Restauro ecológico: estratégias para um futuro sustentável”

Maria João Feio

24–25 novembro 2025
FLAD
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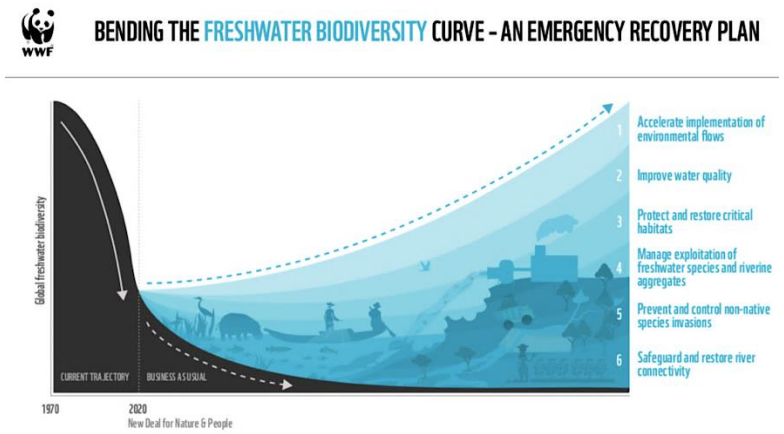
U C
Universidade de Coimbra
MARE
AR NET
Freshwater Ecology

Que futuro para os rios?



Ambio 2021, 50:85–94
https://doi.org/10.1007/s13280-020-01318-8

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PERSPECTIVE

Scientists' warning to humanity on the freshwater biodiversity crisis

James S. Albert, Georgi
Anne E. Magurran, Thi
Kirk O. Winemiller, Willia

Science

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LETTER

The freshwater biodiversity crisis

IAN HARRISON, ROBIN ABELL, WILLIAM DARWALL, MICHELE L. THIEME, DAVID TICKNER, AND INGRID TIMBOE Authors Info & Affiliations

SCIENCE • 21 Dec 2018 • Vol 362, Issue 6421 • p. 1369 • DOI: 10.1126/science.aav9242

Over 450 scientists urge the EU to keep its waters clean and healthy

Posted on March, 24 2025

Scientists are rallying for action against 'forever chemicals' in EU waters.

Hundreds of harmful substances are being detected in our rivers, posing serious risks to aquatic life and our access to clean water. Alarmingly, less than 50% of Europe's water bodies are in good health today.

Current EU monitoring practices are failing citizens, as they rely on an outdated and limited list of pollutants, leaving many harmful substances unchecked.

As the European Commission, EU Member States, and the European Parliament discuss EU water pollution standards in trilogue negotiations, over 450 scientists are urging them to address the increasing threat of chemical pollution, including PFAS ('forever chemicals'), in Europe's freshwater ecosystems.

Read their letter here.

Less than 50% of Europe's water bodies are in good health today.
© Getty Images

NOS NOUVELLES

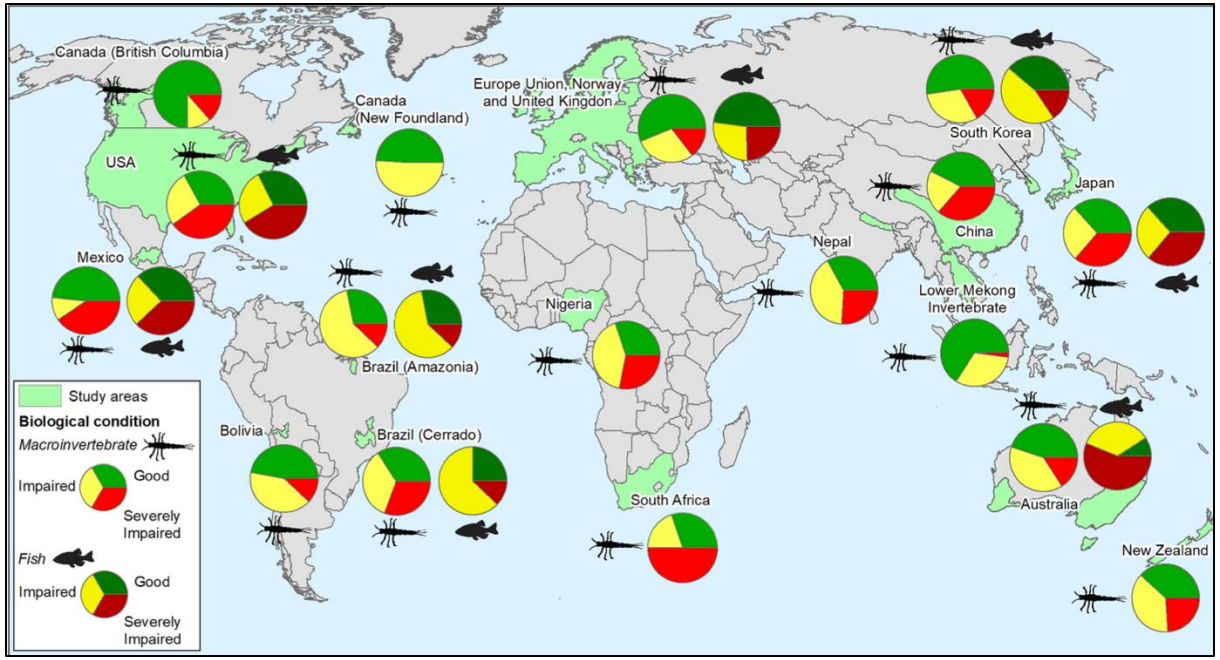
5,500+ scientists call on European Commission to defend the EU water law

Posté le **6 décembre 2019**

Scientists and academics concerned by the dire state of European rivers, lakes and wetlands have released a statement calling on the EU to fully implement and enforce its own water law - the EU Water Framework Directive (WFD) - in order to halt and reverse the catastrophic decline in the world's freshwater biodiversity.

Resultados da avaliação ecológica dos rios

Macroinvertebrados: 72,275 locais
Peixes: 37,676 locais
64 regiões, 45 países



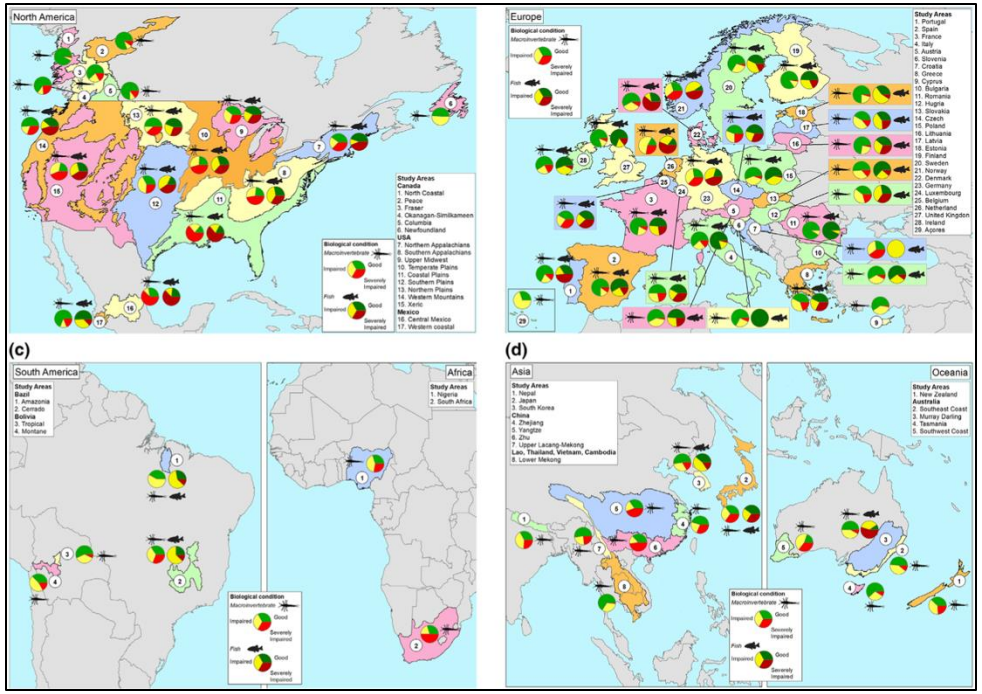
Received: 3 February 2022 | Revised: 6 August 2022 | Accepted: 2 September 2022
DOI: 10.1111/gcb.16439

RESEARCH ARTICLE

Global Change Biology WILEY

Fish and macroinvertebrate assemblages reveal extensive degradation of the world's rivers

Maria João Feio[1] | Robert M. Hughes[2,3] | Sónia R. Q. Serra[1] | Susan J. Nichols[4] | Ben J. Kefford[4] | Mark Lintermans[4] | Wayne Robinson[5] | Oghenekaro N. Odume[6] | Marcos Callisto[7] | Diego R. Macedo[8] | Jon S. Harding[9] | Adam G. Yates[10] | Wendy Monk[11] | Keigo Nakamura[12] | Terutaka Mori[13] | Masanao Sueyoshi[13] | Norman Mercado-Silva[14] | Kai Chen[15,16] | Min Jeong Baek[17] | Yeon Jae Bae[18] | Ram Devi Tachamo-Shah[19] | Deep Narayan Shah[20] | Ian Campbell[21] | Nabor Moya[22] | Francis O. Arimoro[23] | Unique N. Keke[23] | Renato T. Martins[24] | Carlos B. M. Alves[25] | Paulo S. Pompeu[26] | Subodh Sharma[27]



O que ter em conta para um restauro sustentável…


water

Review

The Biological Assessment and Rehabilitation of the World's Rivers: An Overview

Maria João Feio [1,*], Robert M. Hughes [2,3], Marcos Callisto [4], Susan J. Nichols [5], Oghenekaro N. Odume [6], Bernardo R. Quintella [7,8], Mathias Kuemmerlen [9], Francisca C. Aguiar [10], Salomé F.P. Almeida [11], Perla Alonso-EguíaLis [12], Francis O. Arimoro [13], Fiona J. Dyer [5], Jon S. Harding [14], Sukhwan Jang [15], Philip R. Kaufmann [3,16], Samhee Lee [17], Jianhua Li [18], Diego R. Macedo [19], Ana Mendes [20], Norman Mercado-Silva [21], Wendy Monk [22], Keigo Nakamura [23], George G. Ndiritu [24], Ralph Ogden [25], Michael Peat [26], Trefor B. Reynoldson [27], Blanca Rios-Touma [28], Pedro Segurado [8] and Adam G. Yates [29]

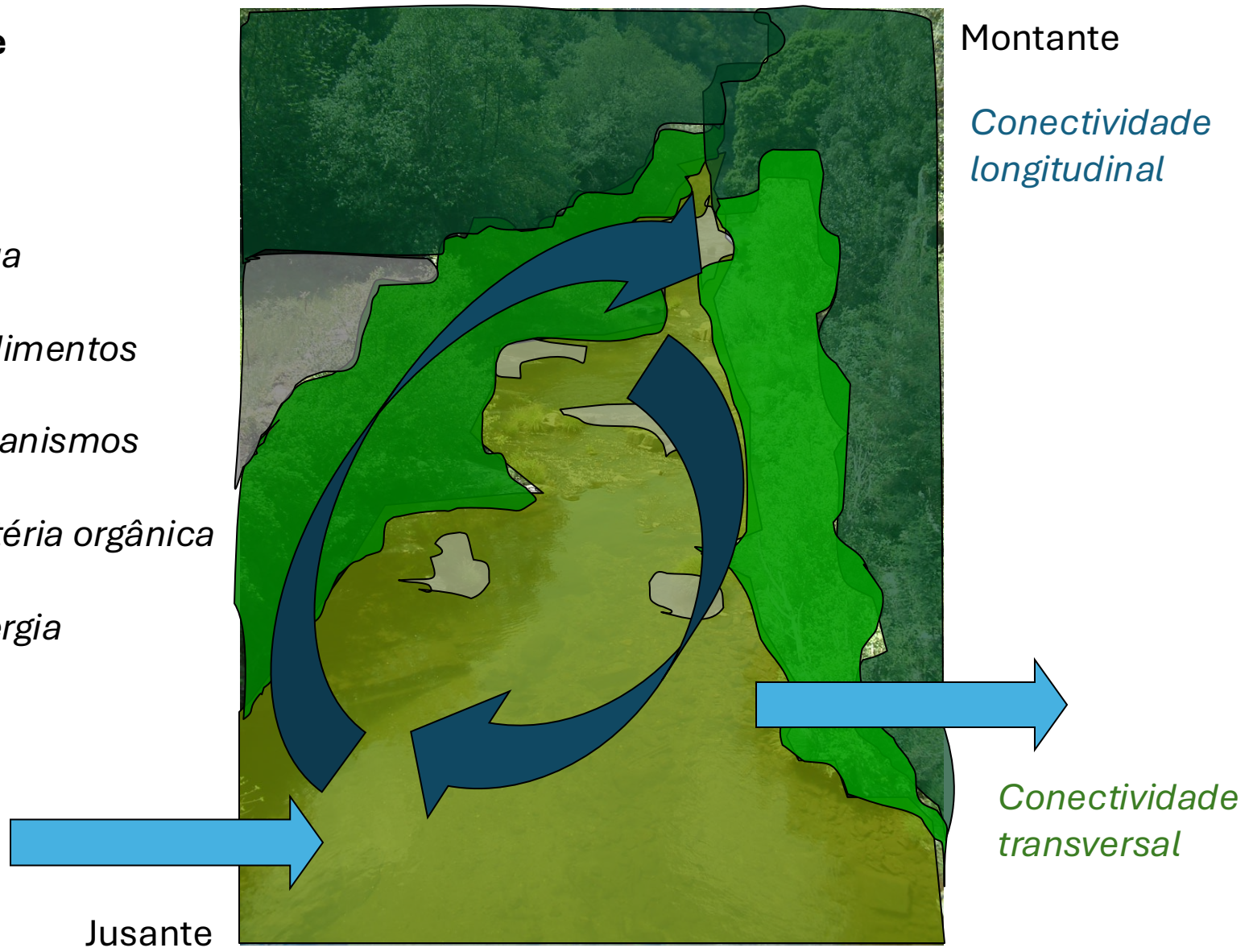
- Utilizar e fomentar o **conhecimento aprofundado dos ecossistemas a recuperar: biodiversidade, funções e serviços, pressões (tipo e efeito) – séries temporais, bases de dados, artigos científicos, relatórios, conhecimento internacional**
- Proteger - estabelecimento de **zonas de reserva, fiscalização, monitorização**
- Promover um planeamento e gestão **transdisciplinar**
- Fomentar **a gestão internacional** dos rios
- Investir na **sensibilização/educação**

- Estabelecer **objetivos de restauro realistas mas ambiciosos** (em termos de pressões a reduzir ou eliminar, e de efeitos no ecossistema) - *utilizar simulações do efeito das medidas*
- Usar **técnicas de restauro cientificamente comprovadas**
- Avaliar **o sucesso do restauro com monitorização ecológica** – comparar com valores de referência, monitorização anterior e posterior
- Analisar **criticamente soluções e resultados**

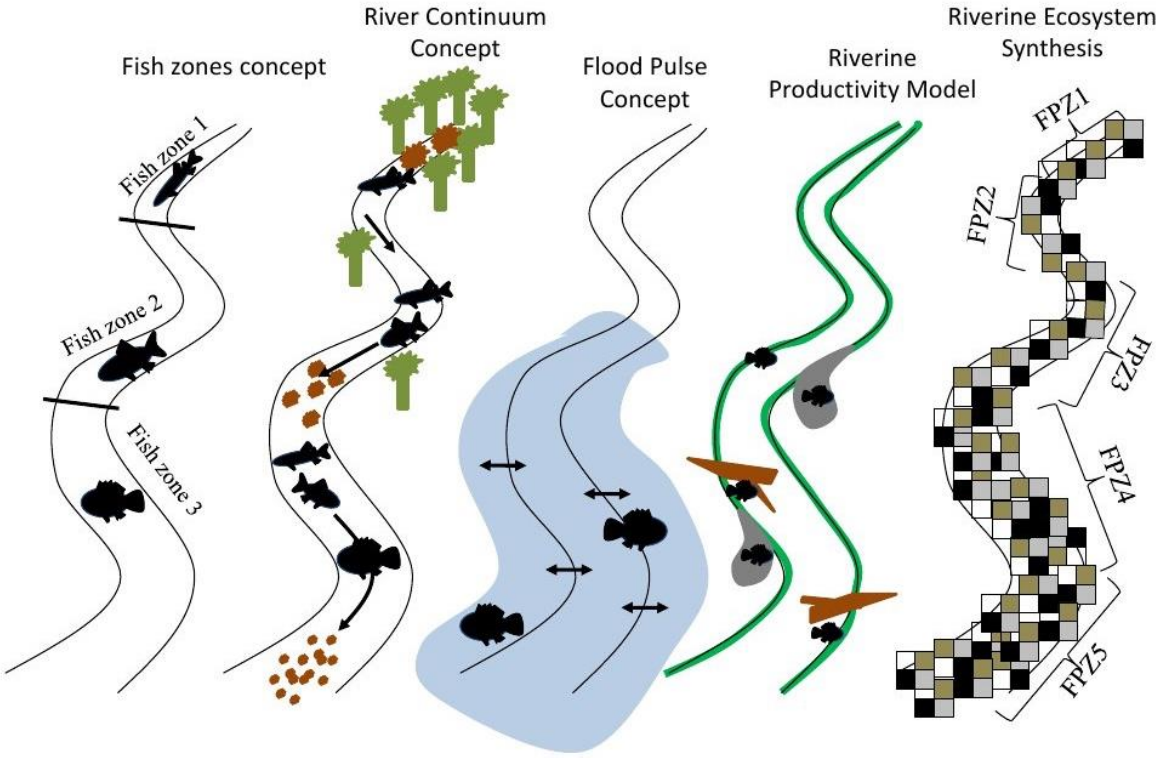
- 17 capítulos. 69 especialistas
- Biodiversidade aquática e Terrestre
- Monitorização
- Pressões
- Restauro

Os ecossistemas ribeirinhos. **Estrutura e Processos funcionais. Água e terra.**

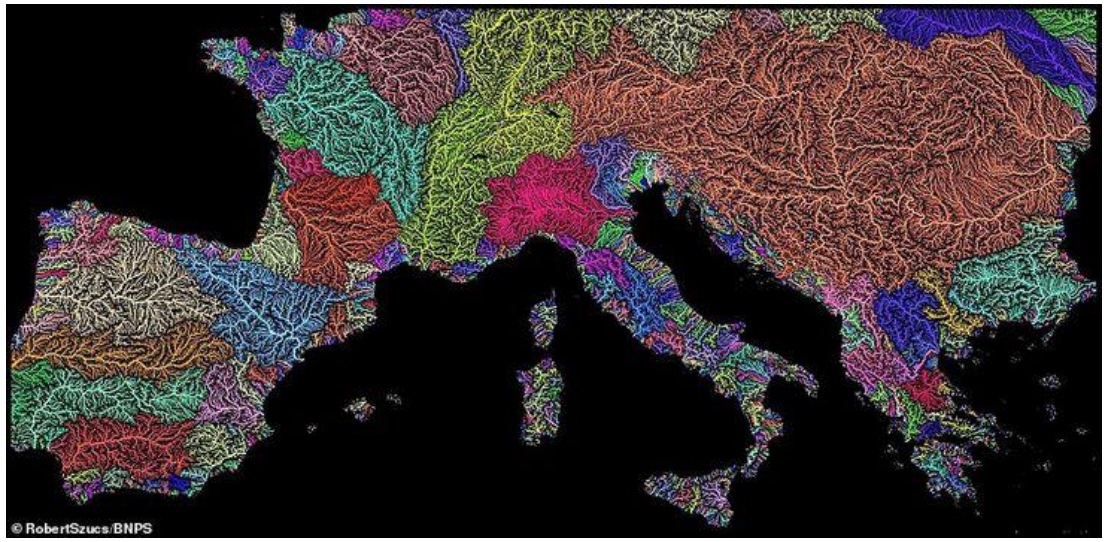
Canal	*Água*
Habitats aquáticos	*Sedimentos*
Taludes/Margens	*Organismos*
Zona ripária	*Matéria orgânica*
Leito de cheia	*Energia*



Os ecossistemas ribeirinhos Variações longitudinais. As bacias hidrográficas.



Humphries, 2012. River Ecology and Research



Os ecossistemas ribeirinhos. **Comunidades ribeirinhas – aquáticas e terrestres.**

Interação entre as espécies

Interação com o meio

Os ecossistemas ribeirinhos

As espécies estão adaptadas às condições locais devido às suas **múltiplas características biológicas (*traits*)** e **portanto também à zonação dos rios,** clima, geologia, etc

Os *traits* biológicos estão indiretamente relacionados com as **funções ecológicas dos organismos** (*Statzner et al.,2001*)

Velocidade da corrente elevada

Animais achatados, com capacidade de fixação e animais mais pequenos.

Habitat theory templet (***Townsend & Hildrew 1994; Townsend, Dolédec, Scarsbrook 1997***)

A avaliação ecológica dos rios portugueses

Em busca das Condições Referência dos rios Portugueses e caracterização das comunidades aquáticas.

Campanha INAG 2004-2005

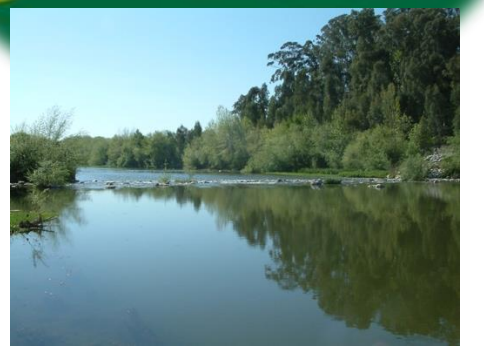












A avaliação ecológica dos rios portugueses

Condição referência

Critérios gerais (*normative definitions of ecological status*)

Qualidade elevada:

Sem ou quase nenhumas alterações de origem antropogénica aos valores fisico-químicos e hidromorfológicos.

Nenhuma distorção aos valores biológicos normais do tipo.

Qualidade boa:

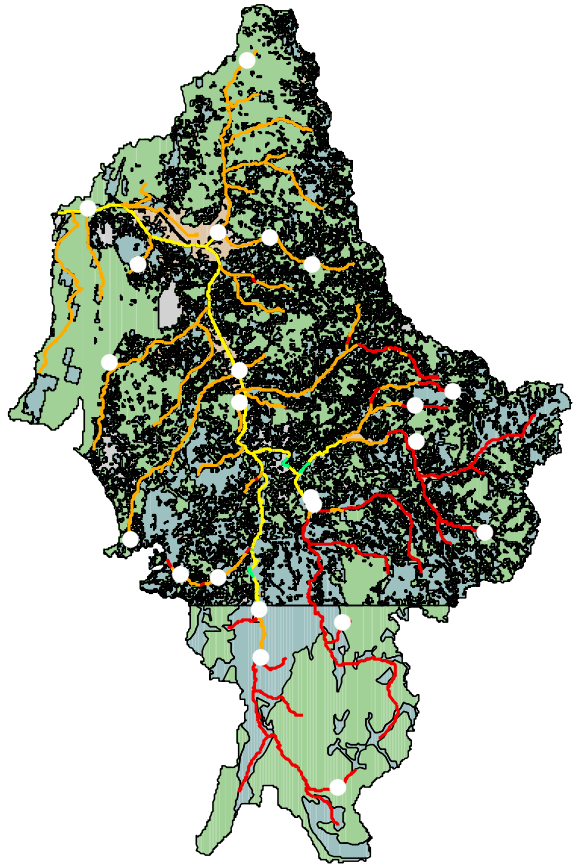
Ligeiros desvios dos valores biológicos aos normalmente associados ao tipo, devido a actividades antropogénicas.

Qualidade moderada:

Ligeiros desvios dos valores biológicos aos normalmente associados ao tipo, devido a actividades antropogénicas.

FQ	Variáveis FAME	Ocupação de Solo
% O2	1 - Ocupação do solo	Agric. intensiva (Drenagem)
O2 (mg/l)	2 - Área urbana	Agric. extensiva (Drenagem)
pH	3 - Zona ripária	Áreas naturais (Drenagem)
Condutividade	4 - Carga de sedimentos	Áreas artificiais (Drenagem)
Oxidabilidade	5 - Regime hidrológico	Agric. intensiva (5 km)
Alcalinidade	6 - Acidificação e toxicidade	Agric. extensiva (5 km)
Dureza	7 - Condição morfológica	
SST	8 – Cont. orgânica e nutrientes	
Nitratos	9 – Mass. água lênticas artificiais	
Nitritos	10 - Conectividade rio/segmento	
Amónia		
N-Total		
P-Total		
Ortofosfatos		

Locais de referência



Campanha INAG 2004-2005

A avaliação ecológica dos rios portugueses

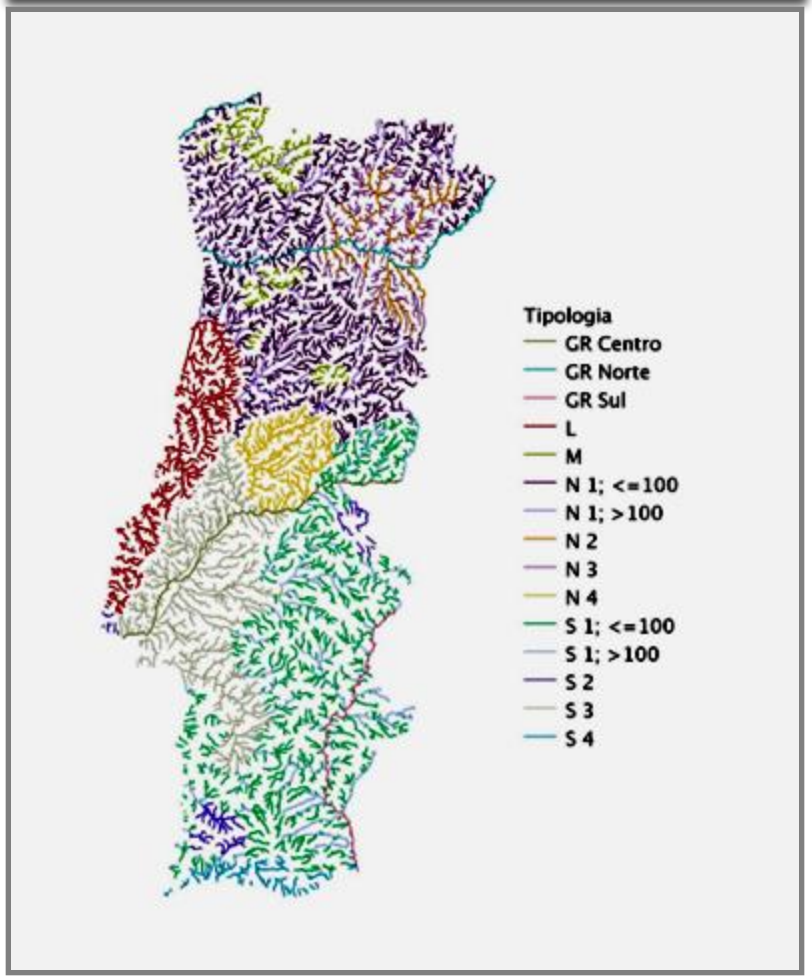
Tipologia de rios *sensu* DQA

27 tipos abióticos

+

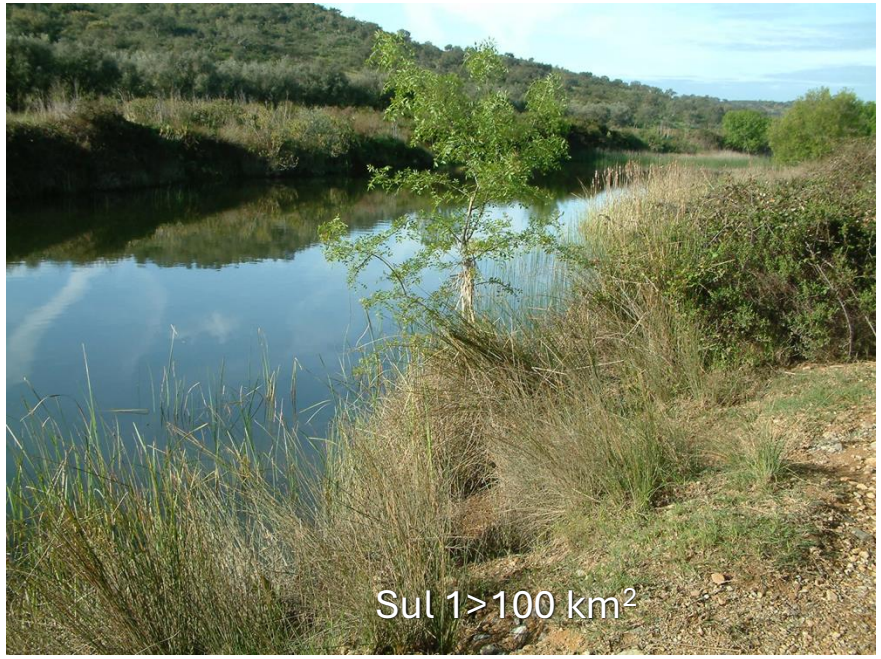
Classificação biológica dos locais de referência

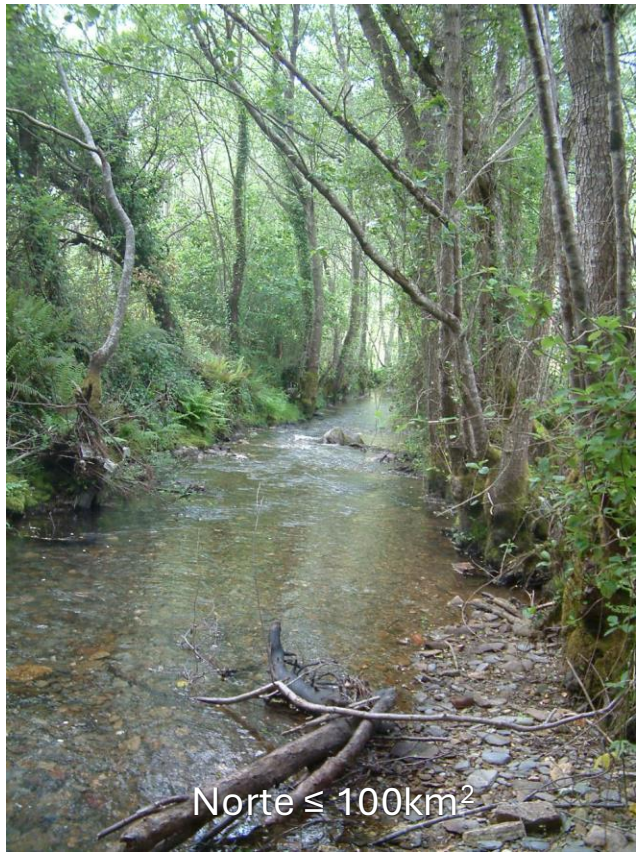
15 tipos de rios portugueses



A avaliação ecológica dos rios portugueses

Tipologia de rios *sensu* DQA





A avaliação ecológica dos rios portugueses

Tipologia de rios *sensu* DQA

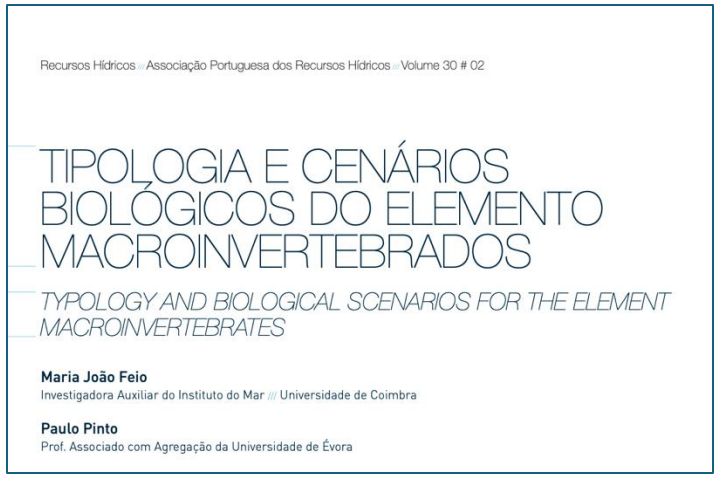
Grandes Rios

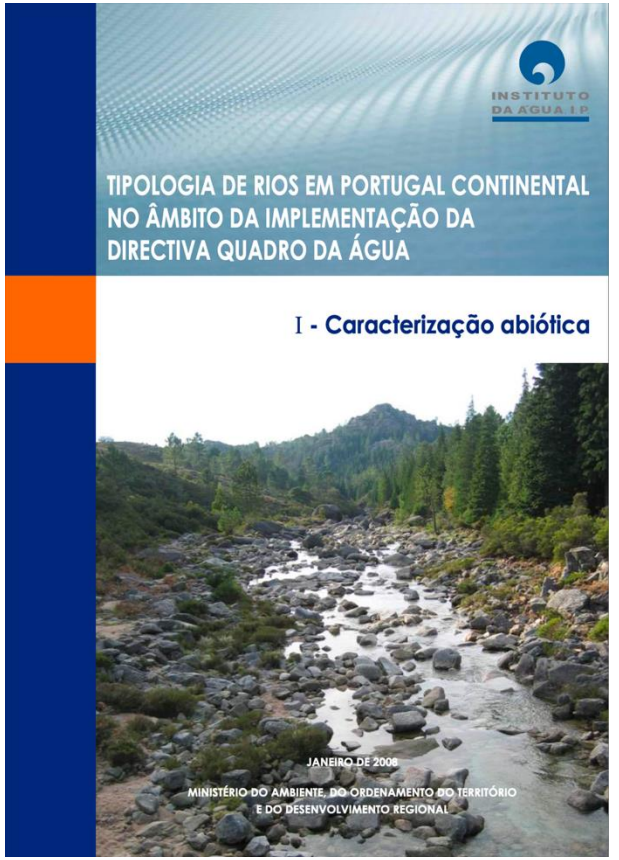
Rio Minho

Rio Guadiana

A avaliação ecológica dos rios portugueses

Tipologia de rios *sensu* DQA





Colaboraram neste documento:

Maria Helena Alves (Coordenação), João Ferreira, João Pádua, João Pedro Martins, Teresa Rafael, Gonçalo Tomaz, Hélio Figueiredo, João Manuel Bernardo, Paulo Pinto, Manuela Morais, Maria Ilhéu, Paula Matono, Pedro Raposo de Almeida, Maria Teresa Ferreira, Francisca Aguiar, Bernardo Ruivo Quintella, António Rodrigues, Manuel Graça, Maria João Feio, Salomé Almeida, Rui Cortes, Simone Oliveira, Nuno Formigo, David da Fonte.

Métodos de avaliação ecológica dos rios

Elementos de qualidade biológica

Índices DQA

Índice multimétrico: combinação de vários critérios se julgam relevantes para avaliar as comunidades biológicas.

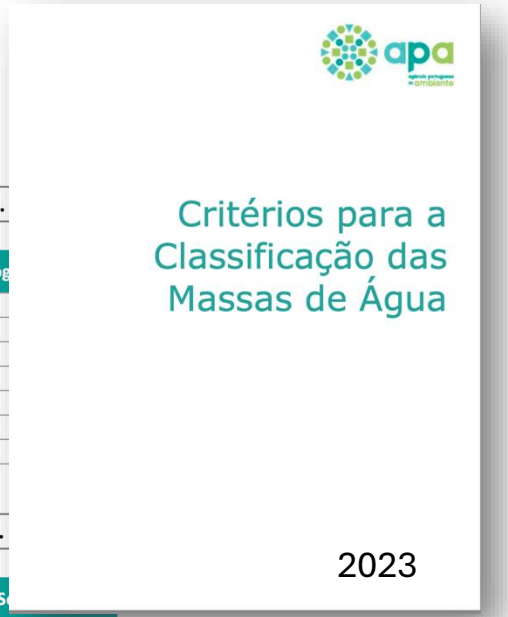
Índice Português de Invertebrados

$IPtI_N$ = **Nº Famílias** x 0,25 + **EPT** x 0,15 + **Equitabilidade** x 0,1 + **(IASPT – 2)** x 0,3 + **Log (Sel. ETD+1)** x 0,2

$IPtI_S$ = **NºFamílias** x 0,4+ **EPT** x 0,2 + **(IASPT–2)** x 0,2 + **Log (Sel. EPTCD + 1)** x 0,2

2 passos de normalização

Rácio de Qualidade Ecológica (0-1)



Quadro 3.5 – Valores de referência das métricas do índice $IPtI_N$ em rios.

Tipo nacional	Índice de qualidade	N.º *taxa*	EPT *taxa*	Evenness	IASPT-2	Log
M	$IPtI_N$	29,0	16,0	0,65	4,48	
N1 > 100 km2	$IPtI_N$	26,0	13,0	0,63	3,97	
N1 ≤ 100 km2	$IPtI_N$	30,0	16,0	0,71	4,52	
N2	$IPtI_N$	31,5	14,0	0,64	3,80	
N3	$IPtI_N$	39,0	18,0	0,61	4,17	
N4	$IPtI_N$	30,5	12,0	0,64	3,67	
S2	$IPtI_N$	26,0	10,5	0,56	3,73	

Quadro 3.6 – Valores de referência das métricas do índice $IPtI_S$ em rios.

Tipo nacional	Índice de qualidade	N.º *taxa*	EPT *taxa*	IASPT-2	Log(S
L	$IPtI_S$	20,0	8,0	3,60	2,57
S1 > 100 km2	$IPtI_S$	21,0	9,0	3,37	2,57
S1 ≤ 100 km2	$IPtI_S$				
S3	$IPtI_S$				
S4	$IPtI_S$				

Quadro 3.20 – Fronteiras de referência das métricas do índice $IPtI_N$ em grandes rios.

Tipo nacional	N.º *taxa*	EPT *taxa*	Evenness	IASPT-2	Log(Sel ETD+1)
GR Norte GR Centro GR Sul	31,5	15,0	0,61	4,42	1,70

No segundo passo de normalização do índice é considerado o valor de referência apresentado no Quadro 3.21, seguindo a mesma lógica de cálculo atrás descrita. Nesta tabela são ainda apresentados os limiares de qualidade aplicáveis para classificação deste elemento de qualidade em grandes rios. Quando o valor do RQE corresponde ao valor-fronteira, considera-se a classe de qualidade superior (p.e., 0,849 corresponde a Excelente).

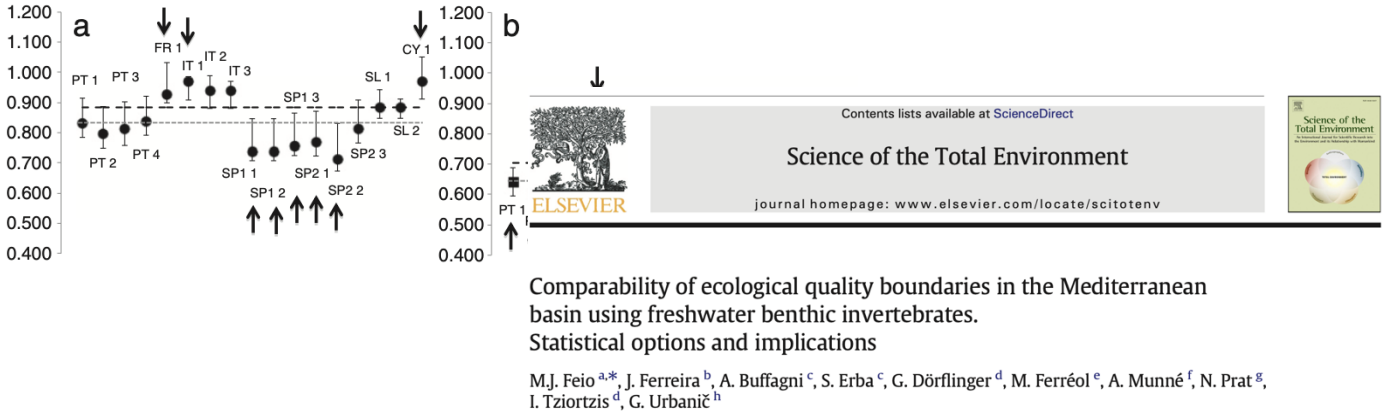
Quadro 3.21 – Fronteiras de qualidade do índice $IPtI_N$ em grandes rios.

Tipo nacional	Valor de referência	Excelente/ Bom	Bom/ Razoável	Razoável/ Medíocre	Medíocre/ Mau
GR Norte GR Centro GR Sul	0,992	0,849	0,637	0,425	0,212

Métodos de avaliação ecológica dos rios

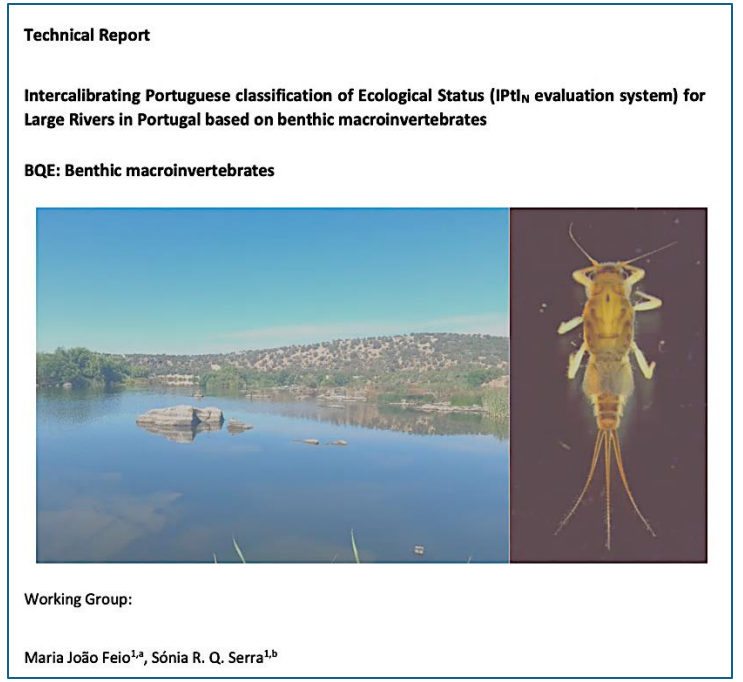
Exercício de intercalibração: índices de qualidade biológica

- Avaliar se os índices cumprem os requisitos da DQA
- Avaliar se as classes de qualidade são comparáveis: *o Bom corresponde ao mesmo nível de degradação para todos?*



Comparability of ecological quality boundaries in the Mediterranean basin using freshwater benthic invertebrates. Statistical options and implications

M.J. Feio [a,*], J. Ferreira [b], A. Buffagni [c], S. Erba [c], G. Dörflinger [d], M. Ferréol [e], A. Munné [f], N. Prat [g], I. Tziortzis [d], G. Urbanič [h]



Technical Report

Intercalibrating Portuguese classification of Ecological Status ($IPtI_N$ evaluation system) for Large Rivers in Portugal based on benthic macroinvertebrates

BQE: Benthic macroinvertebrates

Working Group:

Maria João Feio[1,a], Sónia R. Q. Serra[1,b]

Exercício de intercalibração GR 2019-2020

Causas da baixa qualidade ecológica

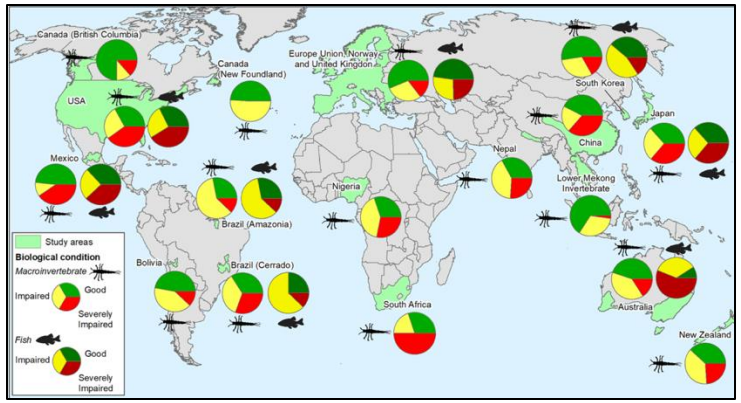
Received: 3 February 2022 | Revised: 6 August 2022 | Accepted: 2 September 2022
DOI: 10.1111/gcb.16439

RESEARCH ARTICLE

Global Change Biology WILEY

Fish and macroinvertebrate assemblages reveal extensive degradation of the world's rivers

Maria João Feio[1] | Robert M. Hughes[2,3] | Sónia R. Q. Serra[1] | Susan J. Nichols[4] | Ben J. Kefford[4] | Mark Lintermans[4] | Wayne Robinson[5] | Oghenekaro N. Odume[6] | Marcos Callisto[7] | Diego R. Macedo[8] | Jon S. Harding[9] | Adam G. Yates[10] | Wendy Monk[11] | Keigo Nakamura[12] | Terutaka Mori[13] | Masanao Sueyoshi[13] | Norman Mercado-Silva[14] | Kai Chen[15,16] | Min Jeong Baek[17] | Yeon Jae Bae[18] | Ram Devi Tachamo-Shah[19] | Deep Narayan Shah[20] | Ian Campbell[21] | Nabor Moya[22] | Francis O. Arimoro[23] | Unique N. Keke[23] | Renato T. Martins[24] | Carlos B. M. Alves[25] | Paulo S. Pompeu[26] | Subodh Sharma[27]



Severely Impaired conditions were correlated with:

- higher **Human Development Index** scores – more developed countries!
- poorer physico-chemical water quality
- **lower proportions of protected freshwater areas**

Good biological conditions were associated with:

- good water physico-chemical quality
- **increased forested areas**

Evolução da qualidade ecológica dos rios europeus

nature

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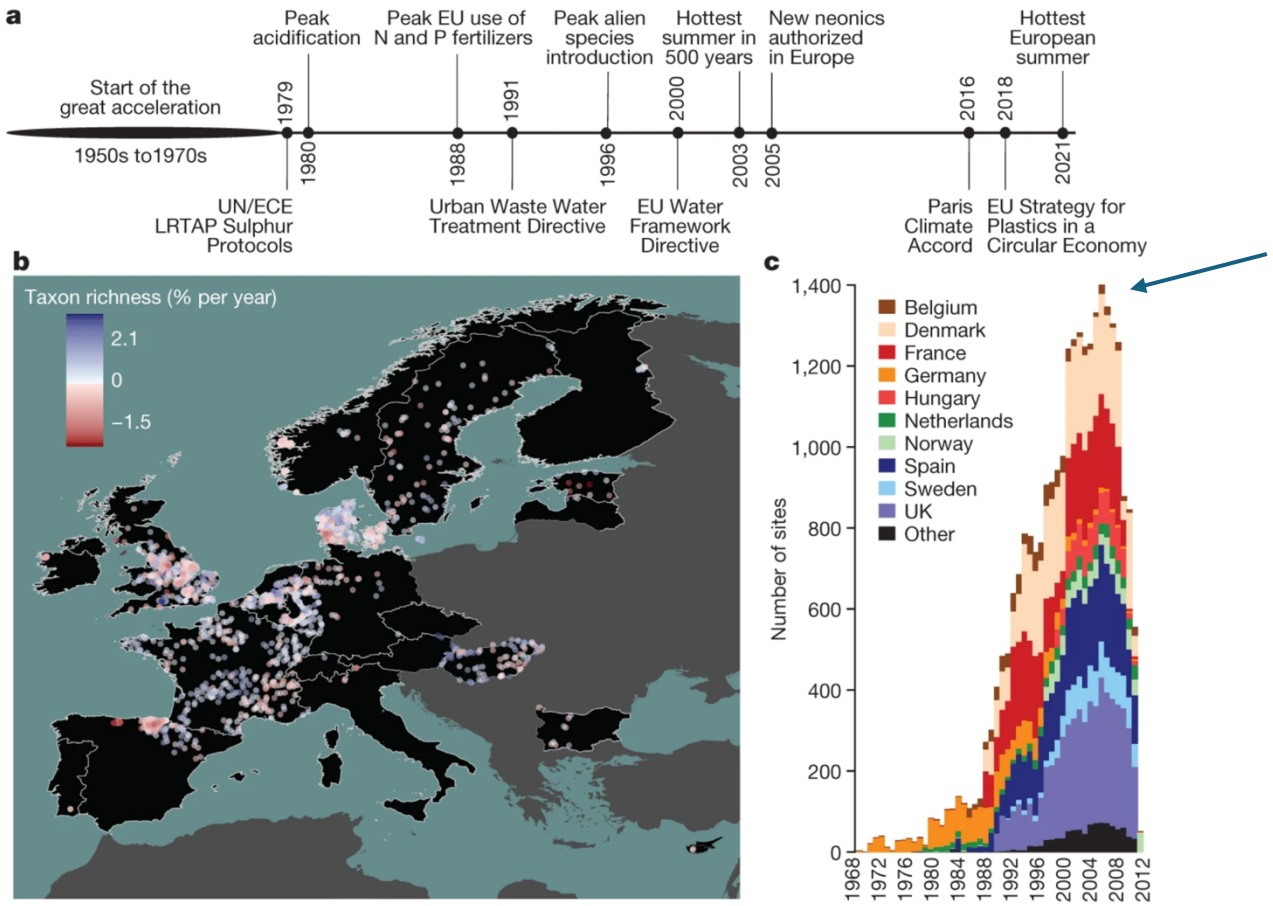
Article | Open access | Published: 09 August 2023

The recovery of European freshwater biodiversity has come to a halt

Peter Haase, Diana E. Bowler, Nathan J. Baker, Núria Bonada, Sami Domisch, Jaime R. Garcia Marquez, Jani Heino, Daniel Hering, Sonja C. Jähnig, Astrid Schmidt-Kloiber, Rachel Stubbington, Florian Altermatt, Mario Álvarez-Cabria, Giuseppe Amatulli, David G. Angeler, Gaït Archambaud-Suard, Iñaki Arrate Jorrín, Thomas Aspin, Iker Azpiroz, Iñaki Bañares, José Barquín Ortiz, Christian L. Bodin, Luca Bonacina, Roberta Bottarin, Miguel Cañedo-Argüelles, Zoltán Csabai, Thibault Datry, Elvira de Eyto, Alain Dohet, Gerald Dörflinger, Emma Drohan, Knut A. Eikland, Judy England, Tor E. Eriksen, Vesela Evtimova, Maria J. Feio, Martial Ferréol, Mathieu Floury, Maxence Forcellini, Marie Anne Eurie Forio, Riccardo Fornaroli, Nikolai Friberg, Jean-François Fruget, Galia Georgieva, Peter

1,816 series temporais de comunidades de invertebrados de águas doces de 22 países europeus, recolhidas **entre1968 and 2020**

- **Novos fatores de stress**
- **Poucas séries temporais para Portugal**



a, A timeline of major stressors (above the line) and environmental legislation (below the line) affecting Europe's freshwater ecosystems (citations are provided in Supplementary Table 1). UN/ECE LTRAP, United Nations Economic Commission for Europe Long-Range Transboundary Air Pollution. **b**, The sampling sites (points) and the rate of temporal change in taxon richness of freshwater invertebrate communities (colour of points) across 22 European countries (black). **c**, The distribution of sampling sites over time and countries. 'Other' includes countries with fewer than 50 sampling sites.

Efeito das espécies exóticas na avaliação ecológica

Journal of Environmental Management 374 (2025) 123874

Contents lists available at ScienceDirect

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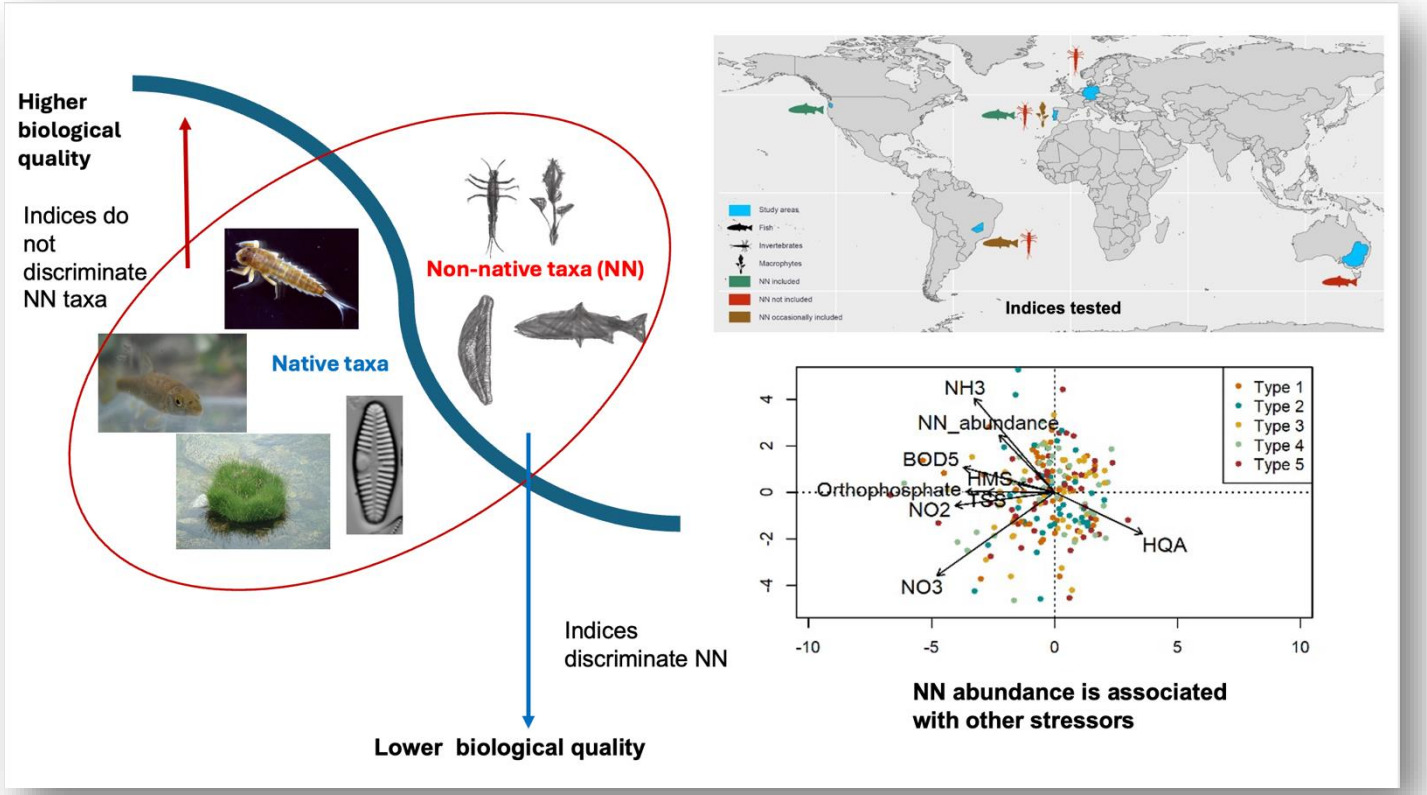
journal homepage: www.elsevier.com/locate/jenvman

Research article

The impacts of alien species on river bioassessment

Maria João Feio [a,*], Janine P. da Silva [a], Robert M. Hughes [b,c], Francisca C. Aguiar [d], Carlos B.M. Alves [e], Sebastian Birk [f], Marcos Callisto [g], Marden S. Linares [e], Diego R. Macedo [h], Paulo S. Pompeu [i], Wayne Robinson [j], Christian Schürings [k], Salomé F.P. Almeida [l], Pedro M. Anastácio [m], Francis O. Arimoro [n], Min Jeong Baek [o], Mirian Calderón [p], Kai Chen [q], Peter Goethals [r], Marie Anne E. Forio [r], Jon S. Harding [s], Ben J. Kefford [t], Martyn G. Kelly [u,v], Unique N. Keke [w], Mark Lintermans [x], Renato T. Martins [y], Terutaka Mori [z], Keigo Nakamura [aa], Oghenekaro N. Odume [ab], Filipe Ribeiro [ac], Renata Ruaro [ad], Sónia RQ. Serra [a], Deep Narayan Shah [ae], Masanao Sueyoshi [af], Ram Devi Tachamo-Shah [ag]



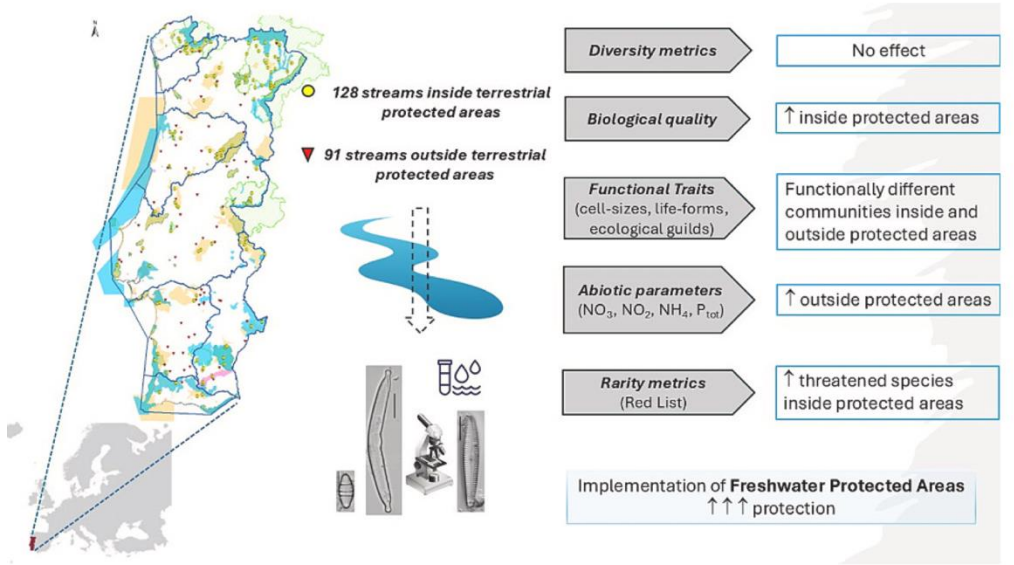
Reservas fluviais

Biodiversity and Conservation (2024) 33:439–462
https://doi.org/10.1007/s10531-023-02774-w

REVIEW PAPER

Fluvial protected areas as a strategy to preserve riverine ecosystems—a review

Helena I. L. Valentim[1,2] · Maria João Feio[2] · Salomé F. P. Almeida[1]



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Assessing the effectiveness of terrestrial protected areas towards riverine ecosystems

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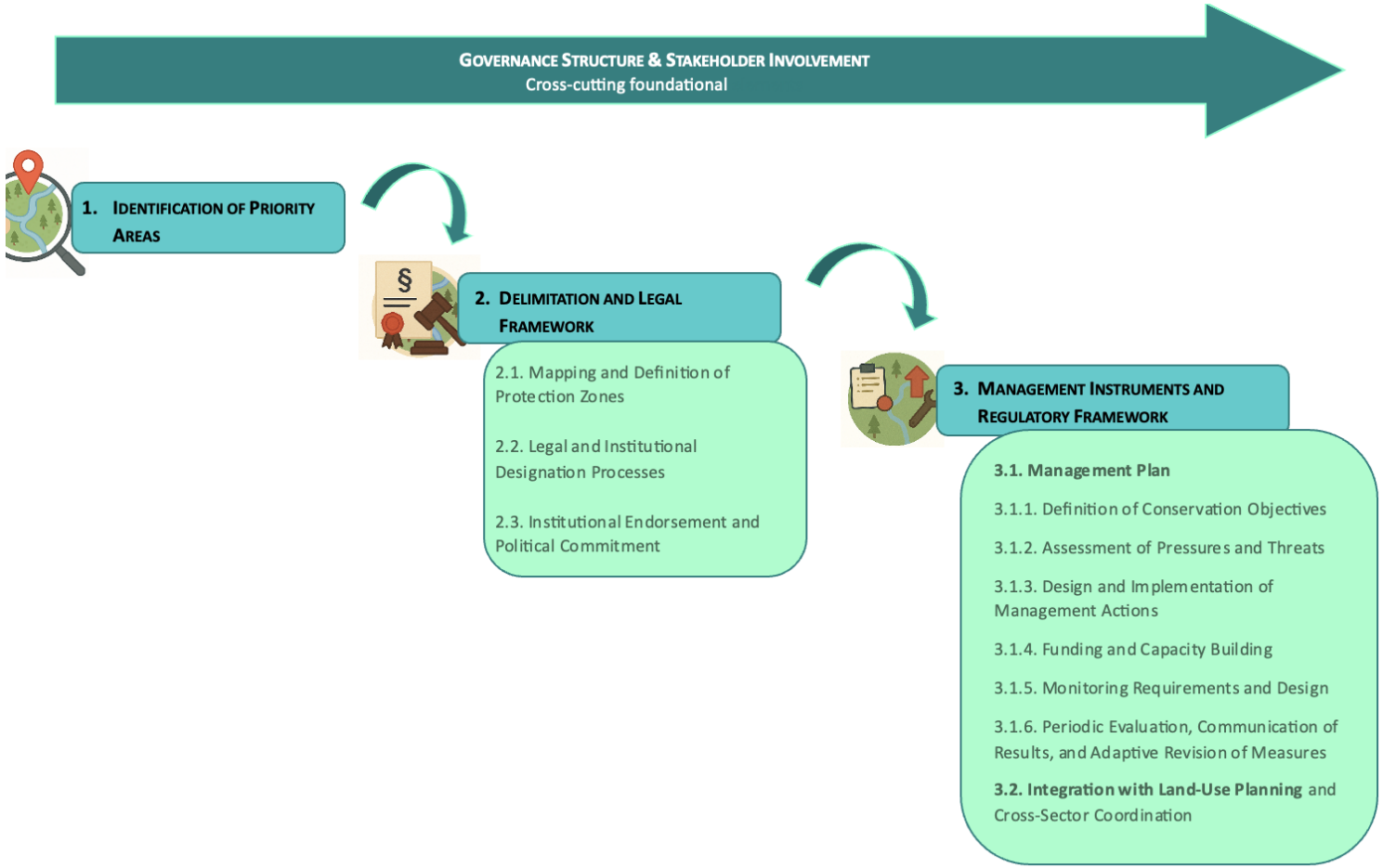
- As **áreas protegidas terrestres** fornecem alguma proteção aos rios dentro de seus limites.

- A preservação eficaz requer a implementação de **áreas fluviais protegidas dedicadas**

Reservas fluviais

- **Implementação – para discussão**



Serviços dos ecossistemas ribeirinhos

Provisionamento
Água, alimento, plantas aromáticas e medicinais madeira,…

Regulação
da qualidade da água do ar e solos, clima, mitigação de cheias, proteção contra ruído, vento, polinização…

Funções e Habitat
Habitat, Produção primária, reciclagem de nutrients e energia, decomposição de matéria orgânica…

Culturais
Lazer, valor estético, relaxamento, educação, …

Common International Classification of Ecosystem Services (CICES), European Environment Agency

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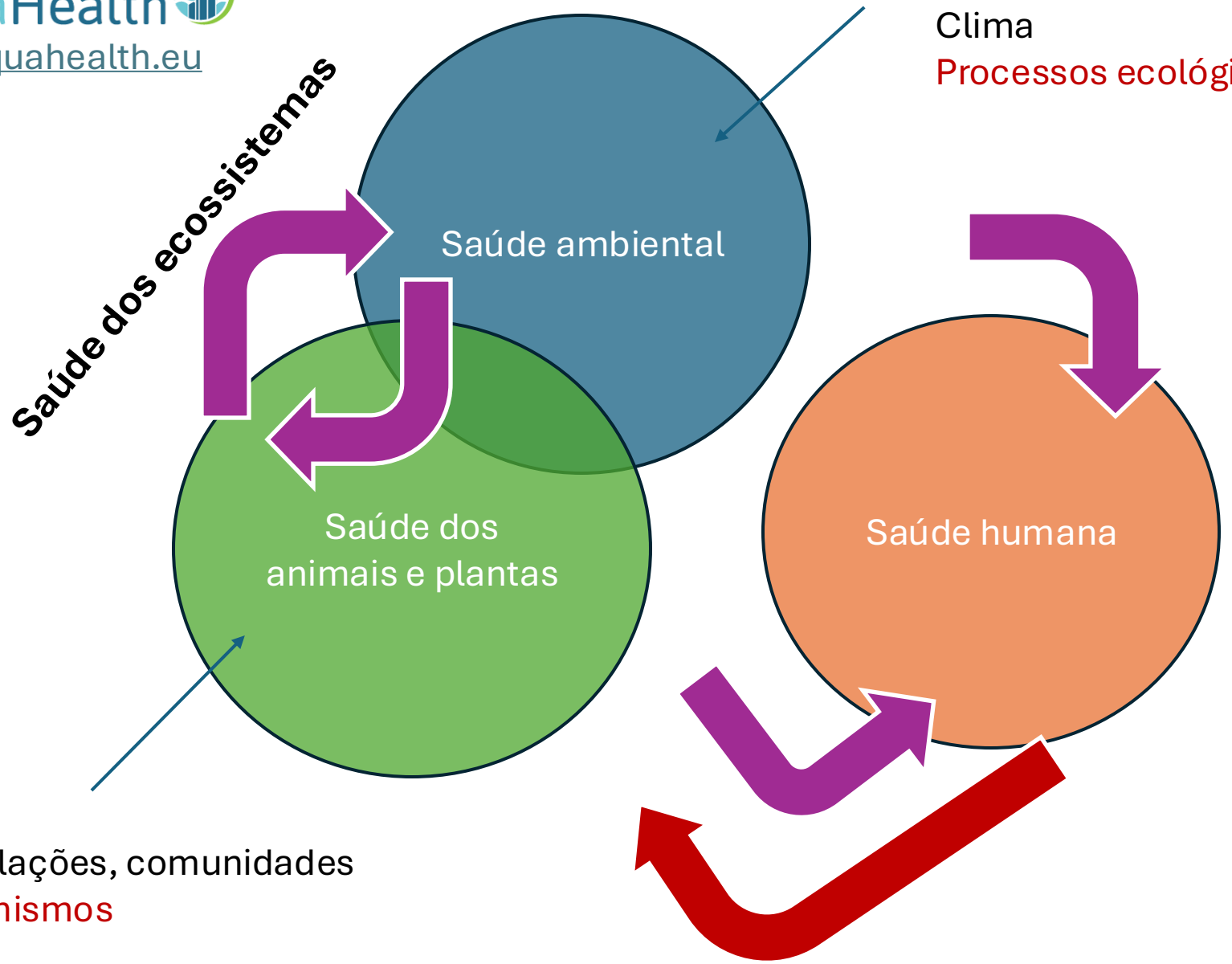
Condições abióticas Habitats
Clima
Processos ecológicos

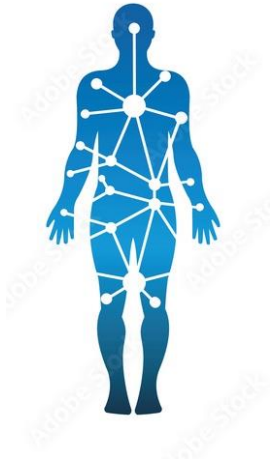


Populações, comunidades
Organismos

Importante no contexto da **sustentabilidade, aumento da urbanização** na **prevenção de epidemias, pandemias e prevenção dos efeitos de eventos extremos**

E portanto, é importante a ter em conta **no contexto do restauro ecológico.**

Riscos para a saúde humana da degradação dos ecossistemas ribeirinho



Conversão do valor do serviço em % de risco (perda do serviço)

Serviços	Problemas de Saúde Humana associados	Risco para a população da cidade (variação entre indicadores do mesmo serviço)
Regulação climática	Doenças cardiovasculares e respiratórias, problemas de pele…	26% - **56%**
Qualidade do ar	Doenças pulmonares e neurológicas, impactos no fígado, bexiga, sangue, sistema reprodutor e cardiovasculares	**59%**
Qualidade da água	Doenças entéricas, e associadas a vetores	13% - **55%**
Educação e desenvolvimento cognitivo	Perda de oportunidades para a manutenção de capacidades cognitivas (e.g. demência, alzeimer), educação ambiental, sociabilização, conexão com a natureza	19% - 36%
Serviços terapeuticos	Pior saúde mental	0 – **69%**

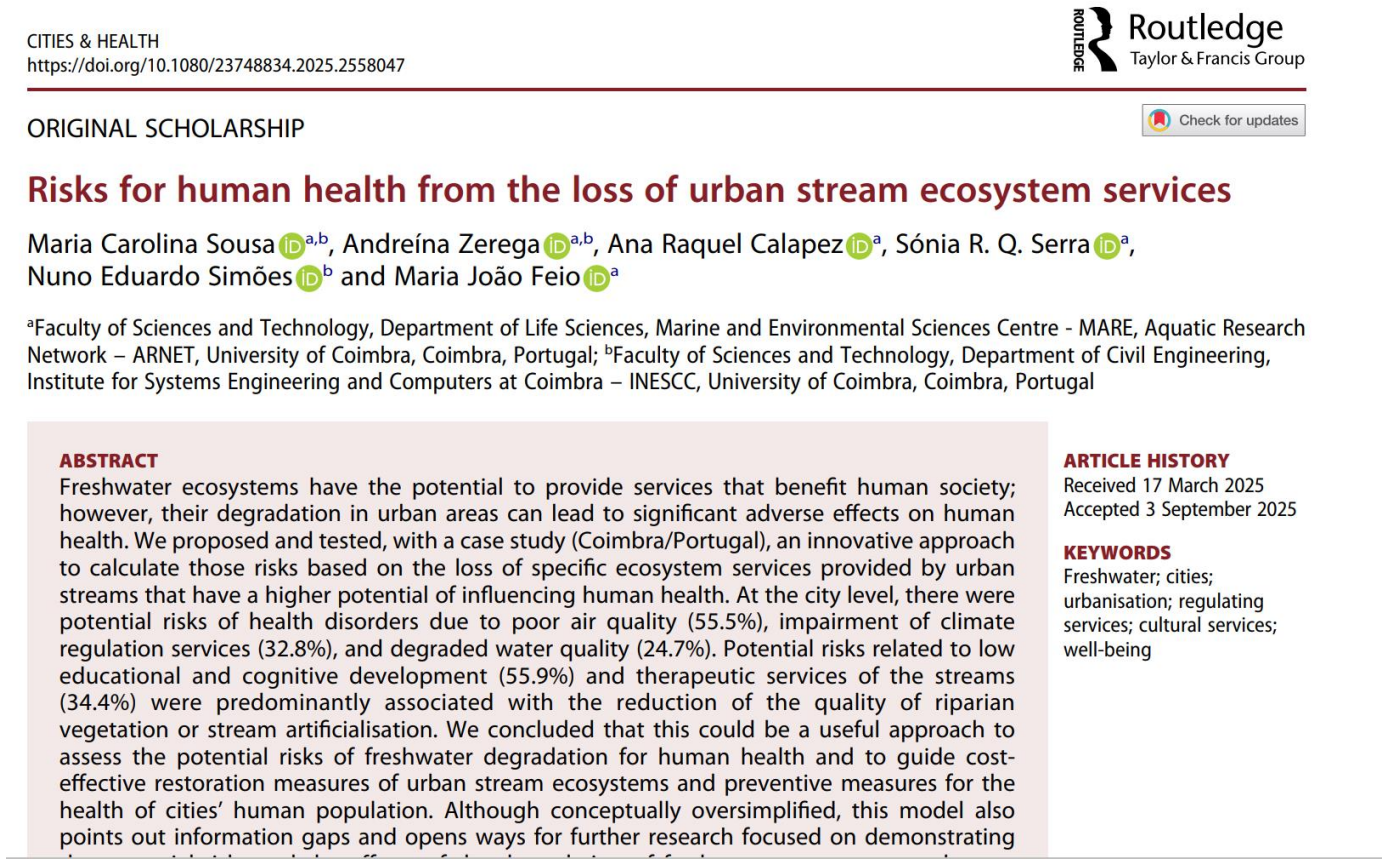
Sousa et al. 2025. Cities and Health

Riscos de saúde física associados à **má regulação climática** (especialmente temperaturas e humidade), e **má qualidade do ar** devido à **degradação das zonas ripícolas** e **baixa qualidade ecológica das ribeiras**

Elevado potencial de desenvolvimento cognitivo mas **serviços terapêuticos associados a zonas calmas e tranquilas e *temporal getway* muito limitadas.**

Riscos para a saúde humana da degradação do ecossistema

Gestão transdisciplinar



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Risks for human health from the loss of urban stream ecosystem services

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ABSTRACT

Freshwater ecosystems have the potential to provide services that benefit human society; however, their degradation in urban areas can lead to significant adverse effects on human health. We proposed and tested, with a case study (Coimbra/Portugal), an innovative approach to calculate those risks based on the loss of specific ecosystem services provided by urban streams that have a higher potential of influencing human health. At the city level, there were potential risks of health disorders due to poor air quality (55.5%), impairment of climate regulation services (32.8%), and degraded water quality (24.7%). Potential risks related to low educational and cognitive development (55.9%) and therapeutic services of the streams (34.4%) were predominantly associated with the reduction of the quality of riparian vegetation or stream artificialisation. We concluded that this could be a useful approach to assess the potential risks of freshwater degradation for human health and to guide cost-effective restoration measures of urban stream ecosystems and preventive measures for the health of cities' human population. Although conceptually oversimplified, this model also points out information gaps and opens ways for further research focused on demonstrating

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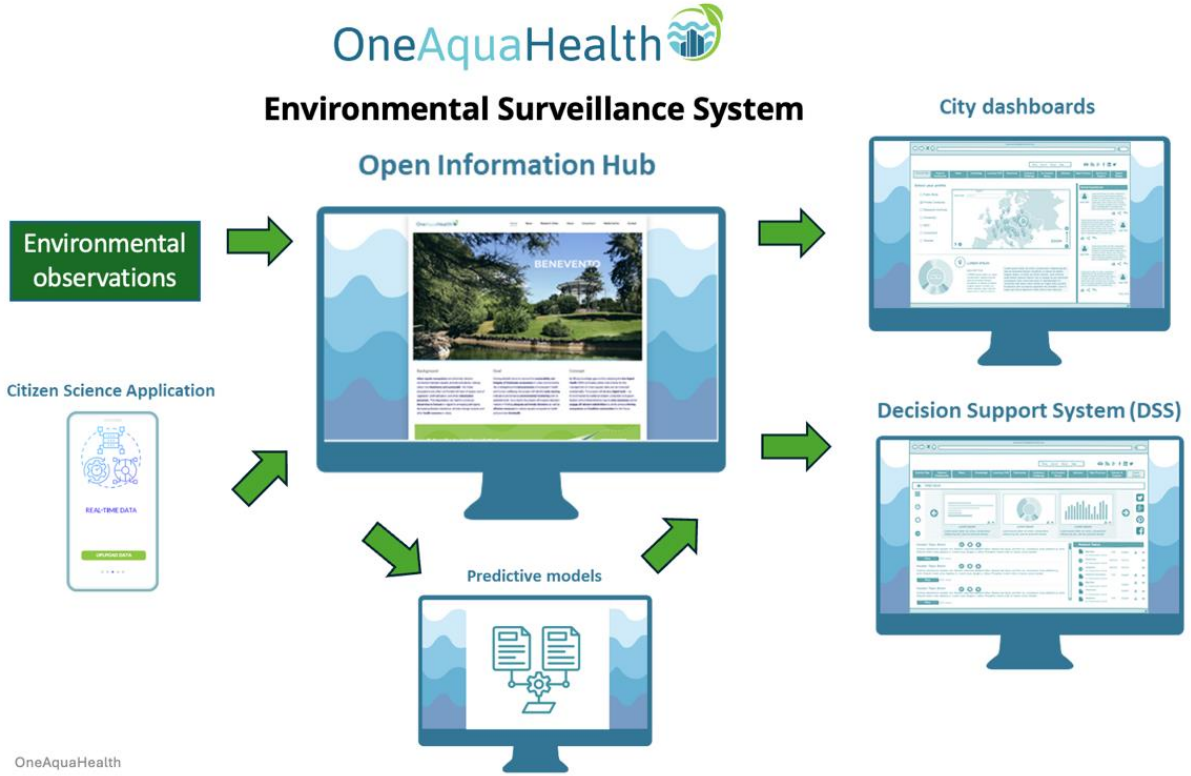

Para decisores, cidadãos, investigadores

Para decisores

Investigadores

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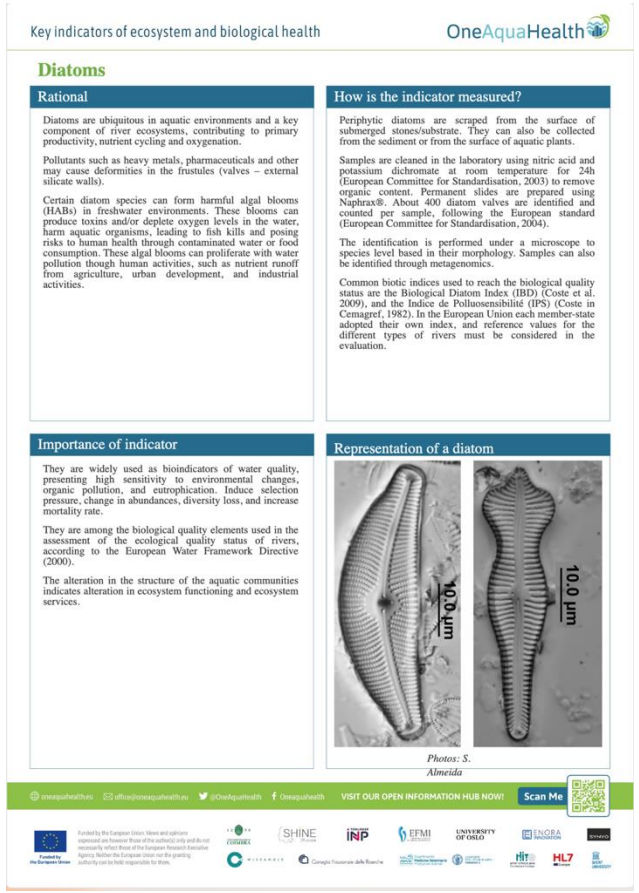

Key indicators of ecosystem and biological health

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Diatoms

Rational

Diatoms are ubiquitous in aquatic environments and a key component of river ecosystems, contributing to primary productivity, nutrient cycling and oxygenation.

Pollutants such as heavy metals, pharmaceuticals and other may cause deformities in the frustules (valves – external silicate walls).

Certain diatom species can form harmful algal blooms (HABs) in freshwater environments. These blooms can produce toxins and/or deplete oxygen levels in the water, harm aquatic organisms, leading to fish kills and posing risks to human health through contaminated water or food consumption. These algal blooms can proliferate with water pollution though human activities, such as nutrient runoff from agriculture, urban development, and industrial activities.

How is the indicator measured?

Periphytic diatoms are scraped from the surface of submerged stones/substrate. They can also be collected from the sediment or from the surface of aquatic plants.

Samples are cleaned in the laboratory using nitric acid and potassium dichromate at room temperature for 24h (European Committee for Standardisation, 2003) to remove organic content. Permanent slides are prepared using Naphrax®. About 400 diatom valves are identified and counted per sample, following the European standard (European Committee for Standardisation, 2004).

The identification is performed under a microscope to species level based in their morphology. Samples can also be identified through metagenomics.

Common biotic indices used to reach the biological quality status are the Biological Diatom Index (IBD) (Coste et al. 2009), and the Indice de Polluosensibilité (IPS) (Coste in Cemagref, 1982). In the European Union each member-state adopted their own index, and reference values for the different types of rivers must be considered in the evaluation.

Importance of indicator

They are widely used as bioindicators of water quality, presenting high sensitivity to environmental changes, organic pollution, and eutrophication. Induce selection pressure, change in abundances, diversity loss, and increase mortality rate.

They are among the biological quality elements used in the assessment of the ecological quality status of rivers, according to the European Water Framework Directive (2000).

The alteration in the structure of the aquatic communities indicates alteration in ecosystem functioning and ecosystem services.

Representation of a diatom

Photos: S. Almeida

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Key indicators of ecosystem and biological health

OneAquaHealth

Amphibians

Rational

Amphibians are vital vertebrates whose dependence on aquatic ecosystems for reproduction makes them vulnerable to environmental changes. Their physiological sensitivity, especially their permeable skin, allows them to function as excellent bio-indicators of ecosystem health, providing early warnings of environmental contamination.

Furthermore, amphibians deliver important ecosystem services by controlling pest populations (e.g., reducing the transmission of mosquito-borne diseases), serving as a food source for other wildlife, and facilitating nutrient cycling between terrestrial and aquatic ecosystems.

How is the indicator measured?

Amphibians are sampled with a hand net (mesh size 3-5mm), by wading a total length of 100 meters in each stream, covering various habitat types (i.e., lentic and lotic zones). Along each transect, amphibians (adults, larvae and eggs) are captured, identified and counted.

The body condition of the animals is assessed through their weight and size (using a calliper). In addition, buccal and skin swabbing may be conducted. The swabs are placed in a sterile, labelled tube and stored on ice for later analysis of *Ranavirus* and Bd..

All animals are released. Standardised biosecurity and sanitation procedures should be implemented between each individual sampled and across various sampling sites. Nitrile gloves should be used to handle the animals, and callipers and weigh pans must be thoroughly wiped down with 70% ethanol and rinsed with distilled water after each use.

Importance of indicator

Urbanization seems to influence the diversity, population, and disease dynamics of amphibians.

Habitat loss and water contamination are extensively documented causes of amphibian population declines.

The number of endemic and vulnerable species is associated to a better ecological condition of streams while more degraded streams may be a source of several pathogens affecting amphibians.

Infectious diseases have been recognised as key drivers of amphibian extinctions, specially those resulting of infection by ranaviruses and chytridiomycosis (caused by the fungal pathogens *Batrachochytrium dendrobatidis* (Bd), and *Batrachochytrium salamandrivorans*.

Photos of amphibian surveys

Photos: C. Vigiléos and G. Silva

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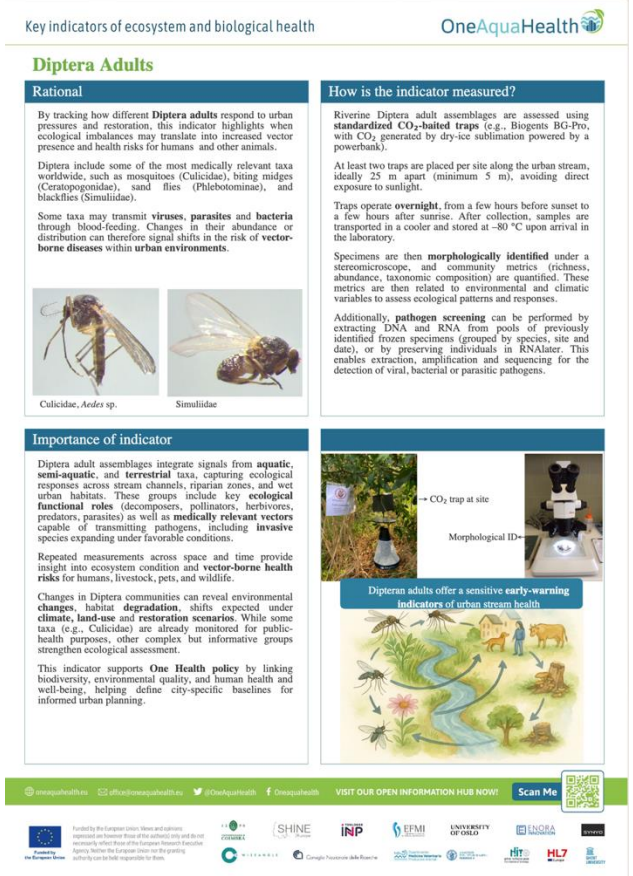

Key indicators of ecosystem and biological health

OneAquaHealth

Diptera Adults

Rational

By tracking how different **Diptera adults** respond to urban pressures and restoration, this indicator highlights when ecological imbalances may translate into increased vector presence and health risks for humans and other animals.

Diptera include some of the most medically relevant taxa worldwide, such as mosquitoes (Culicidae), biting midges (Ceratopogonidae), sand flies (Phlebotominae), and blackflies (Simuliidae).

Some taxa may transmit **viruses**, **parasites** and **bacteria** through blood-feeding. Changes in their abundance or distribution can therefore signal shifts in the risk of **vector-borne diseases** within **urban environments**.

Culicidae, *Aedes* sp. Simuliidae

How is the indicator measured?

Riverine Diptera adult assemblages are assessed using **standardized CO_2-baited traps** (e.g., Biogents BG-Pro, with CO_2 generated by dry-ice sublimation powered by a powerbank).

At least two traps are placed per site along the urban stream, ideally 25 m apart (minimum 5 m), avoiding direct exposure to sunlight.

Traps operate **overnight**, from a few hours before sunset to a few hours after sunrise. After collection, samples are transported in a cooler and stored at –80 °C upon arrival in the laboratory.

Specimens are then **morphologically identified** under a stereomicroscope, and community metrics (richness, abundance, taxonomic composition) are quantified. These metrics are then related to environmental and climatic variables to assess ecological patterns and responses.

Additionally, **pathogen screening** can be performed by extracting DNA and RNA from pools of previously identified frozen specimens (grouped by species, site and date), or by preserving individuals in RNAlater. This enables extraction, amplification and sequencing for the detection of viral, bacterial or parasitic pathogens.

Importance of indicator

Diptera adult assemblages integrate signals from **aquatic**, **semi-aquatic**, and **terrestrial** taxa, capturing ecological responses across stream channels, riparian zones, and wet urban habitats. These groups include key **ecological functional roles** (decomposers, pollinators, herbivores, predators, parasites) as well as **medically relevant vectors** capable of transmitting pathogens, including **invasive** species expanding under favorable conditions.

Repeated measurements across space and time provide insight into ecosystem condition and **vector-borne health risks** for humans, livestock, pets, and wildlife.

Changes in Diptera communities can reveal environmental **changes**, habitat **degradation**, shifts expected under **climate, land-use** and **restoration scenarios**. While some taxa (e.g., Culicidae) are already monitored for public-health purposes, other complex but informative groups strengthen ecological assessment.

This indicator supports **One Health policy** by linking biodiversity, environmental quality, and human health and well-being, helping define city-specific baselines for informed urban planning.

Dipteran adults offer a sensitive **early-warning indicators** of urban stream health

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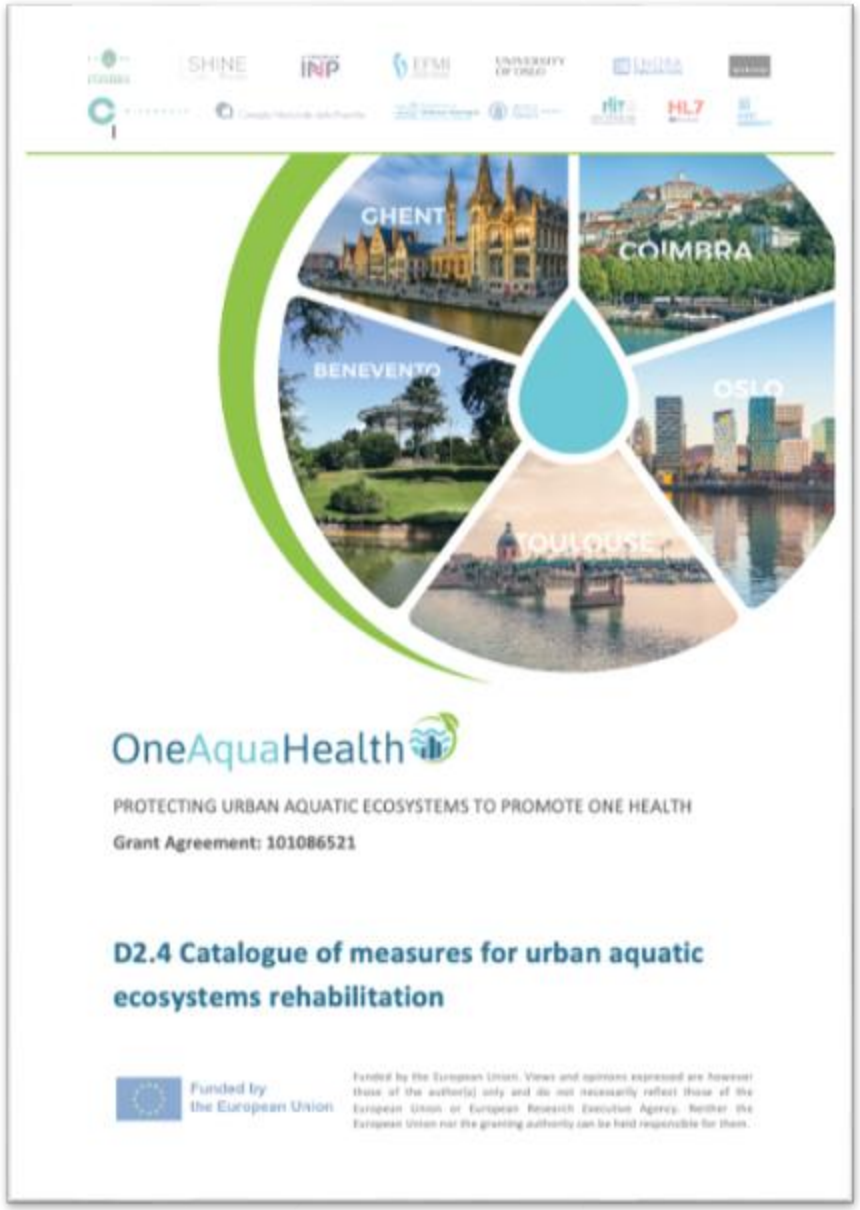

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