

Amphibian chytrid fungi in the Netherlands

From outbreak to action: a summary of current research

Dr. Wouter Beukema

Olm, 01-10-2026



RAVON

Reptielen Amfibieën Vissen Onderzoek Nederland

Short introduction

- **Project manager & researcher** at RAVON (Reptile, Amphibian & Fish Conservation Netherlands), in reality mostly a (data) scientist.
- Scientific and applied research into impact and mitigation of amphibian chytrid fungi, but also;
 - Evidence-based conservation of spadefoot toad and fire salamander
 - N2000 monitoring
 - Nature Restoration Law analyses





Eupen, 2013





Nearly 15 years passed – what is the status quo?

Expanding Distribution of Lethal Amphibian Fungus *Batrachochytrium salamandrivorans* in Europe

Annemarieke Spitzen-van der Sluijs, An Martel, Johan Asselberghs, Emma K. Bales, Wouter Beukema, Molly C. Bletz, Lutz Dalbeck, Edo Goverse, Alexander Kerres, Thierry Kinet, Kai Kirst, Arnaud Laudelout, Luis F. Marin da Fonte, Andreas Nöllert, Dagmar Ohlhoff, Joana Sabino-Pinto, Benedikt R. Schmidt, Jeroen Speybroeck, Frank Spikmans, Sebastian Steinfartz, Michael Veith, Miguel Vences, Norman Wagner, Frank Pasmans, Stefan Lötters

and salamanders); the fungus was most likely introduced from East Asia into Europe via the pet trade (2). In Europe, *Bsal* infection has led to dramatic declines of fire salamander (*Salamandra salamandra*) populations in the Netherlands and Belgium (2). Within 7 years after the supposed introduction of the fungus, a population in the Netherlands declined by 99.9% (3,4). In the United Kingdom and Germany, *Bsal* has been detected in captive salamanders and newts (5,6). Infection trials suggest that *Bsal* represents an unprecedented threat to diversity of Western Palearctic urodeles (2); nevertheless, reports

Amphibia-Reptilia 34 (2013): 233-239

Rapid enigmatic decline drives the fire salamander (*Salamandra salamandra*) to the edge of extinction in the Netherlands

Annemarieke Spitzen-van der Sluijs^{1,4,*}, Frank Spikmans¹, Wilbert Bosman¹, Marnix de Zeeuw², Tom van der Meij², Edo Goverse¹, Marja Kik³, Frank Pasmans⁴, An Martel⁴

ONLINE REPORT

Inconsistent Strategies to Mitigate the Effects of *Batrachochytrium salamandrivorans*, Europe

Philipp Böning, Stefan Lötters, Vojtech Baláz, Wouter Beukema, Jaime Bosch, Salvador Carranza, Andrew A. Cunningham, Jesse Erens, Matthew C. Fisher, Trenton W.J. Garner, Maarten J. Gilbert, Florian Glaser, Christian Gortazar, Elena Grasselli, Matthew J. Gray, Daniel Fernández-Guiberteau, Thierry Kinet, Rok Kostanjšek, David Lastra González, Arnaud Laudelout, An Martel, Albert Martínez-Silvestre, Claude Miaud, Maciej Pabjan, Amadeus Plevnia, Doris Preininger, Riinu Rannap, Sebastiano Salvio, Maximilian Schweinsberg, Annemarieke Spitzen-van der Sluijs, Raf Stassen, Ilias Strachinis, Barbora Thumsová, Jonas Virgo, Jifi Vojar, Michael Veith, Frank Pasmans

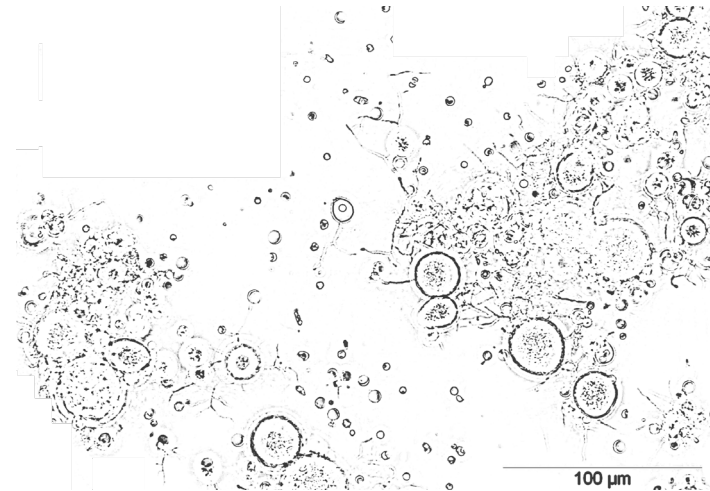
Landscape epidemiology of *Batrachochytrium salamandrivorans*: reconciling data limitations and conservation urgency

Wouter Beukema^{1,2,9}, Jesse Erens¹, Vanessa Schulz^{3,4}, Gwij Stegen¹, Annemarieke Spitzen-van der Sluijs⁵, Tariq Stark⁵, Arnaud Laudelout⁶, Thierry Kinet⁶, Tom Kirschev⁷, Marie Poulain⁸, Claude Miaud⁸, Sebastian Steinfartz³, An Martel¹ and Frank Pasmans¹

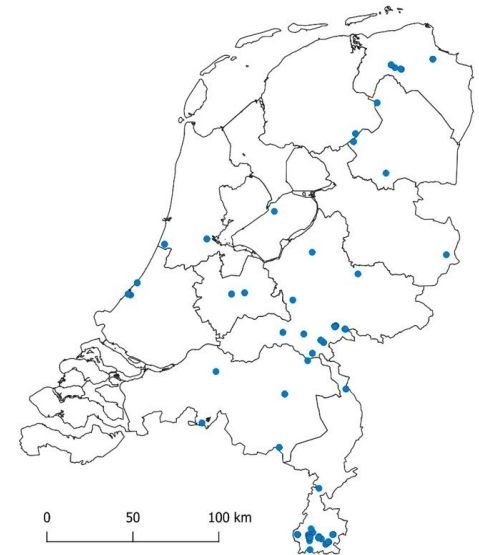
Batrachochytrium salamandrivorans sp. nov. causes lethal chytridiomycosis in amphibians

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

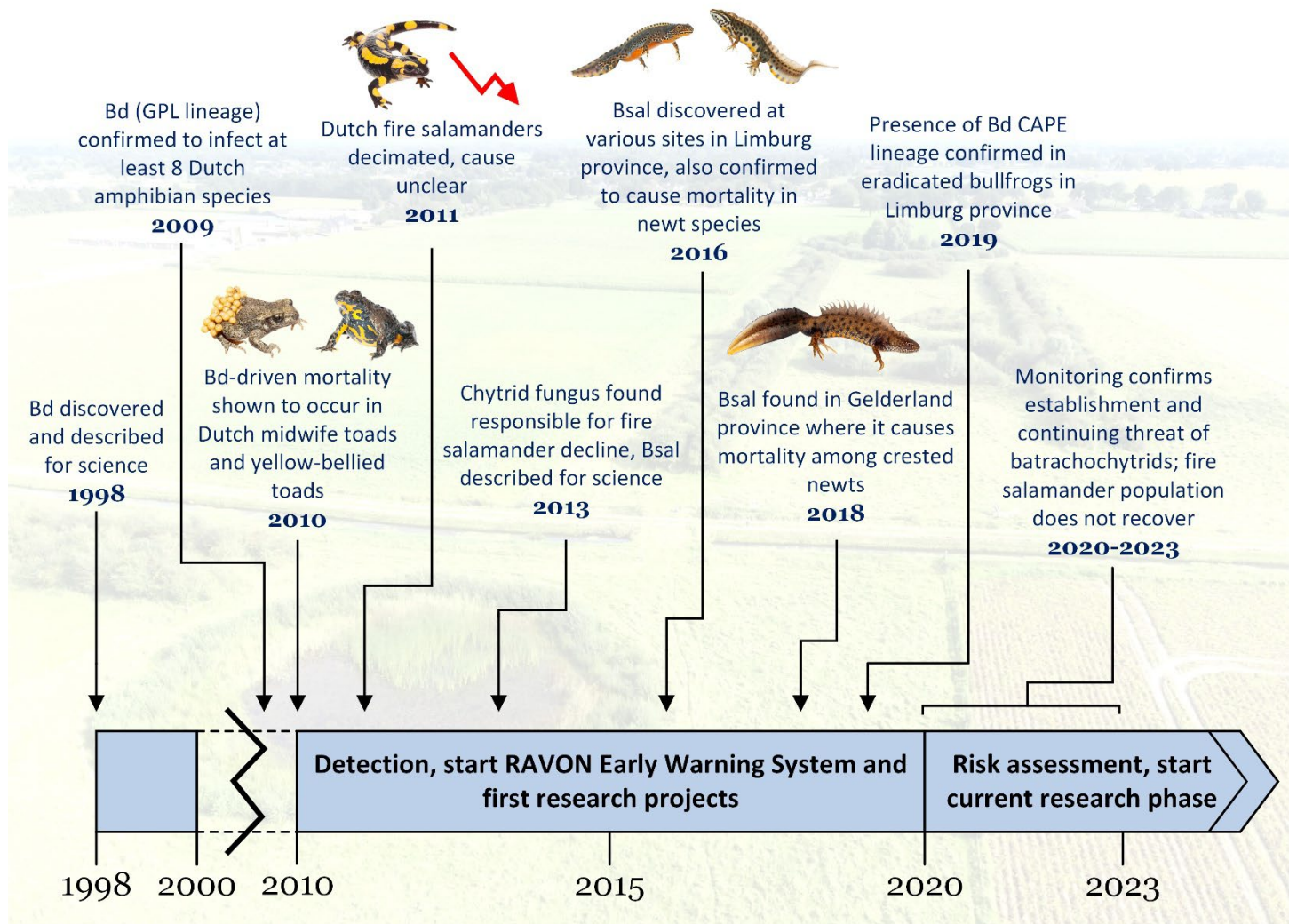
- Chytridiomycosis in the Netherlands
- Compensation mechanisms as framework for research
- Current research in the Netherlands
- Towards mitigation – providing perspective



Chytridiomycosis in the Netherlands



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Bd (GPL lineage) confirmed to infect at least 8 Dutch amphibian species

2009

Dutch fire salamanders decimated, cause unclear

2011

Bsal discovered at various sites in Limburg province, also confirmed to cause mortality in newt species

2016

Presence of Bd CAPE lineage confirmed in eradicated bullfrogs in Limburg province

2019

Bd-driven mortality shown to occur in Dutch midwife toads and yellow-bellied toads

2010

Chytrid fungus found responsible for fire salamander decline, Bsal described for science

2013

Bsal found in Gelderland province where it causes mortality among crested newts

2018

Monitoring confirms establishment and continuing threat of batrachochytrids; fire salamander population does not recover

2020-2023

Detection, start RAVON Early Warning System and first research projects

Risk assessment, start current research phase

1998

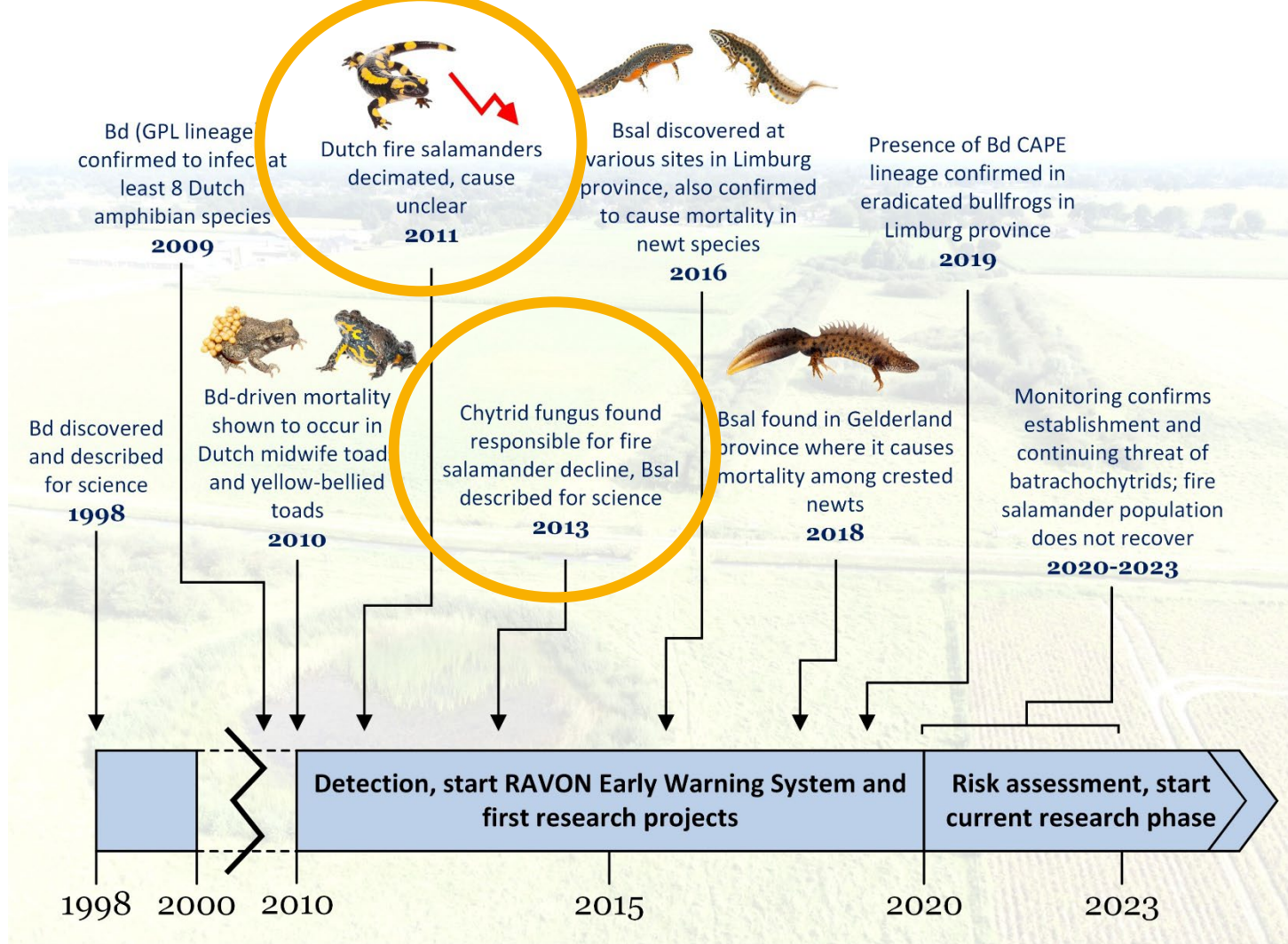
2000

2010

2015

2020

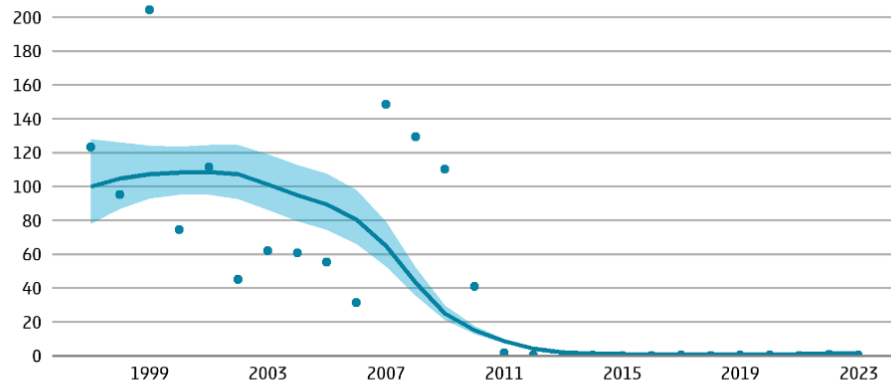
2023





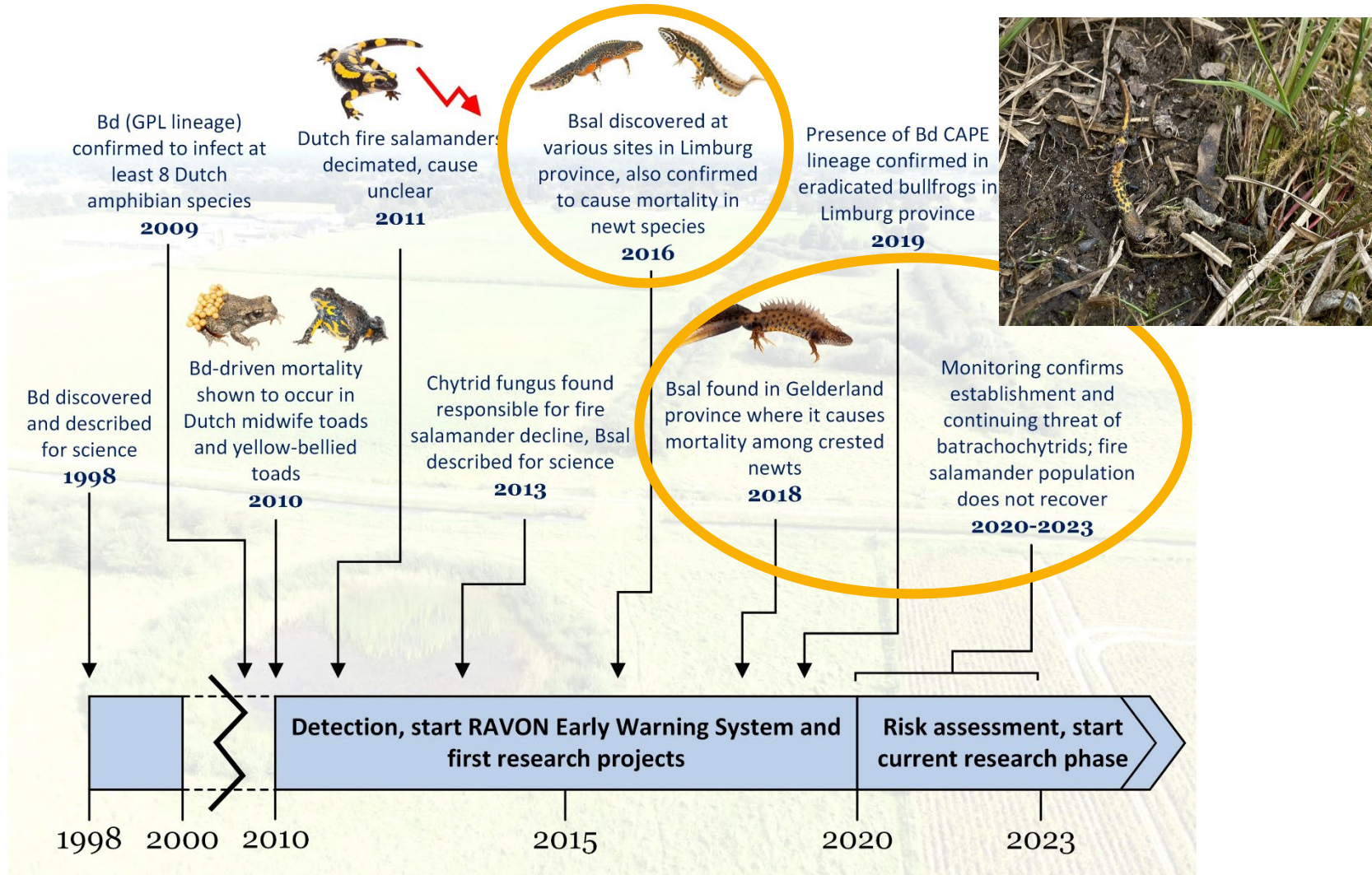
Vuursalamander, Nederland

Index (1997=100)

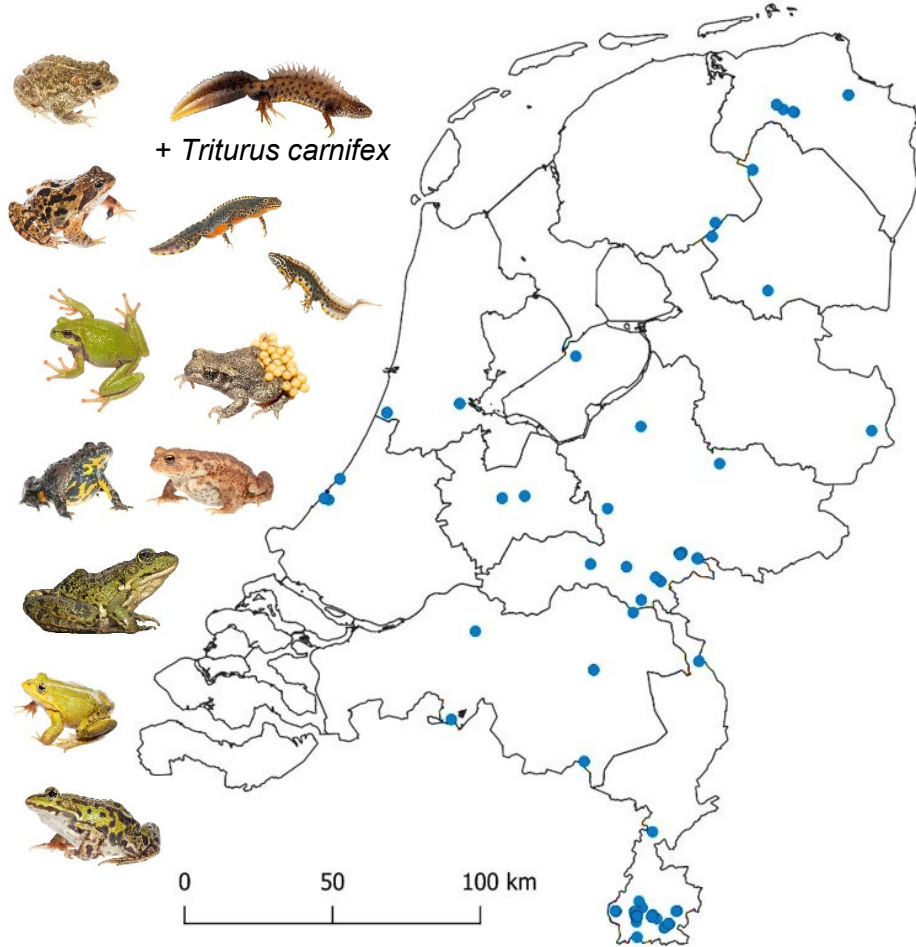


Bron: NEM (RAVON, CBS), 2024

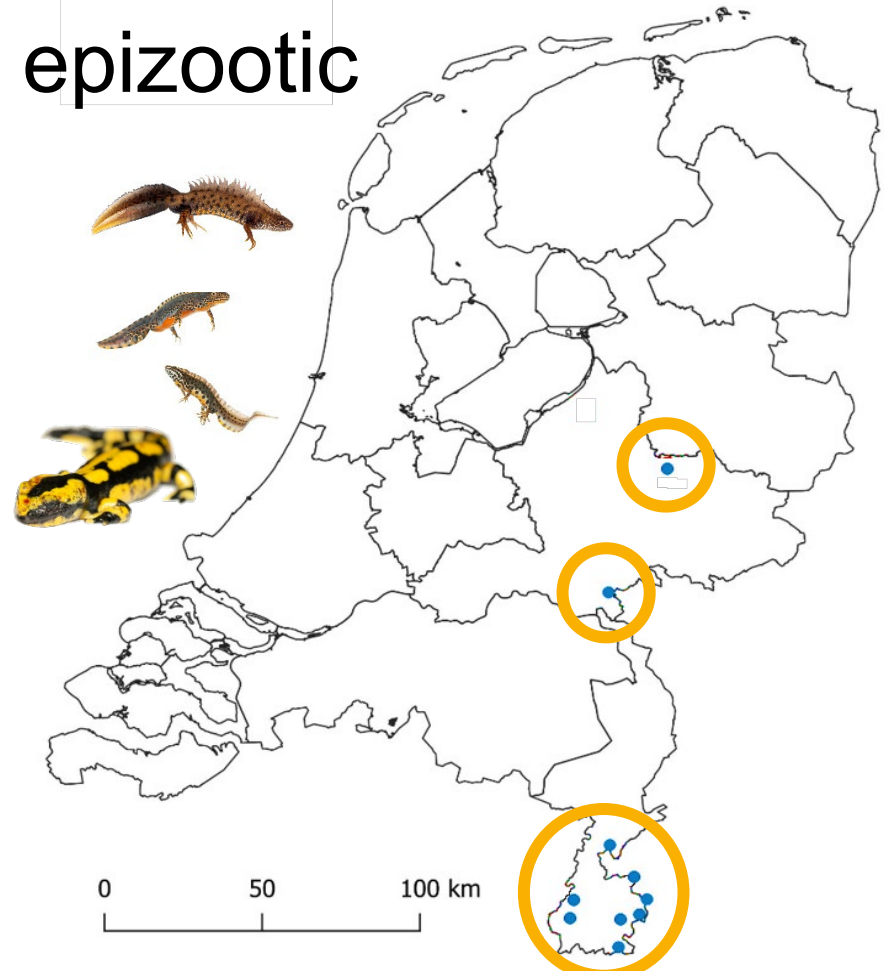




Bd - enzootic



Bsal - enzootic & epizootic

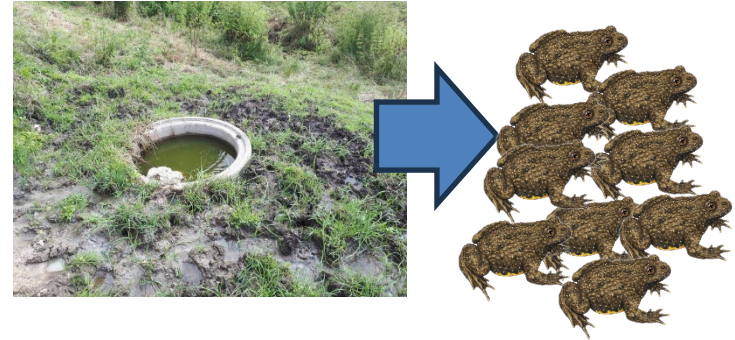


Status quo in the Netherlands and standpoint

- **We can't get rid of the fungi anymore** – eradication / elimination is not realistic.
- Conservation efforts need to **prioritise management of host populations and their environments.**
- But how exactly, where is the need the highest – where do you start?



Compensation mechanisms as framework for research



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Bombina variegata in the Netherlands

- Research of Annemarieke Spitzen; first evidence-based study, revealing yearly mortality among *Bombina*.
- But also: general conservation actions provide opportunities for **higher recruitment**, buffering populations against disease impact.

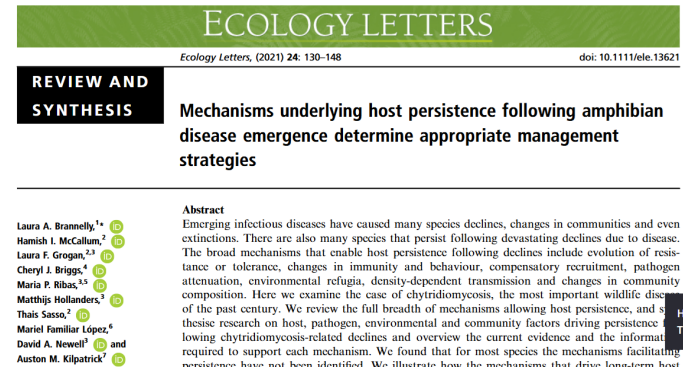


Fragile coexistence of a global chytrid pathogen with amphibian populations is mediated by environment and demography

Annemarieke Spitzen-van der Sluijs^{1,2,†}, Stefano Canessa^{2,†}, An Martel² and Frank Pasmans²

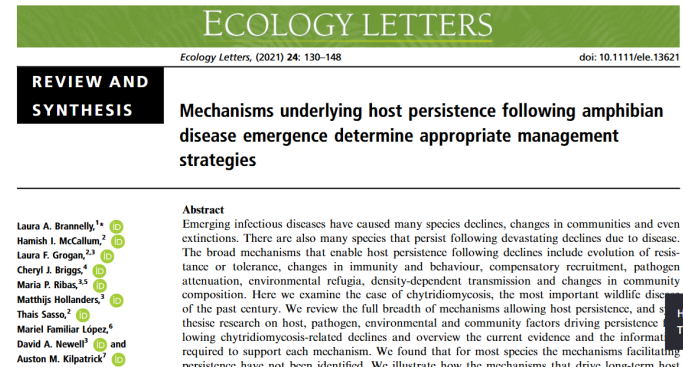
Compensation mechanisms are key

- Higher recruitment is a **compensation mechanism** – what works for other species?
 - Increased host resistance and/or tolerance
 - Pathogen attenuation
 - Density-dependent transmission
 - Compensatory recruitment
 - Behavioural changes
 - Shifts in community composition
 - Environmental factors



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- Grant of the Dutch government allows for **multi-year research into chytrid disease ecology (2023-2028)**.
- Collaboration with Ghent University (Wildlife Health Ghent), data analysis consultancy Quantecol, Research Institute for Nature and Forest (INBO).
- **Aim:** gaining a better understanding of amphibian chytrid disease ecology to guide policy and design targeted mitigation actions.



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Current research in the Netherlands



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Compensation mechanisms



Immunity
Behaviour
Compensatory recruitment
Pathogen attenuation
Environment
Density-dependent transmission
Amphibian community

Immunity	Bsal				
Behaviour	Bsal				
Compensatory recruitment					
Pathogen attenuation	Bsal				
Environment	Bsal	Bd + Bsal		Bd	Bd + Bsal
Density-dependent transmission	Bsal				
Amphibian community	Bd + Bsal	Bsal			Bsal

Proof that mechanism plays a role

	Strong
	Circumstantial
	Weak
	No proof
	Not investigated



Immunity
Behaviour
Compensatory recruitment
Pathogen attenuation
Environment
Density-dependent transmission
Amphibian community

Immunity								
Behaviour								
Compensatory recruitment		Bd						
Pathogen attenuation								
Environment	Bd	Bd			Bd	Bd		
Density-dependent transmission								
Amphibian community			Bsal		Bsal		Bsal	Bsal

Main research lines 2023-2028

- Impact of Bsal on newts, especially *Triturus cristatus* (Habitat Directive)
- Influence of environmental factors on Bsal and Bd disease dynamics
- Influence of the amphibian community on disease dynamics
- Determining risk of Bsal-Bd coinfections







Determining impact is generally not easy

- The basis is traditional capture-recapture research.
- Recapture rate is influenced by chance of animal detection, disease state, chance of pathogen detection in a qPCR, and dispersal (open population).
- You cannot determine impact using 'traditional' statistic methods.



RESEARCH ARTICLE

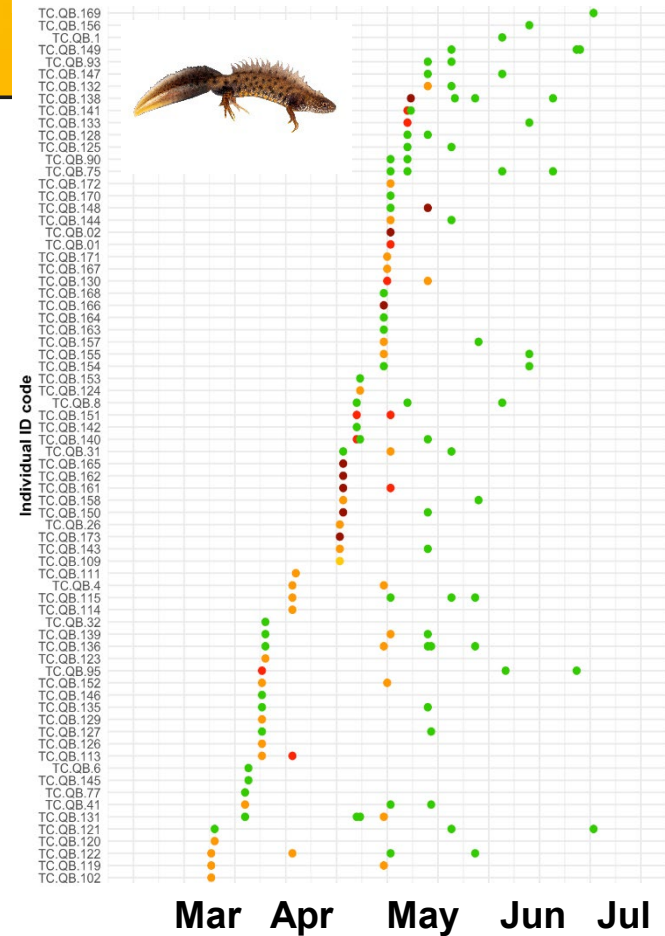
Methods in Ecology and Evolution 

Know what you don't know: Embracing state uncertainty in disease-structured multistate models

Matthijs Hollanders¹  | J. Andrew Royle² 

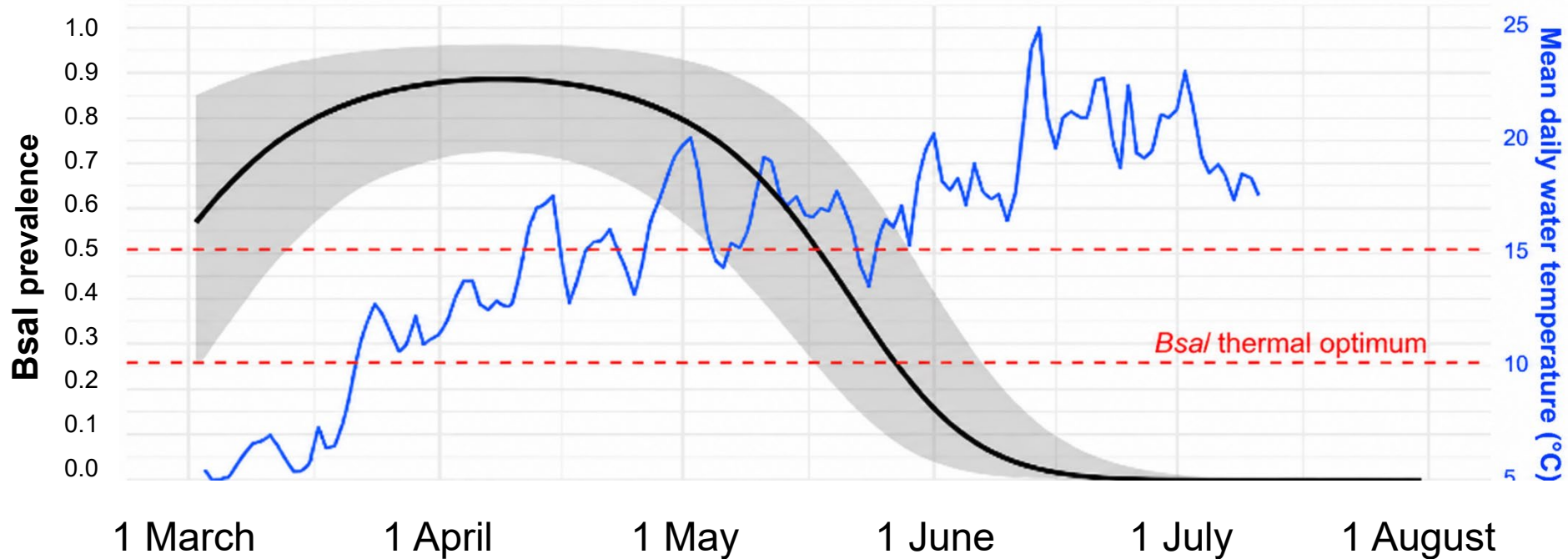
Capture-recapture

- Both recoveries and mortality are recorded
- What is the actual **impact**?
- What **(a)biotic factors** cause these seasonal infection patterns?



Influence of water temperature

Presence of Bsal on aquatic *Triturus*, 2021-2025

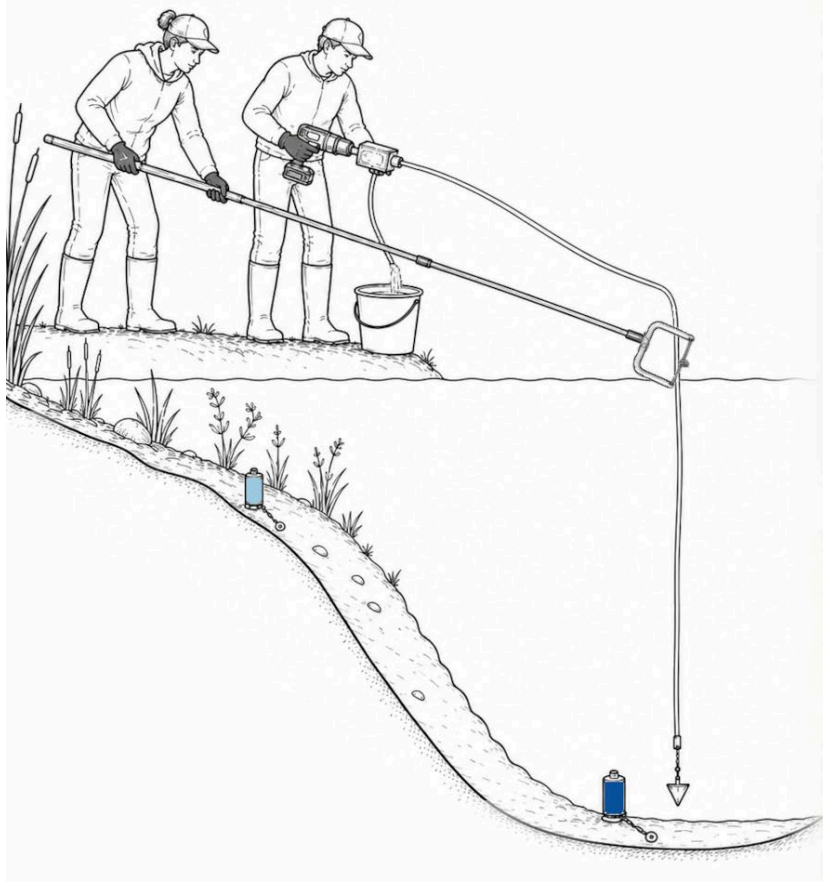


Work in progress, but...

- Mortality is significantly higher in infected *Triturus*.
- Animals are already **infected when migrating in February**.
- Populations may **decline to 20-30%** of original size; no shifts in demography; no recovery observed yet.
- Part of the adult population successfully overcomes infection and reproduces yearly.
- Disease dynamics clearly influenced by environment, especially **temperature**.

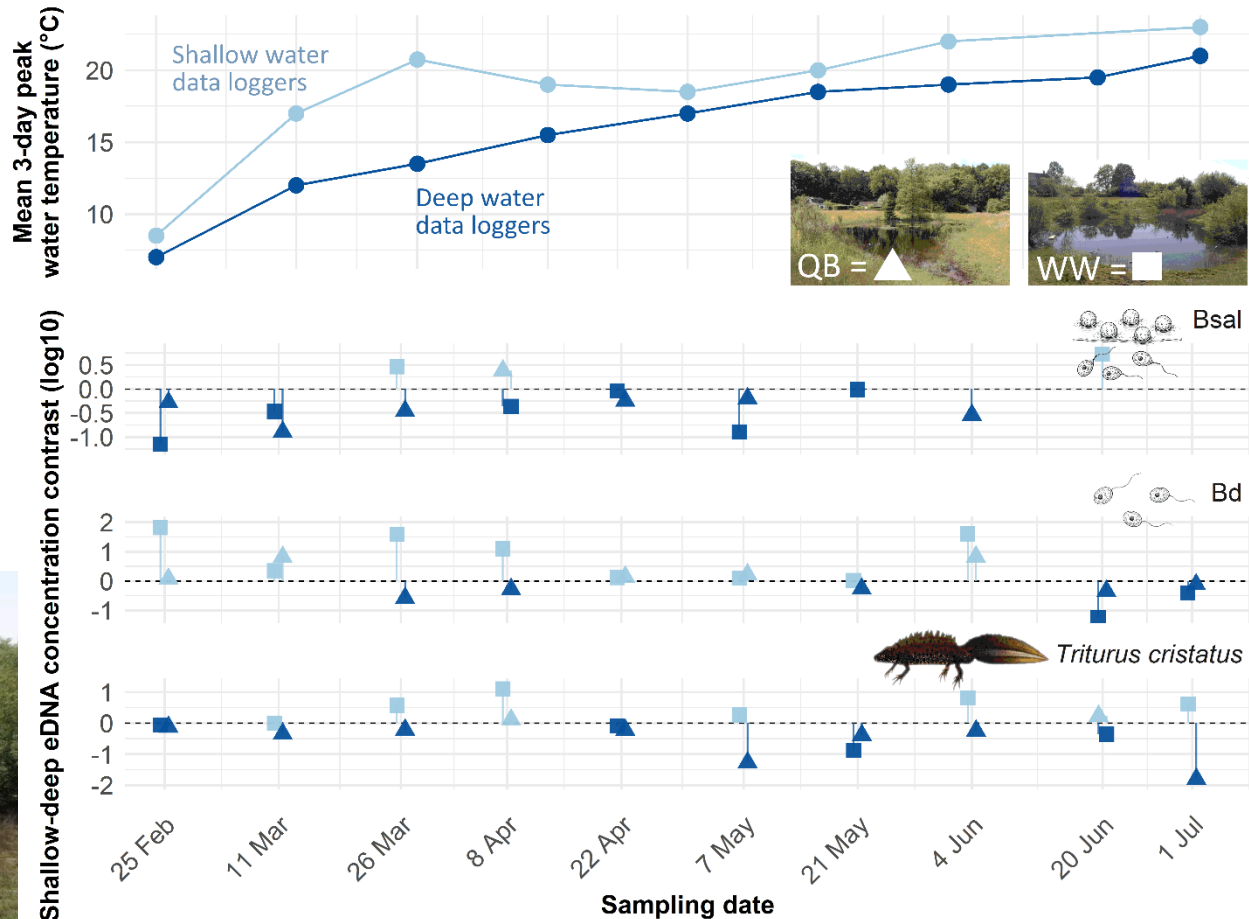


eDNA research: Bsal at different pond depths



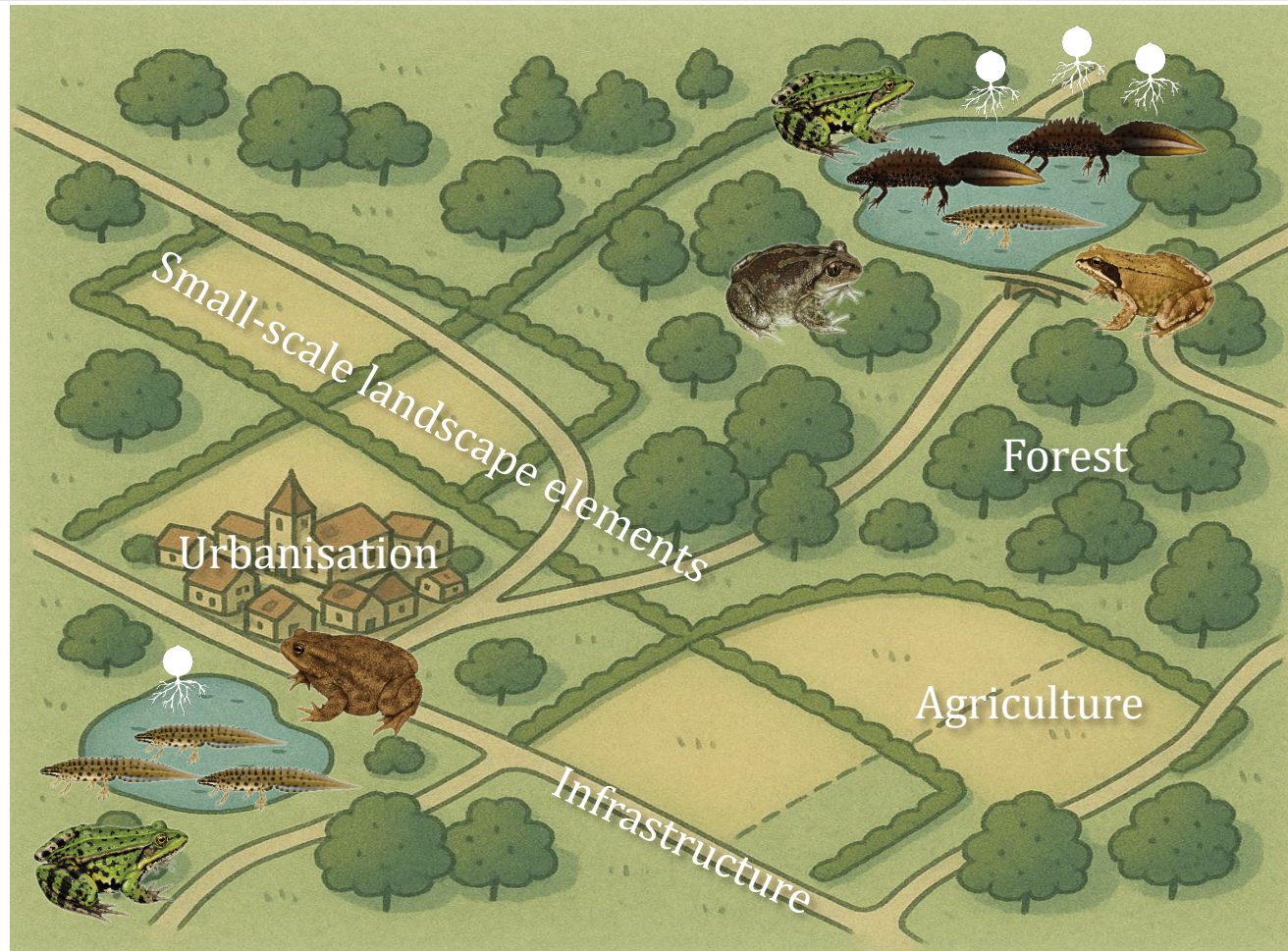
eDNA research: Bsal at different pond depths

- Deeper, colder pond layers are a Bsal refuge.
- Bsal 'disappears' in the beginning of June.



Influence of environment and community (no results yet)

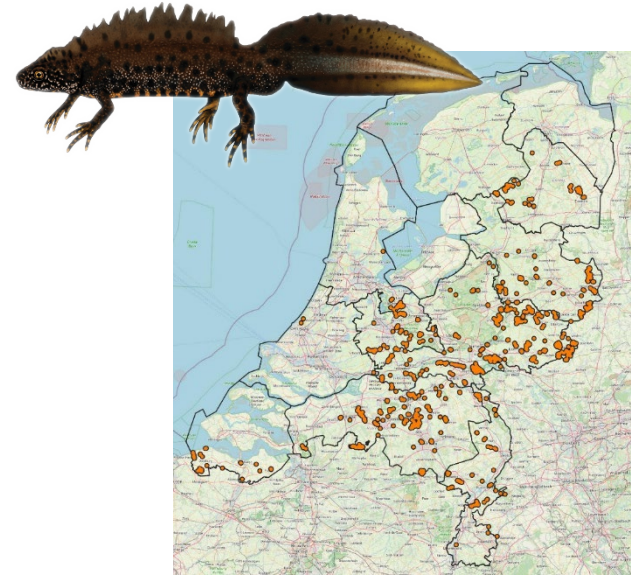
- Quantitative eDNA (ddPCR) of 45 ponds.
- Bd, Bsal, amphibian community.
- Local and landscape environmental factors.



- 33/xx



Towards mitigation – providing perspective



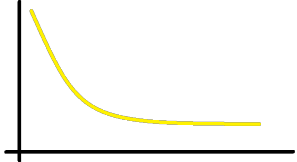
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Towards mitigation

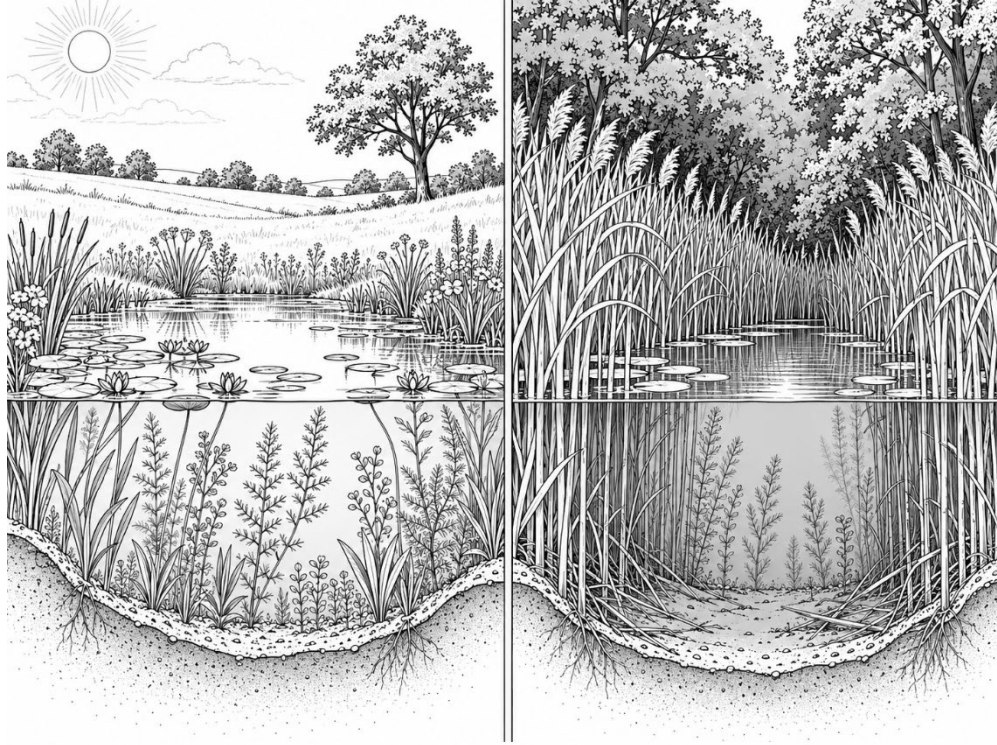
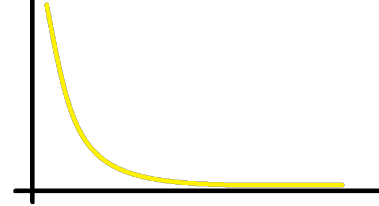
- Ongoing research / work in progress - this is not the whole story. But...
- Conservation efforts need to **prioritize management of host populations and their environments.**
- Promising avenues:
 - *Pond management*
 - *Pond design*
 - *Improving connectivity*



Timely pond management is essential



- Manage **environment**
- Buy time for **immunity** buildup



Timely pond management is essential

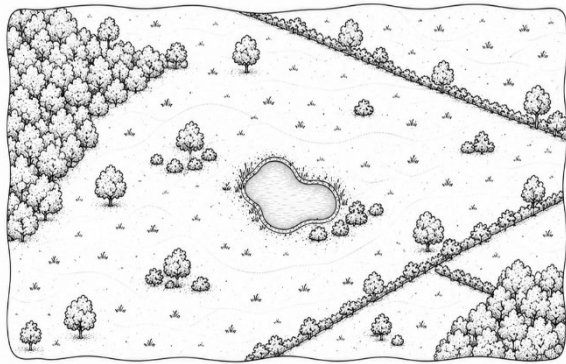
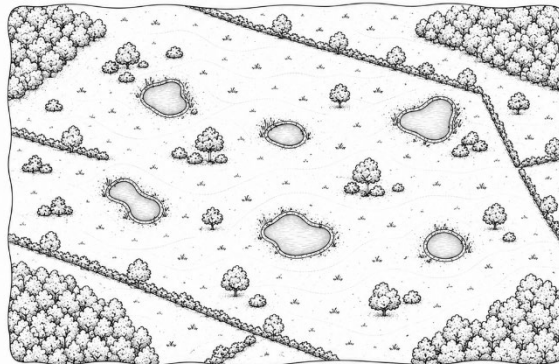
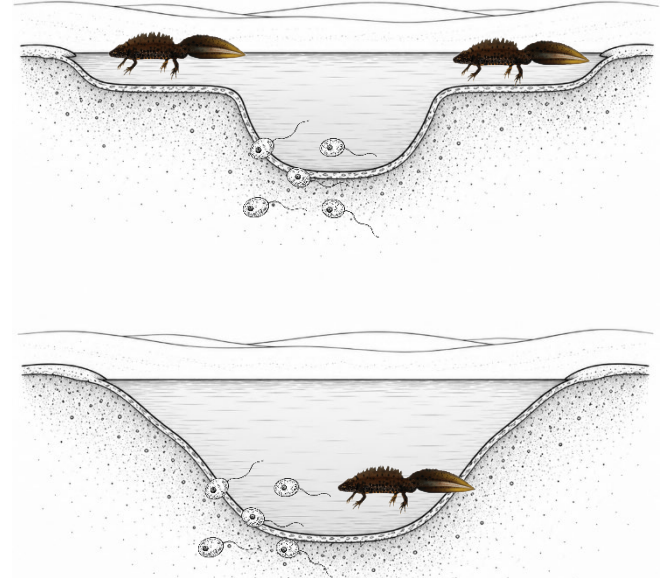


- Manage **environment**
- Provide means for **compensatory recruitment**
- Buy time for **immunity** buildup



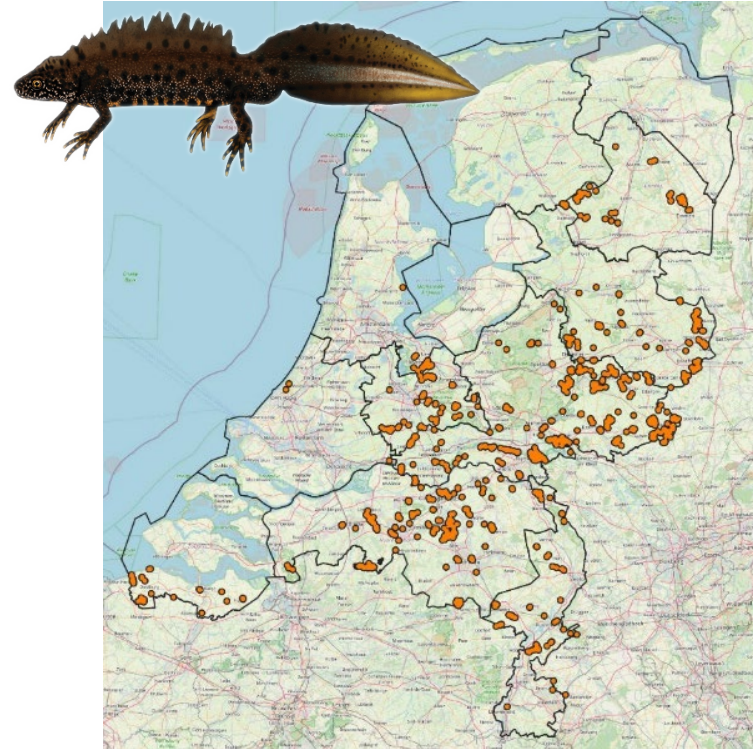
Experimenting with pond design

- Manage **environment**, accommodate shifts in **behaviour**.
- Provide means for **compensatory recruitment**.



Restoring metapopulations

- The majority of Dutch **amphibian populations are not viable / durable** according to (inter)national criteria.
- Vulnerable to stochastic factors, limited environmental heterogeneity.
- Increasing connectivity / restoring metapopulations may also lead to increased spread of invasive species and disease.



You're not telling anything new



Closing remarks

- In a lot of cases, **persistence of infected populations is in the first place contingent on habitat restoration and management** – we need to buy time.
- Disease surveillance and research into other means of Bd-Bsal mitigation (e.g. bioaugmentation, vaccination) remains important. Yet, such research, and maintaining ex-situ populations, is costly.
- Part of the solution lies in conservation actions that we already take. **Plan and optimize chytrid mitigation actions accordingly.**



Many thanks to...

Karin Akkers, Arwen Baggen, Niklas Banowski, Joyce Beenen, Jesper Berndsen, Philipp Böning, David Broek, Sofie De Bruyckere, Rein Brys, Charles Duchatel, Max van Elsen, Teun Everts, Léa Fieschi-Méric, Maarten Gilbert, Wim Hakvoort, David Halfmaerten, Luc Haverhals, Jelger Herder, Matthijs Hollanders, Jan en Heleen Hoogland, Jöran Janse, Jan Kranenbarg, Naomi Lambrixx, Pieter de Leeuw, Stefan Lötters, Jesse Looren de Jong, Albert van de Maat, An Martel, Tom en Marleen van der Meulen, Kevin Mulder, Sabrina Neyrinck, Martin van Oosterhout, Rowen Post, Emily Louise Pascoe, Frank Pasmans, Erna Pieters-van Wageningen, Thijs Schippers, Wendy van Sligter, Annemarieke Spitzen, Ellen ter Stege, Tariq Stark, Erwin Virginia, Wouter de Vries, Ronald Zollinger & all terrain owners in and near Zutphen



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Questions?