Ecology - 2

Global Change Biology of Fluvial Ecosystems 2024

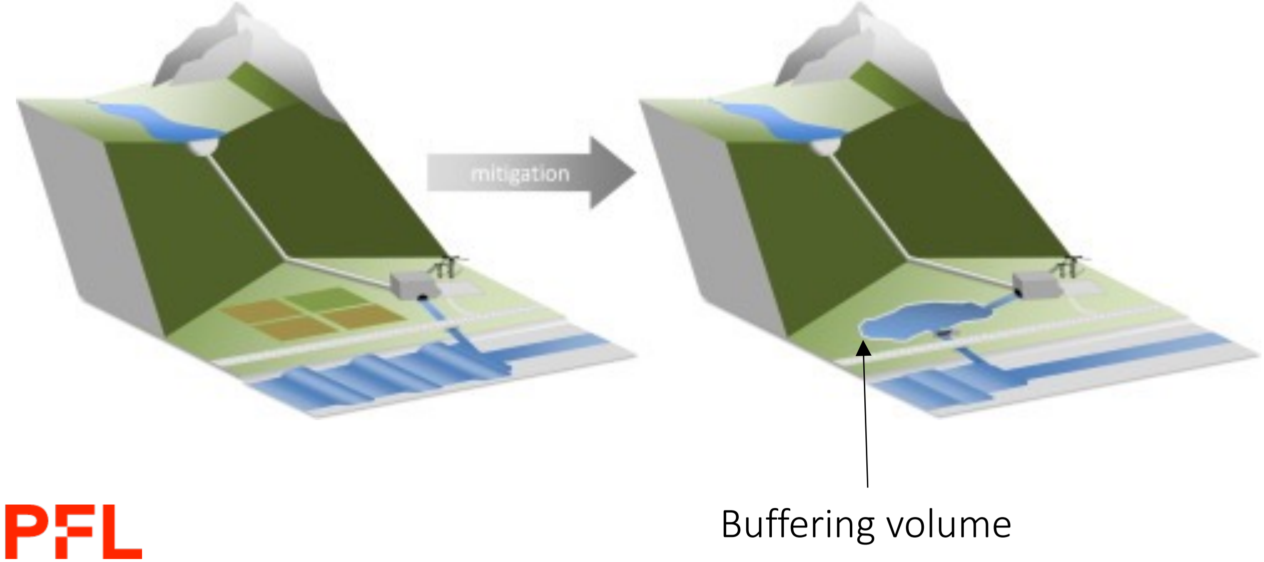
EPFL

SCIENTIFIC REPORTS

Changes in short term river flow regulation and hydropeaking in Nordic rivers

Faisal Bin Ashraf[1], Ali Torabi Haghighi[1], Joakim Riml[2], Knut Alfredsen[3], Jarkko J. Koskela[4], Bjørn Kløve[1] & Hannu Marttila[1]

Hydropeaking affects downstream life



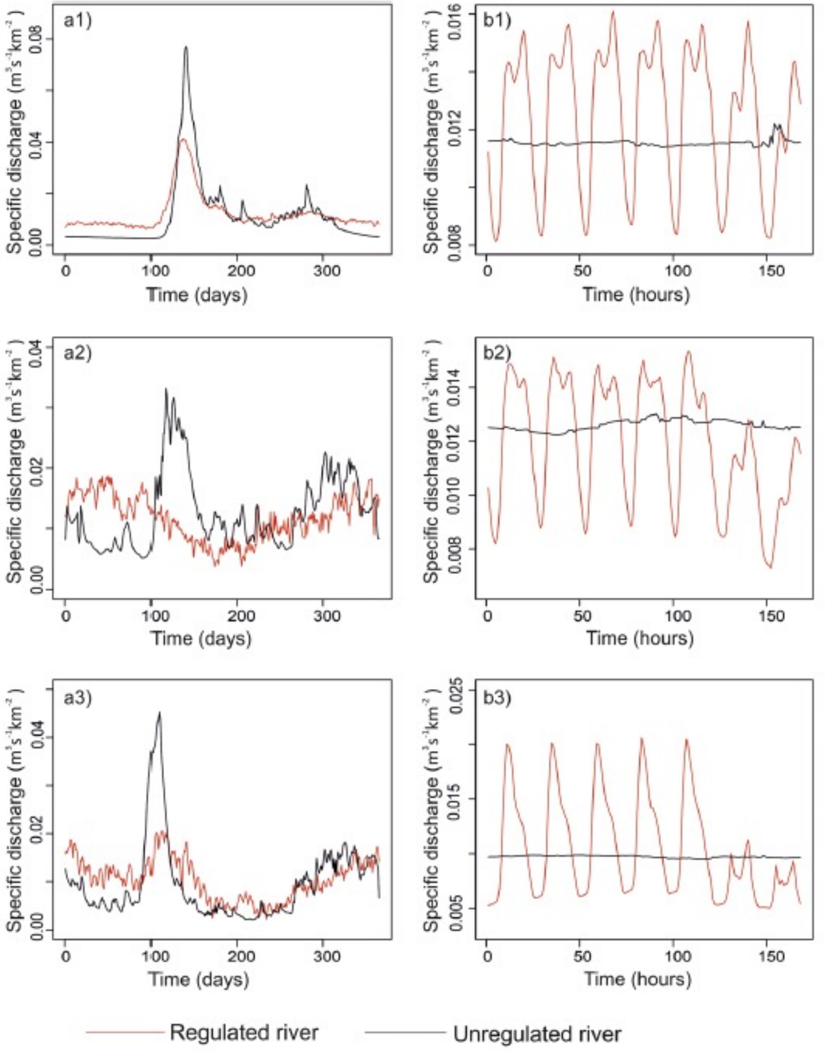


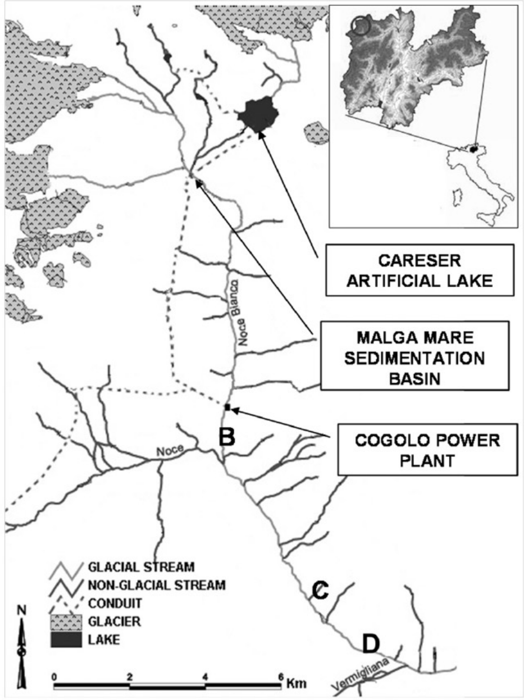
Figure 5. Aggregated mean long term regulation (**a**) and aggregated mean short term regulation (**b**) pattern in terms of specific discharge on large (1) medium (2) and small river (3) and that of comparable unregulated stations. Taivalkoski (regulated), Ounasjoki at kongas (unregulated) on daily scale (**a1**) and hourly scale (**b1**). Montta (regulated), Sanginjoki (unregulated) on daily scale (**a2**) and hourly scale (**b2**). Kyröskoski (regulated), Vakkola (unregulated) on daily scale (**a3**) and hourly scale (**b3**). The x-axis shows (**a1–a3**) show days of the year and (**b1–b3**) hours of the day.

EPFL

Limnologica 40 (2010) 281–290
Contents lists available at ScienceDirect
Limnologica
journal homepage: www.elsevier.de/limno

Short time-scale impacts of hydropeaking on benthic invertebrates in an Alpine stream (Trentino, Italy)

Maria Cristina Bruno*, Bruno Maiolini, Mauro Carolli, Luana Silveri



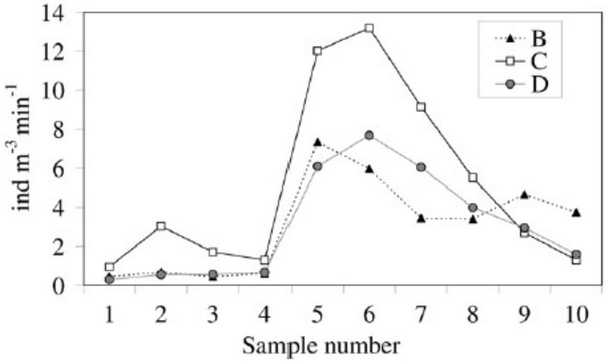


Fig. 6. Loss from bed of drifting aquatic invertebrates (ind m^{-3} min^{-1}) in each station for each drift sample in the Noce Bianco Stream, Trentino, Italy, calculated by averaging three replicates for each sample. For sampling station locations, see Fig. 1.

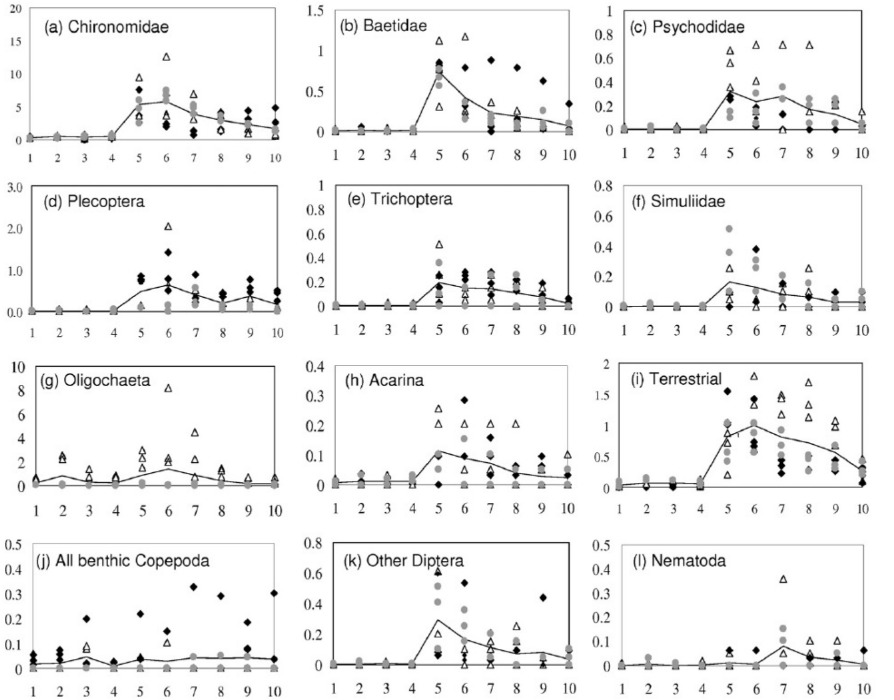


Fig. 5. Mean loss from bed of drifting aquatic invertebrates (ind m^{-3} min^{-1}) in each station for each time sample in the Noce Bianco Stream, Trentino, Italy. Taxa in figure are those that contributed most to the dissimilarities between all three stations (see Table 2). All terrestrial taxa, Nematoda, and all Copepoda are added because they represent the impact on riparian habitat, and on the benthic/hyporheic interface, respectively. Black rhombs: station B; white triangles: station C; grey circles: station D; continuous line: mean of all samples. For sampling station locations, see Fig. 1.

Hydropeaking induces loss of benthic biodiversity and biomass (at least transiently)

Aquat Sci (2011) 73:499–511
DOI 10.1007/s00027-011-0203-x
Aquatic Sciences
RECENT PERSPECTIVES ON TEMPORARY RIVER ECOLOGY

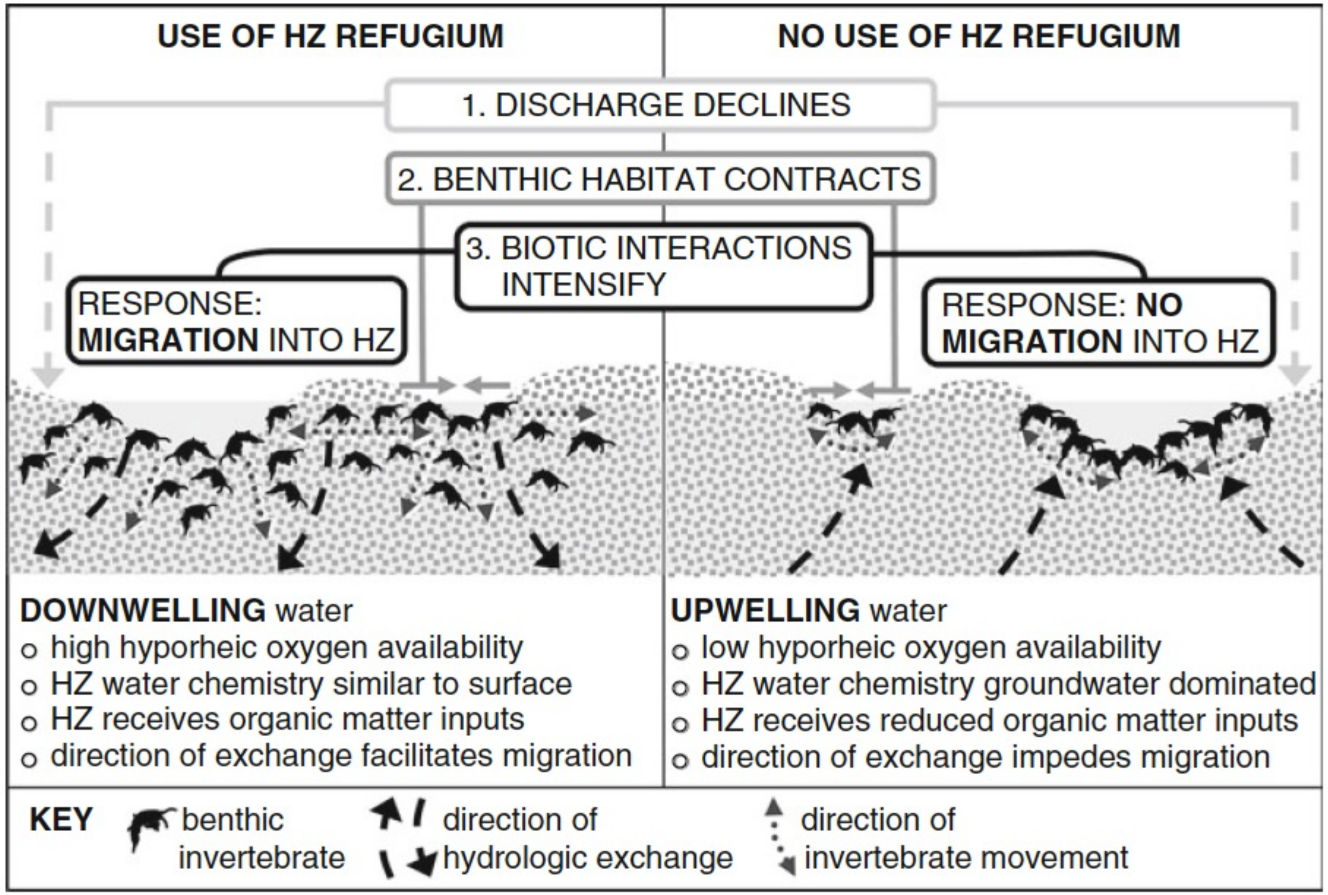
Spatial variability in the hyporheic zone refugium of temporary streams

Rachel Stubbington · Paul J. Wood · Ian Reid

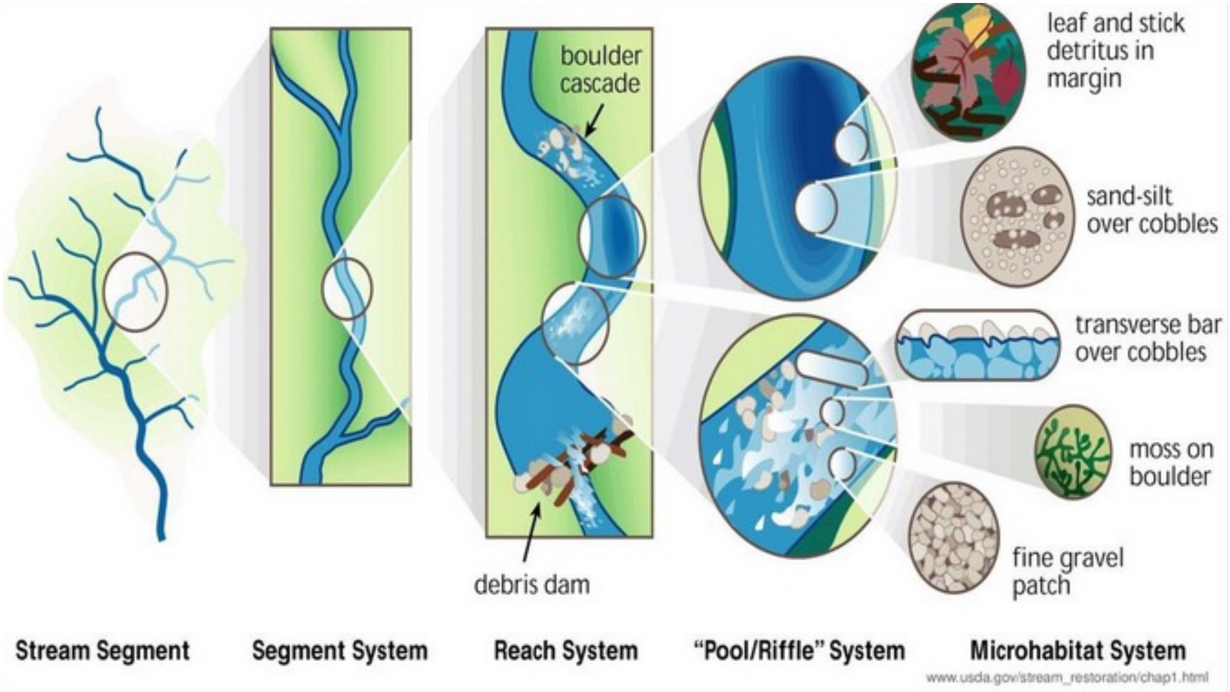
The hyporheic zone (stream/riverbed) as a refugium for invertebrates during low discharge — **intermittent flow**.

Unless the sediment is clogged. Bed clogging (fine sediments) and armoring reduce the capacity of the hyporheic zone as a refugium. This is often the case in streams below smaller dams.

Benthic habitats contract, invertebrates migrate into the streambed – if oxygen allows. Depends on geomorphology, hydrodynamic exchange, trophic status etc.



A role for hydraulic heterogeneity
Environmental heterogeneity across spatial scales

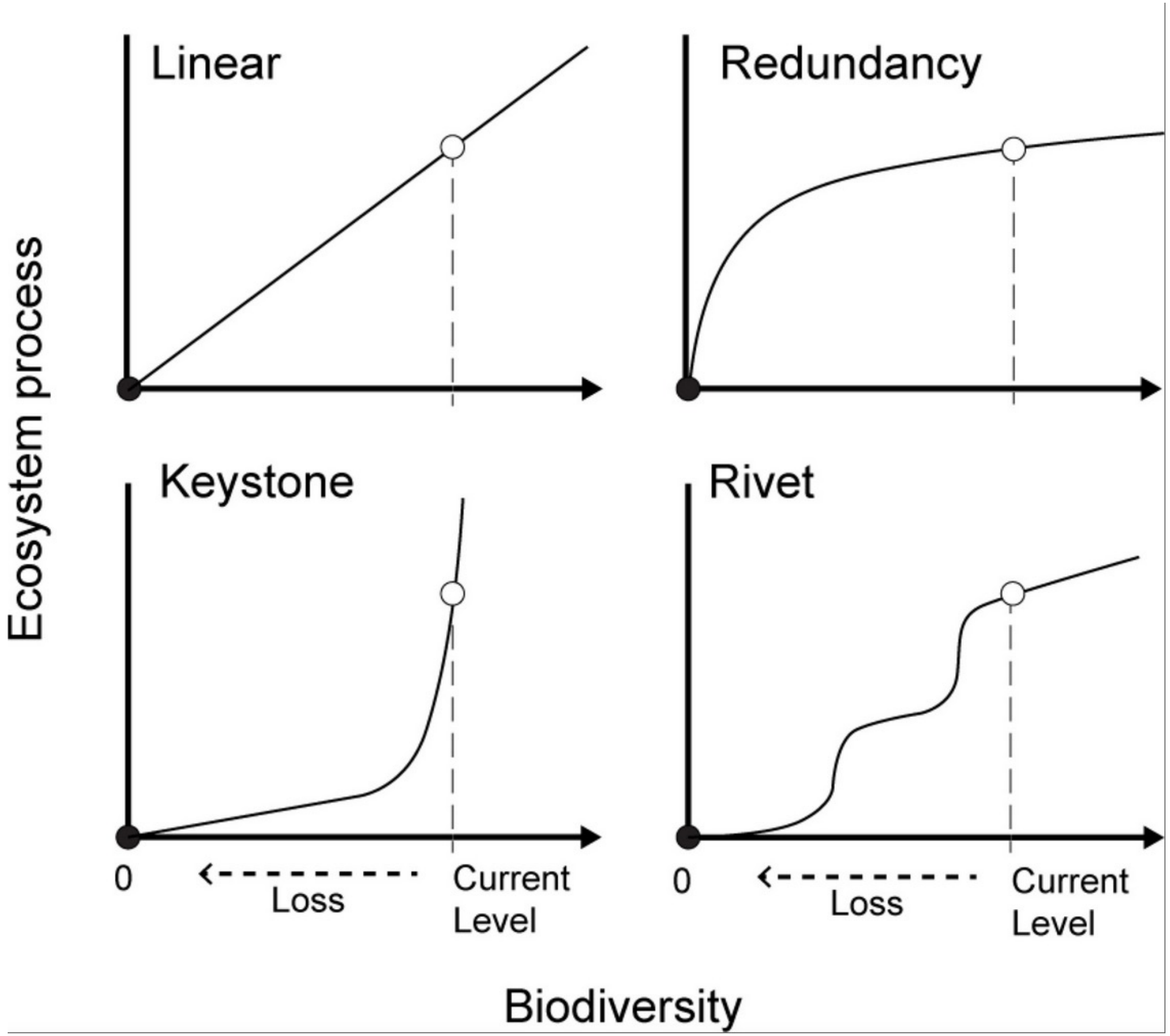


Stream and river beds are heterogeneous

Does heterogeneity in space and time affect biodiversity and functions?

Relating biodiversity to ecosystem functioning

How do ecosystem functions/processes respond to biodiversity loss?



Relating biodiversity to ecosystem functioning

How do ecosystem functions/processes respond to biodiversity loss?

LETTER
doi:10.1038/nature23886

Biodiversity effects in the wild are common and as strong as key drivers of productivity

J. Emmett Duffy[1], Casey M. Godwin[2] & Bradley J. Cardinale[2]

Evidence from experimental and observational studies that species richness increases biomass production across various systems.

How would this observation relate to monocultures?

shutterstock.com · 1662168922

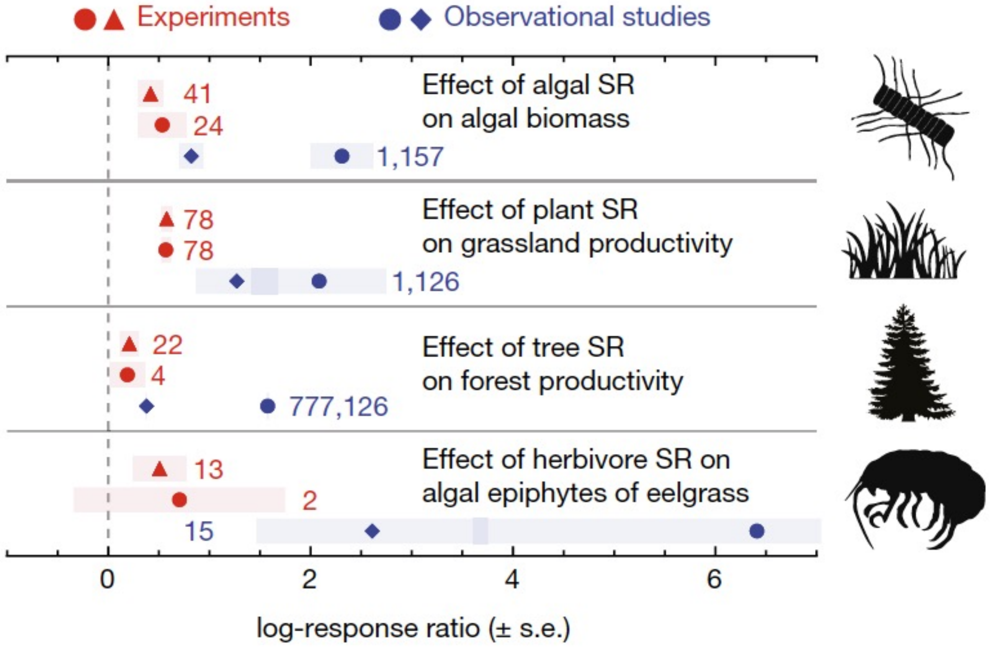


Figure 3 | Comparison of diversity effects on biomass production in observational versus experimental studies. Mean effect sizes are from experiments (red) and observational studies after accounting for covariates (blue). Observational estimates are calculated from the full dataset (circles) and over the narrower range of species richness (SR) used in experiments (diamonds). Triangles show log-response ratios calculated directly from experiments with ≥2 levels of species richness (without fitting a power function), whereas red circles show log response ratios calculated from the fitted power function. Numbers of experiments or sites included are shown. Horizontal bands denote standard errors. Extended Data Figs 1 and 2 show direct estimates of β and illustrate derivation of estimates, respectively.

EPFL

SCIENCE'S COMPASS • REVIEW

REVIEW: ECOLOGY

Biodiversity and Ecosystem Functioning: Current Knowledge and Future Challenges

M. Loreau,[1*] S. Naeem,[2] P. Inchausti,[1] J. Bengtsson,[3] J. P. Grime,[4] A. Hector,[5] D. U. Hooper,[6] M. A. Huston,[7] D. Raffaelli,[8] B. Schmid,[9] D. Tilman,[10] D. A. Wardle[4]

Mechanisms underlying the relationship between biodiversity and ecosystem functioning

- Dominance or selection effect
- Complementarity

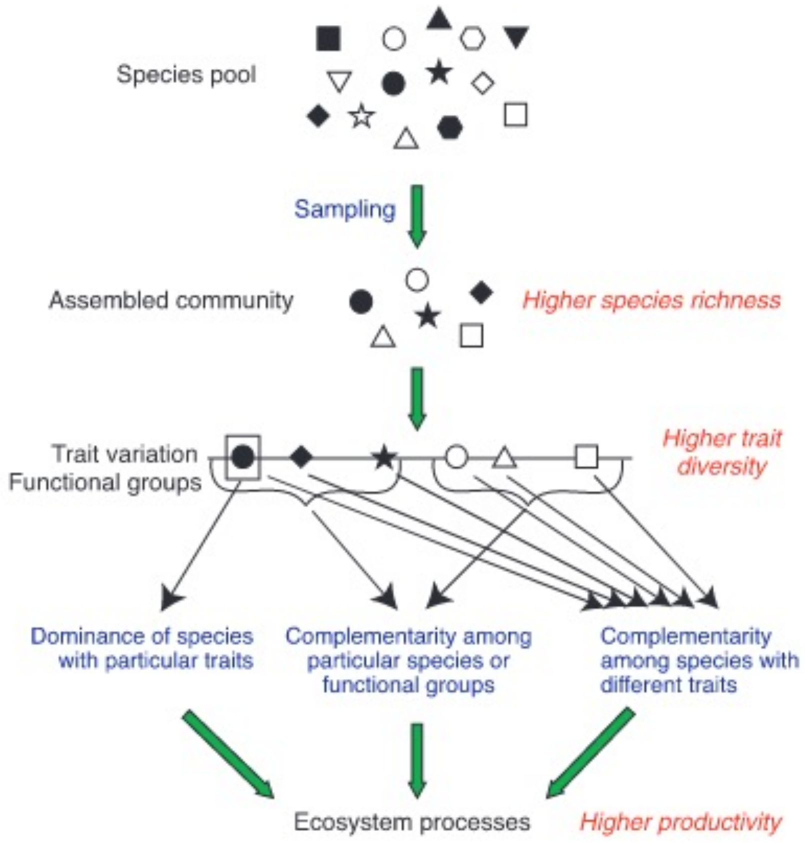


Fig. 2. Hypothesized mechanisms involved in biodiversity experiments using synthetic communities. Sampling effects are involved in community assembly, such that communities that have more species have a greater probability of containing a higher phenotypic trait diversity. Phenotypic diversity then maps onto ecosystem processes through two main mechanisms: dominance of species with particular traits, and complementarity among species with different traits. Intermediate scenarios involve complementarity among particular species or functional groups or, equivalently, dominance of particular subsets of complementary species.

LETTER

doi:10.1038/nature09904

Biodiversity improves water quality through niche partitioning

Bradley J. Cardinale[1]

Relating environmental heterogeneity to biodiversity and ecosystem functioning

LETTER
doi:10.1038/nature09904

Biodiversity improves water quality through niche partitioning

Bradley J. Cardinale[1]

Disturbance/environmental heterogeneity

- Nitrate removal increases with species richness
- Algal biomass increases with richness
- Niche complementarity overwhelms; more diverse species drive nitrate removal

No disturbance/environmental 'homogeneity'

- Nitrate removal saturates with species richness
- Algal biomass saturates with richness
- Selection effects overwhelms; one dominant species drives nitrate removal

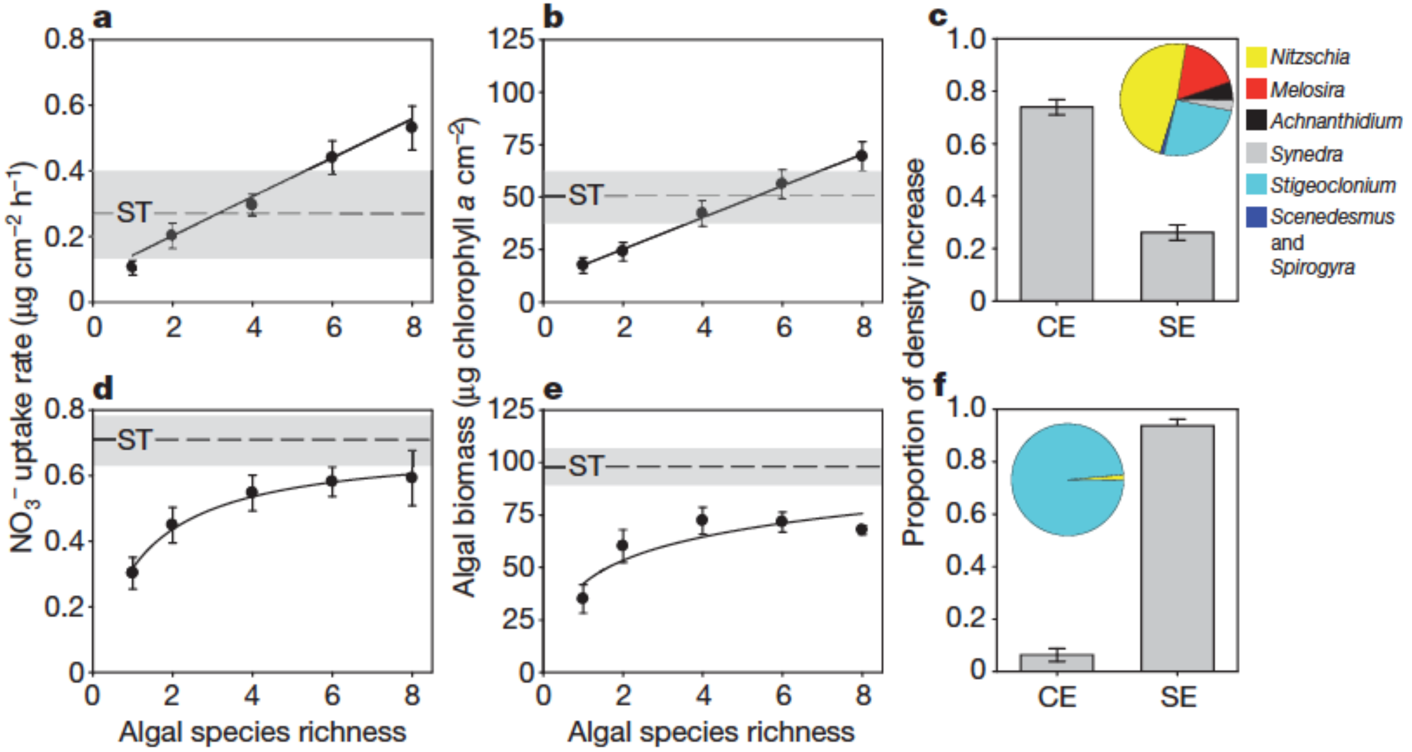


Figure 1 | Algal diversity effects on NO_3^-, algal biomass and final population sizes. **a–c**, Heterogeneous streams, with flow varying spatially and habitats varying in successional age. **d–f**, Homogeneous streams, in which niche opportunities had been removed. Data are presented as mean ± s.e.m. of 24 replicates for monocultures, 15 replicates for 2–6 species polycultures and 6 replicates for 8-species polycultures. Best fitting functions (Table 1) are plotted as solid lines. The horizontal line and the grey shaded area show mean ± s.e.m. for *Stigeoclonium*, which achieved the highest values of all of the monocultures. **c**, **f**, The proportion of increased polyculture cell densities driven by niche complementarity (CE) or selection effects (SE; that is, the influence of dominant species).

EPFL

Ecology, 83(2), 2002, pp. 412–422

THE INFLUENCE OF SUBSTRATE HETEROGENEITY ON BIOFILM METABOLISM IN A STREAM ECOSYSTEM

Bradley J. Cardinale,[1,3] Margaret A. Palmer,[1] Christopher M. Swan,[1] Shane Brooks,[1] and N. LeRoy Poff[2]

- Damming and flow regulation affect sediment dynamics
- Consequences for streambed sediment distribution
- Experimental change (homogenization) of the streambed environment (sediment distribution, associated hydraulics)

Fig. 1. (A) One of ten tile units that were placed on the benthic habitat of a low heterogeneity riffle. (B) The central incubation site showing tiles sealed inside 0.5-L metabolism chambers being held at a constant temperature in water baths. Also shown are examples of (C) low heterogeneity (LH) and (D) high heterogeneity (HH) riffles after manipulation of substrate variability.

Ecology, 83(2), 2002, pp. 412–422

THE INFLUENCE OF SUBSTRATE HETEROGENEITY ON BIOFILM METABOLISM IN A STREAM ECOSYSTEM

Bradley J. Cardinale,[1,3] Margaret A. Palmer,[1] Christopher M. Swan,[1] Shane Brooks,[1] and N. LeRoy Poff[2]

- Damming and flow regulation affect sediment dynamics
- Consequences for streambed sediment distribution
- Experimental change (homogenization) of the streambed environment (sediment distribution, associated hydraulics)

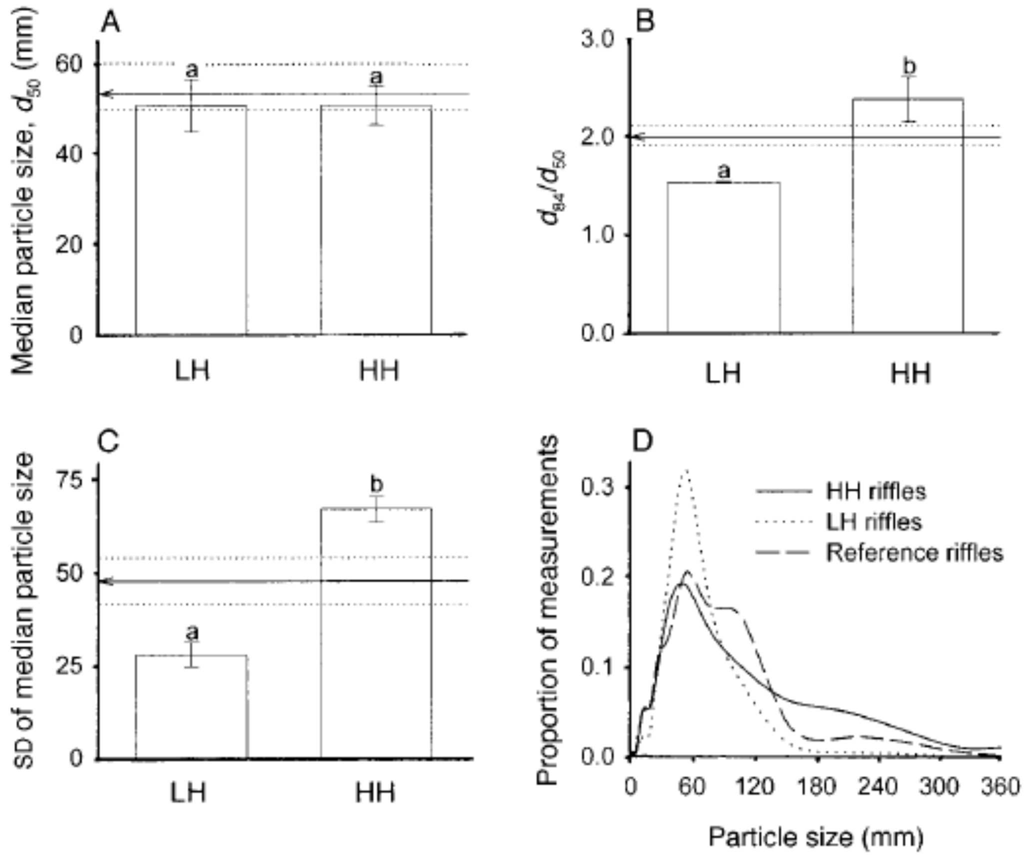


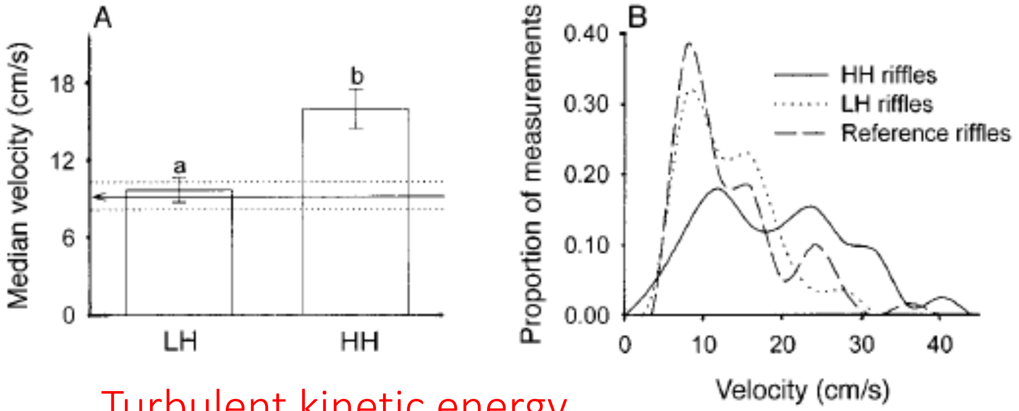
FIG. 2. (A) The median particle size in a riffle (d_{50}) and two measures of particle size heterogeneity: (B) the geomorphic ratio d_{84}/d_{50}, and (C) the standard deviation from the median particle size. Histograms show the means ± 1 SE for $N = 3$ low and $N = 4$ high heterogeneity riffles measured on day 20 of the experiment. Columns marked with different letters are significantly different from each other (t tests, $P < 0.05$). For comparison to natural characteristics of substrata in the stream, dotted lines show the maximum and minimum values, and the solid arrows show the mean value of $N = 3$ reference riffles that were not manipulated during the experiment. Also shown is (D) the frequency distribution of all particle measurements in the treatment and reference riffles. Smoothed trend lines are presented for clarity.

Ecology, 83(2), 2002, pp. 412–422

THE INFLUENCE OF SUBSTRATE HETEROGENEITY ON BIOFILM METABOLISM IN A STREAM ECOSYSTEM

Bradley J. Cardinale,[1,3] Margaret A. Palmer,[1] Christopher M. Swan,[1] Shane Brooks,[1] and N. LeRoy Poff[2]

Flow velocity



Turbulent kinetic energy

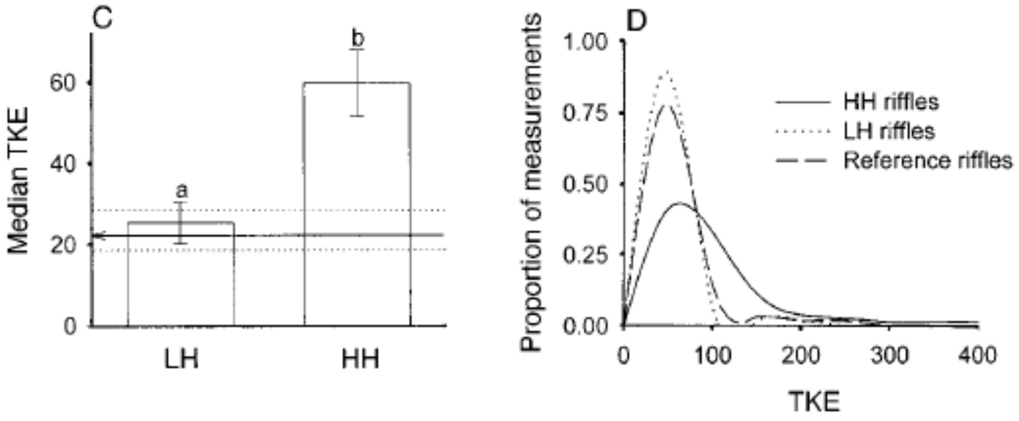


Fig. 3. (A) Median velocity, (B) the frequency distribution of velocity measurements, (C) median turbulent kinetic energy (TKE), and (D) the frequency distribution of TKE measurements in riffles on day 20 of the experiment. Data in plots (A) and (C) are mean values ± 1 se of $N = 3$ low and $N = 4$ high heterogeneity riffles. Columns with different letters are significantly different from each other (*t* tests, $P < 0.05$). For comparison to natural characteristics of the stream, dotted lines show the maximum and minimum values, and the solid arrows show the mean value of $N = 3$ reference riffles that were not manipulated during the experiment. Data in plots (B) and (D) represent all measurements collected in the treatments and reference riffles with smoothed trend lines presented for clarity.

- Damming and flow regulation affect sediment dynamics
- Consequences for streambed sediment distribution
- Experimental change (homogenization) of the streambed environment (sediment distribution, associated hydraulics)

EPFL

Ecology, 83(2), 2002, pp. 412–422

THE INFLUENCE OF SUBSTRATE HETEROGENEITY ON BIOFILM METABOLISM IN A STREAM ECOSYSTEM

Bradley J. Cardinale,[1,3] Margaret A. Palmer,[1] Christopher M. Swan,[1] Shane Brooks,[1] and N. LeRoy Poff[2]

- Homogenization of sediment distribution and associated hydraulics affect benthic metabolism (respiration, GPP)

- Environmental heterogeneity/homogeneity matter for biodiversity and critical ecosystem processes in streams and rivers

- This relates to the hydraulic niches for invertebrates and microbes

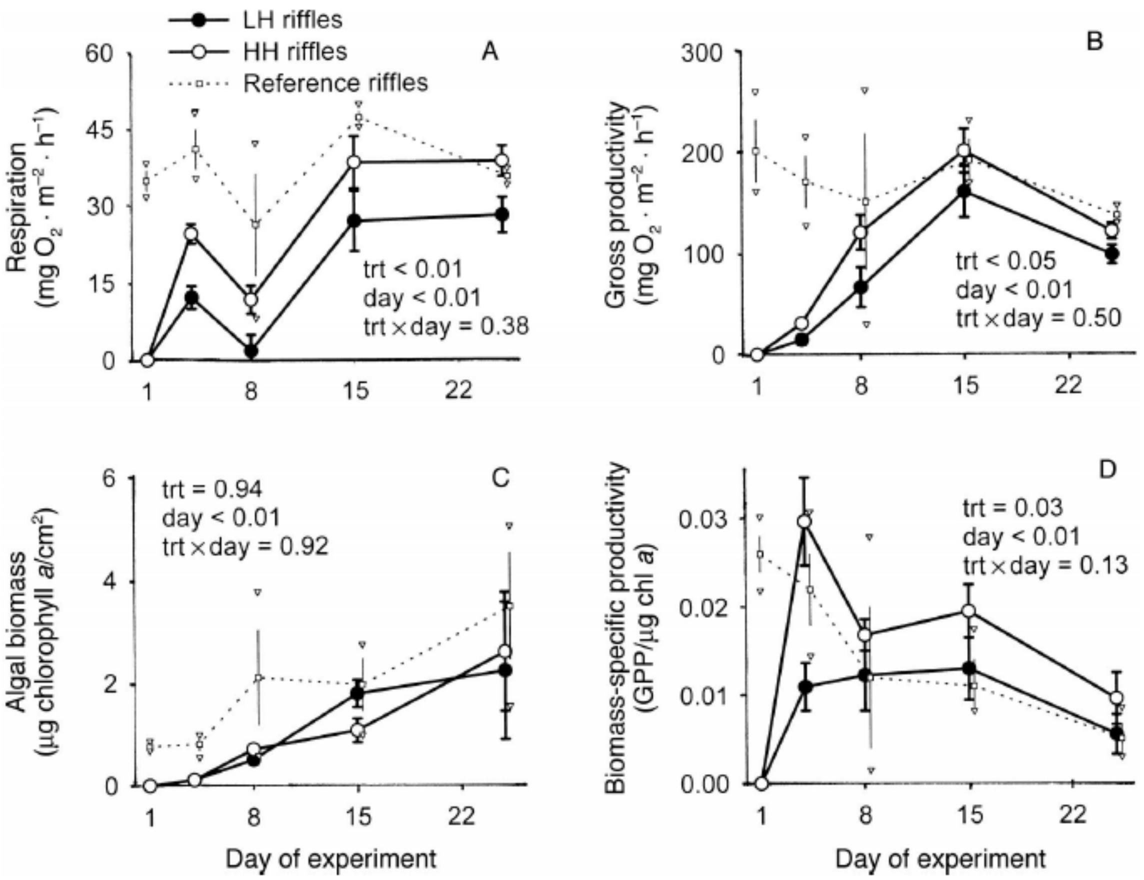


Fig. 4. (A) Respiration, (B) GPP, (C) algal biomass, and (D) biomass-specific productivity of the benthic biofilm on standardized ceramic tiles colonized in the riffle habitats. Data points are the mean ± 1 SE of N = 3 low heterogeneity, N = 4 high heterogeneity, and N = 3 reference riffles. Open triangles show the maximum and minimum values for the reference riffles on each date. P values from repeated-measures ANOVAs comparing the LH and HH treatments are displayed for each variable. Mean temperatures during incubation of the tiles were held at ambient stream temperature (day 1 = 23.5°C, day 4 = 23.3°C, day 8 = 23.4°C, day 15 = 23.6°C, and day 25 = 24.7°C), and lighting conditions were identical for all tiles within a date (see *Methods*).

Environmental heterogeneity does matter for biodiversity and ecosystem processes and functioning

Global change reduces environmental heterogeneity (in space and time), thereby reducing biodiversity and deteriorating ecosystem functioning

From the benthic zone to the hyporheic zone

EPFL

water

MDPI

Communication

Is the Hyporheic Zone Relevant beyond the Scientific Community?

Jörg Lewandowski [1,2,*], Shai Arnon [3], Eddie Banks [4], Okke Batelaan [4], Andrea Betterle [5,6], Tabea Broecker [7], Claudia Coll [8], Jennifer D. Drummond [9], Jaime Gaona Garcia [1,10,11], Jason Galloway [1,2], Jesus Gomez-Velez [12], Robert C. Grabowski [13], Skuyler P. Herzog [14], Reinhard Hinkelmann [7], Anja Höhne [1,15], Juliane Hollender [5], Marcus A. Horn [16,17], Anna Jaeger [1,2], Stefan Krause [9], Adrian Löchner Prats [18], Chiara Magliozzi [13,19], Karin Meinikmann [1,20], Brian Babak Mojarrad [21], Birgit Maria Mueller [1,22], Ignacio Peralta-Maraver [23], Andrea L. Popp [5,24], Malte Posselt [8], Anke Putschew [22], Michael Radke [25], Muhammad Raza [26,27], Joakim Riml [21], Anne Robertson [23], Cyrus Rutere [16], Jonas L. Schaper [1,22], Mario Schirmer [5], Hanna Schulz [1,2], Margaret Shanafield [4], Tanu Singh [9], Adam S. Ward [14], Philipp Wolke [1,28], Anders Wörman [21] and Liwen Wu [1,2]

The hyporheic zone of streams and rivers

- Interface between surface and subsurface (groundwater) water
- Porous flow
- No light available
- Large sedimentary surface area
- Microbial growth, chemical reactions
- Chemical gradients (redox)

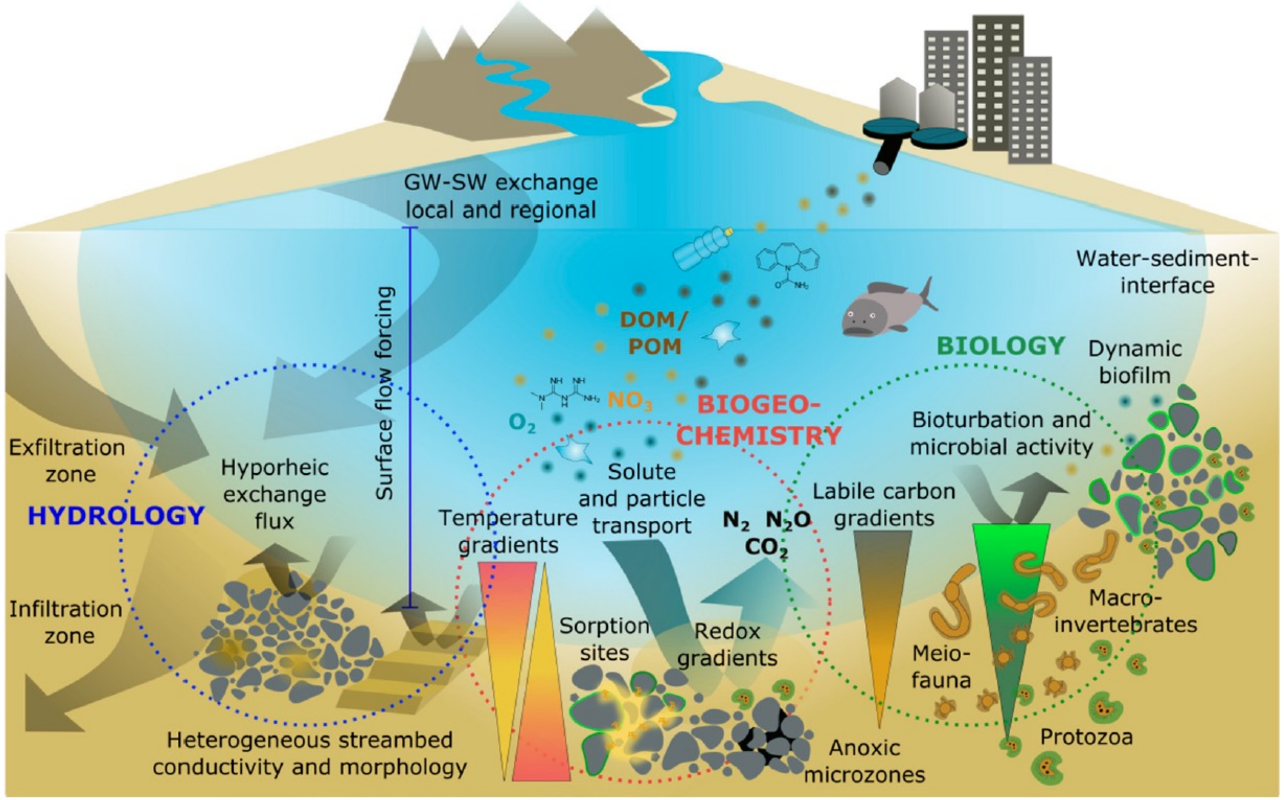
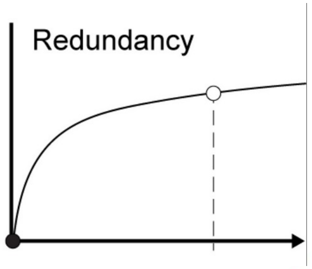
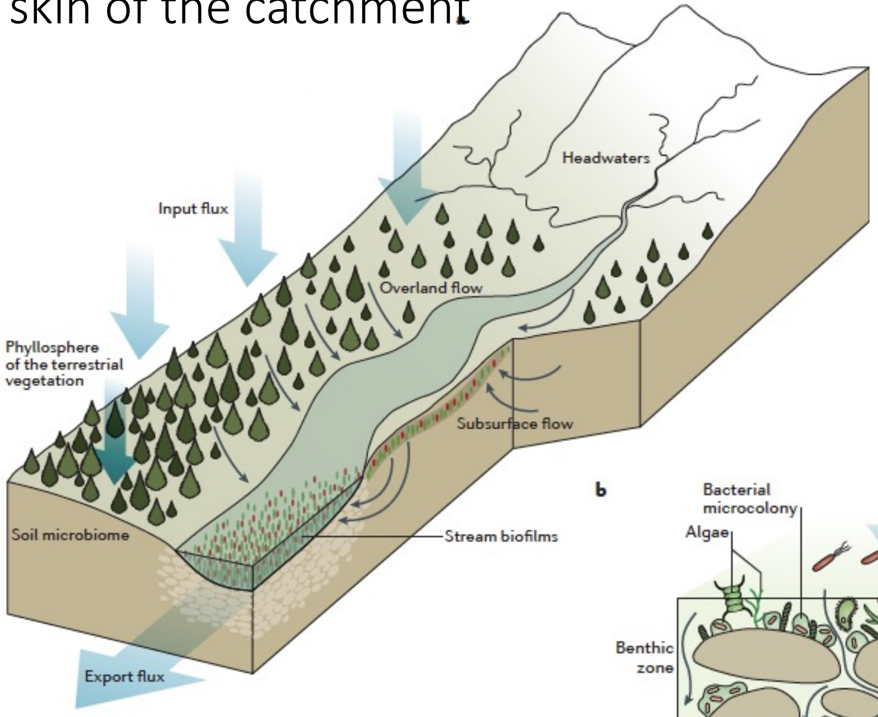


Figure 1. Conceptual model of the major hyporheic zone drivers and processes, as discussed in Section 2 of the present review. Dashed circles indicate the separation of disciplines in current hyporheic research, despite the high system complexity and manifold interconnections of hyporheic processes. GW-SW exchange is groundwater-surface water exchange; DOM and POM are dissolved or particulate organic matter, respectively.

The streambed and its biofilms
The microbial skin of the catchment



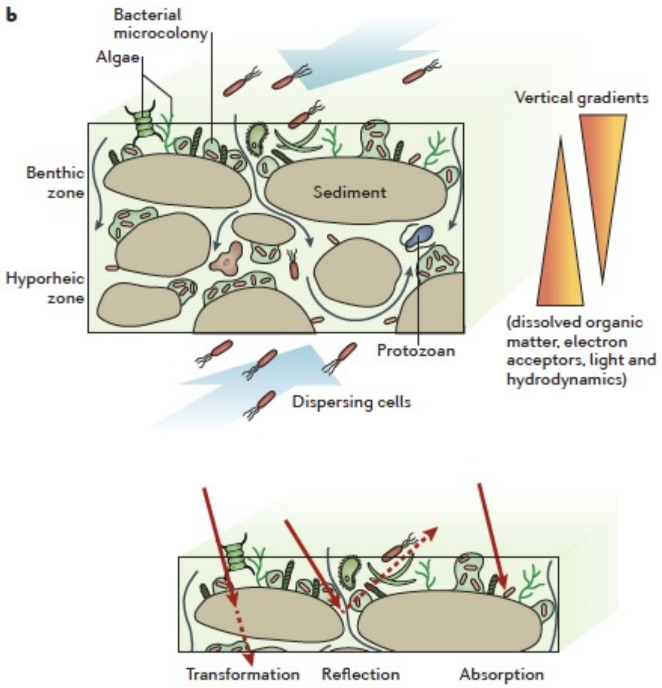


MICROBIAL BIOFILMS

The ecology and biogeochemistry of stream biofilms

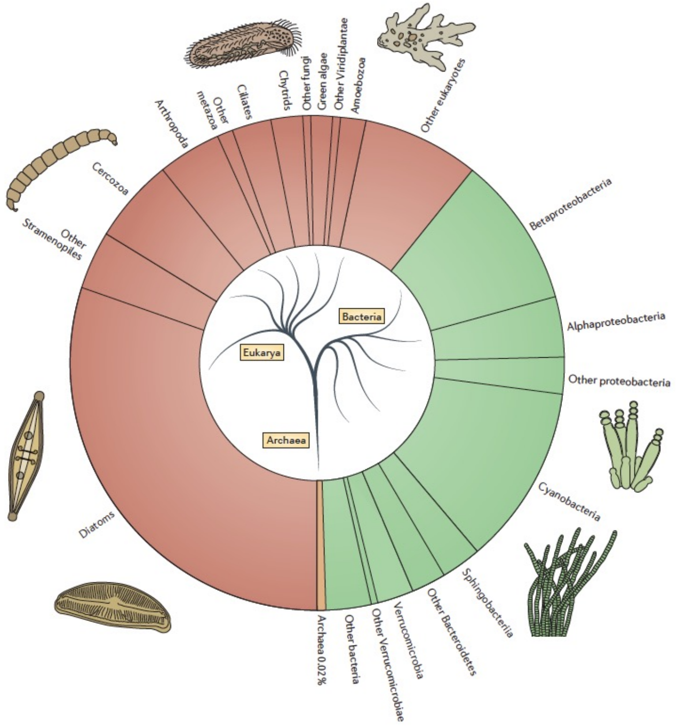
Tom J. Battin[1], Katharina Besemer[2], Mia M. Bengtsson[3], Anna M. Romani[4] and Aaron I. Packmann[5]

NATURE REVIEWS | MICROBIOLOGY



Stream biofilms

- Surface-attached microbial communities
- Encapsulated in a polymeric matrix
- Highly diverse — spanning all three domains of life, plus viruses
- Biofilm activity induces microscale chemical gradients within the streambed/hyporheic zone



EPFL

The biofilm matrix

Hans-Curt Flemming and Jost Wingender

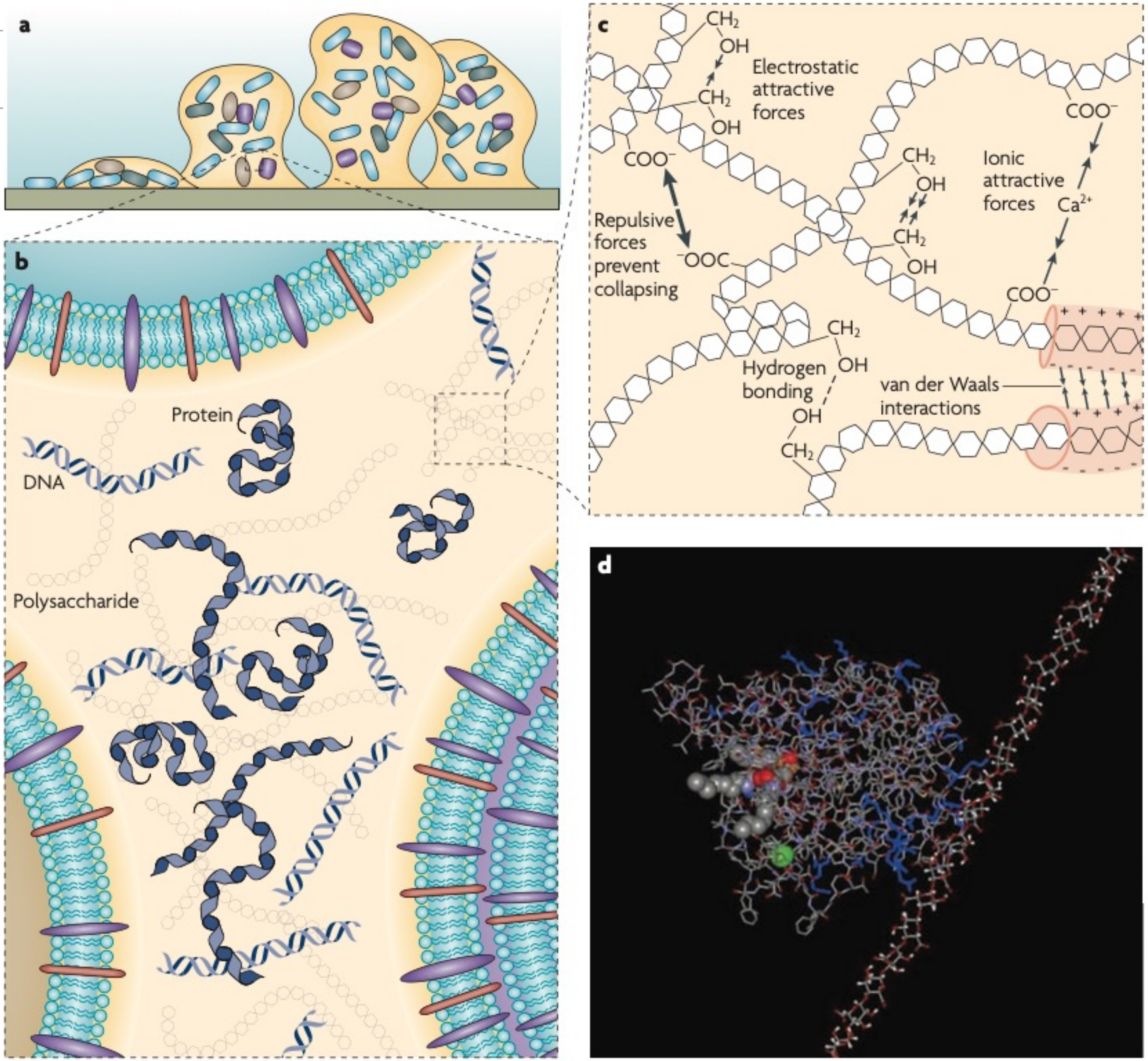
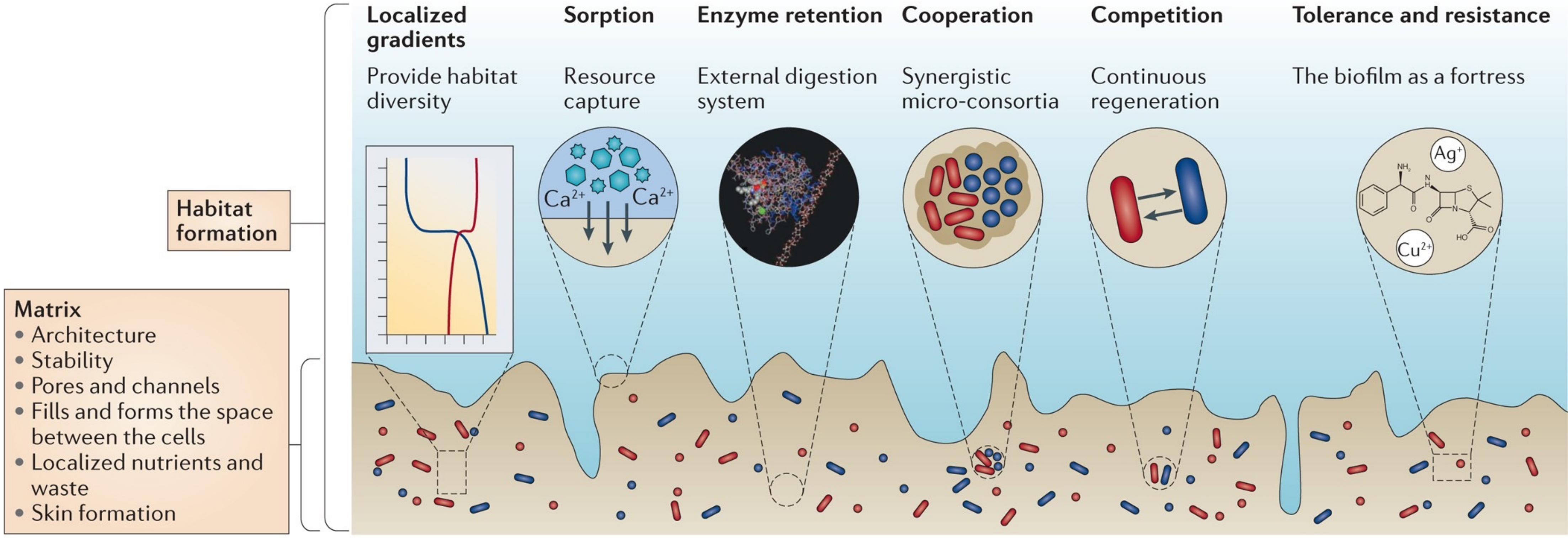


Figure 1 | **The extracellular polymeric substances matrix at different dimensions. a** | A model of a bacterial biofilm attached to a solid surface. Biofilm formation starts with the attachment of a cell to a surface. A microcolony forms through division of the bacterium, and production of the biofilm matrix is initiated. Other bacteria can then be recruited as the biofilm expands owing to cell division and the further production of matrix components. **b** | The major matrix components — polysaccharides, proteins and DNA — are distributed between the cells in a non-homogeneous pattern, setting up differences between regions of the matrix. **c** | The classes of weak physicochemical interactions and the entanglement of biopolymers that dominate the stability of the EPS matrix[47]. **d** | A molecular modelling simulation of the interaction between the exopolysaccharide alginate (right) and the extracellular enzyme lipase (left) of *Pseudomonas aeruginosa* in aqueous solution. The starting structure for the simulation of the lipase protein was obtained from the Protein Data Bank[117]. The coloured spheres represent 1,2-dioctylcarbamoyl-glycero-3-O-octylphosphonate in the lipase active site (which was present as part of the crystal structure), except for the green sphere, which represents a Ca^{2+} ion. The aggregate is stabilized by the interaction of the positively charged amino acids arginine and histidine (indicated in blue) with the polyanionic alginate. Water molecules are not shown. Image courtesy of H. Kuhn, CAM-D Technologies, Essen, Germany.

What are the advantages of the biofilm mode of life?

(since 3.2 billion years)



Nature Reviews | Microbiology

MICROBIAL BIOFILMS

Biofilms: an emergent form of bacterial life

Hans-Curt Flemming[1], Jost Wingender[1], Ulrich Szewzyk[2], Peter Steinberg[3], Scott A. Rice[4] and Staffan Kjelleberg[4]

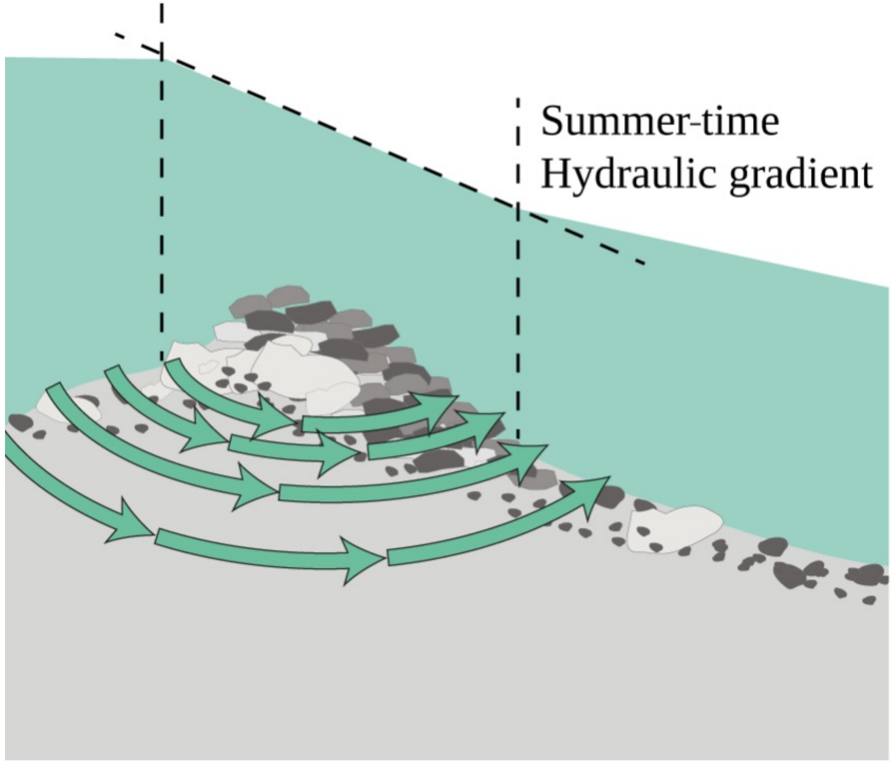
EPFL

Bedform features and related hydraulic gradients promote hyporheic exchange

Advective transport of solutes and gases into the hyporheic zone — increased residence times (porous flow!) facilitate chemical reaction and microbial growth

Bedform features (i.e., roughness) also promote turbulence, hence gas (e.g., O_2) transfer through the water surface

Replenishing gas transport into the hyporheic zone — as a <u>bioreactor</u>
(vessel where raw materials are transformed into specific products through a series of organic reactions, creating optimal conditions for microbial growth and ecological processes.)

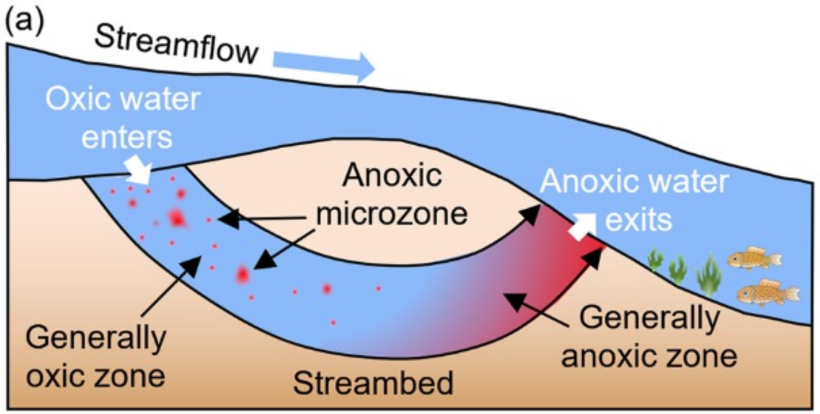


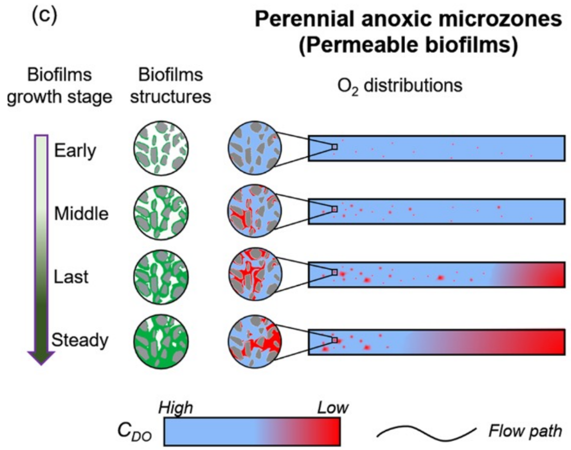
Geophysical Research Letters

Research Letter | Free Access

Permeable Biofilms Can Support Persistent Hyporheic Anoxic Microzones

Yang Xian, Menggui Jin, Hongbin Zhan, Xing Liang





EPFL

The hyporheic zone as a bioreactor

- Increased residence times and inputs from various sources (e.g., surface water, groundwater)
- Transformation and greenhouse gas production
- Impacts for downstream biogeochemistry
- ‘Self-purification’ – removal of pollutants

Requires a holistic view across disciplines

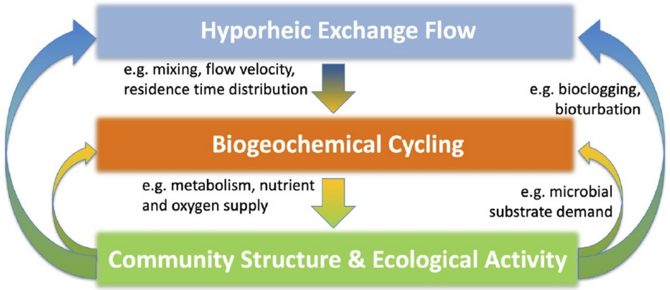
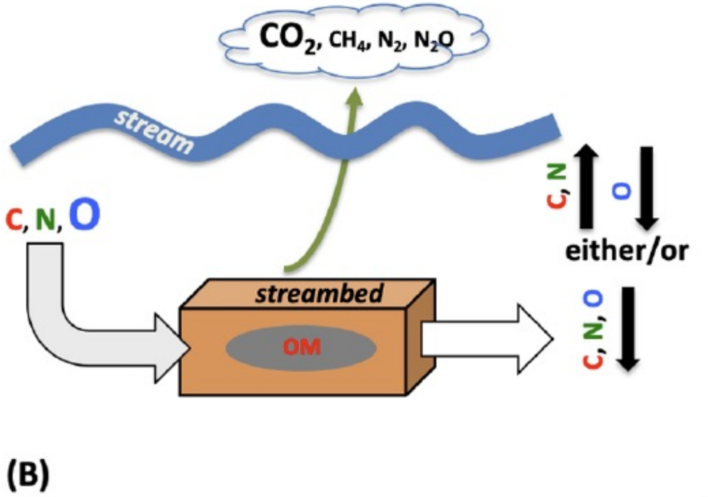
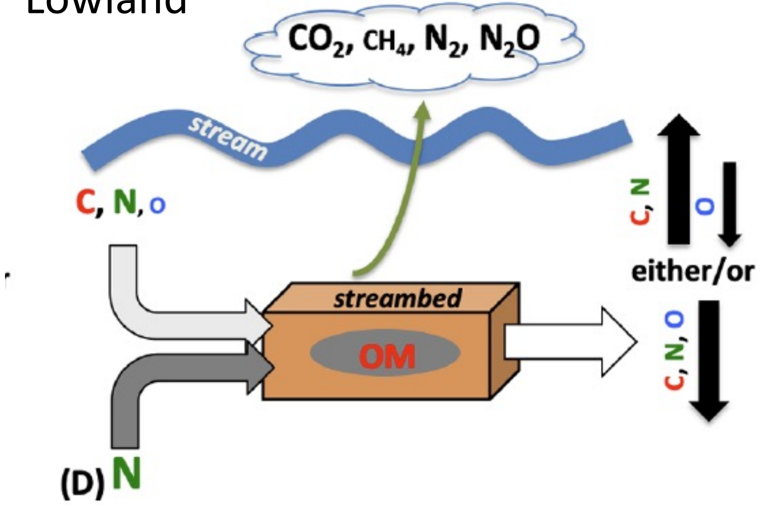


Figure 5. Multi-directional interactions between physical controls of hyporheic exchange flow, streambed biogeochemical cycling, and biological community structure and ecological (metabolic) functioning (red arrows), including ecological feedbacks on streambed biogeochemistry biogeochemistry [e.g., microbial demand for substrate shifting porewater from oxic to anoxic (aerobic to anaerobic metabolic pathways)] as well as hyporheic exchange (e.g., bioturbation, bioclogging, and ecosystem engineering).

Headwaters



Lowland



Water Resources Research®

REVIEW ARTICLE

10.1029/2021WR029771

Organizational Principles of Hyporheic Exchange Flow and Biogeochemical Cycling in River Networks Across Scales

Stefan Krause[1], Benjamin W. Abbott[2], Viktor Baranov[3], Susana Bernal[4], Phillip Blaen[1], Thibault Datry[5], Jennifer Drummond[4], Jan H. Fleckenstein[6], Jesus Gomez Velez[7], David M. Hannah[1], Julia L. A. Knapp[8], Marie Kurz[9], Jörg Lewandowski[10], Eugènia Martí[4], Clara Mendoza-Lera[11], Alexander Milner[1], Aaron Packman[12], Gilles Pinay[13], Adam S. Ward[14], and Jay P. Zarnetzke[15]

Key Points:

- The complexity of HZ rivers and controls exceeds the range of conditions considered in previous conceptualizations and model formulations
- Understanding organizational

EPFL

Restoring the bioreactor


ELSEVIER

Water Research

Volume 150, 1 March 2019, Pages 140-152

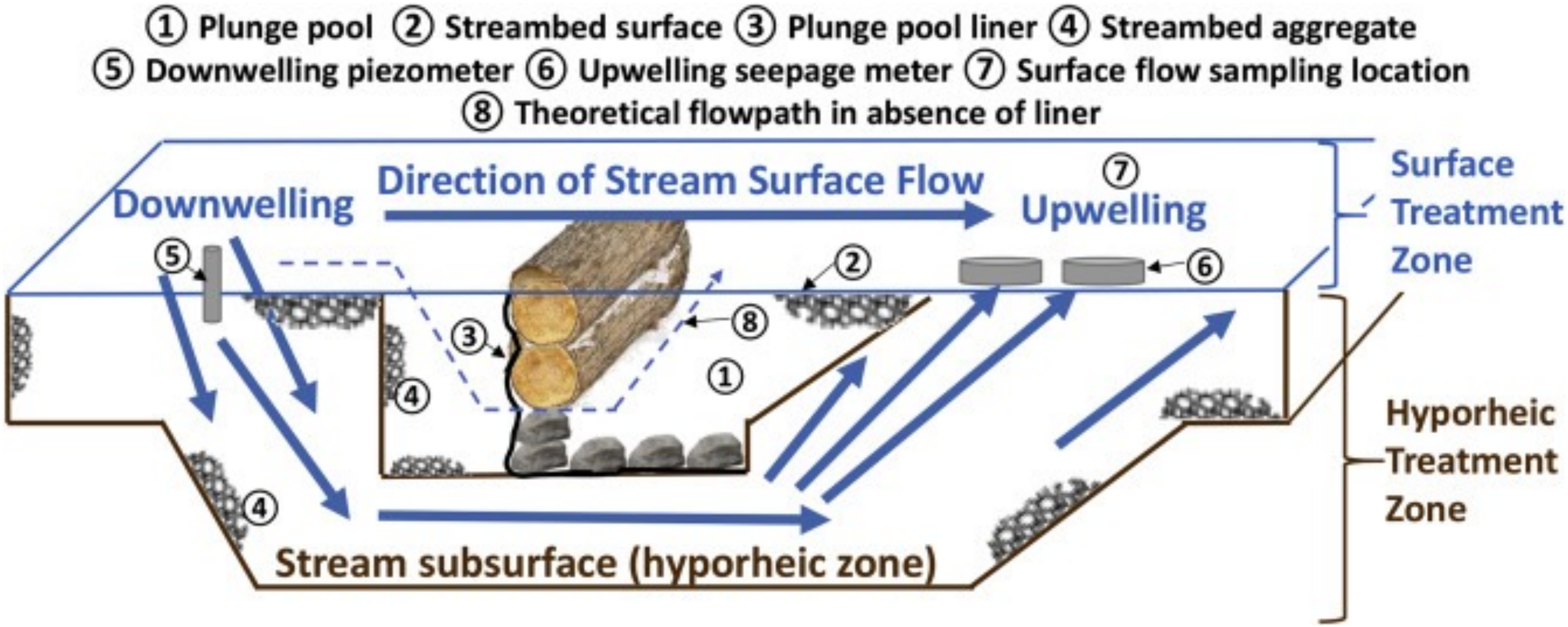
Evaluating emerging organic contaminant removal in an engineered hyporheic zone using high resolution mass spectrometry

Katherine T. Peter [a b], Skuyler Herzog [c], Zhenyu Tian [a b], Christopher Wu [a b], John E. McCray [c], Katherine Lynch [d], Edward P. Kolodziej [a b e]

- Forcing surface water flow into the streambed
- Engineering the streambed
- Learn from nature (riffle-pool-riffle sequence)

“substantial water quality improvement in hyporheic flowpaths relative to surface flow and improved contaminant removal with longer hyporheic HRT”

“strong contributions of hydrophobic sorption towards observed contaminant attenuation”



EPFL

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Federal Office for the Environment FOEN

2015: ‘*….there is no microplastics in Swiss rivers…*’

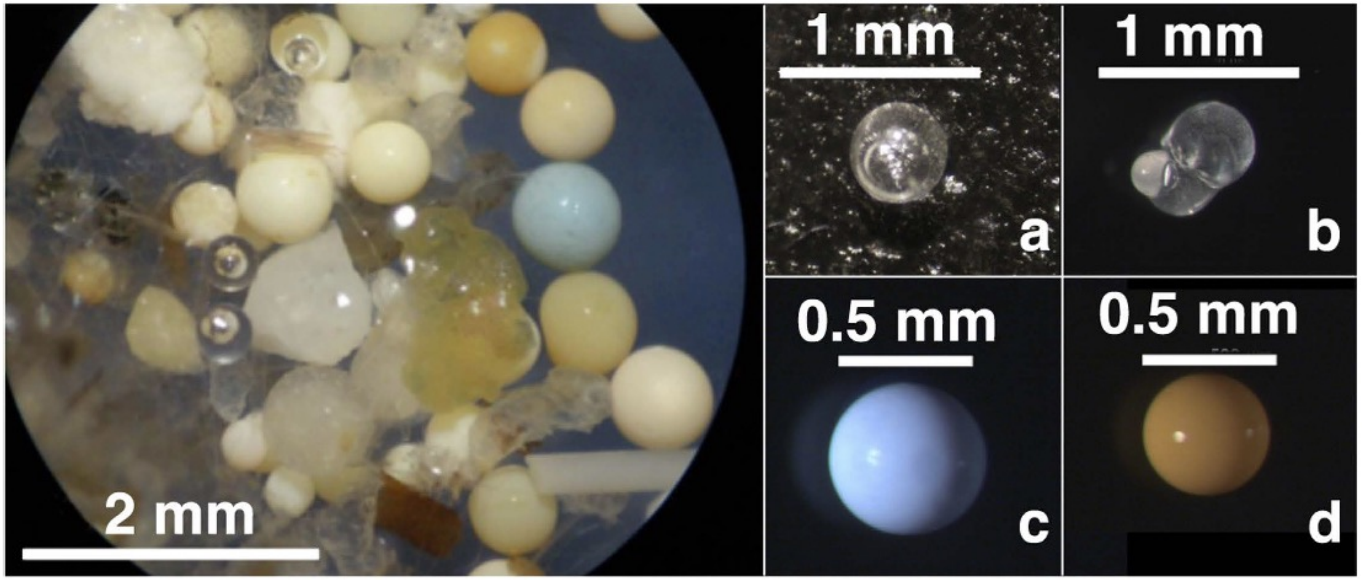
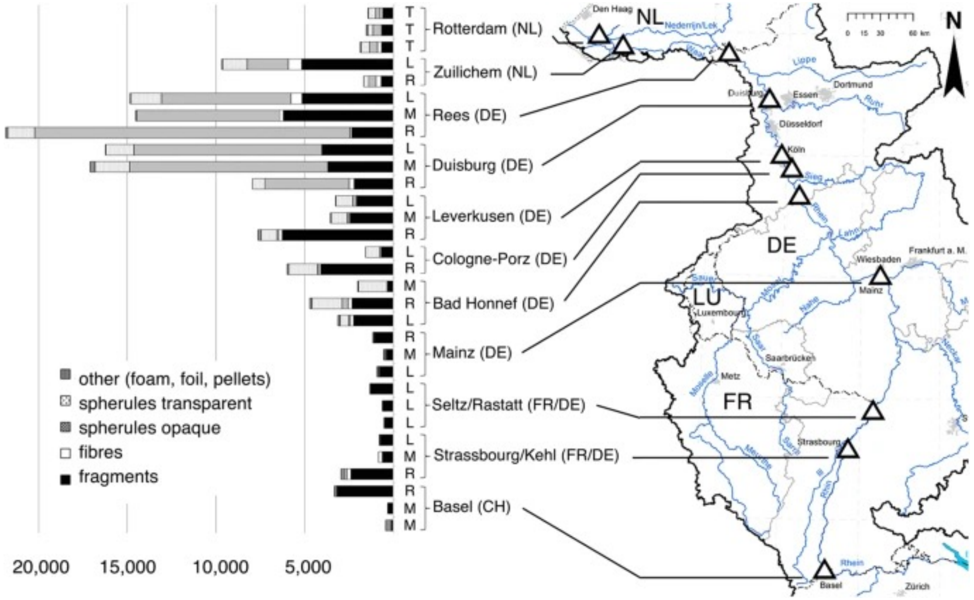


Figure 2. Typical microplastic categories in the Rhine. Left: Duisburg sample consisting of 65% opaque spherules, further fragments and fibres, bar: 2 mm. (**a/b**) transparent spherules with gas bubbles, polymethyl-methacrylate (Zuilichem), bars: 1 mm; (**c/d**) opaque spherules, polystyrene (Duisburg, Rees), bars: 500 µm.

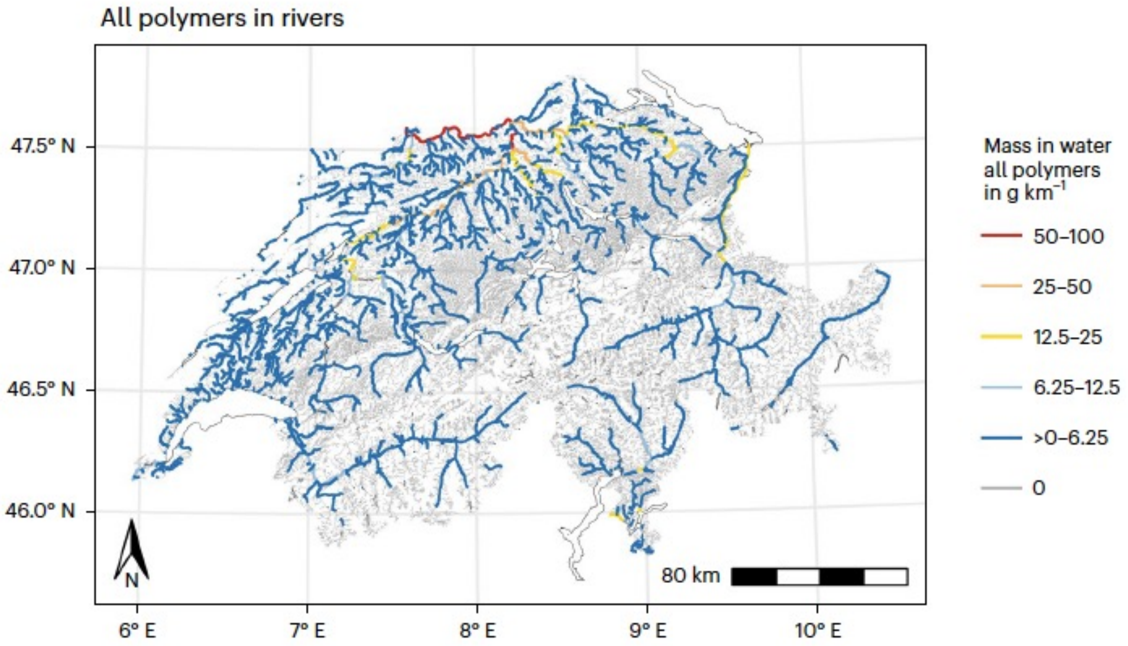
Microplastics profile along the Rhine River

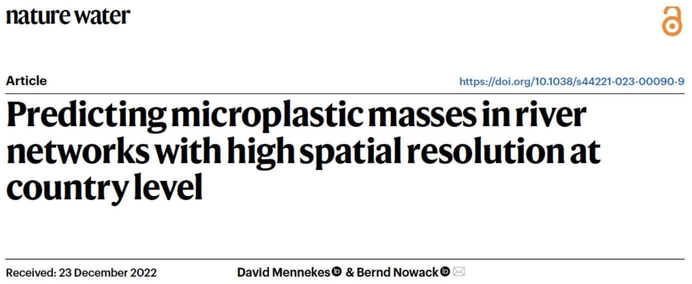
Thomas Mani[1], Armin Hauk[2], Ulrich Walter[2] & Patricia Burkhardt-Holm[1,3]



Microplastics in rivers

- There is microplastics in Swiss rivers and streams
- Regional/catchment heterogeneity
- Downstream accumulation of MP
- Deposition in lakes and rivers



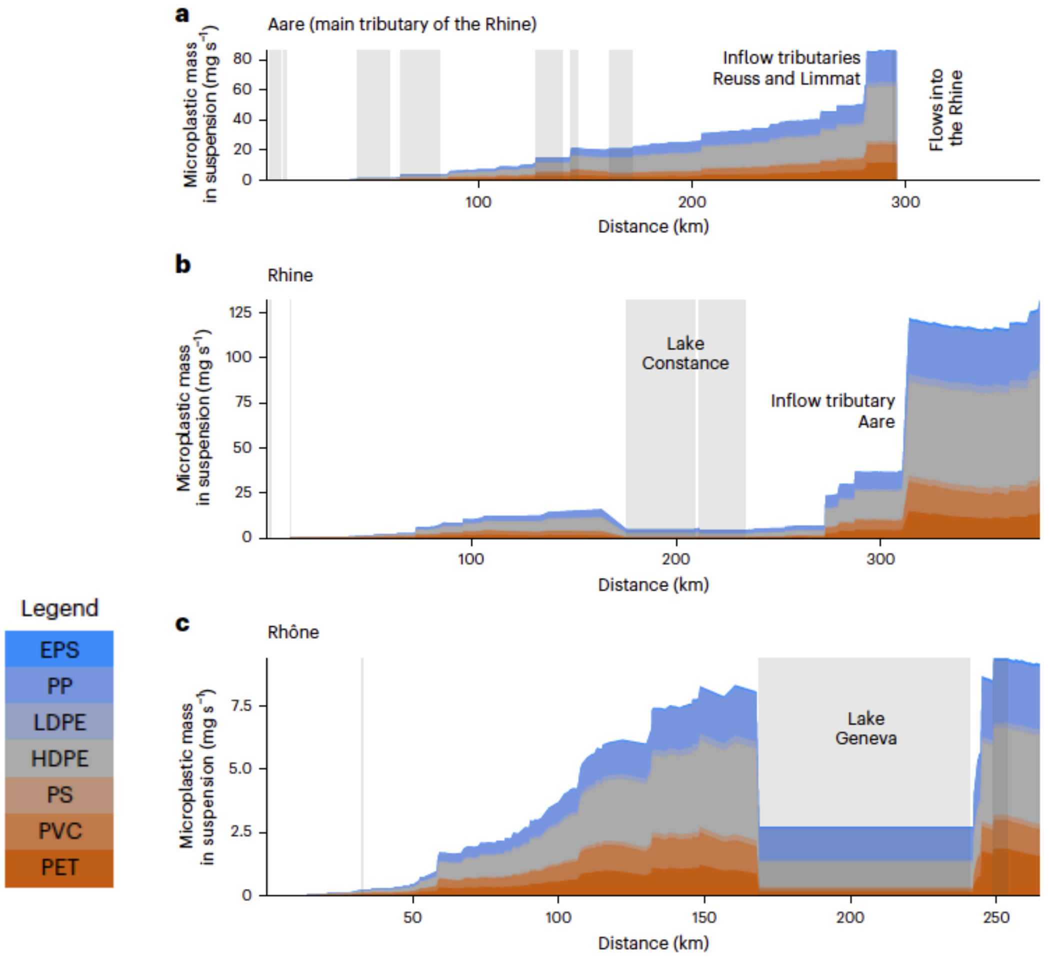

nature water

Article https://doi.org/10.1038/s44221-023-00090-9

Predicting microplastic masses in river networks with high spatial resolution at country level

Received: 23 December 2022

David Mennekes & Bernd Nowack



Expanded polystyrene (EPS), polypropylene (PP), low density polyethylene (LDPE), high-density polyethylene (HDPE), polystyrene (PS), polyvinyl chloride (PVC) and polyethylene terephthalate (PET)

Microplastics in rivers

nature water

Article https://doi.org/10.1038/s44221-023-00090-9

Predicting microplastic masses in river networks with high spatial resolution at country level

Received: 23 December 2022

David Mennekes & Bernd Nowack

- There is microplastics in Swiss rivers and streams
- Regional/catchment heterogeneity
- Downstream accumulation of MP
- Deposition in lakes and rivers

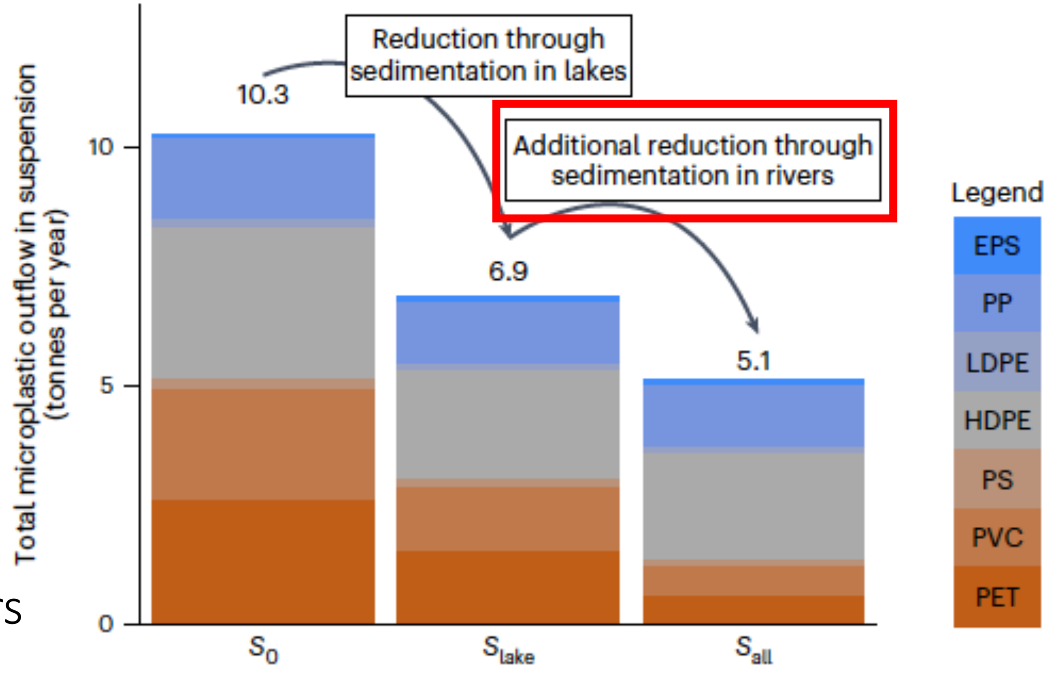


Fig. 2 | Microplastic retention of all analysed polymers differentiated by different colours in entire Switzerland. The scenarios S_0, S_{lake} and S_{all} are different model runs that consider no sedimentation and accumulation (S_0) sedimentation and accumulation only in lakes (S_{lake}) and sedimentation and accumulation in lakes and rivers (S_{all}). S_0 equals the input emission to the system based on Kawecki and Nowack[26]. The results represent a steady-state system for the year 2014.

Expanded polystyrene (EPS), polypropylene (PP), lowdensity polyethylene (LDPE), high-density polyethylene (HDPE), polystyrene (PS), polyvinyl chloride (PVC) and polyethylene terephthalate (PET)

Modeled scenarios of microplastics loads

- S_0: no accumulation and sedimentation
- S_{lake}: accumulation and sedimentation in lakes
- S_{all}: accumulation and sedimentation in lakes and rivers

A role for streams and rivers

A role for the hyporheic zone?

EPFL

Microplastics in rivers and the hyporheic zone

SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

Microplastic accumulation in riverbed sediment via hyporheic exchange from headwaters to mainstems

Jennifer D. Drummond[1]*, Uwe Schneidewind[1], Angang Li[2], Timothy J. Hoellein[3], Stefan Krause[1,4], Aaron I. Packman[2]

- Legacy effects
- Fragmentation
- Degradation

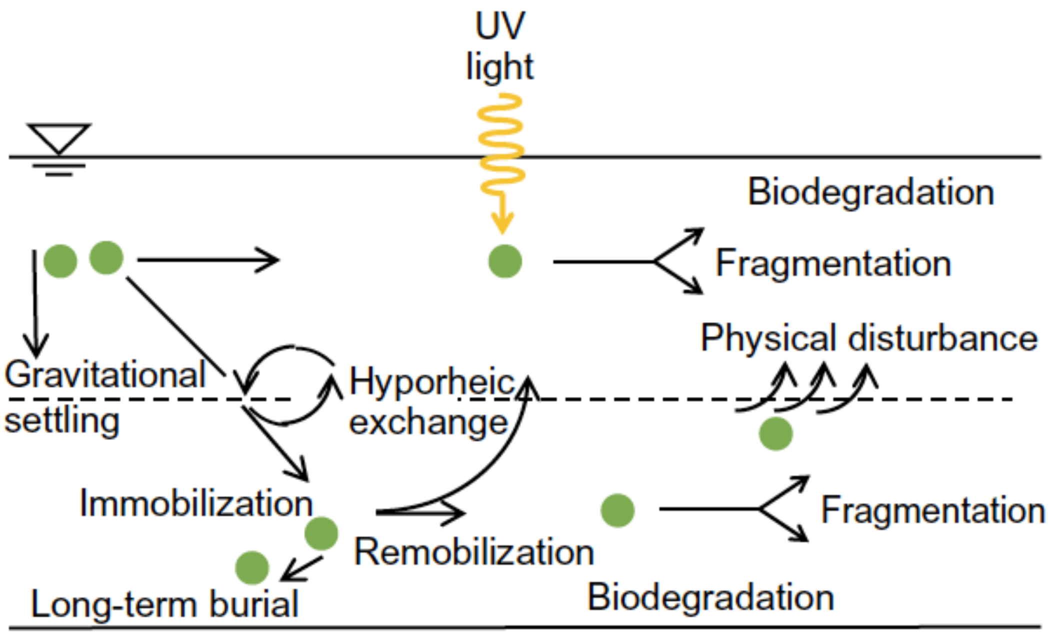
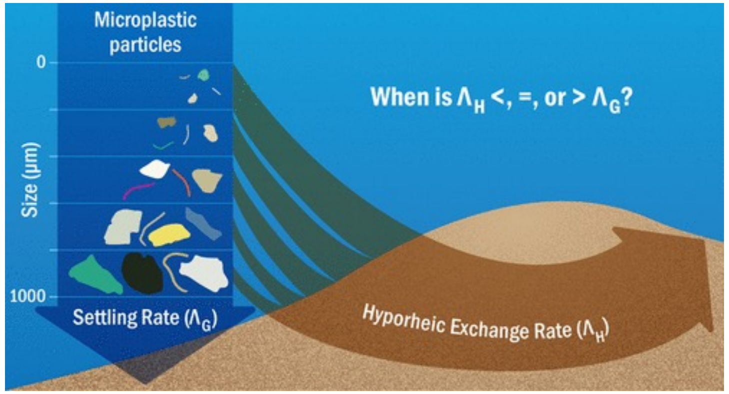


Fig. 1. Processes that control MP accumulation in rivers. Both gravitational settling and hyporheic exchange transport MPs into riverbed sediment, followed by either long-term burial, biodegradation and fragmentation, or remobilization to the water column.

Microplastics in rivers and the hyporheic zone



SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

Microplastic accumulation in riverbed sediment via hyporheic exchange from headwaters to mainstems

Jennifer D. Drummond[1]*, Uwe Schneidewind[1], Angang Li[2], Timothy J. Hoellein[3], Stefan Krause[1,4], Aaron I. Packman[2]

- Simulations indicate that the longest microplastic residence times occur in headwaters, the most abundant stream classification.
- In headwaters, residence times averaged 5 hours/km and increased to 7 years/km during low flow.

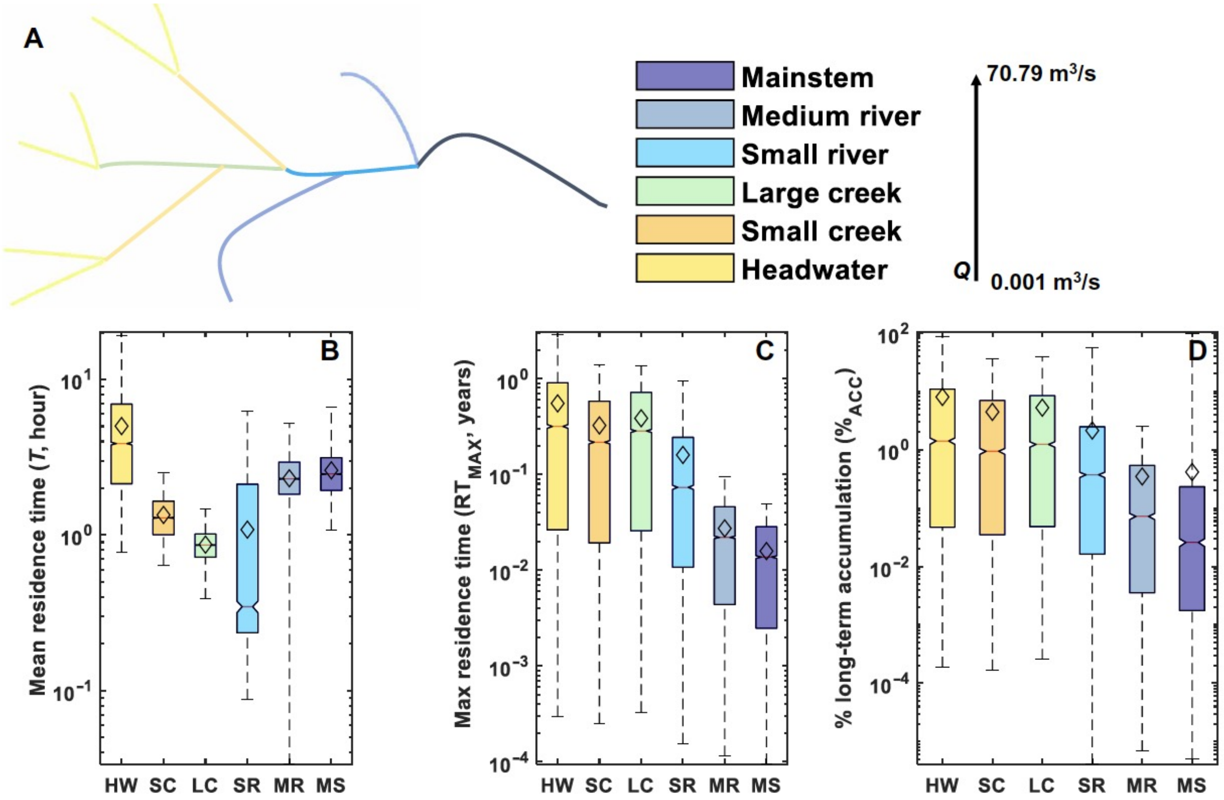
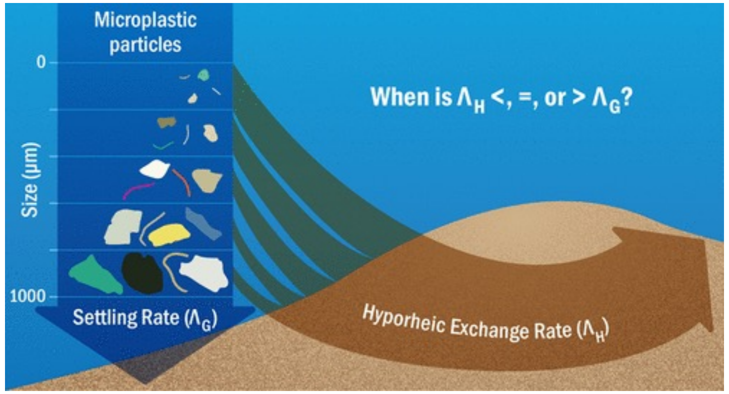
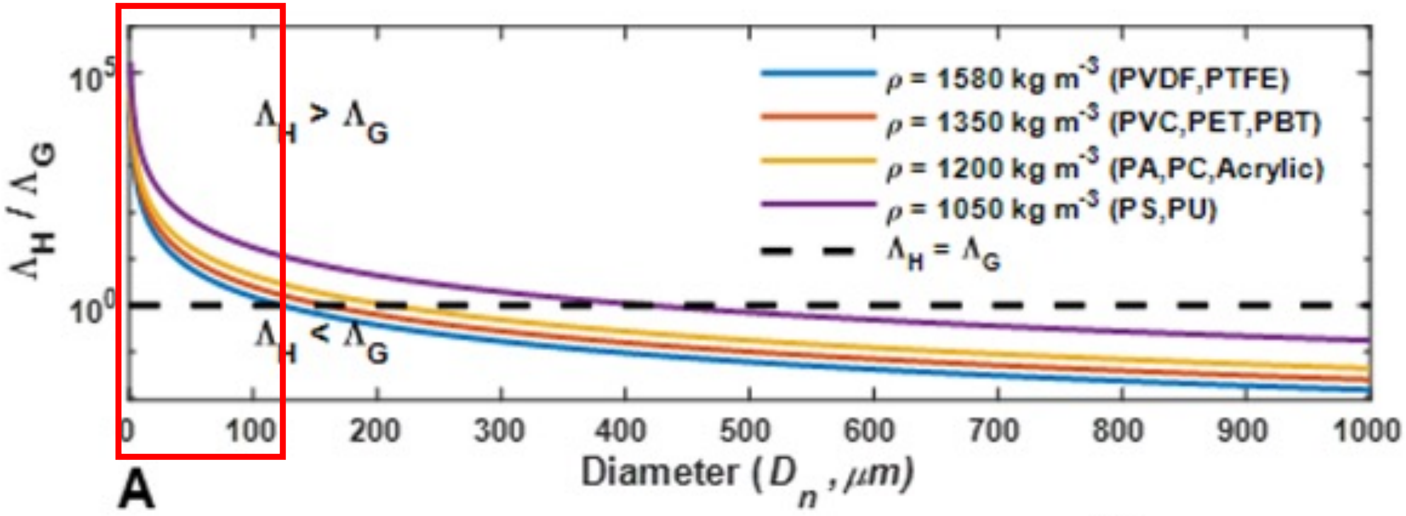


Fig. 2. Retention times and accumulation of MPs in riverbed sediment per kilometer in headwaters to mainstems for the range in average annual streamflow conditions. Schematic of stream classification by discharge (**A**). MP (**B**) mean residence times ($\bar{T}$), (**C**) maximum residence time (RT_{MAX}) for the particles that transport downstream and are not retained, and (**D**) percentage of long-term accumulation (i.e., >317 years) in riverbed sediment ($\%_{ACC}$) per kilometer by stream classification of headwaters to mainstems (Table 2). The black diamond is the mean value for each stream classification. HW, headwater; SC, small creek; LC, large creek; SR, small river; MR, medium river; MS, mainstem.

EPFL

Microplastics in rivers and the hyporheic zone



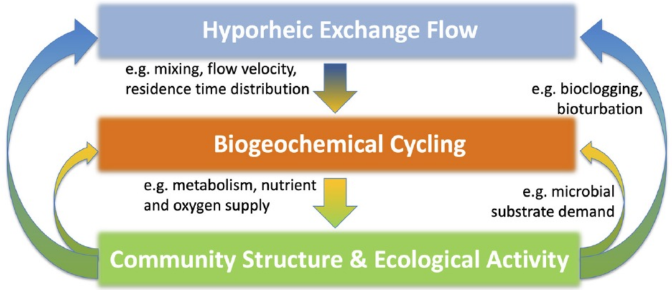


Environmental Science & Technology LETTERS
pubs.acs.org/journal/estlcu
Letter

Significance of Hyporheic Exchange for Predicting Microplastic Fate in Rivers

Jennifer D. Drummond,* Holly A. Nel, Aaron I. Packman, and Stefan Krause

A field showed that 23% of all microplastic combinations have a hyporheic exchange rate that is higher than their settling rate. This fraction was as high as 42% for microplastics composed of low-density polymers, such as polyethylene.

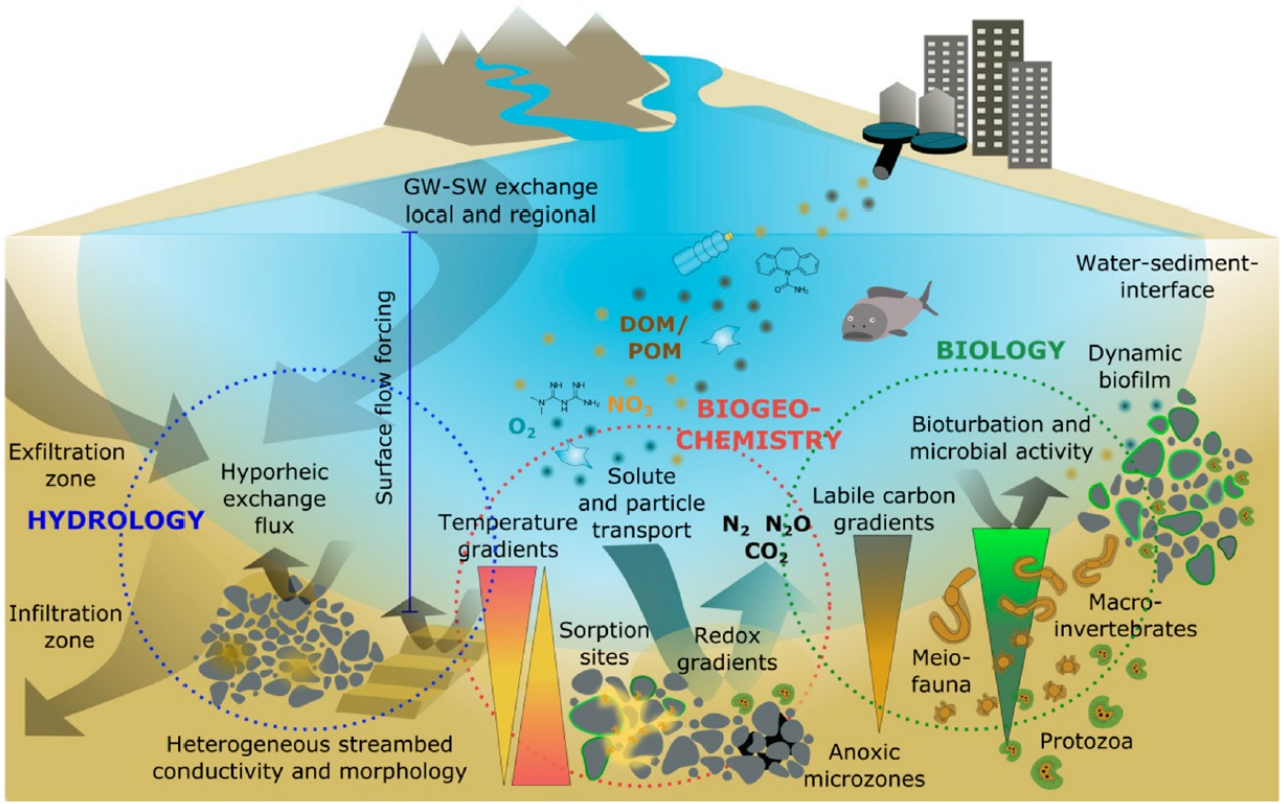


Microplastics in the hyporheic zone and ecosystem functioning?

Hyporheic exchange is important for the transport and fate of particles that are <100 µm in diameter, irrespective of polymer type.

EPFL

Hyporheic processes matter for stream/river ecosystem functioning



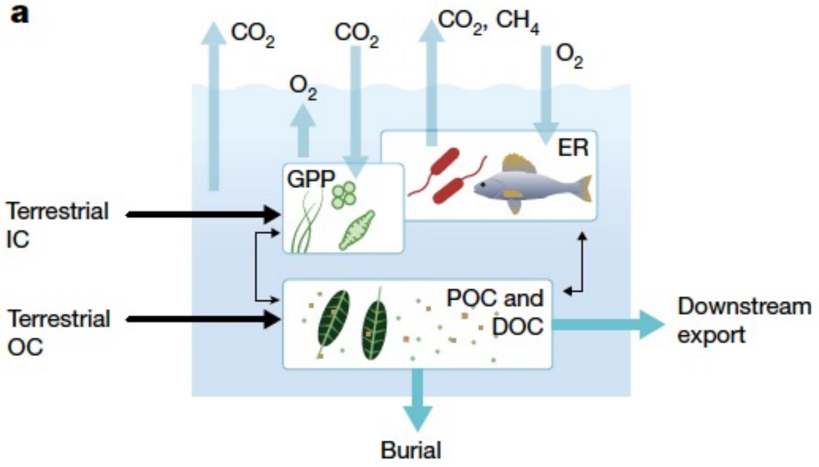
Hyporheic zone: Contribute to the role streams and rivers play for global biogeochemistry

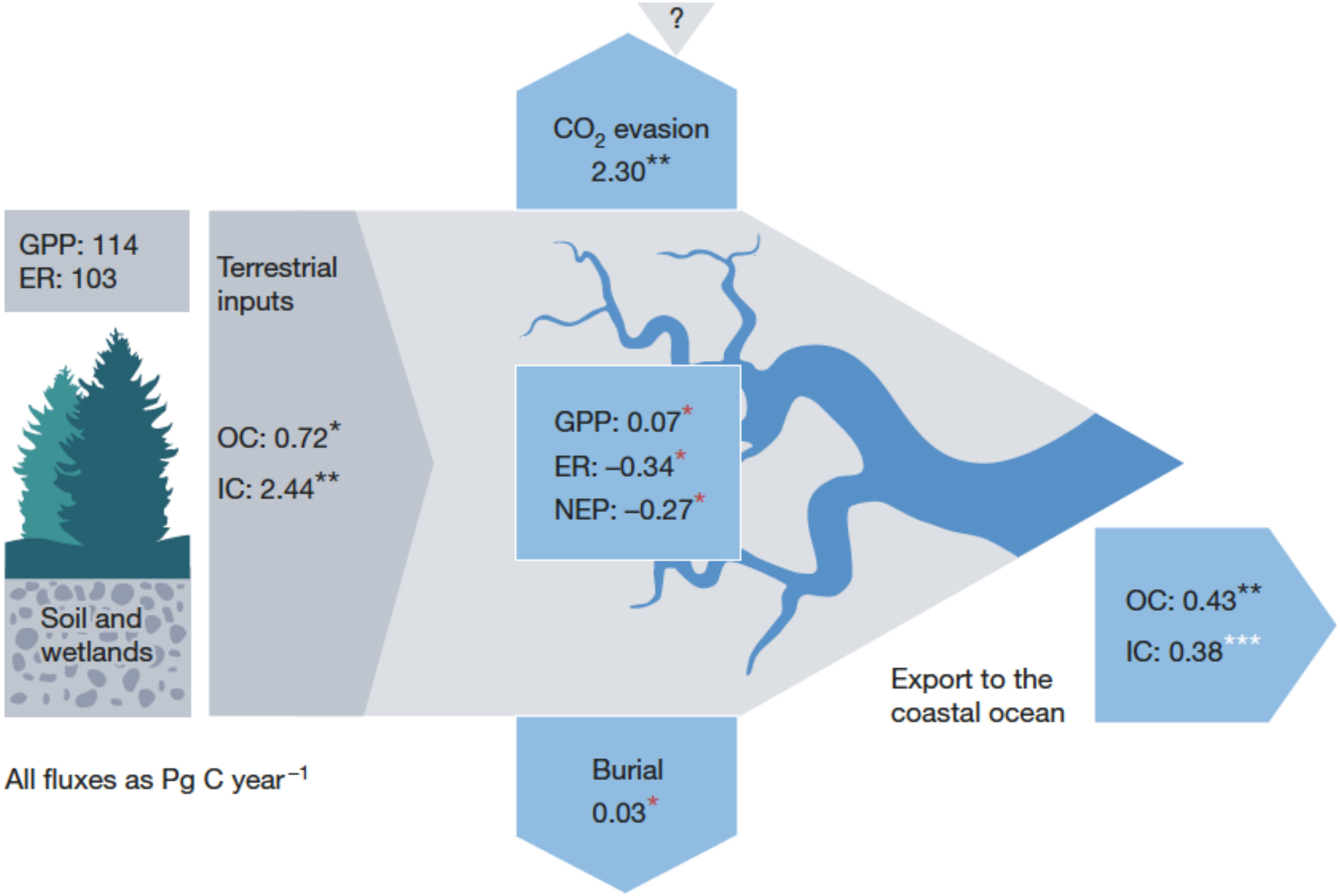
Review

River ecosystem metabolism and carbon biogeochemistry in a changing world

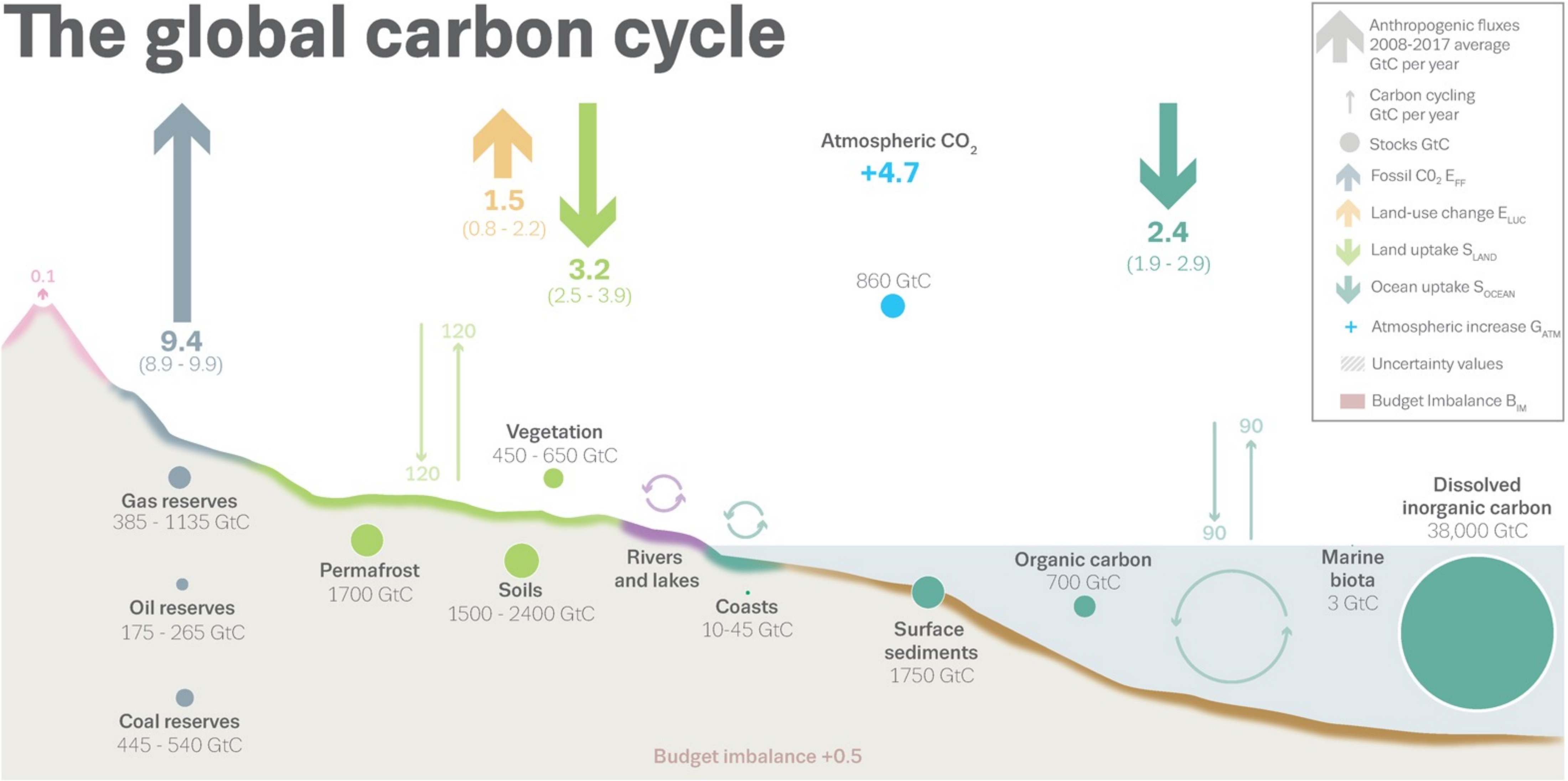
https://doi.org/10.1038/s41586-022-05500-8
Received: 12 March 2021

Tom J. Battin[1], Ronny Lauerwald[2], Emily S. Bernhardt[3], Enrico Bertuzzo[4], Lluís Gómez Gener[5], Robert O. Hall Jr[6], Erin R. Hotchkiss[7], Taylor Maavara[8], Tamlin M. Pavelsky[9], Lishan Ran[10,11], Peter Raymond[12], Judith A. Rosentreter[12,13] & Pierre Regnier[14]





The global carbon cycle



Corinne Le Quéré, Robbie M. Andrew, Pierre Friedlingstein, Stephen Sitch, Judith Hauck, Julia Pongratz, Penelope A. Pickers, Jan Ivar Korsbakken, Glen P. Peters, Josep G. Canadell, Almut Arneth, Vivek K. Arora, Leticia Barbero, Ana Bastos, Laurent Bopp, Frédéric Chevallier, Louise P. Chini, Philippe Ciais, Scott C. Doney, Thanos Gkritzalis, Daniel S. Goll, Ian Harris, Vanessa Haverd, Forrest M. Hoffman, Mario Hoppema, Richard A. Houghton, George Hurtt, Tatiana Ilyina, Atul K. Jain, Truls Johannesen, Chris D. Jones, Etsushi Kato, Ralph F. Keeling, Kees Klein Goldewijk, Peter Landschützer, Nathalie Lefèvre, Sebastian Lienert, Zhu Liu, Danica Lombardozzi, Nicolas Metzl, David R. Munro, Julia E. M. S. Nabel, Shin-ichiro Nakaoka, Craig Neill, Are Olsen, Tsueno Ono, Prabir Patra, Anna Peregon, Wouter Peters, Philippe Peylin, Benjamin Pfeil, Denis Pierrot, Benjamin Poulter, Gregor Rehder, Laure Resplandy, Eddy Robertson, Matthias Rocher, Christian Rödenbeck, Ute Schuster, Jörg Schwinger, Roland Séférian, Ingunn Skjelvan, Tobias Steinhoff, Adrienne Sutton, Pieter P. Tans, Hanqin Tian, Bronte Tilbrook, Francesco N Tubiello, Ingrid T. van der Laan-Luijkx, Guido R. van der Werf, Nicolas Viovy, Anthony P. Walker, Andrew J. Wiltshire, Rebecca Wright, Sönke Zaehle, Bo Zheng: Global Carbon Budget 2018, Earth Syst. Sci. Data, 2018b. https://doi.org/10.5194/essd-10-2141-2018

Summary

- Streams and rivers are inherent components of the landscape
- Streams and rivers are highly biodiverse
- Biodiversity in streams and rivers at risk
- Anthropogenic alterations across scales (from global change to damming, flow regulation and pollution)
- Environmental heterogeneity critical for biodiversity and ecosystem functions
- Hyporheic processes (physical, chemical and biological) are fundamental for stream and river ecosystem functioning and biogeochemical fluxes