A review of the chytrid fungus *Batrachochytrium salamandrivorans*: the threat of a second amphibian pandemic

Garcerán Gómez, Laura

UAB Universitat Autònoma de Barcelona

June 2020

INTRODUCTION

Until the year 2013, the chytrid fungus *Batrachochytrium dentrobatidis* (*Bd*) was thought to be the exclusive cause of chytridiomycosis, a disease that has impacted amphibian biodiversity globally. However, from 2010 onward a rapid decline in populations of fire salamanders (*Salamandra salamandra*) in the Netherlands led to the discovery of a second, highly pathogenic chytrid fungus: *Batrachochytrium salamandrivorans* (*Bsal*). Although the host range of *Bsal* appears to be more restricted compared to *Bd*, its ability to infect a large number of urodelan species poses a threat to amphibian biodiversity and has raised concerns about a second amphibian pandemic. The objective of this review is to analyze the current and limited knowledge about *Bsal* and suggest future research directions that may contribute to improving the understanding and management strategies for chytridiomycosis.

41% of the amhiphian species currently classified as endangered by the **IUCN Red List**

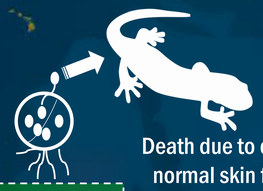
KINGDOM: Fungi
PHYLUM: Chytridiomycota
ORDER: Rhizophydiales
GENUS: *Batrachochytrium*
SPECIES: *salamandrivorans*

TWO MAIN LIKE STAGES + ENCYSTED SPORE

❖**Motile zoospore:**
-Free-living aquatic phase
-Infectious and dispersal form
-Infects epidermal cells of stratified surfaces of amphibians

❖**Zoosporangia (thallus):**
Reproductive body that asexually produces zoospores
Located inside the keratinocytes

Infectious, non-motile, increased environmental resilience ⚠ (Not found in *Bd*)



Death due to disruption of normal skin functioning

HOST RANGE (not fully characterized yet)

❖Disease seems limited to post-metamorphosed urodeles
❖Some anurans (2 toad species so far) can be infected without clinical signs→ Potential *Bsal* vectors ⚠
❖Unknown effects on amphibian larvae, which could be potential reservoirs as occurs with anuran larvae in *Bd* ⚠

CLINICAL SIGNS

Ulcers, erosions, dysecdysis, lethargy, anorexia, ataxia, and abnormal posturing prior to death

HISTOPATHOLOGY

Epidermal ulcerations, intracellular colonial talli, no inflammatory cell infiltrates

Adapted from Van Rooij et al. 2015

NORTH AMERICA

Global hotspot for salamander diversity (~50% of species worldwide)
Current evidences suggest that *Bsal* is absent in Northern and Latin America, but *Bsal* invasion probability is high.

EUROPE

⚠ Unprecedented threat to Western Paleartic urodelans

ASIA

AMPHIBIAN TRADE

Likeliest route for the introduction of *Bsal* into Europe

Asian salamanders and newts are being traded internationally in large numbers

DISEASE MANAGEMENT AND PREVENTION

Lack of adequate wildlife trade regulations and appropriate policies that explicitly address wildlife diseases. There is no international body that assumes responsibility for setting standards and organizing responses against wildlife diseases

PATHOGEN HOST ENVIRONMENT

VARIATION IN HOST RESPONSES

Between individuals species, populations and life stages

Complex interactions →many knowledge gaps need to be addressed

Pre-exposure measures: there is a need of more controls, bans and restrictions in amphibian trade, including anurans; screening and treatment of captive collections; and biosecurity measures.
Post-exposure measures: *in situ* treatment of hosts and environment, physical barriers, removal of hosts and *ex situ* captive breeding programmes (currently the only active conservation method geared to avoid species loss). There is a need of long-term measures, such as provoking a hereditary reduction in the disease susceptibility of susceptible species and methods to strengthen the resilience of amphibians (vaccination, bio-augmentation of cutaneous microbiota). However, resistance and tolerance against *Bsal* are poorly understood.
Support actions: there is a need of a global early-warning system, with active and passive surveillance, and the development of an evidence –based emergency action plan for species at risk.

ORIGIN AND SPREAD

Recent studies point an Asian origin of both *Batrachochytrium* spp.

Batrachochytrium salamandrivorans is enzootic to Southeast Asia, where urodelan species may act as a disease reservoirs for naive amphibian populations. *Bsal* spread from Asia into Europe has been facilitated by anthropogenic activity, such as the international trade of amphibians. In the Netherlands, Belgium, and Germany *Bsal* has led several wild fire salamander populations near to extinction in a short period of time. The fungus has also been detected in captive animals in the United Kingdom, Germany, and Spain. In this last country, *Bsal* has recently caused mortalities in *Triturus marmoratus*, likely through spillover from introduced alien pet amphibians. Actually, the current knowledege of the distribution of *Bsal* is incomplete and it might be present in more European countries than currently known.

CONCLUSIONS

The current knowledge about *Bsal* is limited and disease management is surrounded by a high level of uncertainty. The development of sustainable long-term strategies will require understanding the following critical knowledge gaps: 1) introduction pathways; 2) dispersal pathways between populations; 3) reservoirs of *Bsal*; and 4) host susceptibility to *Bsal* infection. Further studies are needed to better characterize *Bsal* host range and potential reservoir species. Importantly, further research should address the impact and potential role of anuran species and different life stages (especially larvae) in the epidemiology of *Bsal* chytridiomycosis. It is also important to study the underlying mechanisms of resistance and tolerance and the host immune response to *Bsal* infection. Finally, a more collaborative approach between science, policy and society is necessary for the successful implementation of any chytrid mitigations strategies.