Monitoring biodiversity using environmental DNA: the future is already here.

Kristina Cermakova & Jan Pawlowski, Geneva

ID-GENE
ecodiagnostics

Research Symposium SNP+ in Zernez, June 2, 2023

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Environmental DNA (eDNA)

All the **genetic material (DNA)** from living organisms or their traces (skin cells, mucus, scales, urine, feces, saliva, gametes or decomposing bodies) present in the environment (water, soil, biofilm, etc.)

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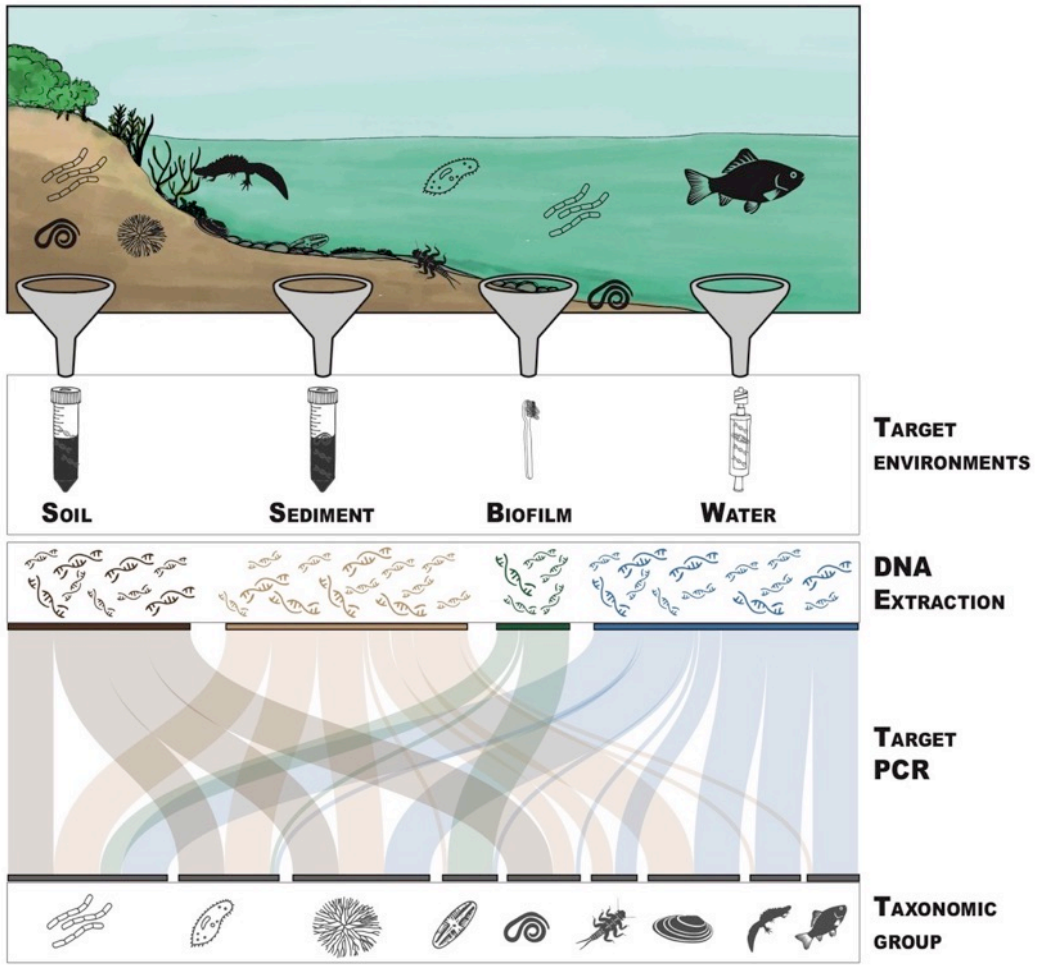
NEWS AND VIEWS
OPINION

MOLECULAR ECOLOGY WILEY

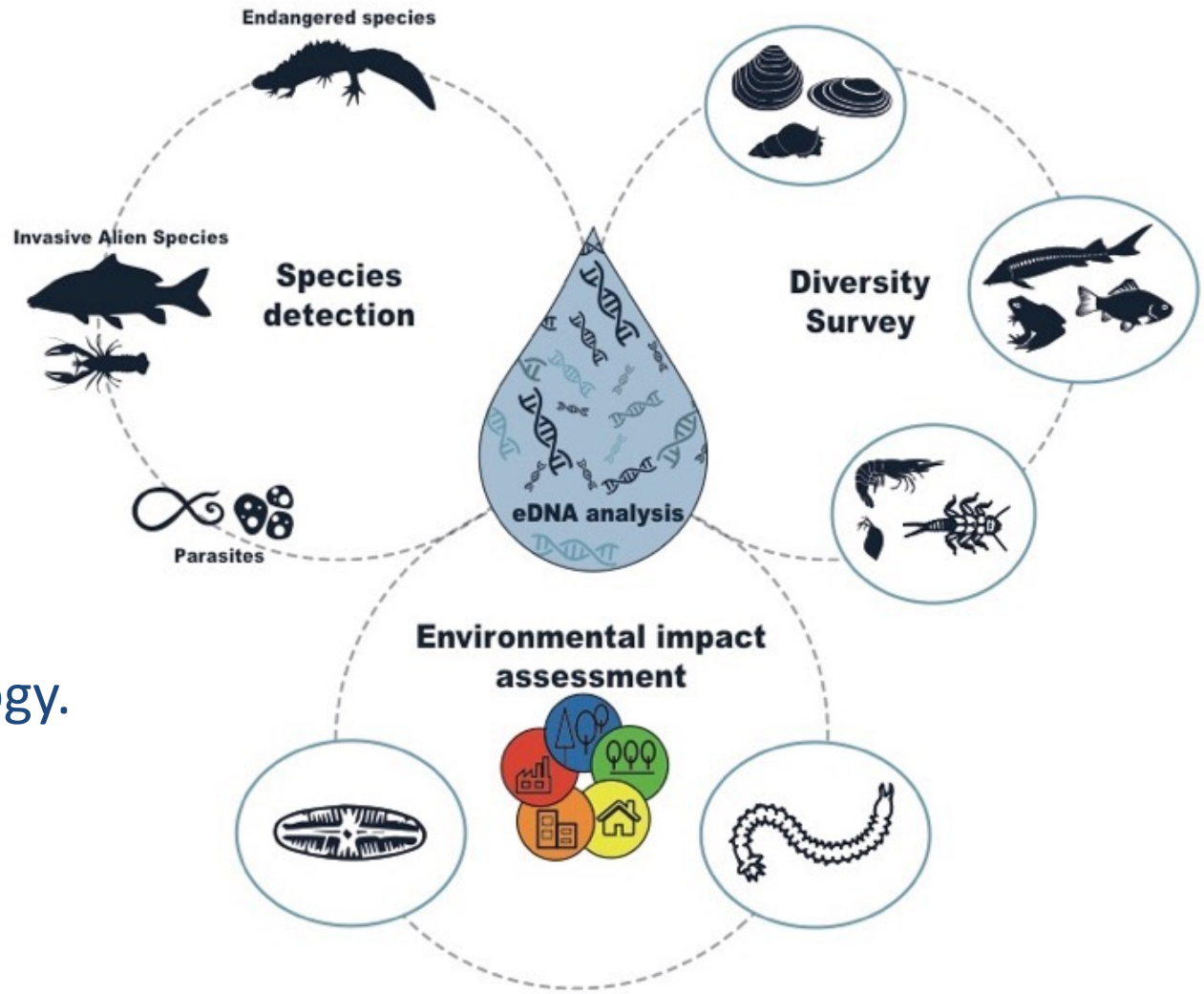
Environmental DNA: What's behind the term? Clarifying the terminology and recommendations for its future use in biomonitoring

Jan Pawlowski[1,2,3] | Laure Apothéloz-Perret-Gentil[1,2] | Florian Altermatt[4,5]

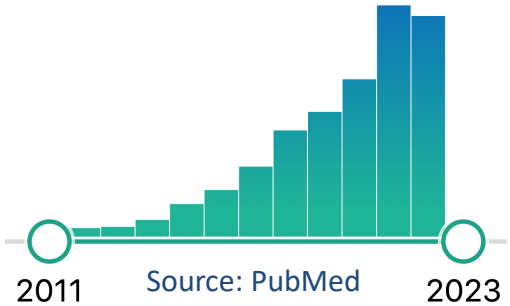


eDNA applications

- Species detection and identification
- Biomonitoring and biodiversity survey
- Environmental impact assessment (biotic indices)

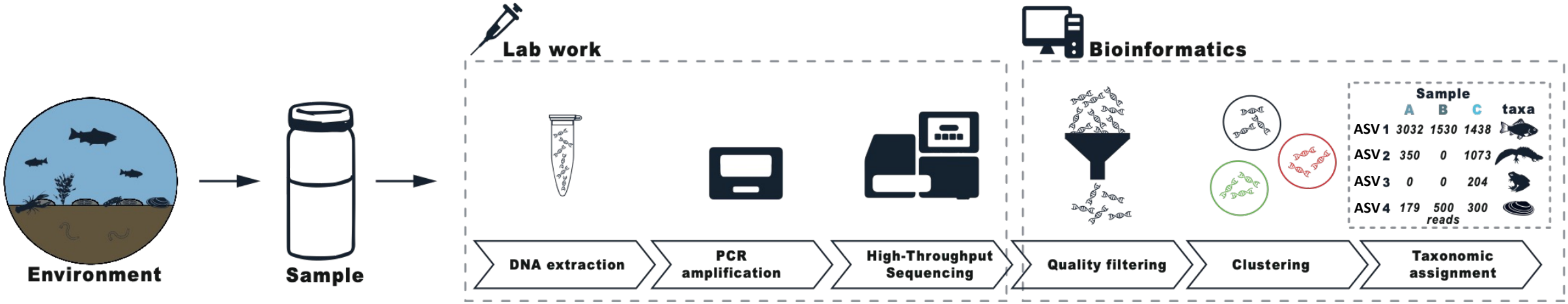


Metabarcoding approach uses high-throughput sequencing technology.



Number of publications on metabarcoding, per year

Metabarcoding workflow



*PCR = chain reaction using polymerase enzyme

Pre- and post-amplification laboratory analyses are conducted in separated rooms.

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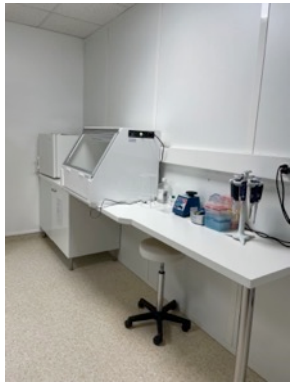
Extraction



PCR

Post-PCR

Sequencing

Holistic approach to biodiversity

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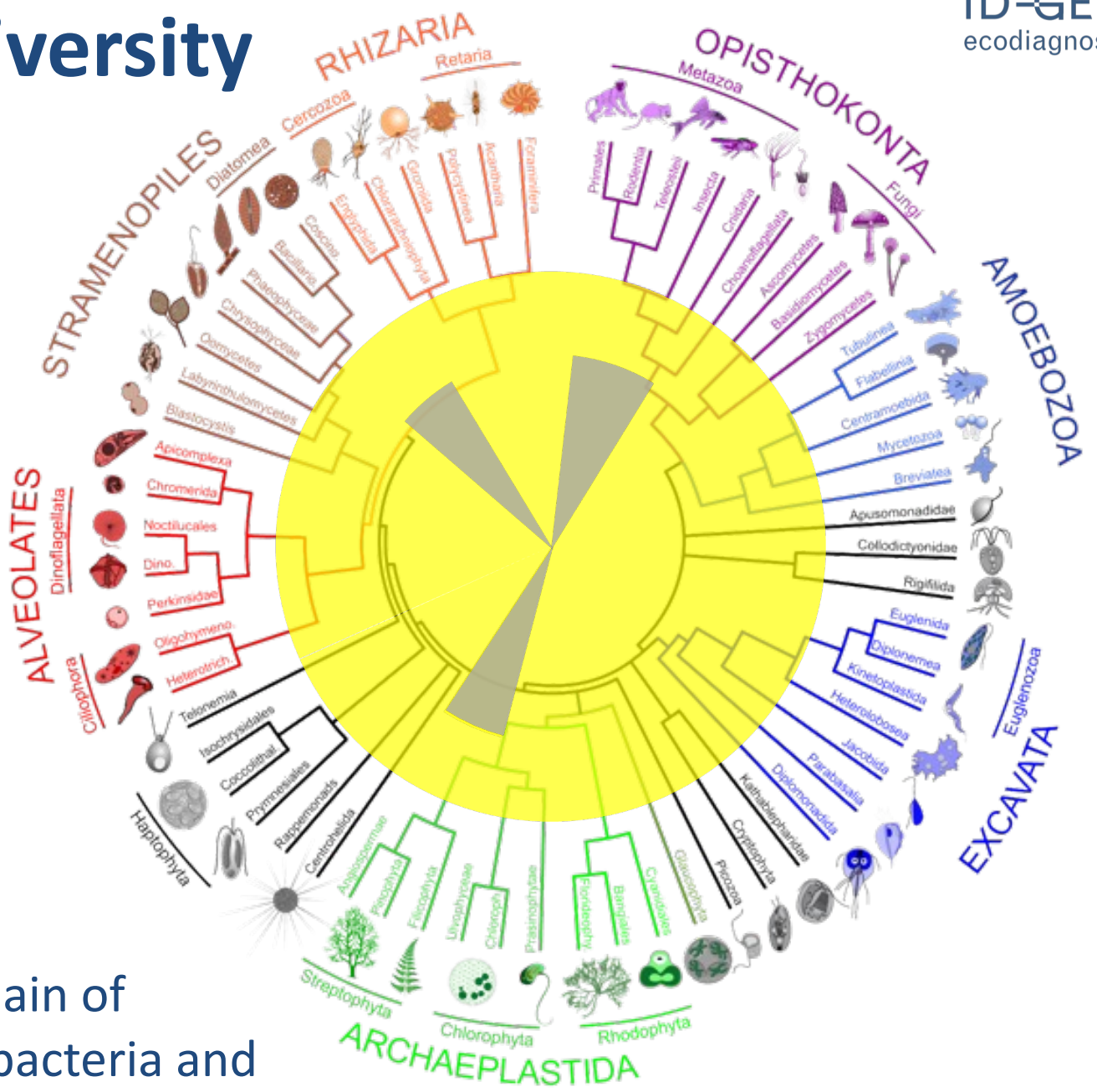
The same environmental sample allows to study eDNA of all the organisms of the Tree of life, from bacteria to animals

groups studied with the Biology module of the Swiss system for analysing watercourses

groups studied with the eDNA approach



Tree of life of the domain of eukaryotes (domains bacteria and archea are not represented)

Holistic biodiversity inventories

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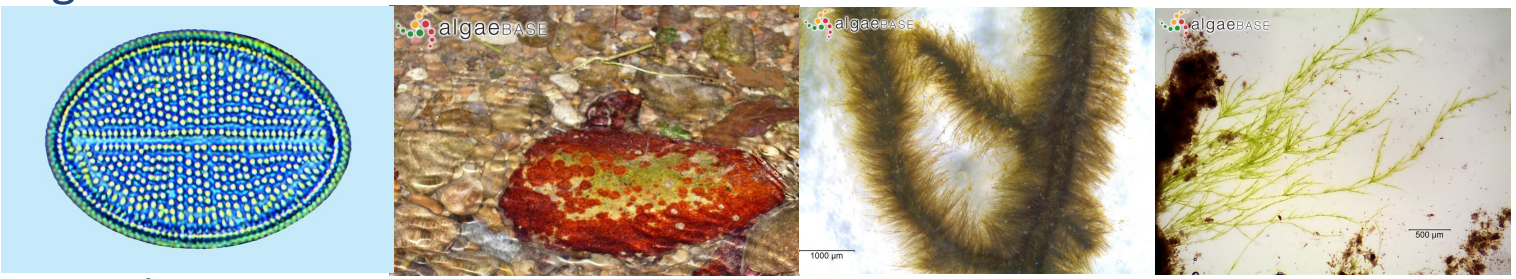
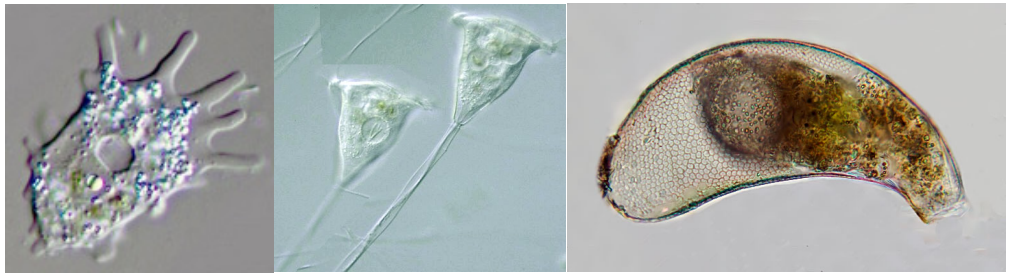
Algae



Protists



Meio-/micro-invertebrates

Macro-invertebrates

Vertebrates

Fish community survey

Species	Common name	Status CH	Drize	Aire	Allondon	Vengeron	Versoix	Seymaz
Salmo labrax	Black Sea salmon	Critically Endangered	X		X		X	X
Thymallus thymallus	European grayling	Endangered			X		X	
Alburnoides bipunctatus	Spirlin	Vulnerable	X					X
Telestes souffia	Souffia	Vulnerable						X
Barbatula barbatula	Stone loach	Near Threatened		X	X		X	X
Barbus barbus	Common barbel	Near Threatened			X		X	X
Cottus gobio	European bullhead	Near Threatened			X		X	
Salmo trutta/trutta fario	Brown trout	Near Threatened	X	X	X		X	X
Esox lucius	Northern pike	Least Concern					X	
Gobio gobio	Gudgeon	Least Concern		X	X		X	X
Perca fluviatilis	European perch	Least Concern	X				X	X
Phoxinus phoxinus	Common minnow	Least Concern	X	X	X	X	X	X
Rutilus rutilus	Common roach	Least Concern	X	X	X		X	X
Squalius cephalus	European chub	Least Concern	X	X	X		X	X
Tinca tinca	Tench	Least Concern						X
Ameiurus nebulosus/melas	Brown/Black bullhead	Introduced	X				X	X
Gasterosteus aculeatus	Three-spined stickleback	Introduced					X	
Lepomis gibbosus	Pumpkinseed	Introduced	X				X	X
Oncorhynchus mykiss	Rainbow trout	Introduced	X	X			X	

Black Sea salmon

European Grayling

Spirlin

Souffia

Common barbel

Congruence of eDNA and conventional inventories:

	eDNA (2022)	conventional method
Vengeron	1 species	0 species in 2021
Seymaz	13 species	13 species in 2019

Photos: species.infofauna.ch et sfv-fsp.ch

Protected species survey

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Metabarcoding allows to detect all species of newts in Switzerland.

Lissotriton helveticus

Lissotriton vulgaris

Lissotriton vulgaris meridionalis

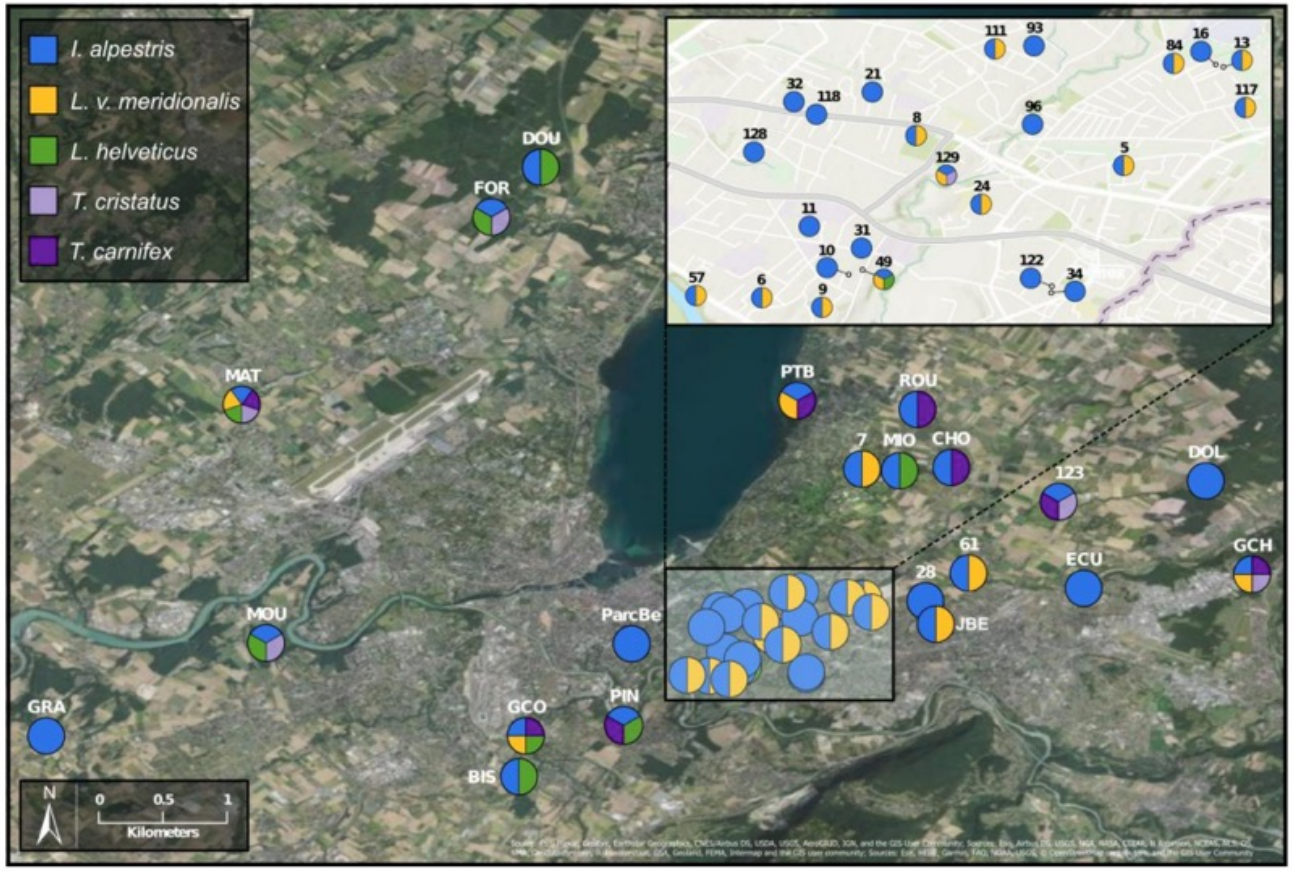
Ichthyosaura alpestris

Triturus cristatus/carnifex

Photos: karch.ch

Monitoring newt communities in urban area using eDNA metabarcoding

Léo Charvoz[1], Laure Apothéloz-Perret-Gentil[1,2], Emanuela Reo[1], Jacques Thiébaud[3] and Jan Pawlowski[1,2,4]



Invasive species detection

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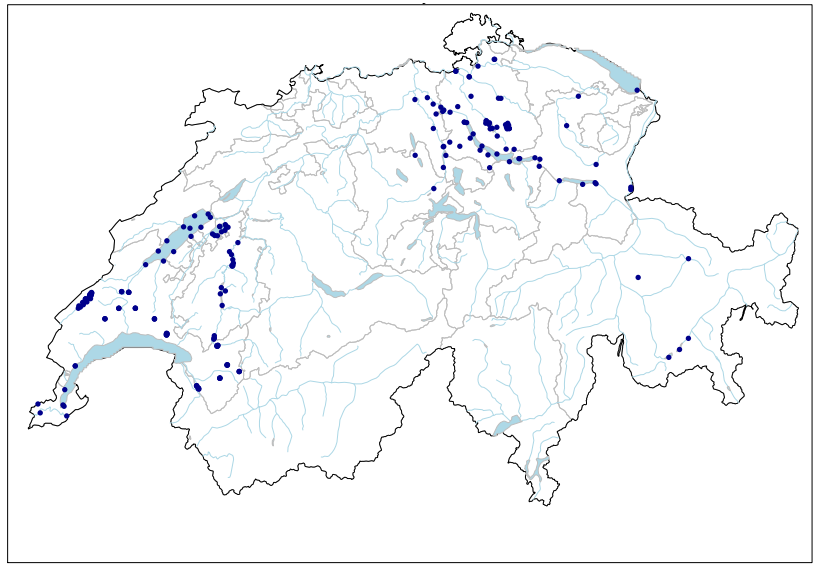
Invasive species monitoring
is recommended by Swiss Federal Office for the Environment and conducted by the cantons.

ID-Gene projects:

- Canton Vaud
- Canton Zürich
- Canton St. Gall
- Canton Argovie
- Canton Grisons
- Canton Geneva



Dreissena bugensis

Corbicula fluminea

Neogobius melanostomus

Ponticola kessleri

Dikerogammarus villosus

Crangonyx pseudogracilis

Physella acuta

Pacifastacus leniusculus

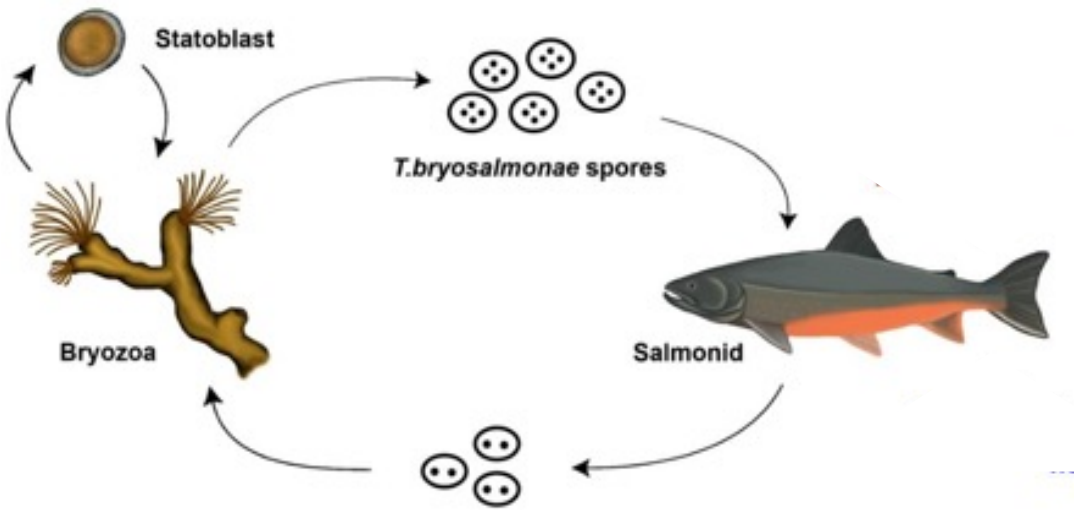
Pathogen detection in water samples

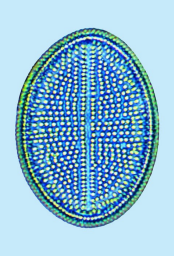
Crayfish pathogens:

- Oomycete *Aphanomyces astaci* causing the Crayfish plague

Fish pathogens:

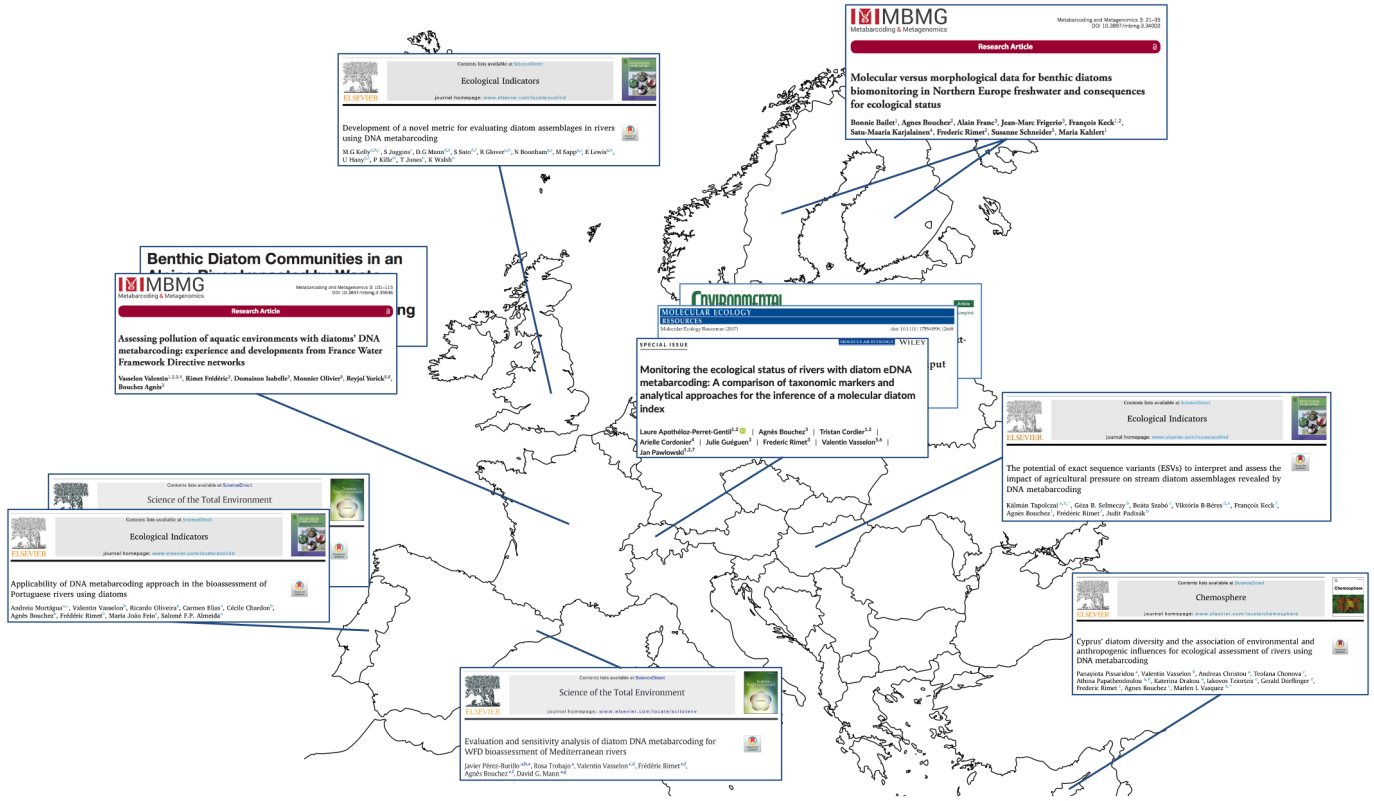
- Oomycete *Saprolegnia parasitica* causing saprolegniasis
- Cnidarian *Tetracapsuloides bryosalmonae* causing the Proliferative kidney disease (PKD)

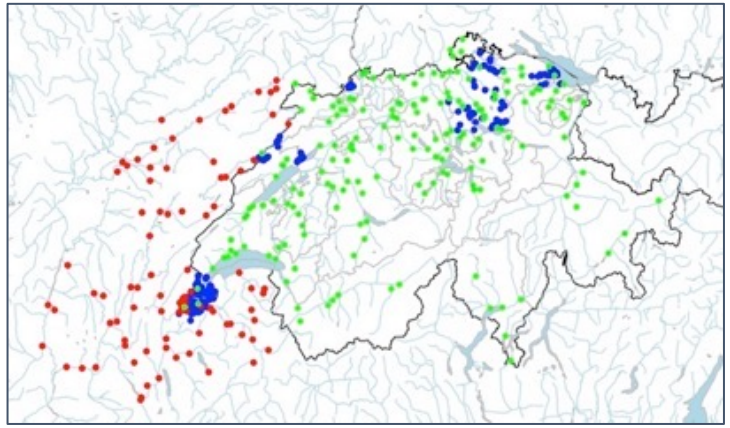


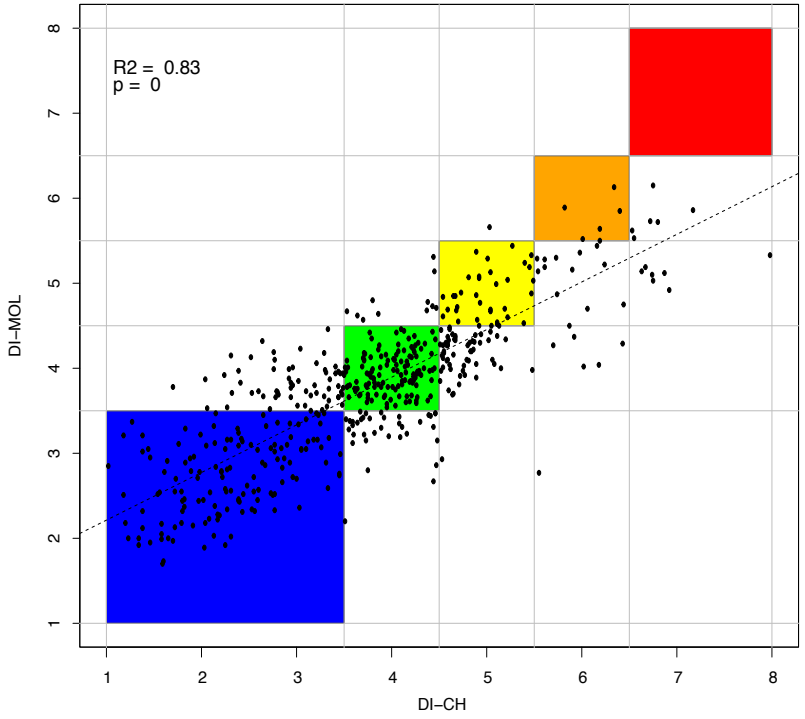


Diatom Molecular Index

DNA-based diatom molecular index has been successfully developed in Switzerland and other European countries showing excellent correlation between molecular and morphological data.







Ring Test: https://www.youtube.com/watch?v=uTM_ReSPtFk

Guidelines

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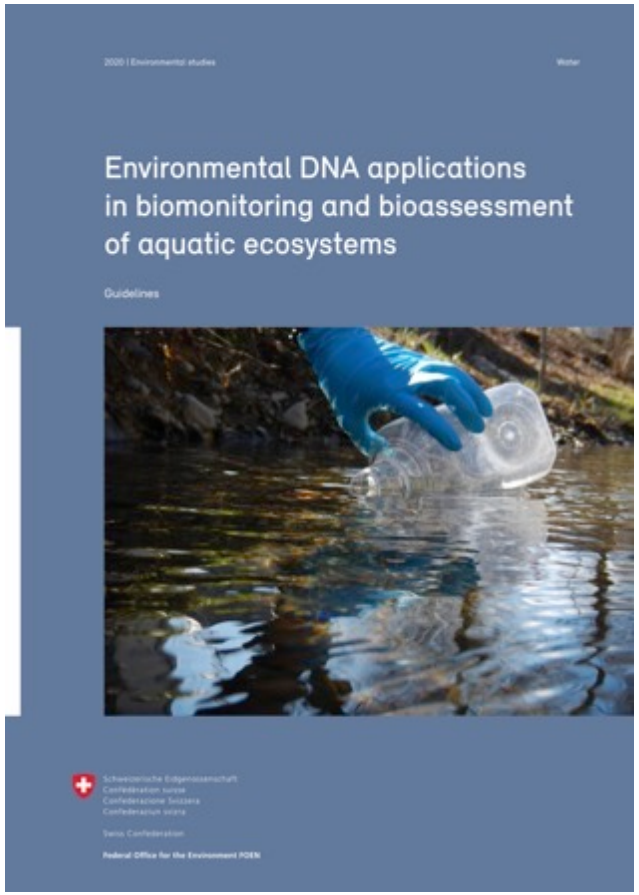

2020

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illumina https://ilmnmkt.illumina.com/2016011140

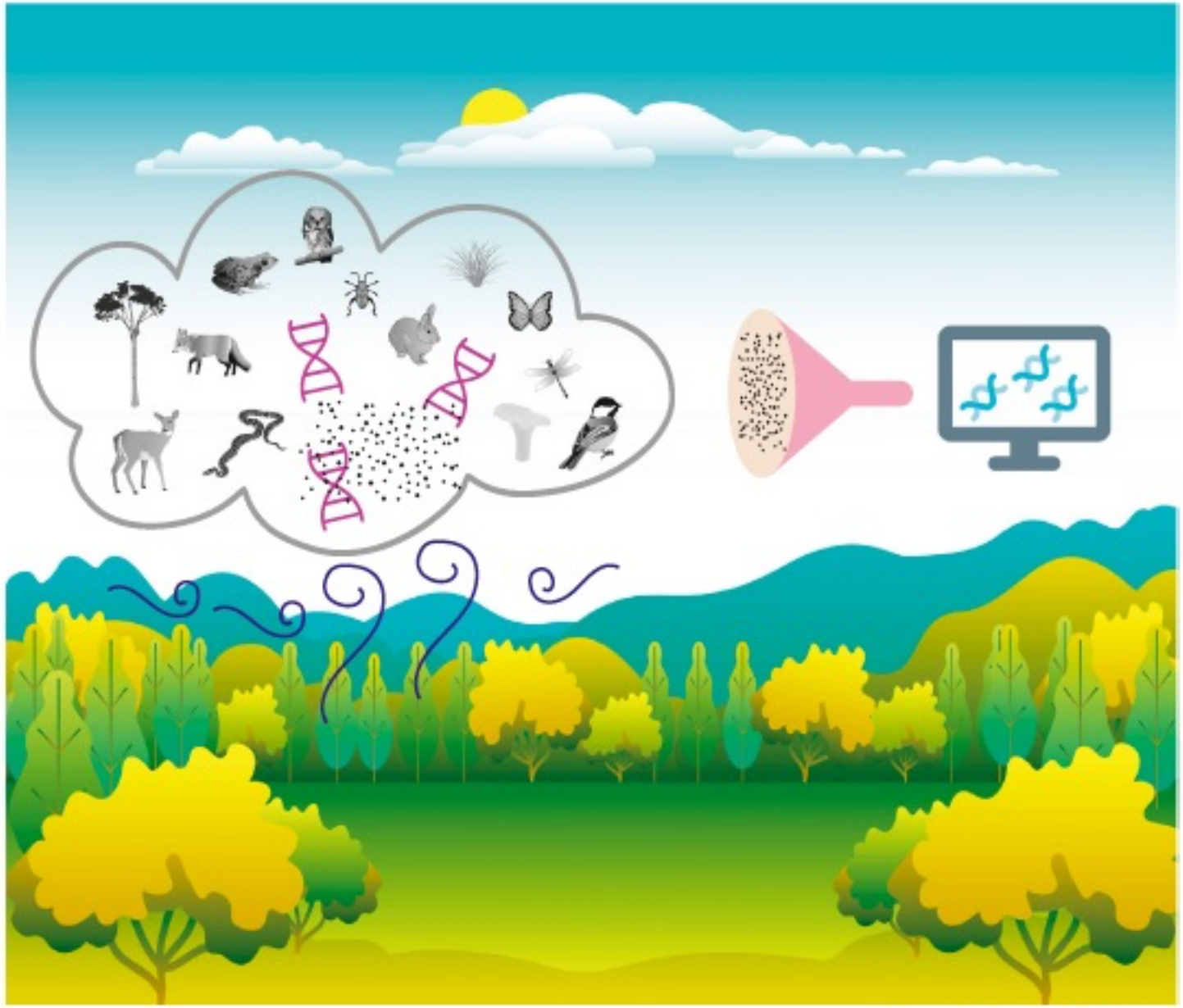
- What is environmental DNA, or eDNA?
- How is eDNA analysis applied for biomonitoring of aquatic ecosystems?
- What are the steps of the eDNA sequencing workflow, from field to lab?
- What are the current challenges and future directions for a wider implementation of eDNA sequencing in routine environmental monitoring?

Perspectives
- Airborne eDNA

measuring biodiversity from DNA in the air

Pilot studies:

- Vertebrates (Lynggaard et al. 2022)
- Insects (Pumkaeo et al. 2021, Roger et al. 2022)
- Plants (Johnson et al. 2021)
- Microbes (de Groot et al. 2021, Gusareva et al. 2022)



Bohmann & Lynggaard 2022

Trends in Ecology & Evolution

Challenges and limitations

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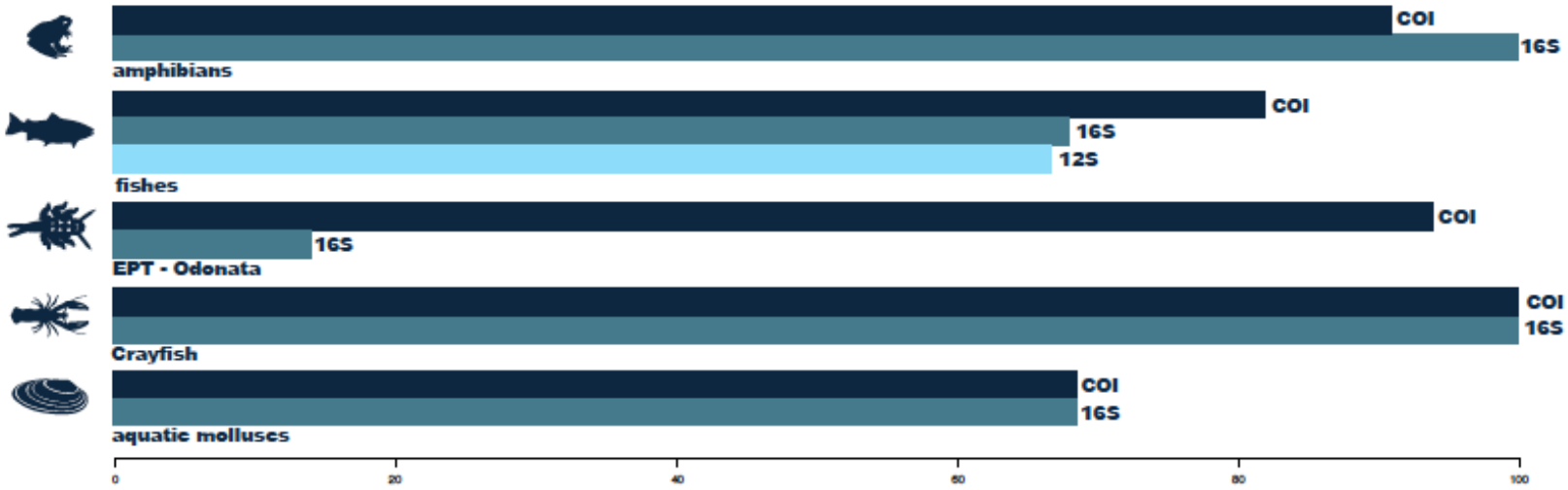
Completing barcoding reference databases

SwissBOL

Swiss Barcode of Life
A genetic inventory of Swiss biodiversity



eDNA does not allow:

- Inferring species abundance
- Detecting changes of any morphological features
- Evaluating physiological state (population age)
- Detecting hybridization

Advantages of eDNA

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Easy and non-invasive sample collecting without toxic fixative substances

Sensitivity – early detection and detection of rare or elusive species

Processing in batches using standardized protocols and automated processes – volume, reproducibility

Biotic indices can be inferred from molecular data, congruency with morphological approach

Fast pipeline - results within few weeks

Conclusion

Metabarcoding approach allows processing of higher numbers of samples and thus allows better coverage and higher frequency of monitorings compared to morphological analysis.

Whole biodiversity from bacteria to animals can be assessed simultaneously from a sample.

- Metabarcoding is a robust ready-to-use tool with potential to improve biomonitoring.

Our partners in Switzerland

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canton de vaud

Kanton Graubünden
Chantun Grischun
Cantone dei Grigioni

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
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Bundesamt für Umwelt BAFU
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THANK YOU FOR YOUR ATTENTION!

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