

Science

FINDINGS

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“Science affects the way we think together.”

Lewis Thomas

The Deadly Amphibian Bsal Disease: How Science-Management Partnerships Are Forestalling Amphibian Biodiversity Losses



Elke Wind

The roughskin newt (Taricha granulosa) is a fixture of Pacific Northwest forests. During initial laboratory tests to determine its susceptibility to the Bsal fungal disease, the subjects quickly died.

“Diseased nature oftentimes breaks forth in strange eruptions.”

—William Shakespeare

Avian influenza, rabies, mad cow disease, and even chronic wasting disease are animal diseases that make the headlines because of the human-health link and the ease in which they spread among animals, regions, and even countries. Lesser known are the nongame wildlife diseases. Although an alert for global amphibian declines began almost 30 years ago, it took

another decade for ecologists to realize that diseases were a top threat to amphibians.

“For nongame wildlife such as amphibians, emerging infectious diseases were not initially on our radar. We didn’t know about mass die-offs from the multispecies pathogens, like those affecting livestock and humans. Although some diseases were certainly known, they were restricted to the specific infected area or context,” says Deanna (Dede) Olson, a research ecologist with the USDA Forest Service Pacific Northwest Research Station. “Then *Bd* [*Batrachochytrium dendrobatidis*]

IN SUMMARY

As central components of food webs worldwide, amphibians provide vital ecosystem services. The continental United States alone has 230 amphibian species and is the world hotspot for salamander species. However, this amphibian biodiversity is threatened by Batrachochytrium salamandrivorans (Bsal), a fungal pathogen native to Asia that spread to Europe and is killing fire salamanders in the wild. Laboratory testing has shown several North American species are also vulnerable to Bsal infection.

The spread of Bsal is a chief concern, and at this time, it is highly probable Bsal will appear in North America. In 2015, a diverse coalition of scientist and managers formed the Bsal task force to identify key Bsal research and decision-support needs, and develop multi-pronged communication and management strategies to forestall and rapidly detect the pathogen if it comes to North America. Deanna Olson, a research ecologist with the USDA Forest Service Pacific Northwest Research Station, served as the Bsal Task Force’s first-year co-chair.

The task force developed the Bsal Strategic Plan, a science-management framework that researchers and managers can use to identify research needs, share research findings prior to publication, and develop policy. The task force also produced a rapid response template that local and federal agencies can customize and deploy in the event that Bsal is detected.

was described. It was a fungal pathogen tied to amphibian die-offs that appeared in multiple places around the world—a novel multispecies disease threat to amphibian biodiversity.”

Bd, the shorthand name amphibian ecologists use when discussing this pathogen, infects the teeth of larvae and the skin of adult amphibians. The skin infection interrupts the electrolyte transport of life-sustaining minerals, such as sodium and calcium; eventually the infected animal may suffer cardiac arrest and die. Unbeknownst to scientists when it was first described, studying *Bd* would lay the groundwork for future studies of *B. salamandrivorans* (*Bsal*), now a major potential threat to more than 200 likely vulnerable amphibian species in North America.

Olson, who specializes in amphibian ecology, was especially interested when *Bd* was described in 1999. Although habitat loss was known as a dominant contributor to worldwide amphibian population declines, some declines occurred in relatively pristine habitats, and the reason wasn't clear. Then *Bd* was found and tied to losses in remote areas of Central America, Australia, and the United States—this opened a new arena for amphibian conservation with a multispecies emerging infectious disease identified as a novel threat. Through the early 2000s, reports of *Bd* infections continued, and inklings of taxonomic and geographic patterns began to emerge.

In 2007, while preparing for an international *Bd* conference, Olson volunteered to map what was then known about the global breadth and scope of *Bd*. “It was a massive global project to figure out what had been done and to pull out reports that had been published or simply buried in file folders,” Olson recalls. By partnering with volunteers around the globe who compiled data for regions or countries, the 9-month “Global *Bd* Mapping Project” resulted in the first worldwide map of *Bd* detections and nondetections. A collaboration with colleagues Mat Fisher and David Aanensen at Imperial College in London, resulted in turning this database into a real-time web portal for worldwide participation.

“The website allowed everybody around the world to be part of this project and know the state of *Bd* knowledge,” she explains. “People could see where studies had occurred, where new projects might be designed, what taxa were infected, and we could start to look at emerging patterns. It's a powerful tool.”

KEY FINDINGS	
<ul style="list-style-type: none"> • Because <i>Batrachochytrium salamandrivorans</i> (<i>Bsal</i>), a fungal disease native to Asia, is lethal to several North American salamander species, the United States now prohibits the import of any salamander genus whose members were found to be carriers or lethally affected by <i>Bsal</i> as of the date of the writing of the ruling. Canada prohibits the import of all salamanders. 	
<ul style="list-style-type: none"> • By using principles of a decision-support framework to address a proactive <i>Bsal</i> management strategy to forestall its emergence in North America, four challenges were identified for further collaborative work: lack of disease policy, fragmented management responsibility, multiple competing objectives, and few options for post-emergence control. 	
<ul style="list-style-type: none"> • Access to real-time information regarding the surveillance for, and detection of, <i>Bsal</i> is critical to preventing the fungal disease from gaining a foothold in the United States and causing the mortality observed in Europe. A data-sharing portal has been created so researchers or wildlife managers can post <i>Bsal</i> surveillance plans and results (https://amphibiandisease.org/). 	
<ul style="list-style-type: none"> • Because <i>Bsal</i> is lethal, it is vital that research findings related to <i>Bsal</i> are shared immediately with the relevant authorities. The <i>Bsal</i> Task Force worked with the leading scientific journals to ensure that prepublication sharing of provisional disease findings could occur without affecting the researcher's ability to later publish these findings. 	

Another Threat Emerges

Since *Bd*'s description in 1999, more than 1,200 research papers have been published on the pathogen. Yet when a novel deadly amphibian fungal pathogen was reported in 2013, scientists and managers were caught off guard. A 2013 report led by An Martel and colleagues from the University of Ghent, Belgium, announced the discovery of a new fungal pathogen causing mortality of wild fire salamanders in Europe. “This news was a shockwave that went through the *Bd* community,” Olson recalls. “This was something completely new.”

The new pathogen was *Bsal*, which belongs to the same genus as *Bd*. Like *Bd*, *Bsal* infects the skin of amphibians. Even more disconcerting was the 2014 followup report that some salamanders from North America, when exposed to *Bsal* during laboratory tests, died within days.

This was a “wake-up call” for researchers around the world, Olson says. And for amphibian ecologists in North America, the stakes were high with over 300 amphibian species residing throughout diverse ecosystems of marshlands, riparian areas, and forests. Every state is home to a number of amphibian species, and 23 states have a state amphibian.

“The United States is the biodiversity hotspot in the world for salamander species, in particular the southern Appalachians and North Carolina,” says Reid Harris, a director with the Amphibian Survival Alliance and former

chair and research-group head for the *Bsal* Task Force. “There's just such a rich diversity and rich natural history in the U.S.”

The loss of amphibians in general, not just salamanders, would negatively affect many food webs. Amphibians are a key component as prey for birds and mammals, and are important predators. It's estimated that 1,000 frogs eat 5 million insects a year.

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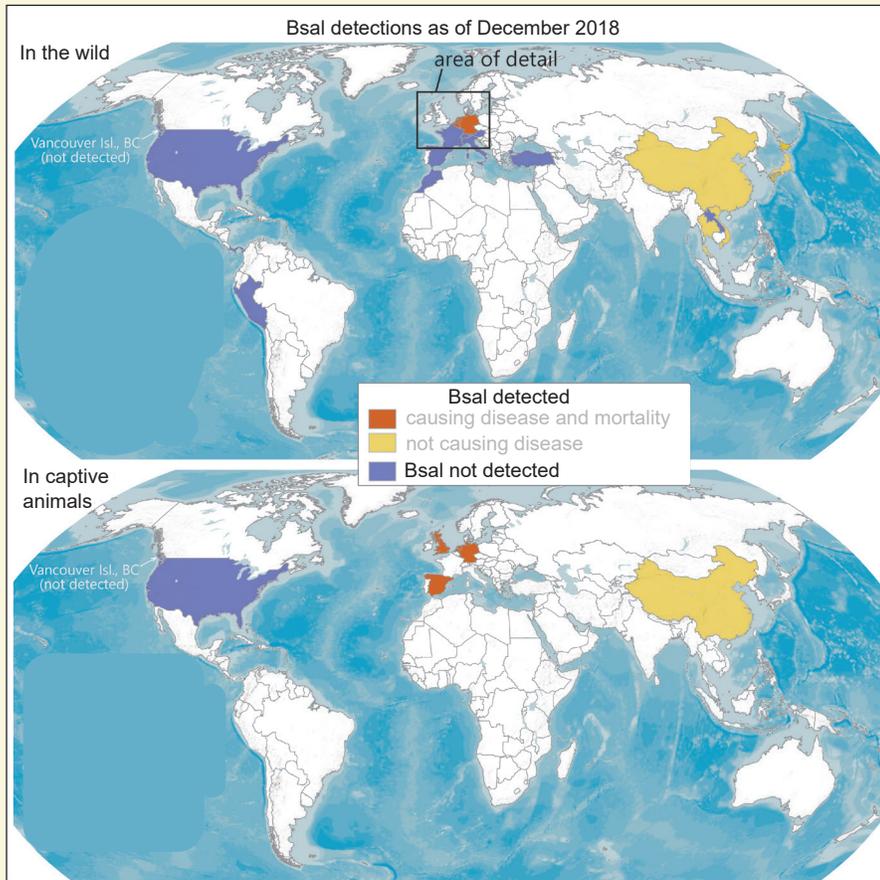
“Amphibians are vital to a functioning ecosystem,” says Mark Mandica, the executive director of The Amphibian Foundation. “In a healthy environment, there are more amphibians than mammals and birds combined. You often don’t see amphibians because they are more secretive. You might not know they’re there, but they’re there.”

In the summer of 2015, the U.S. Geological Survey organized a workshop to develop a decision-support framework to respond to *Bsal*. “That was a very important initial objective, to identify the immediate responses needed to forestall inadvertent transmission of *Bsal* to North America, and to respond if it was already here,” Olson says. “Because concerned researchers and

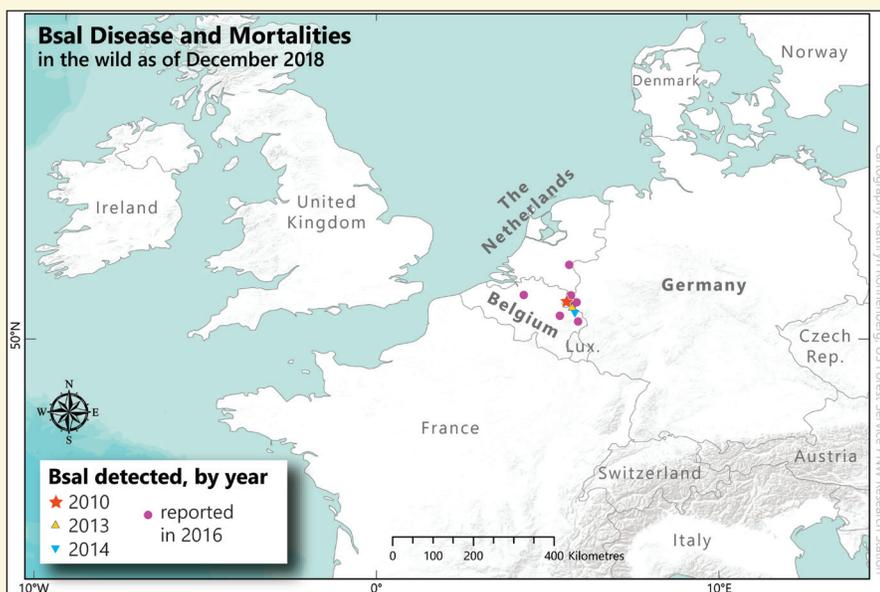


Matt Richards

Biologist Mark Mandica conducts a field survey in Fort Stewart, Georgia to test for the presence of *Bsal* in local amphibian populations.



Kathryn Ronnenberg



Global *Bsal* detections. The status of the fungal disease in most countries (white on map) is unknown. *Bsal* was first detected in Belgium in 2010 following the unusual die-offs of wild fire salamanders. Follow-up research determined that *Bsal* originated in Southeast Asia where amphibians are carriers of the pathogen but are not killed by it. For map references, contact Olson.

agency personnel from the United States and around the world attended, a broader strategic approach to addressing *Bsal* emerged.”

An outcome of the meeting was the formation of the *Bsal* Task Force, which included representatives from the United States, Canada, Mexico, nongovernmental organizations, and the pet trade, with seven working groups that reported to a technical advisory committee. Each working group (surveillance/monitoring, data management, diagnostics, research and management, outreach/communication, response, and decision support) would tackle specific priorities related to *Bsal*. Partners in Amphibians and Reptile Conservation’s National Disease Task Team (PARC DTT), which also formed in 2015, took on ancillary tasks related to expediting communication and biosecurity for *Bsal* and other herpetofaunal diseases.

“A lot of the activities of the *Bsal* Task Force Working Groups and of the PARC DTT are proactive, to get ahead of a potential *Bsal* crisis in North America,” says Olson, who co-chaired the task force in its inaugural year and co-led its data management group. “It’s quite unprecedented to have researcher and manager collaborators divide and conquer like this nationally and internationally, and focus on a joint research-management problem.”

A Collaboration of Science, Management, and Communication

The swift, proactive approach of the *Bsal* Task Force is a response to the slow recognition of *Bd* as a threat and the die-offs that might have been prevented had the science-management community acted more swiftly. Already a number of new strategies have been adopted as a result of the task force’s work.

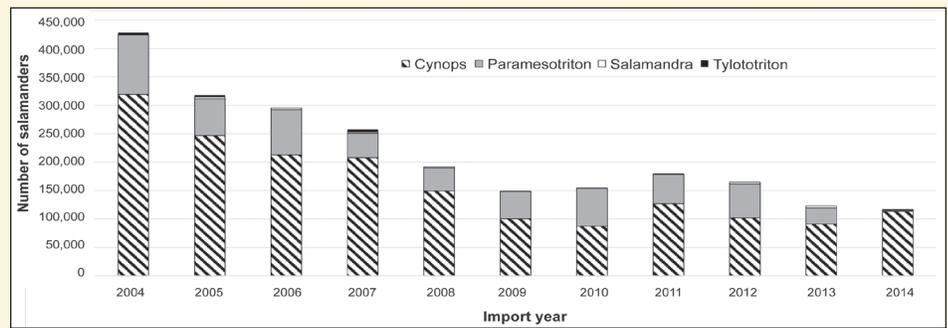
Rapid communication, partnership, and networking are necessary to prevent *Bsal* from gaining a foothold in North America; however, in the research sphere, the norm is to wait and share research results after they are published, which can take 12 to 18 months. This lag in knowledge sharing is impractical given the threat of *Bsal*-related mortalities and the pathogen's potential to spread rapidly. Now, new information about *Bsal* and *Bd* is shared prior to publication, Harris says. The *Bsal* Task Force worked with the leading scientific journals to ensure that prepublication sharing of provisional disease findings wouldn't affect researchers' ability to later publish these findings.

When scientists discovered some North American species of toads and frogs could also become infected with *Bsal*, researchers changed how they conducted field surveys. "Prior to this finding, *Bsal* surveillance had focused on salamanders. With frogs and toads as possible *Bsal* carriers, surveys need to target them as well," Olson says. This message is being repeated in magazine articles, presentations to diverse audiences, and in online resources as the "*Bsal*" acronym may be misinterpreted as being only related to salamanders.

Improved communication channels between researchers and policymakers also allows for faster implementation of policies that can help forestall the appearance of *Bsal* in North America. In Europe, the appearance of *Bsal* was found to be linked to the amphibian pet trade, from specimens originating in Southeast Asia. Although some salamander species from Asia have the *Bsal* fungus on their skin, they don't experience the mortality observed in Europe. Further testing recently confirmed *Bd* also originated in Southeast Asia, and there appears to be a tie to the Korean War, which synchronized with the opening of global trade markets and the spread of *Bd*.

"Globalization has been happening over the last several decades, with people and human-mediated transportation of goods," Olson says. "Now we realize that we're also inadvertently transmitting these microbiota for different species."

In the past decade, the United States imported more than 28 million amphibians, and researchers estimate that, on average, 426 potentially infectious salamanders enter the country each day. The link between the spread of *Bsal* and amphibian trade markets led the U.S. Fish and Wildlife Service in 2016 to ban the import of 201 amphibian species that carry the disease. Canada followed suit and now prohibits the import of all salamanders. The Pet Industry Joint Advisory Council also



Number of live salamanders from four genera (*Cynops*, *Paramesotriton*, *Salamandra*, *Tylototriton*) imported into the United States from 2004 to 2014. These genera comprise 95 percent of all legally traded salamander imports. Researchers estimate that on average, 426 potentially infectious salamanders enter the country each day.



Todd Pierson

Amphibians, such as this eastern newt (*Notophthalmus viridescens*) are a vital component of food webs, serving as both predator and prey. The contiguous United States alone has 230 amphibian species and is the world's hotspot for salamander species.

issued a moratorium on imports of Asian salamanders known to be *Bsal* carriers.

"Since we don't have any mitigation measures such as a vaccine or probiotics ready to go yet, the best thing to do is keep it out or to have a clean-trade program that certifies that disease-free animals are entering the United States," explains Harris.

These improved communication efforts and collaboration of policymakers and scientists are forestalling the appearance of *Bsal* in the United States but are not likely to prevent it. To prepare for this eventuality, the *Bsal* Task Force drafted a template of actions to be taken if an amphibian die-off is detected in either a wild or captive situation in North America, and *Bsal* is suspected. The U.S. Geological Survey also organized a scenario-building exercise that involved a *Bsal* outbreak in Appalachia. By working through plausible scenarios, the group determined the resources agencies need to respond to an outbreak. This exercise helped to finalize the task force's 2018 *Bsal* Rapid Response Plan.

In one scenario, for example, amphibians are dying from an unknown cause. In this situation, state or federal wildlife staff would collect tissue samples for laboratory testing, increase surveillance, and implement biosecurity protocols to ensure field gear don't spread contaminants to other sites. If *Bsal* is detected, a core response team would convene, contain the detection site, and consider rescuing uninfected amphibians.

A crucial step in these scenarios is communication with partners, whether that involves sending a die-off report to the Partners in Amphibian and Reptile Conservation National Disease Task Team or notifying the federal or state agency who has jurisdiction over a suspected *Bsal* site.

"One of the greatest services the (PARC) communications and outreach working group can provide is building a network and having this network in place in the event that *Bsal* is detected in the U.S., so we can all be on the same page as quickly as possible," says Mandica, who also heads the group.

Communication and outreach efforts also extend to the general public, particularly those who are amphibian hobbyists and are affected by the amphibian import ban. A number of *Bsal*-related articles have been published in hobbyist magazines and through social media. However, these efforts only reach members of the public with enough interest in amphibians either to subscribe to such magazines or who might follow the issue on Twitter at @salamanderfungi.

Reaching the public is a challenge, Mandica admits: "The majority of the general public still isn't aware there's a global amphibian crisis, let alone the specific reasons for it. We've got some work cut out for us." The website salamanderfungus.org is the central clearinghouse for *Bsal*-related research, and links to government agency resources and *Bsal* Task Force publications such as its annual reports and the Rapid Response Plan.

Despite the dire situation that appears to be looming over the future of amphibian survival in North America, the threat of *Bsal* has changed the dynamic of the scientific-management community for the better. “There’s a unification of people working together on this issue, which is really unprecedented,” Olson explains. “The collaboration among these various groups—scientists and managers, academia and government—is very powerful.”

The *Bsal* Task Force recently released its strategic plan for North America, which details its coordinated multifaceted response to *Bsal*. There is also keen interest from European managers and scientists in further developing and coordinating *Bsal* management and research priorities. Olson is quick to add that the pathogen is now on the world’s radar, and the global community is eager to forestall this novel threat, as well as its potential interactions with other contributors to amphibian losses.

“Meet the disease at its first stage.”
—Aulus Persius Flaccus, poet

For Further Reading

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- The *Bsal* Task Force created the website <http://www.salamanderfungus.org/> to provide wildlife managers a central clearinghouse of the diagnostic laboratories, biosecurity protocols, communiques about *Bsal* threats to North American species, *Bsal* Task Force reports, and the latest *Bsal* research findings.
- A newly released *North American Strategic Plan to Control Invasions of the Lethal Salamander Pathogen Bsal* identifies core needs for preventing invasion and quickly responding if detected.
- Partners in Amphibian and Reptile Conservation’s National Disease Task Team created the Herp-Disease-Alert-System for anyone to report disease-related wild or captive amphibian and reptile mortalities in North America. This email-alert system aims to accelerate the detection of *Bsal*, and is also relevant for a host of other amphibian-related diseases (<http://parcplace.org/resources/parc-disease-task-team/>).
- A Rapid Response Template (available at <http://www.salamanderfungus.org/>) provides a valuable resource for agencies and institutions to identify how they can respond to the detection of *Bsal* within their management area and what resources are needed to quarantine or eliminate the infected amphibians.

Writer’s Profile

Andrea Watts is a freelance science writer who specializes in covering natural resources topics. Her portfolio is available at <http://www.wattswritings.wordpress.com> and she can be reached at andwatts@live.com.

U.S. Department of Agriculture
Pacific Northwest Research Station
1220 SW Third Avenue
P.O. Box 3890
Portland, OR 97208-3890

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Scientist Profiles



DEEDE OLSON is a supervisory research ecologist with the U.S. Forest Service Pacific Northwest Research Station who studies the conservation biology, behavioral ecology, and population and community ecology of amphibians.

Olson can be reached at:

USDA Forest Service
Pacific Northwest Research Station
3200 SW Jefferson Way
Corvallis, OR 97331

Phone: (541) 750-7373
E-mail: dedeolson@fs.fed.us



REID HARRIS is Director of International Disease Mitigation at Amphibian Survival Alliance and an emeritus professor of biology at James Madison University.

His research focus is on amphibian ecology and evolution, and the use of skin probiotics to combat the *Bsal* fungal disease.

Harris can be reached at:

Department of Biology, MSC 7801
James Madison University
Harrisonburg, VA 22807

Phone: (540) 432-1327
E-mail: rharris@amphibians.org



MARK MANDICA is an amphibian conservation biologist and the executive director of The Amphibian Foundation, a nonprofit with a mission to connect individuals, communities, and organizations to create and implement lasting solutions to the global amphibian extinction crisis.

Mandica can be reached at:

The Amphibian Foundation
4055 Roswell Road NE
Atlanta, GA 30342

Phone: (562) 774-2248
E-mail: mark@amphibianfoundation.org

Collaborators

Michael Adams, Evan H. Campbell Grant,
and M. Camille Hopkins, U.S. Geological
Survey

Matthew Gray, University of Tennessee
Priya Nanjappa, Conservation Science
Partners