrachochytrium* fungi. North American Comparative Immunology Workshop, June 5, 2019.
- e. Rollins-Smith, L.A., Reinert, L.K., Le Sage, M., Carter, E.D., Miller, D.L., and Gray, M.J. Studies of the Skin Secretions of Eastern Newts in Defense Against *Batrachochytrium salamandrivorans*. The Wildlife Society Symposium "*Batrachochytrium salamandrivorans*: The Next Threat to North American Biodiversity. September 30, 2019. Speaker and panel member.
- f. Piovio-Scott, J., Carter, E.D., Romansic, J., Cusaac, J., Rollins-Smith, L., Reineet, L., Miller, D., Pessier, A., Harris, R., Williams, L., Upchurch, A., Nanjappa, P., and Gray M. Susceptibility of North American Amphibian Species to *Batrachochytrium salamandrivorans*. The Wildlife Society Symposium "*Batrachochytrium salamandrivorans*: The Next Threat to North American Biodiversity. September 30, 2019. Contributor and panel member.
- g. John Romansic, Matt Gray, Davis Carter, Allan Pessier, Deb Miller, Jonah Piovio-Scott. Evaluating the Susceptibility of Native Amphibians from Pacific States to the Pathogenic Fungus Bsal. Poster Presentation. American Society of Ichthyologists and Herpetologists; 27 January 2019; Snowbird, Utah.
- h. Jonah Piovio-Scott, John Romansic, Matt Gray, Davis Carter, Deb Miller. Evaluating the Susceptibility of Native Amphibians from Pacific States to the Pathogenic Fungus Bsal. Oral presentation. NW Partners in Amphibian and Reptile Conservation; 28 Feb 2019; Grand Mound, WA.

- i. Doug Woodhams, Brandon LaBumbard, Nina McDonnell, Molly Bletz, (UMass Boston). "Does *Batrachochytrium* infection lead to Dysbiosis or an Adaptive Microbiome? Amphibian Pathogens Meeting, Tempe, Arizona. Oct. 2018.
- j. Ross Whetstone, Andreas Hertz, Deb Miller, Brandon LaBumbard, Molly Bletz, Doug Woodhams, (UMass Boston.) "Larval amphibian susceptibility to the fungal pathogen, *Batrachochytrium salamandrivorans*." Amphibian Pathogens Meeting, Tempe, Arizona. Oct. 2018.
- k. Douglas Woodhams. Immunological ecology, symbiotic microbiota, and conservation medicine. Ronald E. McNair Post-Baccalaureate Achievement Program. Dec. 2018.
- l. Douglas C. Woodhams. The Amphibian Microbiome. UMass Boston NIH-Research Immersion Program. Jan. 2019.
- m. Douglas C. Woodhams. **Ecology and Evolution on Amphibian Skin: Responding to Disease Emergence with Microbial Therapy.** UMass Boston Evolution for non-majors class. Mar. 2019.
- n. Douglas C. Woodhams. Responding to Amphibian Disease Emergence with Microbial Therapy. Gordon Research Conference, West Dover, Vermont. June 2019.
- o. Adams, H., S. M. Hernandez, M. Yabsley, M. J. Gray, and S. Connelly. 2019. Initiating surveillance for the pathogenic fungus, *Batrachochytrium salamandrivorans*, in highland Costa Rican salamander populations. Wildlife Disease Association Annual International Conference, Tahoe City, CA.
- p. Augustino, B., E. D. Carter, M. Bohanon, B. Bajo, P. Watcharaanantapong, D. Malagon, R. Kumar, D. L. Miller, and M. J. Gray. 2019. *Batrachochytrium salamandrivorans* (*Bsal*) could decimate green salamanders (*Aneides aeneus*). Annual Meeting of the Southeast Partners in Amphibian and Reptile Conservation, Black Mountain, NC.
- q. Bajo, B. A., E. D. Carter, M. Bohanon, D. Malagon, B. Augustino, R. Kumar, P. Watcharaanantapong, D. L. Miller, and M. J. Gray. 2019. Changes in Eastern Newt Behavior Associated with *Batrachochytrium salamandrivorans* (*Bsal*) Chytridiomycosis. Annual Meeting of the Southeast Partners in Amphibian and Reptile Conservation, Black Mountain, NC.
- r. Carter, E. D., D. L. Miller, B. A. Bajo, A. C. Peterson, M. Bohanon, K. Ash, and M. J. Gray. 2019. Winter is coming: Temperature dependent virulence of *Batrachochytrium salamandrivorans*. Ecological Society of America Annual Meeting, Louisville, Kentucky.
- s. Carter, E. D., D. L. Miller, B. A. Bajo, A. C. Peterson, M. Bohanon, K. Ash, P. Watcharaanantapong, and M. J. Gray. 2019. Winter is coming: Temperature dependent virulence of *Batrachochytrium salamandrivorans*. Zoological Society of

London Symposium, London, England.

- t. Carter, E. D., M. J. Gray, J. P. W. Cusaac, A. C. Peterson, L. Rollins-Smith, L. Reinert, M. Bohanon, B. A. Bajo*, D. Malagon, R. Kumar, B. Augustino, L. Williams, A. Upchurch, P. Nanjappa, R. N. Harris, and D. L. Miller. 2019. Broad host range of *Batrachochytrium salamandrivorans* equates to high invasion probability in North America. Zoological Society of London Symposium, London, England.
- u. Carter, E. D., D. L. Miller, M. L. Bohanon, B. A. Bajo, D. A. Malagon, R. Kumar, B. J. Augustino, P. Watcharaanantapong, and M. J. Gray. 2019. A Cool-loving Fungus- Temperature Drives Virulence of *Batrachochytrium salamandrivorans* (*Bsal*). Tennessee Chapter of The Wildlife Society Annual Meeting, Gatlinburg, TN.
- v. Carter, E. D., M. J. Gray, D. L. Miller, M. Bohanon, B. Bajo, and P. W. Cusaac. 2019. Temperature influences infectivity of *Batrachochytrium salamandrivorans* (*Bsal*). Annual Meeting of the Southeast Partners in Amphibian and Reptile Conservation, Black Mountain, NC.
- w. Gray, M. J., E. D. Carter, J. P. W. Cusaac, A. C. Peterson*, L. Rollins-Smith, L. Reinert, M. Bohanon, B. A. Bajo, K. Ash, D. A. Malagon, B. Augustino*, R. Kumar, L. Williams, A. Upchurch, P. Nanjappa, R. N. Harris, and D. L. Miller. 2019. Broad host range of *Batrachochytrium salamandrivorans* equates to high invasion probability in North America. Ecological Society of America Annual Conference, Louisville, Kentucky.
- x. Gray, M. J. 2019. North American *Bsal* Task Force: Plans to Prevent an Invasion. Annual Meeting of the Southeast Partners in Amphibian and Reptile Conservation, Black Mountain, NC.
- y. Gray, M. J., E. D. Carter, M. Bletz, P. Cusaac, D. Woodhams, L. Reinert, L. Rollins-Smith, J. Romansic, J. Piovra-Scott, L. Williams, P. Upchurch, P. Nanjappa, and D. L. Miller. 2018. The threat of *Batrachochytrium salamandrivorans* (*Bsal*) to North American Amphibian Biodiversity: Recent Findings and Future Directions. Arizona State University, Tempe, AZ.
- z. Grzelak, A., R. Kumar, K. Ash, E. D. Carter, B. A. Bajo, M. Bohanon, A. C. Peterson, A. E. Towe, M. J. Gray, and D. L. Miller. 2019. Associating anatomical and clinical pathology with *Bsal* chytridiomycosis in the rough skinned newt (*Taricha granulosa*). Wildlife Disease Association Annual International Conference, Tahoe City, CA.
- aa. Hardman, R., G. Parra-Olea, M. G. Garcia-Castillo, O. B. Soria, M. D. Basanta, E. D. Carter*, P. Cusaac*, M. J. Gray, A. Soto, and D. L. Miller. 2019. Case report of high mortality due to chytridiomycosis in transported Broadfoot Mushroomtongue Salamanders, *Bolitoglossa platydactyla*. Wildlife Disease Association- Latin American Section- Biennial conference, San Jose, Costa Rica.

- bb. Kumar, R., A. Grezlak, E. D. Carter, M. Bohanon, M. J. Gray, and D. L. Miller. 2019. More than Skin Deep: Blood Serum Protein Changes in Response to *Batrachochytrium salamandrivorans* Chytridiomycosis. Annual Meeting of the Southeast Partners in Amphibian and Reptile Conservation, Black Mountain, NC.
- cc. Malagon, D. A., L. A. Melara, O. F. Prosper, S. Lenhart, E. D. Carter, D. L. Miller, and M. J. Gray. 2019. Host density and habitat structure influence contact rates and transmission of *Batrachochytrium salamandrivorans*. Ecological Society of America Annual Conference, Louisville, Kentucky.
- dd. Malagon, D. A., E. D. Carter, L. A. Melara, O. F. Prosper, S. Lenhart, D. L. Miller, and M. J. Gray*. 2019. Role of Density and Habitat Structure on Eastern Newt Contact Rates and Pathogen Transmission. Zoological Society of London Symposium, London, England.
- ee. Malagon, D. A., L. Melara, O. F. Prosper, S. Lenhart, E. D. Carter, D. L. Miller, and M. J. Gray. 2019. Role of Density and Habitat Structure on Eastern Newt Contact Rates and Pathogen Transmission. Annual Meeting of the Southeast Partners in Amphibian and Reptile Conservation, Black Mountain, NC.
- ff. Malagon, D. A., L. Melara, O. F. Prosper, S. Lenhart, E. D. Carter, D. L. Miller, and M. J. Gray. 2019. Role of Density and Habitat Structure on Eastern Newt Contact Rates and Pathogen Transmission. The Wildlife Society Annual Meeting, Gatlinburg, TN.
- gg. Rollins-Smith, L. A., L. K. Reinert, M. Le Sage, T. Umile, K. P. C. Minbiole, E. D. Carter*, D. L. Miller, and M. J. Gray. 2019. Immune defenses of amphibians against *batrachochytrium* fungi. North American Comparative Immunology Workshop, Waterloo, Ontario.
- hh. Romansic, J., M. J. Gray, E. D. Carter, A. Pessier, D. L. Miller, and J. Piovita-Scott. 2019. Evaluating the susceptibility of native amphibians from Pacific states to the pathogenic fungus Bsal. Joint Meeting of Ichthyologists and Herpetologists, Snowbird, UT.
- ii. Towe, A., O. Ossiboff, M. J. Gray, and D. L. Miller. 2018. Investigating the pathology of *Batrachochytrium salamandrivorans* in salamanders. University of Tennessee, College of Veterinary Medicine Research Day, Knoxville, TN.
- jj. Watcharaanantpong, P., B. J. Augustino, E. D. Carter, M. Bohanon, B. A. Bajo, D. A. Malagon, R. Kumar, A. C. Peterson, D. L. Miller, M. J. Gray. 2019. *Batrachochytrium salamandrivorans* devours green salamanders (*Aneides aeneus*). The Wildlife Society Annual Meeting, Gatlinburg, TN.
- kk. Wildmann, A., C. Yarber, D. L. Miller, E. D. Carter*, A. Peterson*, M. J. Gray, and A. Pessier. 2019. Estimating the encystment rate of *Batrachochytrium salamandrivorans* zoospores in the skin of Eastern Newts. National Veterinary Scholars Symposium, Worcester, MA.

4. Delivered Outreach Presentations on Bsal

- a. Gray, M. J. Skin devouring frogs: the next threat to salamanders and to biodiversity. University of Tennessee Science Forum, Knoxville, TN, 29 March 2019.
- b. Gray, M. J. *Batrachochytrium salamandrivorans*: The next potential threat to North American biodiversity, Association of Fish and Wildlife Agencies, Fish and Wildlife Health Forum, Reston, VA, 15 November 2018.
- c. Gray, M. J. *Bsal* is NOT BS -- it is a Threat: What can we do?, Association of Fish and Wildlife Agencies, Fish and Wildlife Health Committee, Tampa, FL, 12 September 2018.
- d. Gray, M. J. Ranaviruses and *Bsal*: Global Translocation and Emergence through Trade, Pet Industry Joint Advisory Council (PIJAC), Washington D.C., 1 November 2018.
- e. Gray, M. J. The threat of *Batrachochytrium salamandrivorans* (*Bsal*) to North American Amphibian Biodiversity: Recent Findings and Future Directions, Association of Fish and Wildlife Agencies, Amphibian and Reptile Conservation Committee, Tampa, FL, 11 September 2018.
- f. K. Perier. Saving salamanders. P.E.O. Chapter G Meeting, Pittsburgh, PA, August 2019.

5. Multimedia

- a. Maintained UTIA Bsal Project Website: <https://ag.tennessee.edu/fwf/bsalproject/>
- b. Maintained website for Bsal NSF Project #1814520: <https://ag.tennessee.edu/fwf/NSF/>
- c. Created 5-min SOP Video on Collecting and Shipping Salamanders: <https://www.youtube.com/watch?v=vVY7bBO-QXU&feature=youtu.be>

6. Peer-refereed Publications

- a. Carter, E. D., D. L. Miller, A. C. Peterson, W. B. Sutton, J. P. W. Cusaac, J. A. Spatz, L. Rollins-Smith, L. Reinert, M. Bohanon, L. A. Williams, A. Upchurch, and M. J. Gray. 2019. Conservation risk of *Batrachochytrium salamandrivorans* to endemic lungless salamanders. [Conservation Letters 2019:e12675](#).
- b. Ossiboff, R. J., A. E. Towe, M. A. Brown, A. V. Longo, K. R. Lips, D. L. Miller, E. D. Carter, M. J. Gray, and S. Frasca, Jr. 2019. Differentiating *Batrachochytrium dendrobatidis* and *B. salamandrivorans* in amphibian chytridiomycosis using RNAScope® in situ hybridization. [Frontiers in Veterinary Science 6:304](#)

- c. Mosher, B. A., A. B. Brand, A. N. M. Wiewel, D. A. W. Miller, M. J. Gray, D. L. Miller, and E. H. C. Grant. 2019. Estimating occurrence, prevalence, and detection of amphibian pathogens: insights from occupancy models. [Journal of Wildlife Diseases 55:563-575](#).
- d. Adams, M. J., R. N. Harris, E. H. C. Grant, M. J. Gray, M. C. Hopkins, S. A. Inverson, R. Likens, et al. 2018. Prepublication of research results. [EcoHealth 15:478-481](#).
- e. **Pereira, K.E.**, and Woodley, S.K. (2019). Differences in antimicrobial skin defenses do not explain salamander susceptibility to chytrid fungal pathogens. *In preparation*.
- f. Robinson, K.A., **Pereira, K.E.**, Bletz, M.C., Carter, E.D., Gray, M.J., Piovio-Scott, J., Romansic, J.M., Woodhams, D.C., Fritz-Laylin, L. (2019) Isolation and maintenance of *Batrachochytrium salamandrivorans* cultures. *Diseases of Aquatic Organisms*. *In press*
- g. E. Eskew, bioRxiv preprint here: <https://www.biorxiv.org/content/10.1101/780197v1>
- h. R package access here: <https://github.com/ecohealthalliance/lemis>

7. Popular Literature Publications

- a. Gray, M. J. 2019. Batrachochytrium salamandrivorans: building an understanding of invasion threat in North America with conservation partners. Amphibian Survival Alliance Newsletter, Froggress Report, March 2019:1-3.
- b. Interviews by Amy McDermott about Bd for PNAS Front Matter feature story. The piece is now published online, available open access and in PDF format here: <https://www.pnas.org/content/116/41/20245>.

Surveillance Working Group

Lead

Michael J. Adams, USGS Amphibian Research and Monitoring Initiative

Participants

Jenifer Walke, Olya Milenkaya, Michelle Koo, Daniel Grear, Brittany Mosher, Sasha Greenspan

Outcomes

The surveillance working group was inactive for approximately one year but has now reformed around the idea of creating a student-powered surveillance network. The working group includes about a dozen colleagues across academia and U.S. federal agencies, with a core group of six members who meet monthly or twice monthly.

We met in-person in Corvallis, Oregon in June 2019, to initiate the development of a new project, the Student Network for Amphibian Pathogen Surveillance (SNAPS). SNAPS is currently our primary method for ongoing and coordinated Bsal surveillance.

In developing SNAPS, we created a new model for Bsal surveillance: the incorporation of surveillance into undergraduate curriculum. Here, we leverage the passion and people-power of students to surveil broadly for Bsal, while leveraging Bsal as an opportunity for active student learning. Through SNAPS, we will recruit teaching faculty across North America to either adapt learning modules that we develop, or otherwise include Bsal surveillance (as per our protocols) in their undergraduate curriculum, to benefit both students and salamanders. With broad geographic and taxonomic coverage, we plan to establish an ongoing early-detection system for Bsal in North America.

We wrote SNAPS mission and vision statements.

We developed Bsal sampling protocols by working with the Diagnostics Working Group, among others. These protocols include clear and precise instructions written for our intended audience, professional but novice faculty who may be doing this type of work for the first time. Our protocols include instructions for skin swabbing, finding sick or dead amphibians, shipping samples, barcoding samples, and maintaining hygiene and biosecurity.

We developed preliminary sampling guidelines to inform, but not impede, participation in SNAPS. These guidelines include priorities for taxa, location, and sample size.

We developed one preliminary learning module that incorporates Bsal sampling into the curriculum. Meanwhile, other group members volunteered to develop additional learning modules during the current (2019 – 2020) academic year.

We began the process to request animal care authorization for the entire SNAPS project. This would lower the barrier to entry for many participants and therefore increase participation, while ensuring a consistent adherence to approved protocols and expectations.

We partnered with a professor of graphic design to develop a visual identity for SNAPS. They will use SNAPS as an assignment in one of their courses and the Bsal Surveillance Working Group will later select the winning student design for use as our visual identity, including a logo, color scheme, and so on.

Communications and Outreach Working Group

Leads

Mark Mandica, Amphibian Foundation
Alex Shepack, Florida International University

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

Social Media: We continue to maintain and utilize Twitter (@salamanderfungi) and Facebook (www.facebook.com/salamanderfungus/). As of Sept 5 we have 894 followers on Twitter and 288 on Facebook. Twitter followers have increased by more than 300 since last year, while the Facebook page has received 40 more.

Public Service Video. Working with Freshwaters Illustrated, we produced a short (4:42) video in 2018, aimed at the general public, educating the viewer about the dangers of *Bsal*, including actions one can take to minimize the chance of spreading fungal disease. The video has had 11,700 views to date. <https://vimeo.com/288628617>

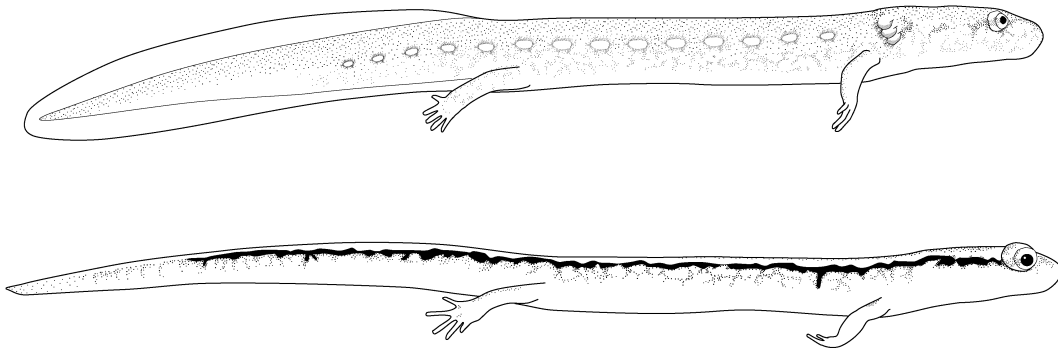
Challenges

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.

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.



Two-lined Salamander (larva and adult), *Eurycea bislineata*
Illustrations by Mark Mandica

Partners in Amphibian and Reptile Conservation (PARC)

Lead

Michelle Christman (Federal Agencies Coordinator, U.S. Fish and Wildlife Service)

Summary

PARC supports the Bsal Task Force by augmenting actions related to Bsal surveillance, transmission, and communication & outreach priorities that also may have relevance to other herpetofaunal diseases or conservation implications.

Key Points and Outcomes

With pathogens among the major threats to amphibians and reptiles, PARC supports a **Disease Task Team (DTT)** to guide disease-related communication and collaboration among PARC regions, federal and state agencies, and other partners. To promote early detection and rapid response to emerging diseases, the DTT maintains the North American Herpetological Disease Alert System (HDAS). In 2019, the HDAS received nine separate reports over eight states from the public and biologists regarding possible disease cases. In each case, DTT representatives alerted disease experts near the reporting site. By facilitating communication, the DTT strengthens PARC's network and provides an important outreach service to conserve herpetofaunal biodiversity. The HDAS has not resulted in any Bsal detections to date. Further details about DTT and HDAS are available at: <http://parcplace.org/resources/parc-disease-task-team/>

Chris Petersen and Rob Lovich of the US Department of Defense (DoD) led a project "Salamander Chytrid Fungus Risk Assessment on DoD Installations" The goal of this project was to identify military installations in the continental U.S that would be at risk of *Bsal* introduction based on geographic location and salamander species diversity. They applied the Richgels et al. (2016) *Bsal* risk model to military lands to categorize risk level per property, and assessed consequent *Bsal* surveillance priorities. The assessment indicated that the majority of military installations with salamander populations have a moderate risk for *Bsal* introduction and military installations with high-risk are located along the Pacific and Atlantic coasts. The results also indicated that the majority of the military installations in the U.S. have a moderate-to-low priority for *Bsal* surveillance. The final report can be downloaded at: https://www.denix.osd.mil/dodparc/parc-resources/materials-for-installation-personnel/salamander-chytrid-fungus-risk-assessment-on-department-of-defense-installations/DoD%20Bsal%20Risk%20Assessment_Final_Jan_2019_cleared_508.pdf

A new manuscript aimed at providing guidance for "Minimizing the Spread of Herpetofaunal Pathogens in Aquatic Habitats by Decontaminating Construction Equipment" was developed by a subgroup of the Northeast Working Group of PARC, led by Jim Julian of the Pennsylvania Department of Conservation and Natural Resources. It is in press in Herpetological Review for 2020 publication.

In 2019, Dr. Katie Haman, Washington state veterinarian, led nine members of the DTT in writing the manuscript “Enhanced Biosecurity to Minimize Herpetofaunal Disease-Causing Pathogen Transmission at High-Risk Field Sites,” which was submitted to *Herpetological Review*; the revision is under review at this time. This paper expands considerations for field biosecurity measures to help prevent disease transmission relative to: 1) species at high-risk due to their rarity or vulnerability to disease emergence; 2) areas considered to be pathogen-free based on known pathogen-occurrence patterns; and 3) protected biodiversity areas where the preservation of native species is of paramount importance.

PARC DTT members are active in the North American Bsal Task Force and participated in technical workshops with a Bsal focus, including: 1) Amphibian skin microbiomes as probiotics for disease management workshop, Zoological Society of London, April 2019; 2) Bsal field management responses workshop, Zoological Society of London, April 2019; and 3) Bsal scenarios and decision modes, Bsal Task Force, Reno, NV, September 2019. The second workshop listed above resulted in the publication:

Canessa, S., A. Spitzen-van der Sluijs, T. Stark, P.J. Bishop, M. Bletz, C.J. Briggs, D. Daversa, M.J. Gray, R.A. Griffiths, R.N. Harris, X.A. Harrison, J.T. Hoverman, P. Jervis, E.L. Muths, D.H. Olson, C.L. Richards-Zawacki, J. Robert, G.M. Rosa, B.C. Scheele, B.R. Schmidt, and T.W.J. Garner. 2019. Conservation decisions under pressure: lessons from an exercise in rapid response to wildlife disease. *Conservation Science and Practice* 2019: e141.