# Global amphibian declines and chytrid fungi

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# Amphibians

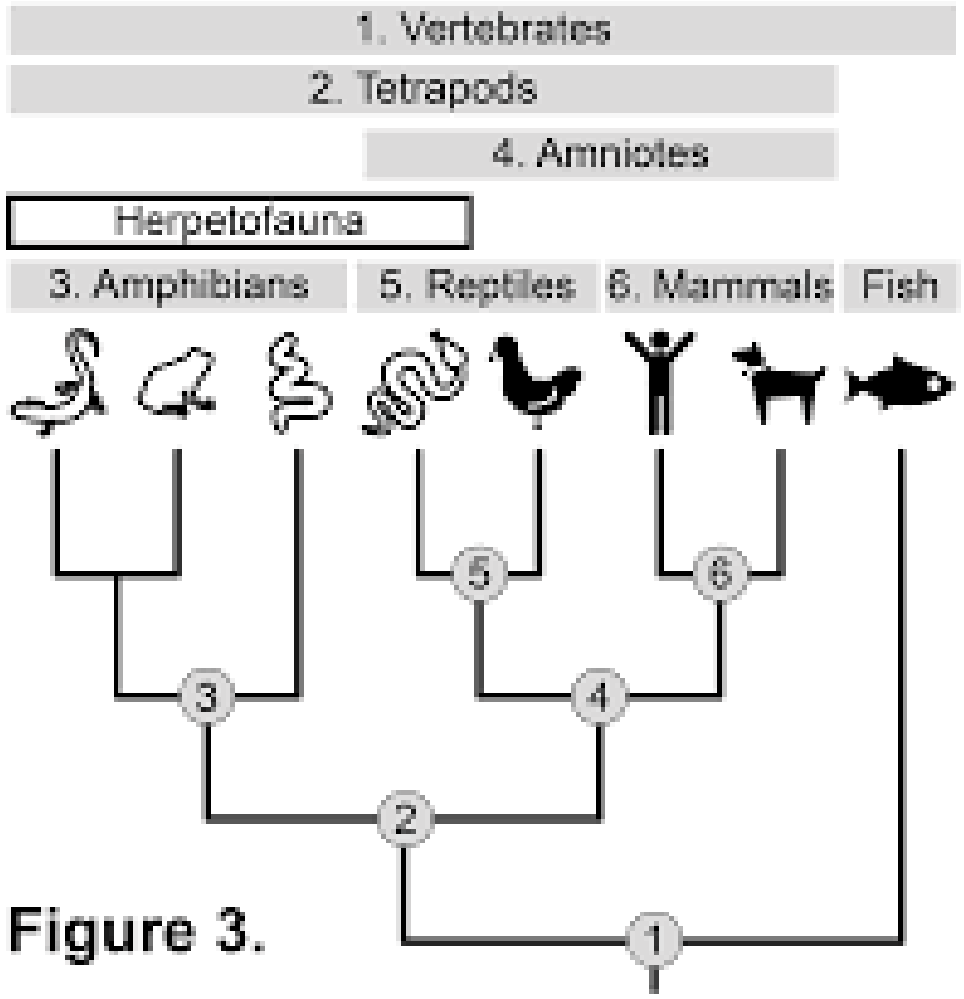



Figure 3.

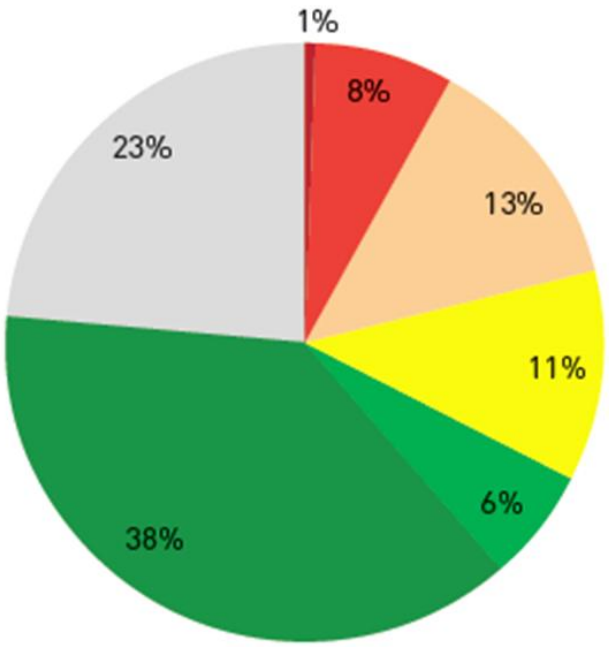
Quelle: Frank Mutschmann, Exomed

# Amphibians

- Numbers (Amphibiaweb)
  - Anura (frogs and toads)
    - Ca. 88%, 7,263 species
  - Caudata (salamanders)
    - Ca. 9%, 759 species
  - Gymnophiona (caecilians)
    - Ca. 3%, 213 species

# Global Amphibian Declines

- First documented 1989 at the first World Congress for Herpetology
- Probably began in the 1970‘s

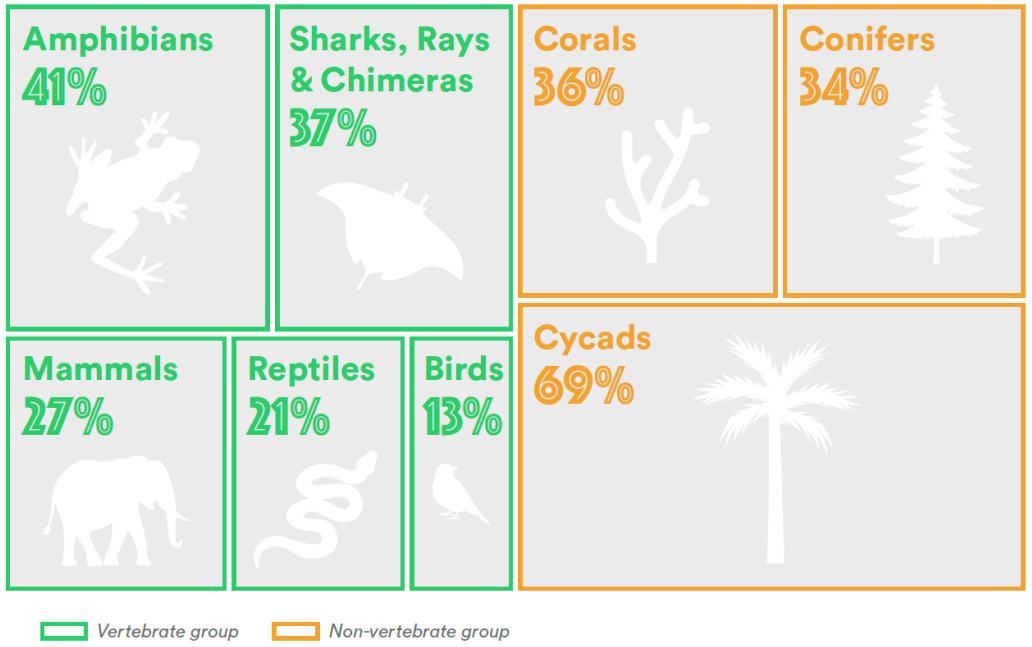



| Red List Category | Number of Species |
|---|---|
| Extinct | 34 |
| Extinct in the wild | 1 |
| Critically Endangered | 455 |
| Endangered | 768 |
| Vulnerable | 670 |
| Near Treatened | 369 |
| Least Concern | 2236 |
| Data Deficient | 1382 |
| **Total Number of Species** | **5915** |

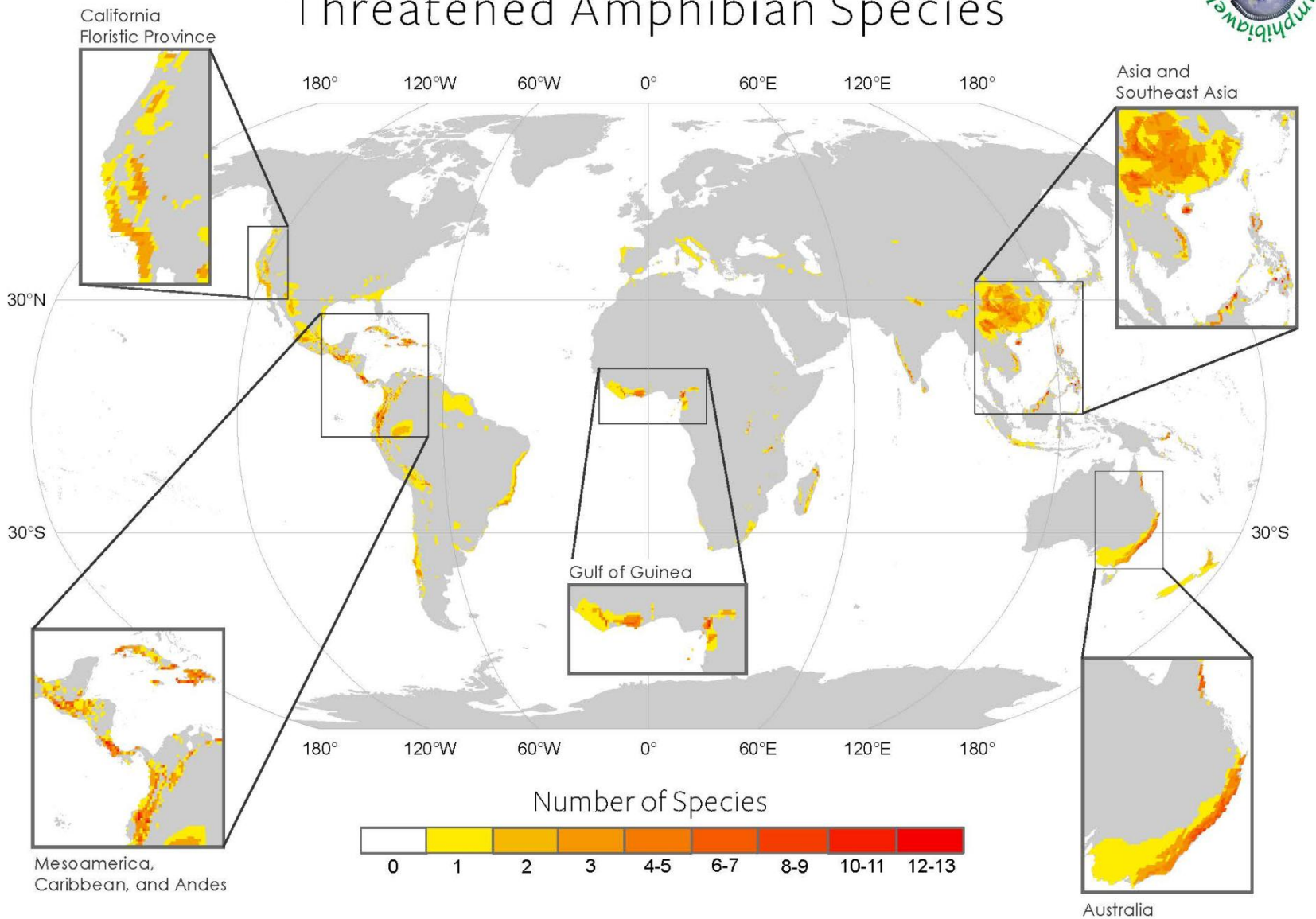
Figure 1. Summary of Red List categories for all amphibians. The percentage of species in each category is displayed on the pie chart (from Stuart et al. 2008) https://journals.openedition.org/sapiens/1406

# Global Amphibian Assessment

- Approx. 32% of the existing amphibian species considered threatened in 2004 (birds: 12%; mammals: 23%) (Stuart et al., 2004. Science)
- Approximately 41% consered threatened 2024 (2nd GAA, 2023)



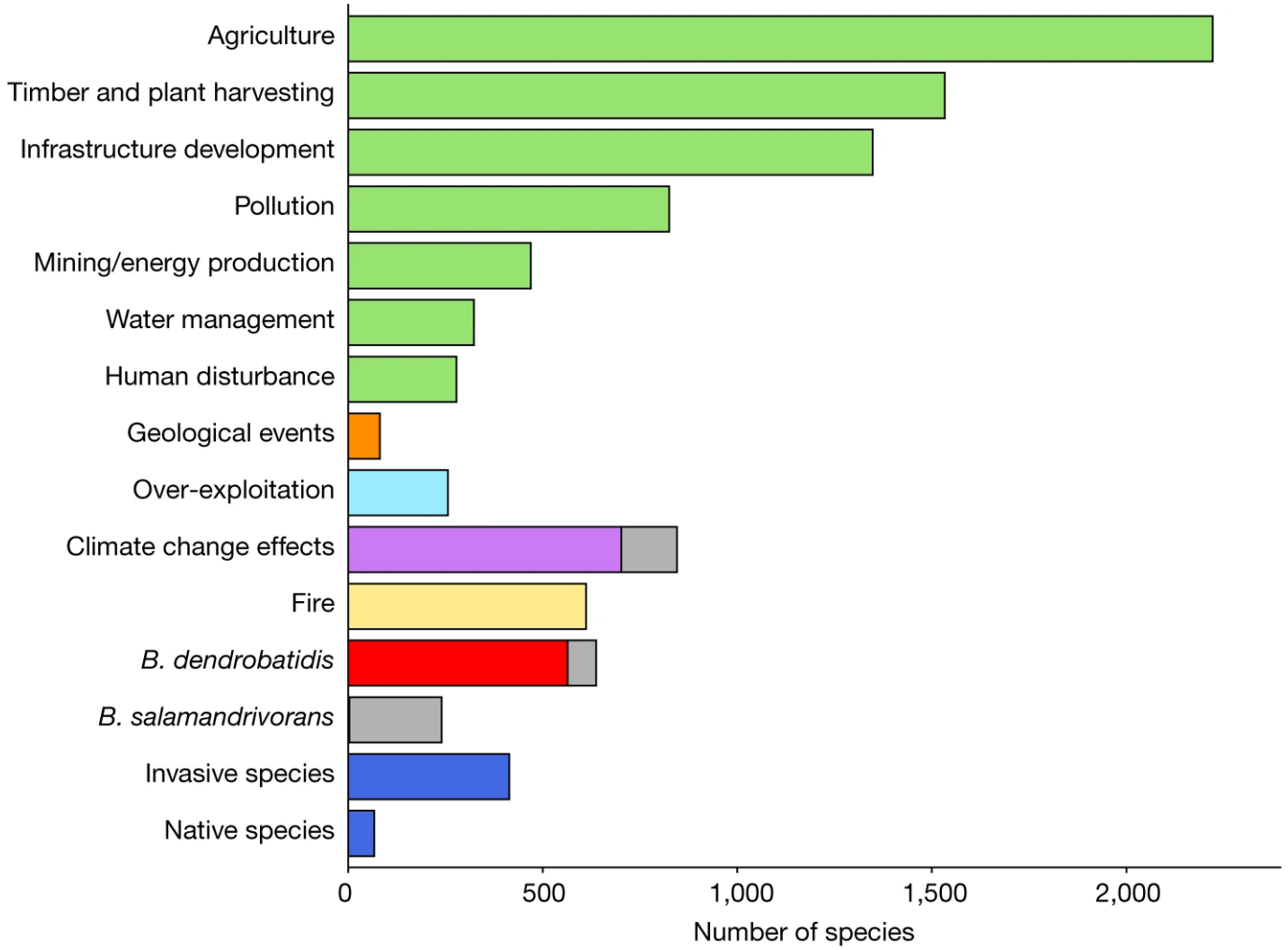
# Threatened Amphibian Species




Data Sources: AmphibiaWeb, IUCN. 2017.

# Global Amphibian Decline

The types of threats affecting amphibian species in threatened categories.

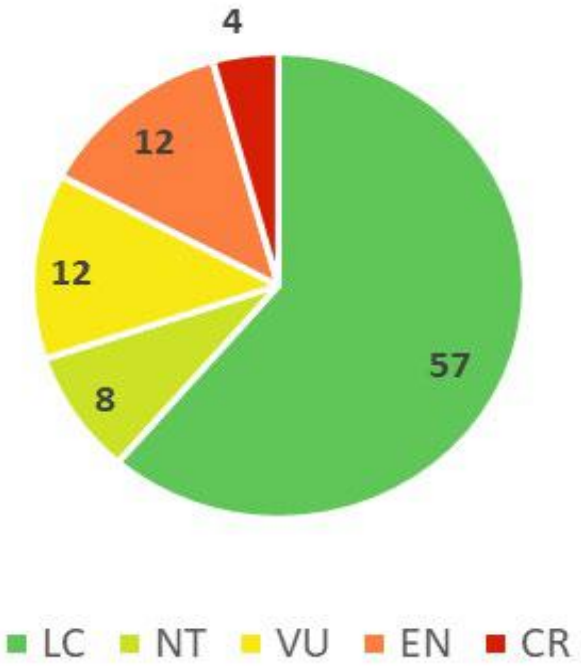



From: Luedtke et al. 2023. Nature 622:308-314.

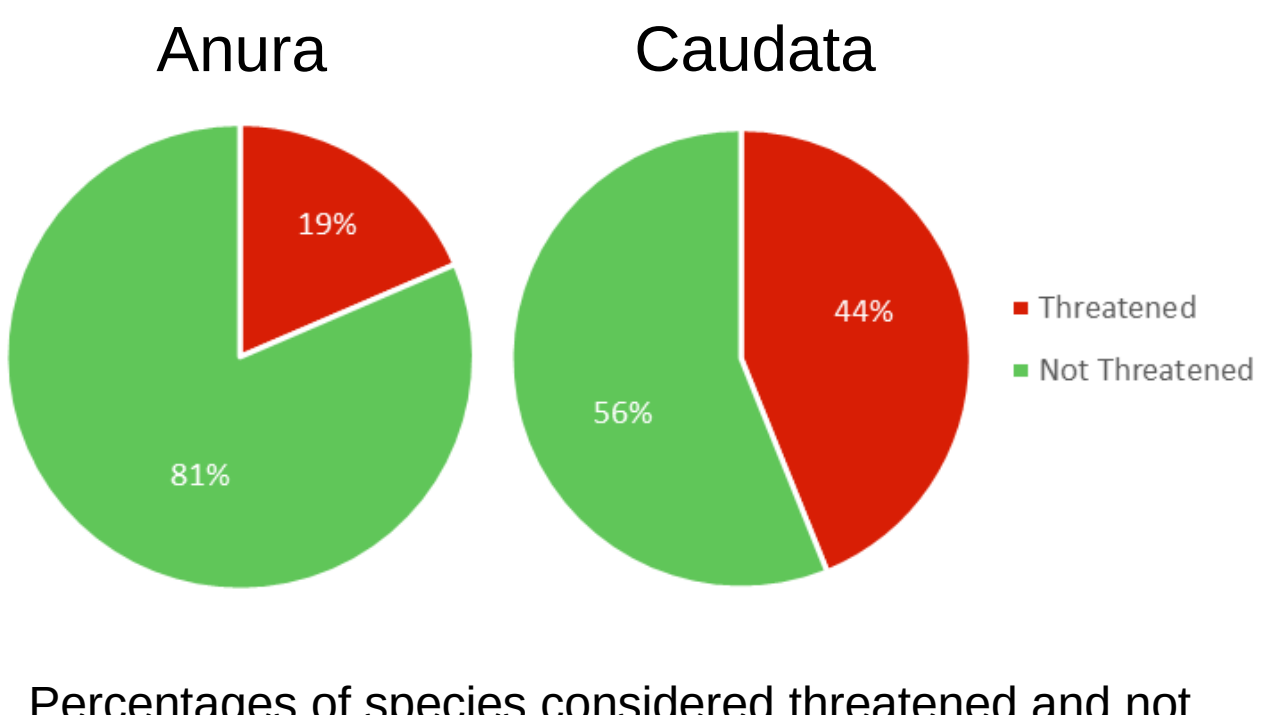
# European amphibians

European Red List of Amphibians. Crnobrnja-Isailović et al. 2025.

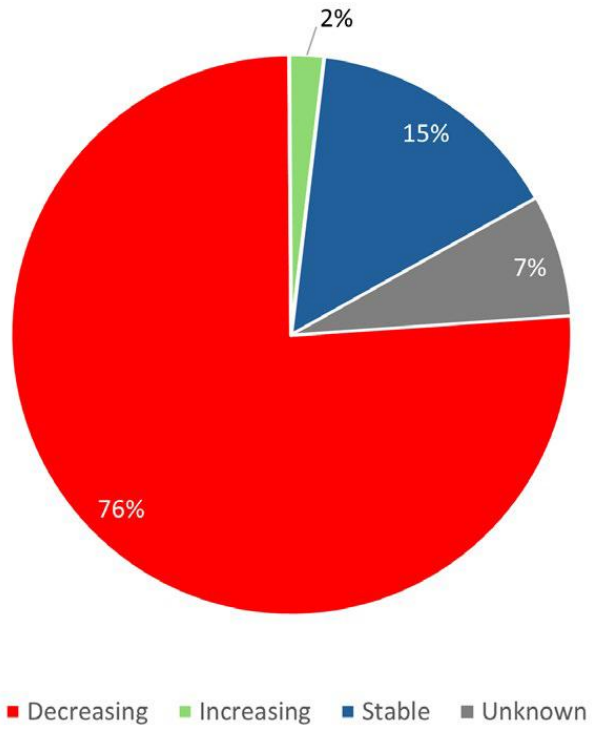
https://doi.org/10.2779/035237




Red list status of amphibians in Europe excluding NA




Percentages of species considered threatened and not threatened




Population trends

# WOAH listed pathogens

- In amphibians:
  - *Batrachochytrium dendrobatides* (Bd)
  - *Batrachochytrium salamandrivorans* (Bsal)
  - Ranaviruses

# Chytrid fungi

- Primitive fungi, generally saprophages
- Many aquatic
- 2 Species found in amphibians:
  - *Batrachochytrium dendrobatidis* (Bd)
  - *Batrachochytrium salamandrivorans* (Bsal)
- Believed to be responsible for population declines of at least 501 species and presumed extinction of 90 species (Fisher et al., 2021)
- Both originated in Asia and spread through the animal trade

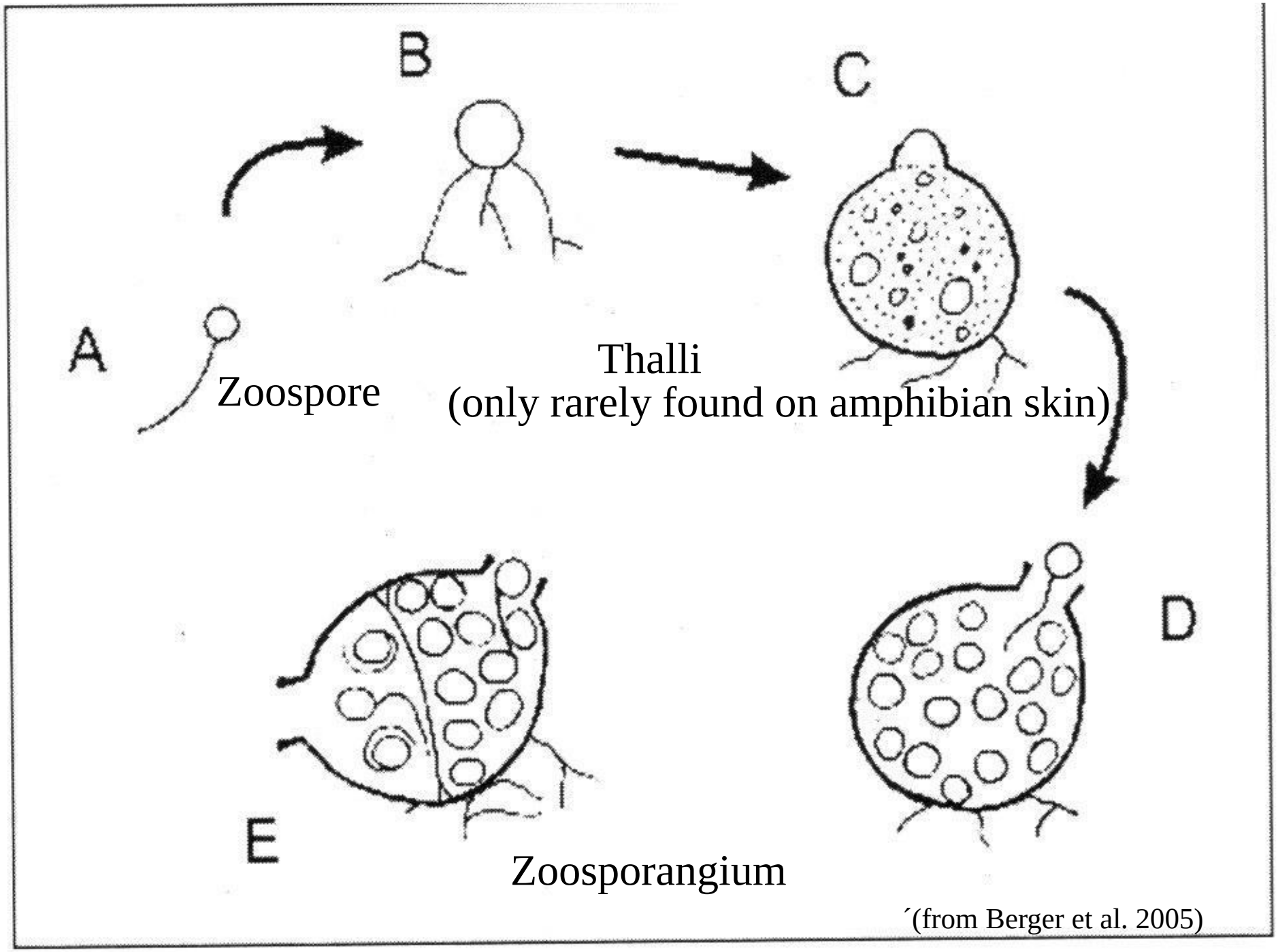
# *Batrachochytrium dendrobatidis*

- Bd first described in 1998 in Australia
- Named in 1999 (Longcore et al.)

*Rana muscosa*, Mountain yellow-legged frog, California, USA. © Vance T. Vredenburg

# Batrachochytrium dendrobatidis

- 2 life stages:
  - Zoosporangium:
    - Non-motile, reproductive
  - Zoospore:
    - Motile
- Infect keratinized skin of amphibians

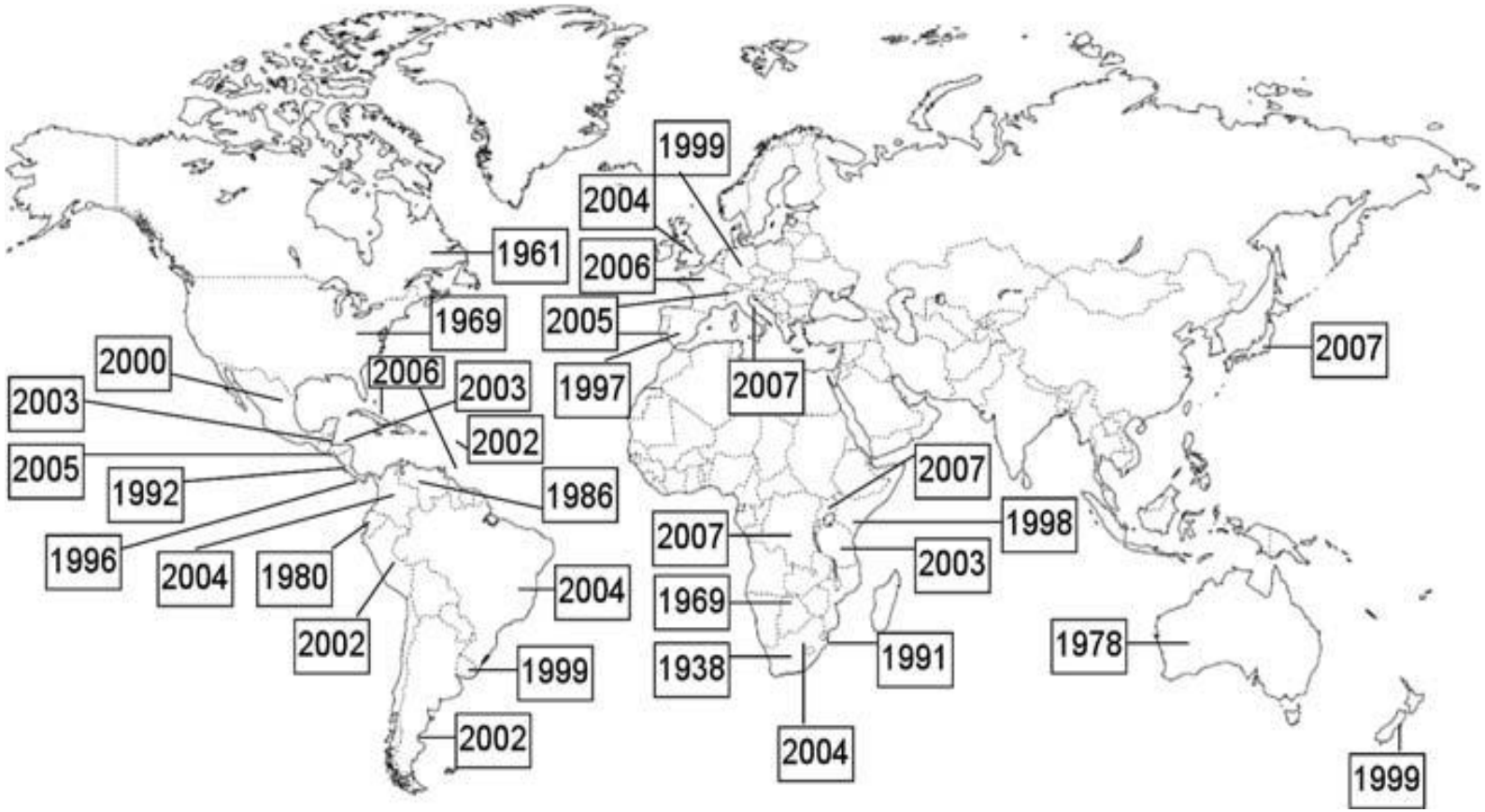



´(from Berger et al. 2005)

# *Batrachochytrium dendrobatidis*

- Extremely high mortality rates in some cases (up to 100% under laboratory conditions)
- In other cases, infections appear to persist with no accompanying population declines
- Influenced by:
  - Host species
  - Pathogen virulence factors
  - Host immune response
  - Host microbiome and mucosome
  - Temperature

# *Batrachochytrium dendrobatidis*

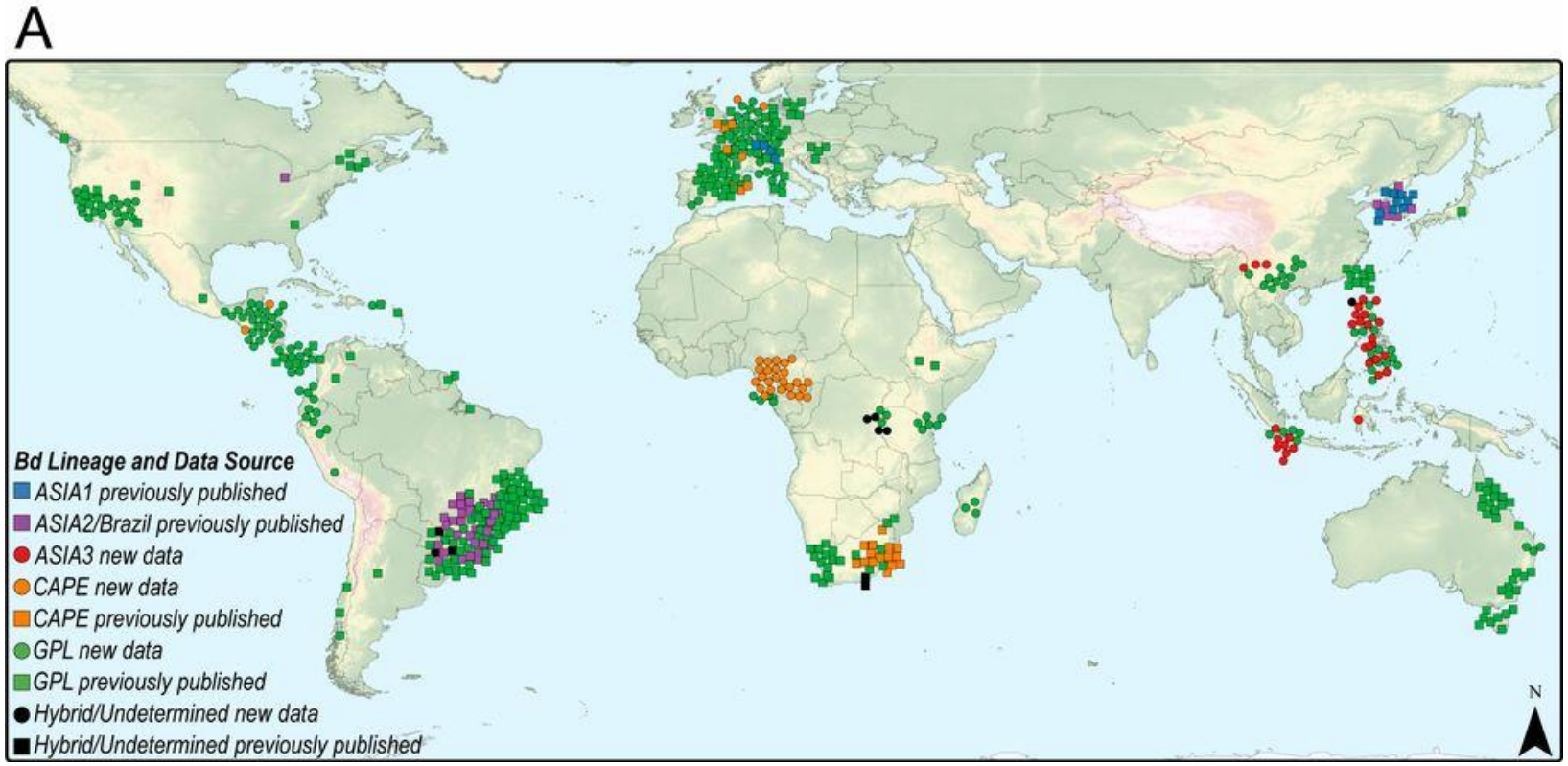



Global spread of Bd and year of first detection

Source: Kriger and Hero, 2009

# *Bd* lineages (Byrne et al., 2019)

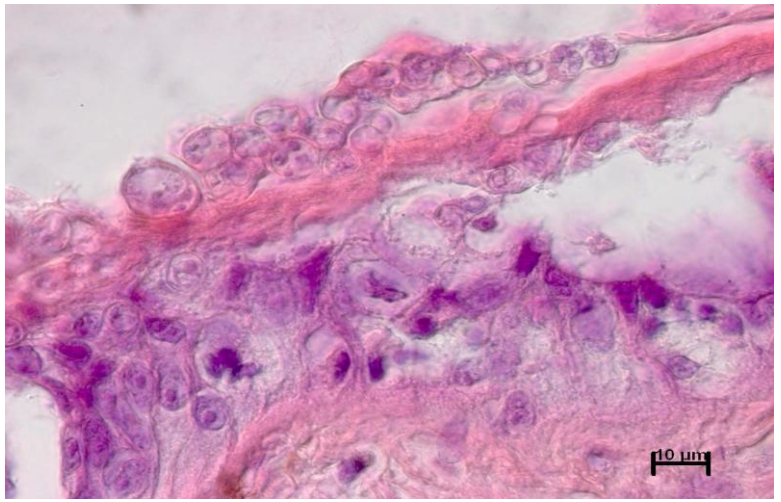
- *Bd*GPL:
  - World wide
- *Bd*CAPE
  - Africa, Europe, and Central America
- *Bd*ASIA1 (*Bd*CH)
  - Asia, Europe
- *Bd*ASIA2/Brazil
  - Asia and South America
- *Bd*ASIA3
  - Asia
- Hybrids
  - Various regions




Source: https://doi.org/10.1073/pnas.1908289116

# *Batrachochytrium dendrobatidis*

- Mostly infects the external skin (*Stratum corneum* down to the *Stratum granulosum*)
- Occasionally also found in intestine and internal tissues (swollowing of infected skin)
- In addition to infecting adults, larvae can also be infected, but much lesser disease (keratinized skin on mouth)
- Dramatic mortality rates during metamorphosis



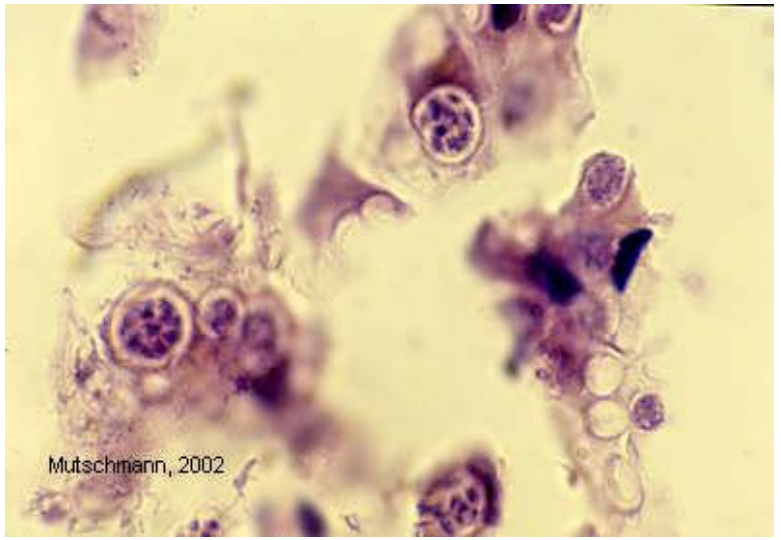




Photo source: Mutschmann, Exomed

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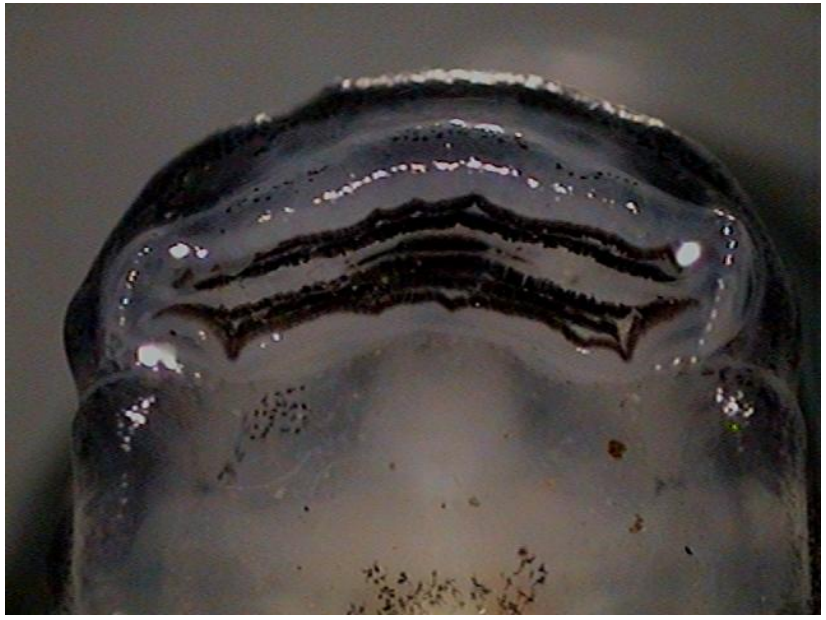
# *Batrachochytrium dendrobatidis*



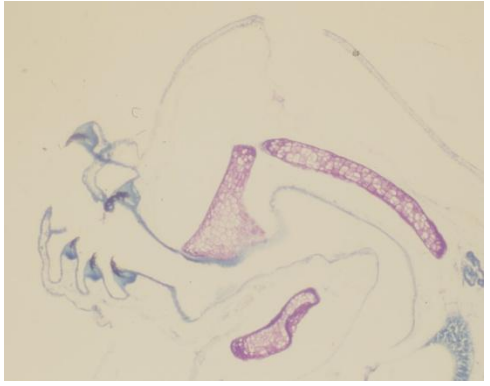


Photo source: Mutschmann, Exomed

# Chytridiomycosis: Clinical signs

- Unspecific signs
- Skin often appears unchanged or „dull“ or depigmented
- Hyperkeratosis and massive shedding with extreme erosions on the skin
- Atypical behaviour (longer time spent in the water)
- Ataxia and CNS signs
- Spontaneous deaths with no previous clinical signs of disease

Photo source: Mutschmann, Exomed

# Chytridiomycosis

Healthy frog

Diseased frog

*Rana (Pelophylax) lessonae,* Pool frog, Zürich, Switzerland

Photo source: Doug Woodhams, Zürich

# *Batrachochytrium dendrobatidis*

- Laboratory transmission studies:
  - In some species, 90-100% mortality
  - Significant mortality esp. after metamorphosis
  - In tadpoles: slower development, smaller size at metamorphosis (followed by increased mortality), behavioural changes

# Chytridiomycosis

- Fatal infections:
  - Bd:
    - Hyperplasia, hyperkeratosis
    - Loss of physiological functions of the skin
    - Electrolyte and fluid homeostasis and respiration impacted
    - Metabolic disorders and heart failure

# *Batrachochytrium dendrobatidis*

- Primary drivers of host response to disease:
  - Fungal pathogen: genetic lineage
  - Time: how long have host and fungus interacted
  - Host population, species ecology, evolutionary biology
  - Environmental conditions

# *Batrachochytrium dendrobatidis*

- Different host species affected in different ways
- Carriers:
  - American bullfrog (*Rana catesbeiana*)
  - African clawed frog (*Xenopus laevis*)
- Many other species: Death within days or weeks

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# *Batrachochytrium dendrobatidis*

- Bd in the environment:
  - Remains infectious for weeks in a (sterile) aquatic environment (Johnson und Speare, 2003)
  - Can stick to feathers and grow there (for hours)
  - Survive for months in wet sand (Johnson und Speare, 2005)
  - Possible saprophytic form?

# Bd: Testing

- Swabs of ventral skin, drink patch, thighs, feet
- qPCR

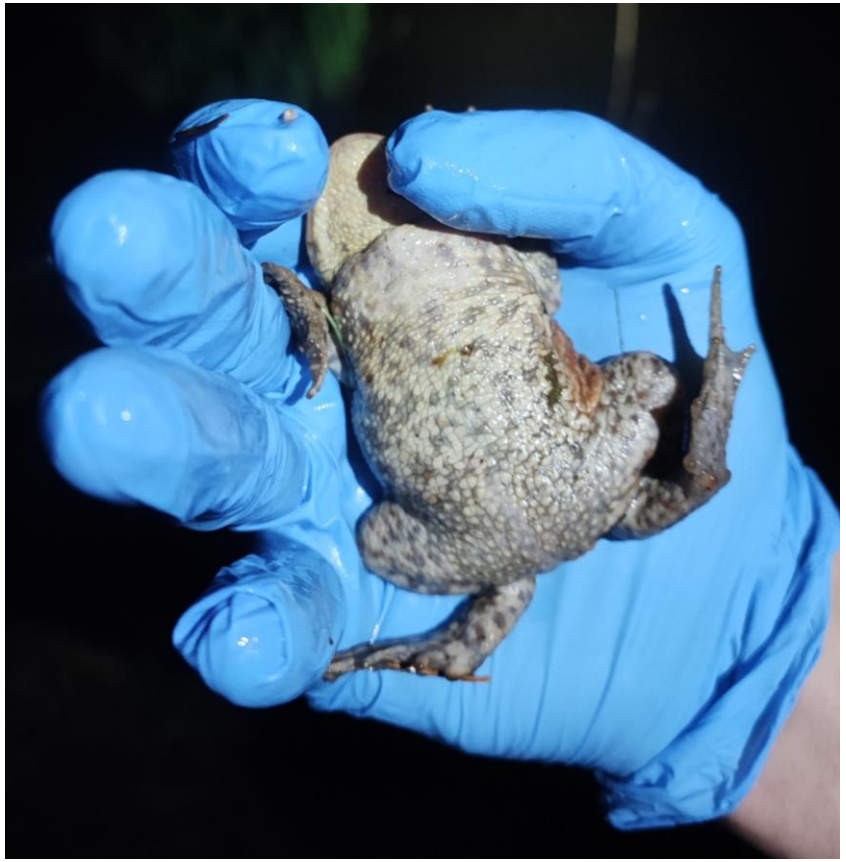

Photo source: Christoph Leineweber

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# Bd: Treatment

- Heat treatment:
  - E.g. two eight-hour periods at 37°C; five days at 32°C, 30°C for 10 days
- Antifungals:
  - Itraconazole (0.01% baths 5-10 min daily for 5-11 days)
  - Voriconazole (1.25 µg/ml spray twice daily for 7 days)
  - Terbinafine (0.005% and 0.01% spray or bath 5 min daily for 5 days)
- Environmental interventions for wild amphibians under discussion
  - Agrochemical fungicides, heat stations

https://www.science.org/content/article/frog-saunas-could-help-endangered-species-beat-deadly-fungus

# *Batrachochytrium salamandrivorans*

- Most closely related to Bd
- Decline in salamander populations in the Netherlands begining 2010
- Description of Bsal 2013

## *Batrachochytrium salamandrivorans* sp. nov. causes lethal chytridiomycosis in amphibians

An Martel[a,1], Annemarieke Spitzen-van der Sluijs[b], Mark Blooi[a], Wim Bert[c], Richard Ducatelle[a], Matthew C. Fisher[d], Antonius Woeltjes[b], Wilbert Bosman[b], Koen Chiers[a], Franky Bossuyt[e], and Frank Pasmans[a]

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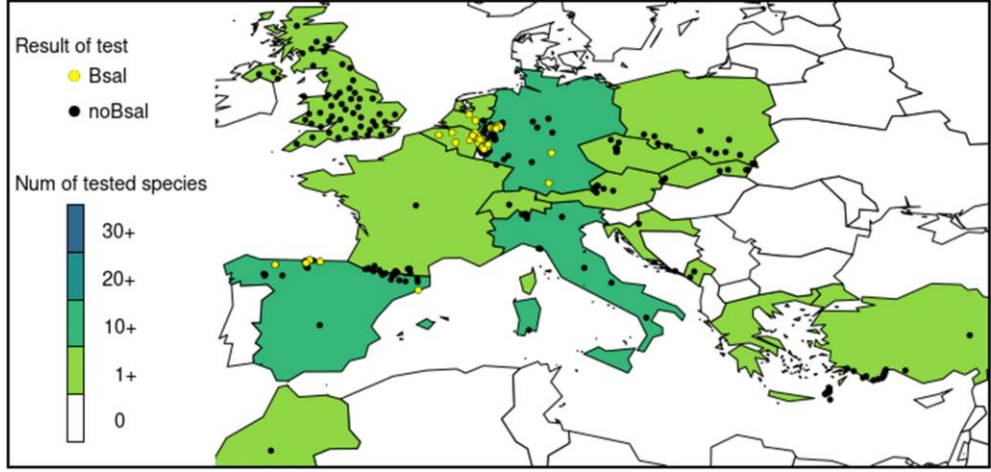
Edited by David B. Wake, University of California, Berkeley, CA, and approved August 1, 2013 (received for review April 18, 2013)

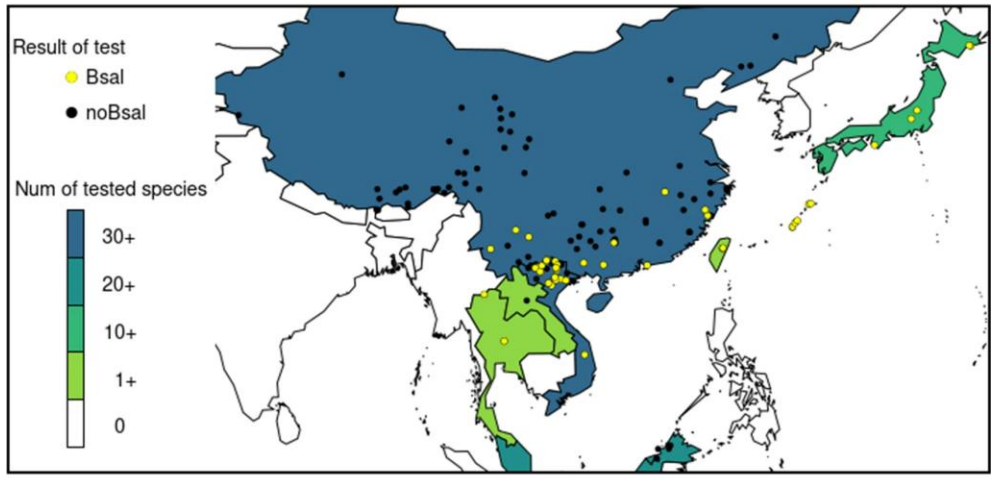
# *Batrachochytrium salamandrivorans*

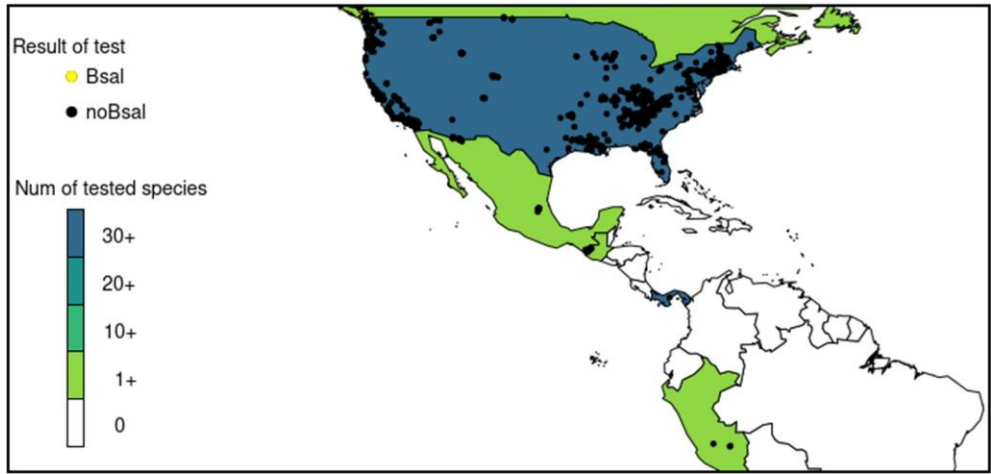
- So far described in:
  - Europe: the Netherlands, Belgium, Germany, the UK (captive), and Spain
  - Asia: Endemic to Southeast and East Asia (Thailand, Vietnam, Japan, China, Hong Kong)
- Lower thermal preference than Bd:
  - Bd: optimal 17-25 °C
  - Bsal: optiomal 10-15 °C

# *B. salamandrivorans*

- Host range:
  - Infects mostly urodeles
    - Non-Asian salamander species (family Salamandridae highly susceptible)
    - Esp. fire salamanders
- Origin: Asia




Castro Monzon et al. 2022. Ecohelath 19(4):475-486.

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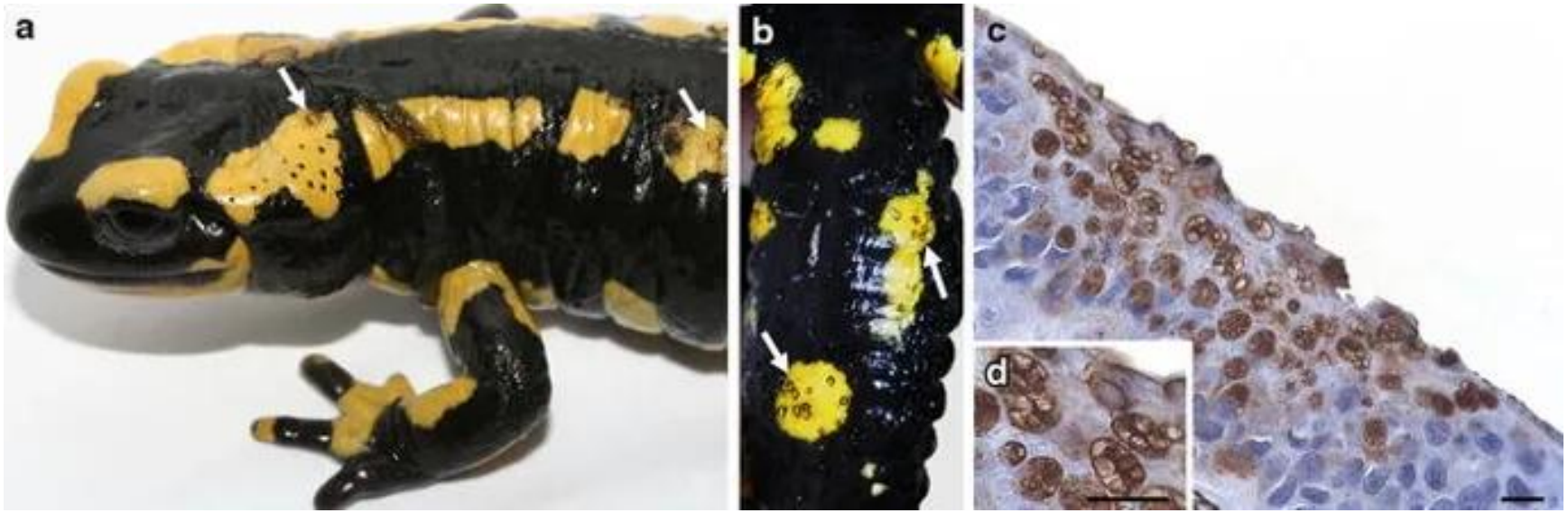
# *Batrachochytrium salamandrivorans*

- Clinical signs:
  - Multifocal superficial erosions
  - Extensive ulcerations all over the body
  - Anorexia, apathy, ataxia, death
  - Appears harmless to larvae
  - Fatalities:
    - Erosion of epidermis
    - Loss of barrier function
    - Lethal septicemia caused by opportunistic bacteria

# *Batrachochytrium salamandrivorans*




From: Van Rooij et al. 2015. Amphibian chytridiomycosis: a review with focus on fungus-host interactions. Vet Res 46:137

# Bsal: Testing

- Swabs of ventral skin, thighs, feet
- qPCR

Photo source: Christoph Leineweber

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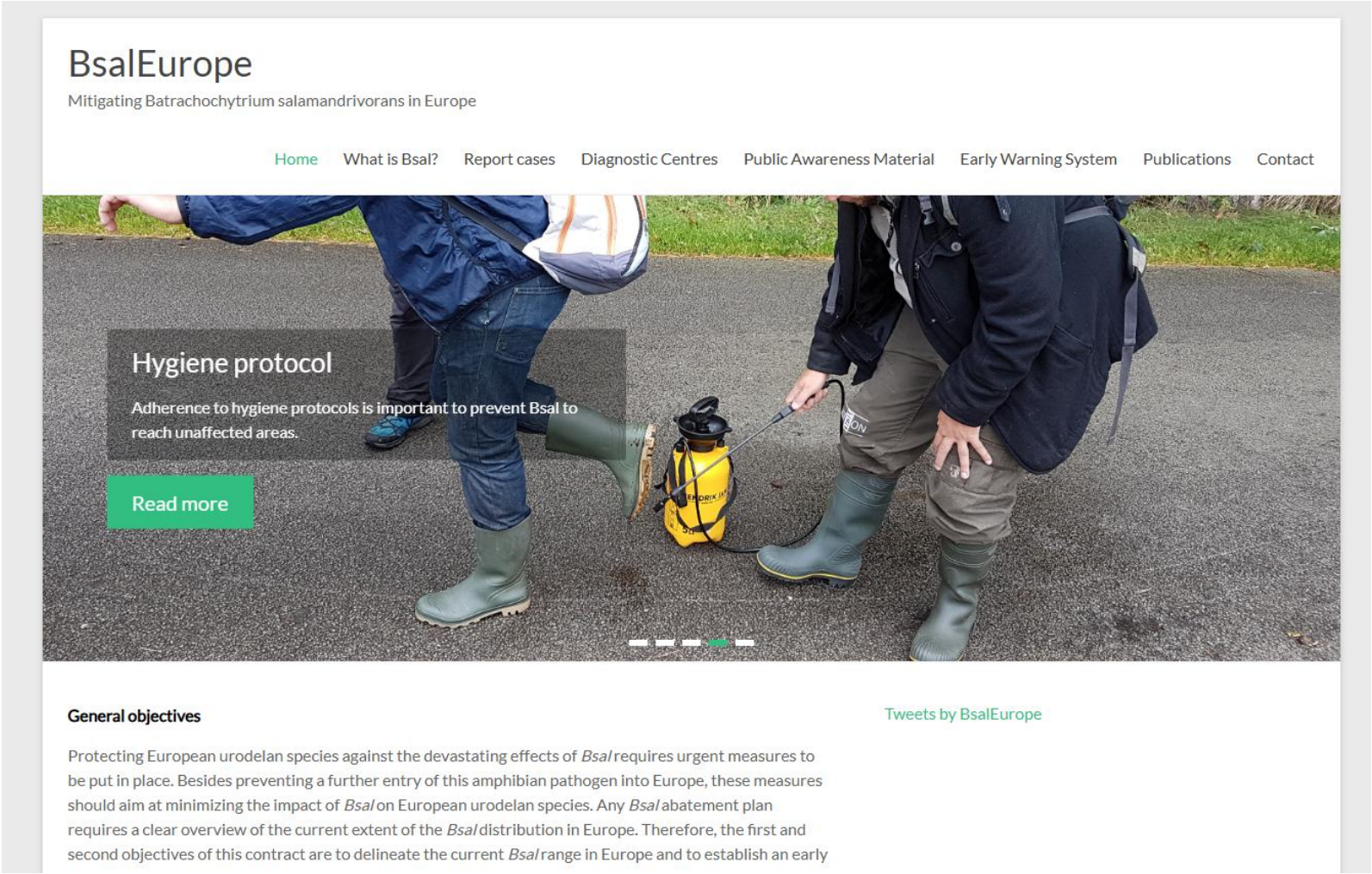
# Bsal: Treatment

- Heat treatment:
  - 25°C for 10 days
- Antifungals:
  - Voriconazole (12.5 µg/ml) and polymyxin E (2000 IU/ml) and 20°C for 10 days (Blloi et al., 2015)

# Bsal

- See BsalEurope (http://bsaleurope.com/) for more info

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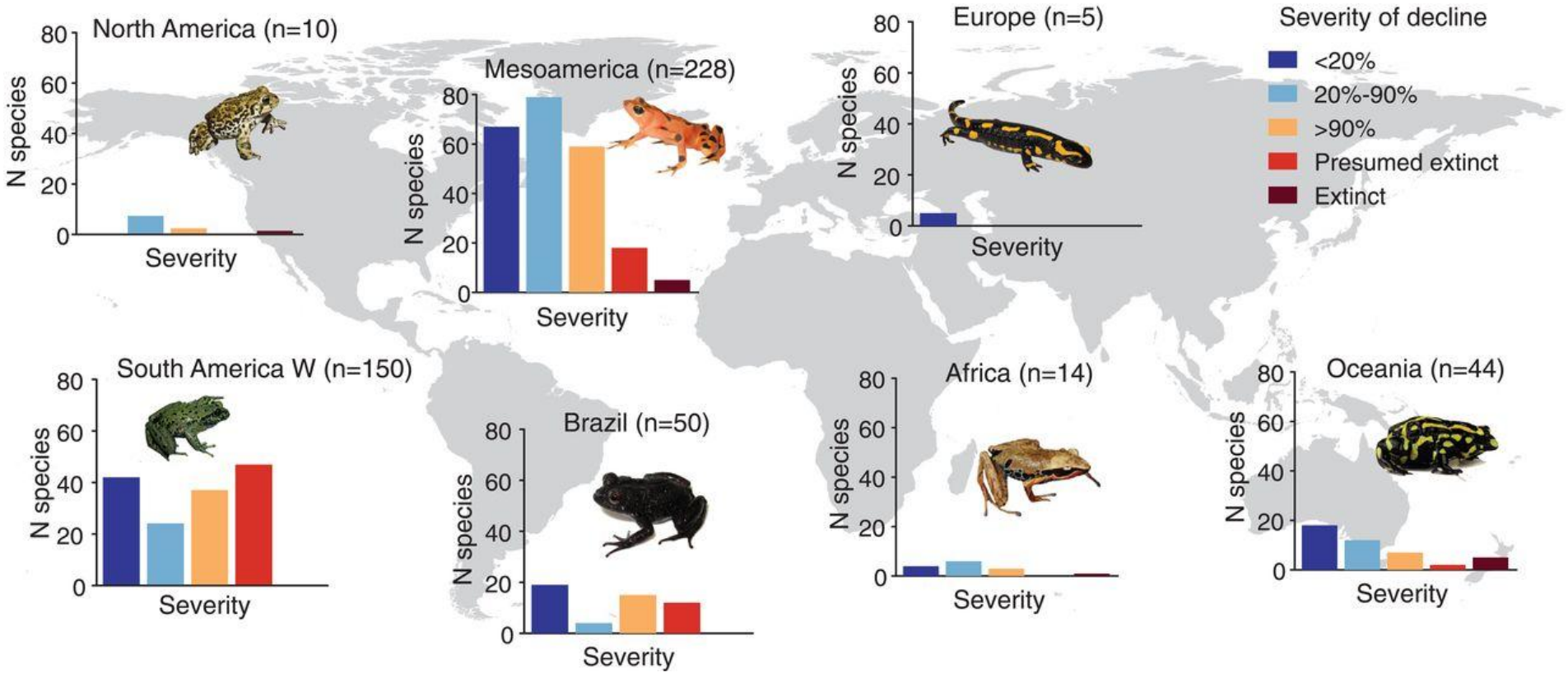


Fig. 1 Global distribution of chytridiomycosis-associated amphibian species declines

Scheele et al. 2019. Amphibian fungal panzootic causes catastrophic and ongoing loss of biodiversity. Science 363(6436):1459-1463.

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# Thank you for your attention!

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