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Chytridiomycosis

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What is chytrid?

Chytrids are a group of fungi known as the *Chytridiomycota* with more than 750 species. Chytrids are ubiquitous and predominantly found in aquatic and moist environments. The zoospores of the *Chytridiomycota* are unique among fungi in that they have flagella, tail-like appendages that help propel them through aquatic environments. In nature they act as decomposers of organic plant material or as parasites of phytoplankton and invertebrates. Recently, one group has been found to infect vertebrates as well, leading to the disease chytridiomycosis.

Bd under microscope.
Credit: Flicker.com/AJC1

What is chytridiomycosis?

Chytridiomycosis is a potentially deadly parasitic infection that affects amphibians. The term "mycosis" means an infection caused by a fungus, in this case a "chytrid" fungus. One genus of chytrid (*Batrachochytrium*) is the infective agent of amphibians leading to chytridiomycosis. Since 1998, two new species of this genus have been discovered that affect vertebrates, specifically amphibians. *Batrachochytrium dendrobatidis* (*Bd*) primarily affects frogs (but can also affect some salamanders and caecilians) and *Batrachochytrium salamandrivorans* (*Bsal*) affects salamanders and newts.

How do *Bd* and *Bsal* affect amphibians?

The skin of amphibians is very important to their lifestyle and survival. Amphibians use their skin to absorb and regulate water and electrolyte balance in the body and for respiration. In the case of many amphibians the skin allows for oxygen exchange and is how they breathe. *Bd* works by infecting the top layers of skin that causes a condition called hyperkeratosis, which causes the skin to thicken. The thickening of the skin prevents the balancing exchange of water, electrolytes and/or oxygen leading to heart failure in many amphibians and suffocation in lungless salamanders. *Bsal* works by creating infecting skin cells and causing ulcers. It is suspected to disrupt water and electrolyte balance and other homeostatic functions across the skin, leading to death.

Are there clinical symptoms of chytridiomycosis?

Signs and symptoms of chytridiomycosis vary greatly between individuals and species. Many outbreaks of chytrid will not show any visible physical signs; with the only identifiable cause for concern are large numbers of dead amphibians in the area. When signs are present, such as reddened skin, excessive skin shedding, and unusual behaviors, they are often symptomatic of many diseases and cannot be readily confirmed as

chytridiomycosis in the field. Chytridiomycosis can be identified using a microscope by examining sections of skin, or through PCR confirmation in a lab.

European Natterjack toad (*Epidalea calamita*) and a European fire salamander (*Salamandra salamandra*) with chytridiomycosis. Altered from Mustchmann 2015. Note the abrasions and discoloration on skin indicated by red arrows.

Are all amphibians affected equally?

No. As with clinical signs, there is much variation in how *Bd* and *Bsal* exhibit themselves between species and localities. *Bd* is very widespread in the environment, but there are not massive die-offs in all areas. *Bsal* is particularly harmful to some groups of salamander (i.e. Salamandridae) but not all have been adequately tested for susceptiability to *Bsal*. While, these chytrid infections are generally devastating to some amphibians there are some species that are unaffected and are considered resistant. The American Bullfrog (*Rana catesbeiana*), for example, does not show ill effects when in contact with *Bd* and is less likely to die from infection. However, these species can act as a reservoir and spread the fungus around to other species of susceptible amphibians.

Swabbing for *Bd*. Credit: Vance Vredenburg

Is there a treatment or cure?

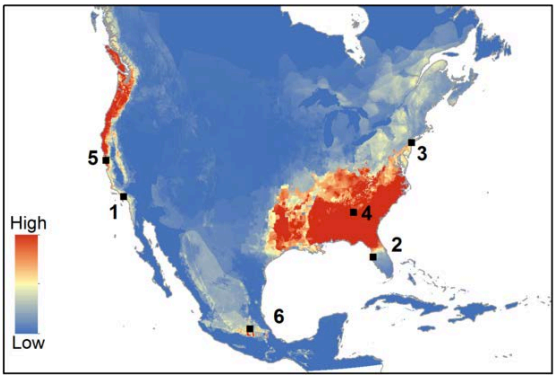
Results have been mixed. There has been some success using anti-fungal medication and warmer temperatures, along with complete disinfection of enclosures in the pet trade. However while these methods have proven successful they are not guaranteed to work. There is no known treatment of wild amphibian populations and the most we can do is preventative, by keeping *Bd* and *Bsal* out of unaffected areas. However, some new research is showing that using symbiotic skin bacteria may help inhibit the spread of chytrid by competing with the fungus for space and resources on the skin.

Where did *Bd* and *Bsal* come from? Where are they found?

Batrachochytrium dendrobatidis (*Bd*) was first discovered in the 1990's in Australia and Panama by groups of researchers performing standard amphibian monitoring surveys. During this time they noticed a large number of frog die-offs at previously healthy sites. They collected specimens for further study and discovered a new species of chytrid fungus, which we now know as *Bd*. Since then, large numbers of amphibians have been declining

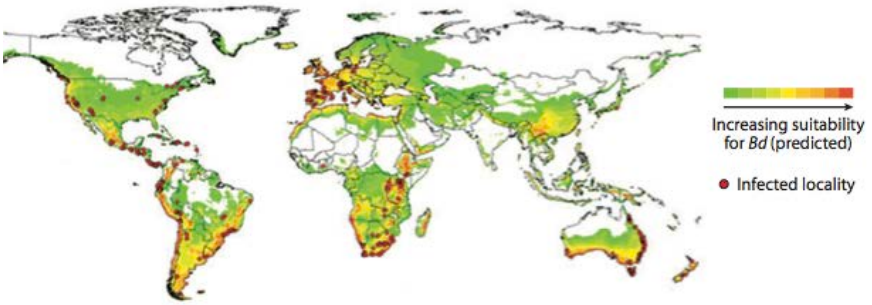
rapidly around the globe in part due to *Bd*. As of now, *Bd* is found on every continent except Antarctica.

Over the next couple decades as research on *Bd* continued, a new species of chytrid specific to salamanders was discovered. In 2013, *Batrachochytrium salamandrivorans* (*Bsal*) was identified as the cause of large numbers of native European fire salamander (*Salamandra salamandra*) deaths starting in the Netherlands. Since then, it has also been found in Asian newts and the potential spread to the US (via the pet trade) is a real threat.



Vulnerable areas in US for Bsal. From Yap et al. 2015

There is still some debate over where these chytrids originated. Were they always in the environment and recently became deadly? Or was the fungus introduced frome elsewhere? Research on these questions is still ongoing, but evidence seems to point to Asia being the region of origin of *Bsal*. Several species in Asia are known to have *Bsal*, but there are no documented declines due to *Bsal*, suggesting the *Bsal*/amphibian system probably evolved there. Also, many amphibians in the pet trade come from Asia, and could be a major factor in the global spread of this fungus. The origin of *Bd* seems much more complex with several lineages across different continents being identified, although an African origin has been hypothesized.



Global distribution and potential spread of Bd. From Fisher et al. 2009

How do *Bd* and *Bsal* persist in the environment? How do they spread?

Bd and *Bsal* are easily spread between individuals through contact or close proximity in aquatic/moist environments. The chytrid fungus releases zoospores, which allow it to spread. As previously mentioned, the zoospores of the *Chytridiomycota* have flagella, which helps propel them through aquatic environments. The zoospores are easily transmitted through water, moist substrates and skin-to-skin contact. Common outbreaks of *Bd* occur when there is a lot of physical contact between individuals such as during the breeding season.

Between different locations, other organisms including humans often spread *Bd* and *Bsal*. Chytrid can exist on the moist soil of our boots and equipment (i.e. tents, fishing gear, etc.) and be transported from place to place when we move around. Chytrid can also spread

from captive to wild animals by releasing captives in the environment, or by human transport of a wild amphibian from one location and releasing back into the wild at a second location. Captive pets should never be released into the wild for many reasons and disease is a principal concern. Other species, such as crayfish and other macro-invertebrates can act as reservoirs of chytrid, harboring the fungus, but not receiving any negative impacts. Birds, especially waterfowl have the potential to transmit chytrid between aquatic environments over long distances as the zoospores cling to feathers and feet.

How can I help prevent the spread of chytrid?

If you spend time collecting or handling amphibians in their habitat it is important to be aware of your potential to spread *Bd* and *Bsal*. It is important to wash your hands or change gloves when handling different individuals and to sterilize your gear (boots, holding containers, etc.) between different localities. Please see the link in the section on where to get further information below for specific methods of decontaminating your gear. To further combat chytrid, the U.S. Fish and Wildlife Service has recently declared 201 species of salamanders as injurious wildlife under the Lacey Act, which prohibits the import and interstate trade of listed species (see below for further information), so be sure to follow all legal and regulatory guidelines.

How do I know if chytrid is in my area? How can I help?

As previously mentioned, chytridiomycosis is hard to detect through visual inspection. There is no way to know for certain without laboratory testing, usually through DNA analysis, to determine if chytrid are present. If you notice an unusually number of dead amphibians, chytrid may be at fault. You can contact your local natural resources or environmental agency that monitors amphibians for further investigation. Some local communities have amphibian-monitoring programs with opportunities to volunteer.

Frog die-off due to Bd. Credit: Vance Vredenburg from Kilpatrick et al. 2010.

Why should I care?

Amphibians are important components of food webs in the environment. They are major predators of invertebrates and help regulate and keep insect populations under control. Without amphibians we would have a lot more ants, termites and flies around causing many problems for us. Amphibians are also great indicator species for many toxic or pollution effects. Because of the permeable nature of their skin, they are a lot more susceptible to the effects of many pollutants that can affect us as well. Since they have both aquatic and terrestrial life stages, they help us to monitor the health of both systems. Some species may have medicinal value as well, and they are important research subjects for biomedical applications such as limb regeneration. Amphibians have been under many threats from pollution to habitat loss, and *Bd* and *Bsal* add to this growing problem.

Where can I go to get more information?

For further information on chytridiomycosis and the chytrid fungi, you can check some of the following:

For more about the Chytridiomycota:
http://bama.ua.edu/~chytrid/

http://www.ucmp.berkeley.edu/fungi/chytrids.html

For more on chytridiomycosis and government monitoring:
http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5423370.pdf

http://www.fws.gov/injuriouswildlife/pdf_files/Chytrid_fungus_FAQs_045679_FINAL_9-15-10.pdf

https://www.environment.gov.au/system/files/resources/279bf387-09e0-433f-8973-3e18158febb6/files/c-disease_1.pdf

http://armi.usgs.gov/story/story.php?contentid=139971

For information on how to disinfect your gear:
http://fwf.ag.utk.edu/mgray/SEPARC/SEPARCDisinfectingGuidelinesFinal.pdf

For information on the USFWS injurious wildlife declaration of salamanders
http://www.fws.gov/injuriouswildlife/pdf_files/Bsal_News_Release_F.pdf

References and Further Reading

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