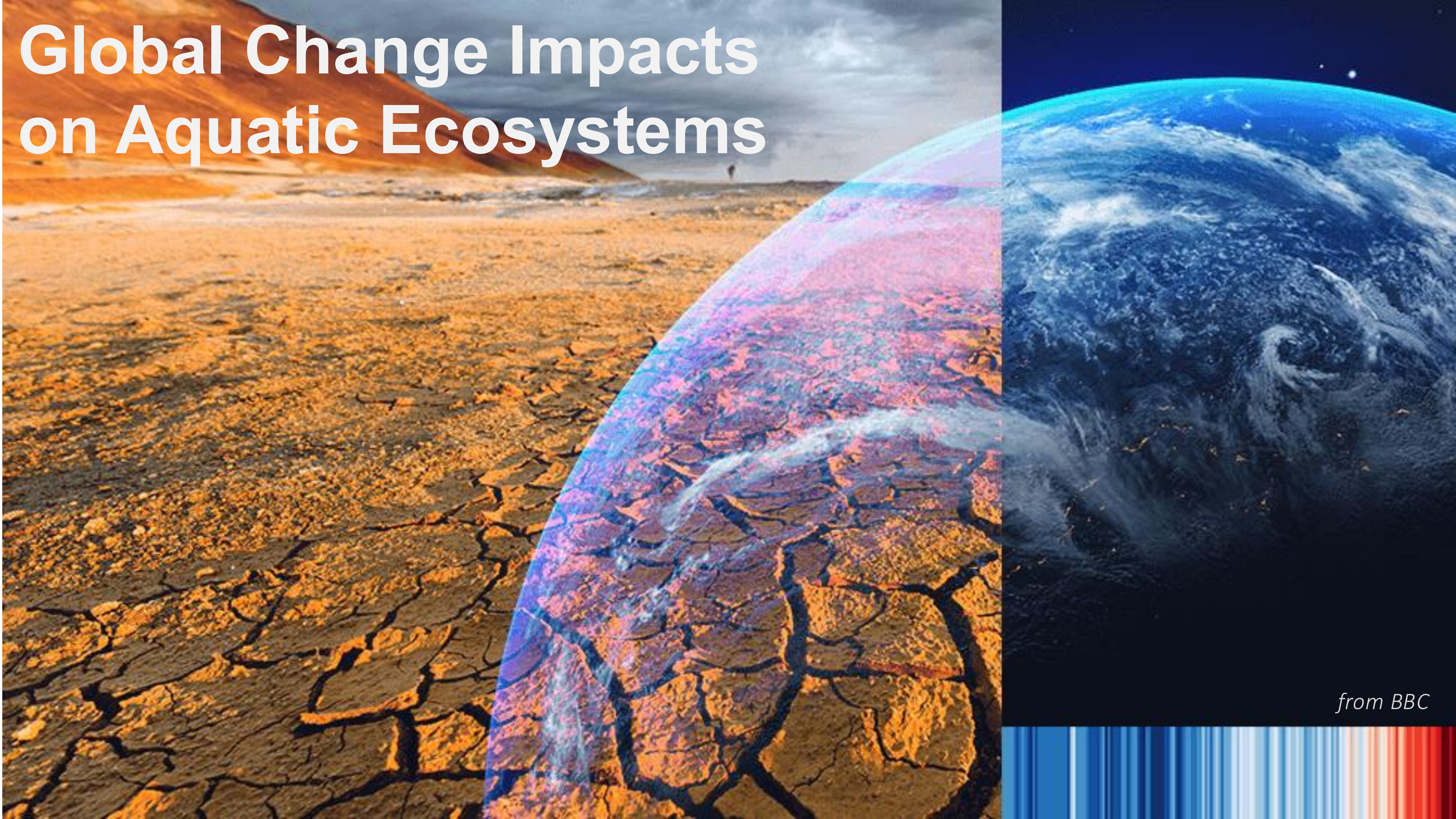
Global Change Impacts on Aquatic Ecosystems



from BBC

Planetary boundaries

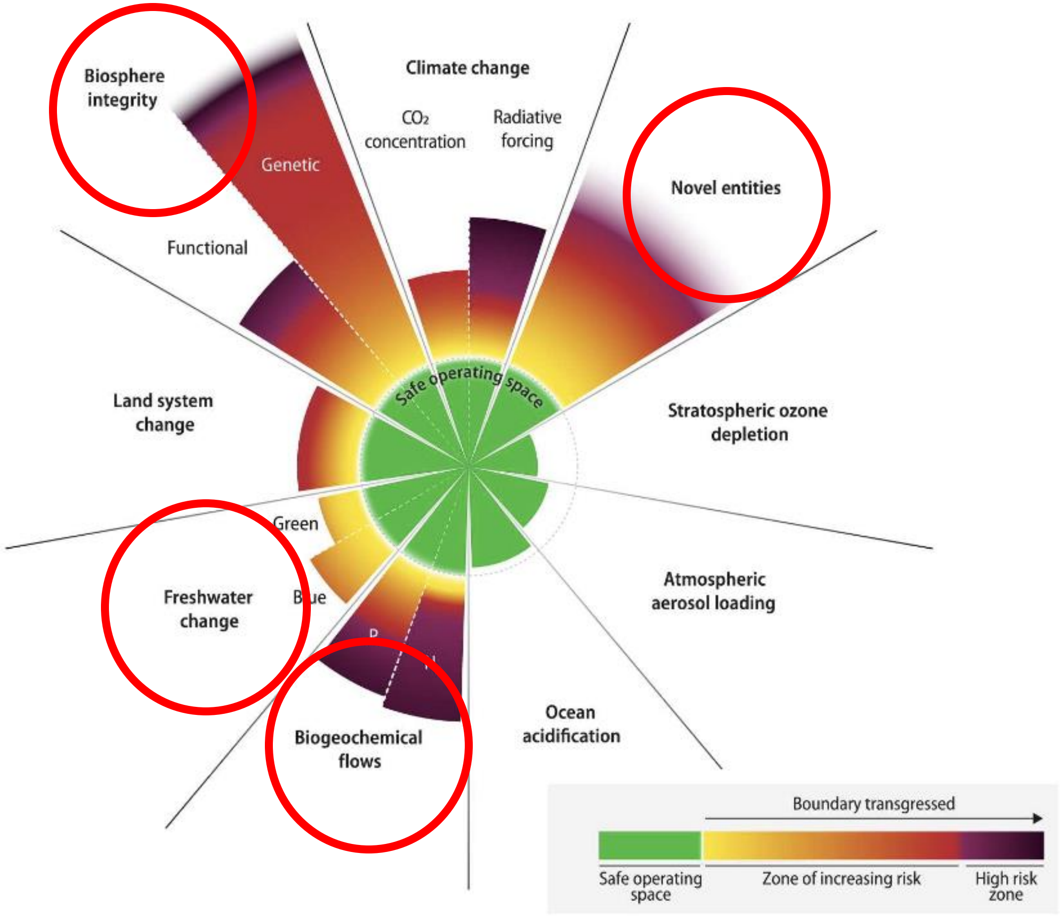


Fig. 1. Current status of control variables for all nine planetary boundaries. Six of the nine boundaries are transgressed. In addition, ocean acidification is approaching its planetary boundary. The green zone is the safe operating space (below the boundary). Yellow to red represents the zone of increasing risk. Purple indicates the high-risk zone where interglacial Earth system conditions are transgressed with high confidence. Values for control variables are normalized so that the origin represents mean Holocene conditions and the planetary boundary (lower end of zone of increasing risk, dotted circle) lies at the same radius for all boundaries (except for the wedges representing green and blue water, see main text). Wedge lengths are scaled logarithmically. The upper edges of the wedges for the novel entities and the genetic diversity component of the biosphere integrity boundaries are blurred either because the upper end of the zone of increasing risk has not yet been quantitatively defined (novel entities) or because the current value is known only with great uncertainty (loss of genetic diversity). Both, however, are well outside of the safe operating space. Transgression of these boundaries reflects unprecedented human disruption of Earth system but is associated with large scientific uncertainties.

Quantitative planetary boundaries within which humanity can continue to develop and thrive for generations to come.

Crossing these boundaries increases the risk of generating large-scale abrupt or irreversible environmental changes –tipping points.

https://www.science.org/doi/epdf/10.1126/sciadv.adh2458

Eutrophication is human made

Where does all the nitrogen and phosphorus come from ?

FEATURE

How a century of ammonia synthesis changed the world

Fritz Haber

Carl Bosch

Ammonia (NH_3)
✓ N_2 from air
✓ H_2 from CH_4

- From ammonia synthesis to proteins for a growing world population
- Annual production of 10^8 tons ammonia (NH_3) accounts for ca.1.4 % of the world energy consumption
-

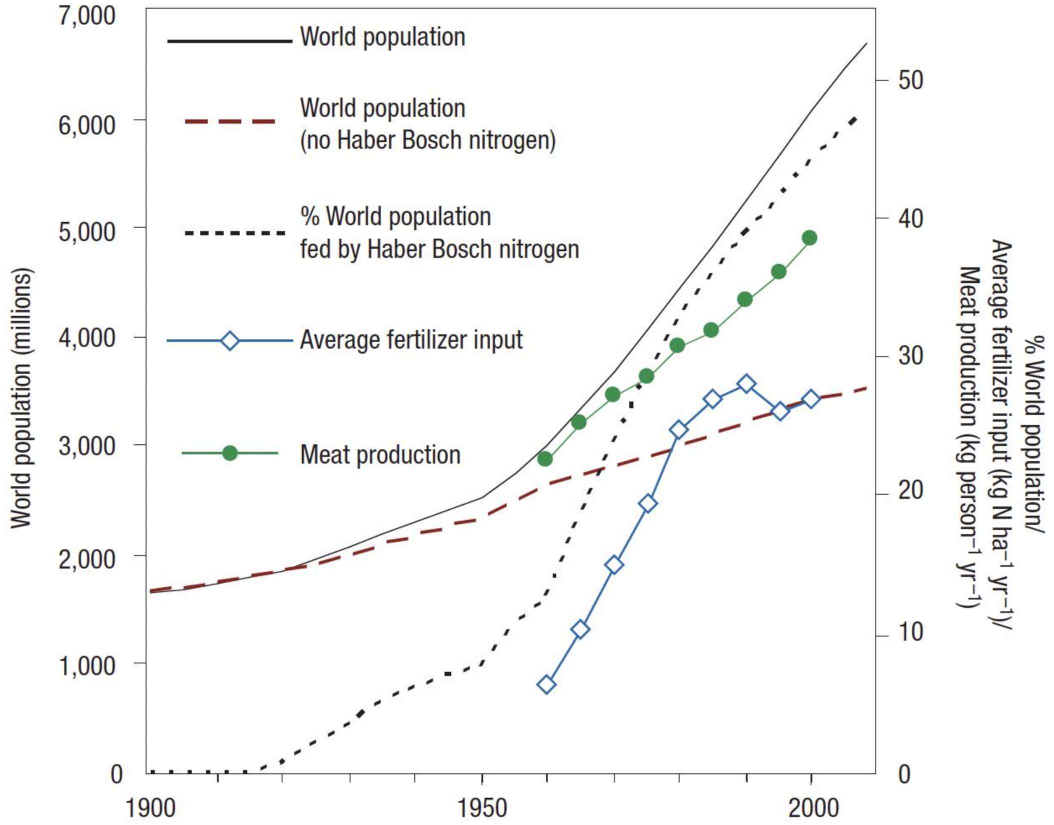
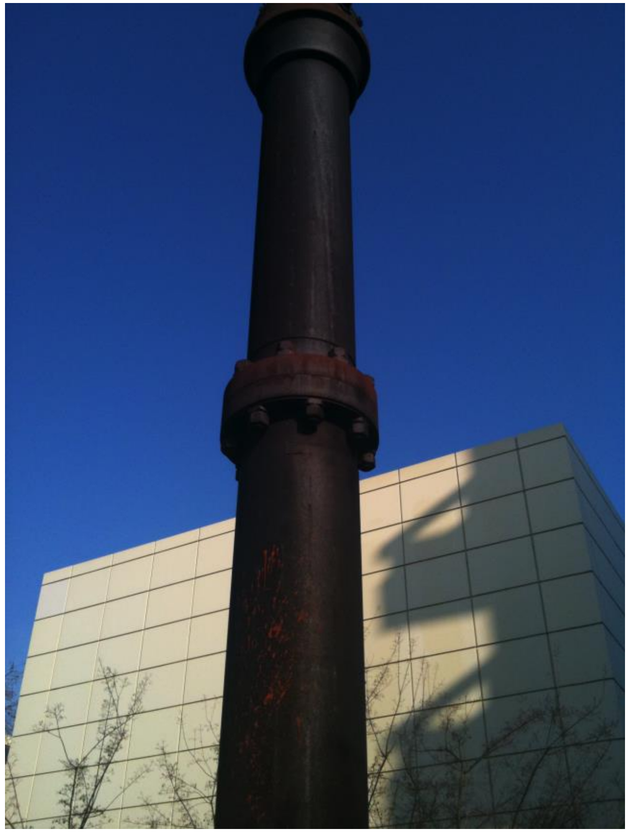


Figure 1 Trends in human population and nitrogen use throughout the twentieth century. Of the total world population (solid line), an estimate is made of the number of people that could be sustained without reactive nitrogen from the Haber–Bosch process (long dashed line), also expressed as a percentage of the global population (short dashed line). The recorded increase in average fertilizer use per hectare of agricultural land (blue symbols) and the increase in per capita meat production (green symbols) is also shown.

EPFL

Fritz Haber

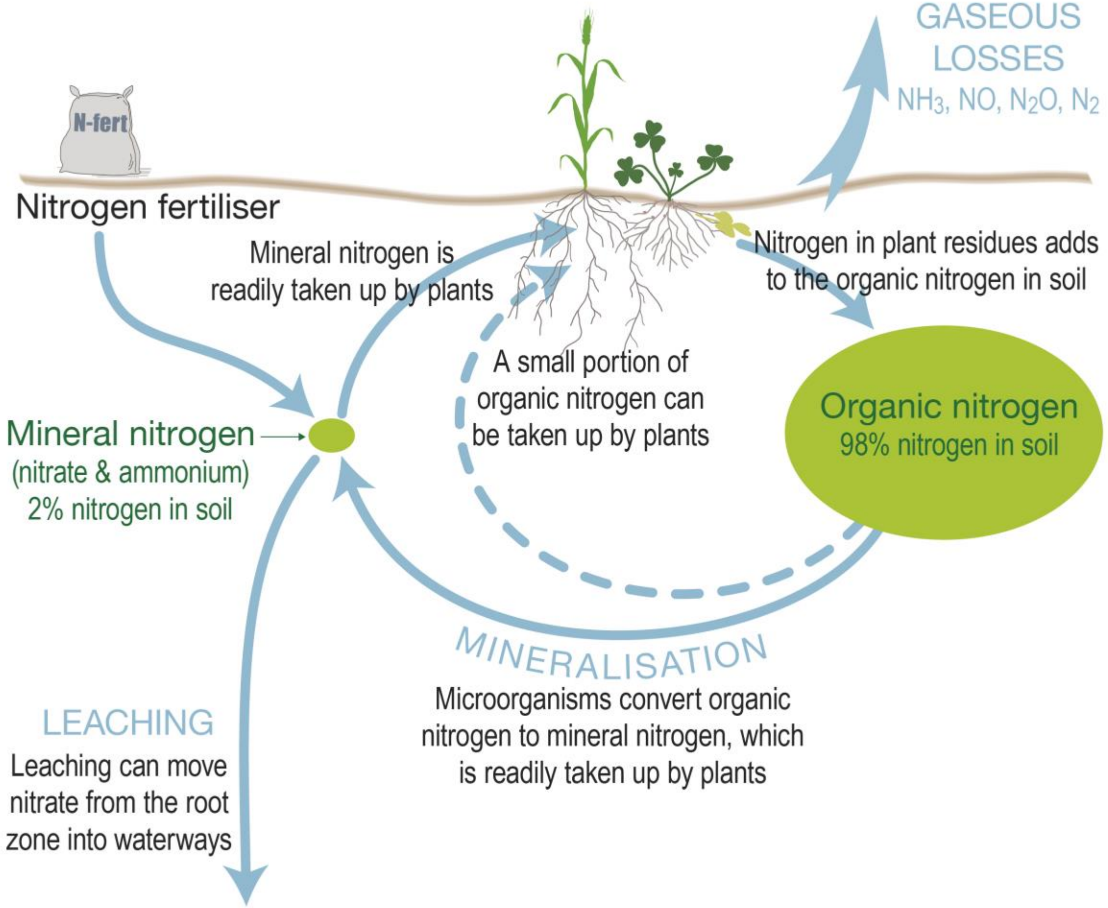


Clara Immerwahr

Ypern, Belgium – First mustard gas attack supervised by F. Haber

Agricultural soils are highly leaky

- Loss of nutrients through runoff and wind
- Poorly protected soils

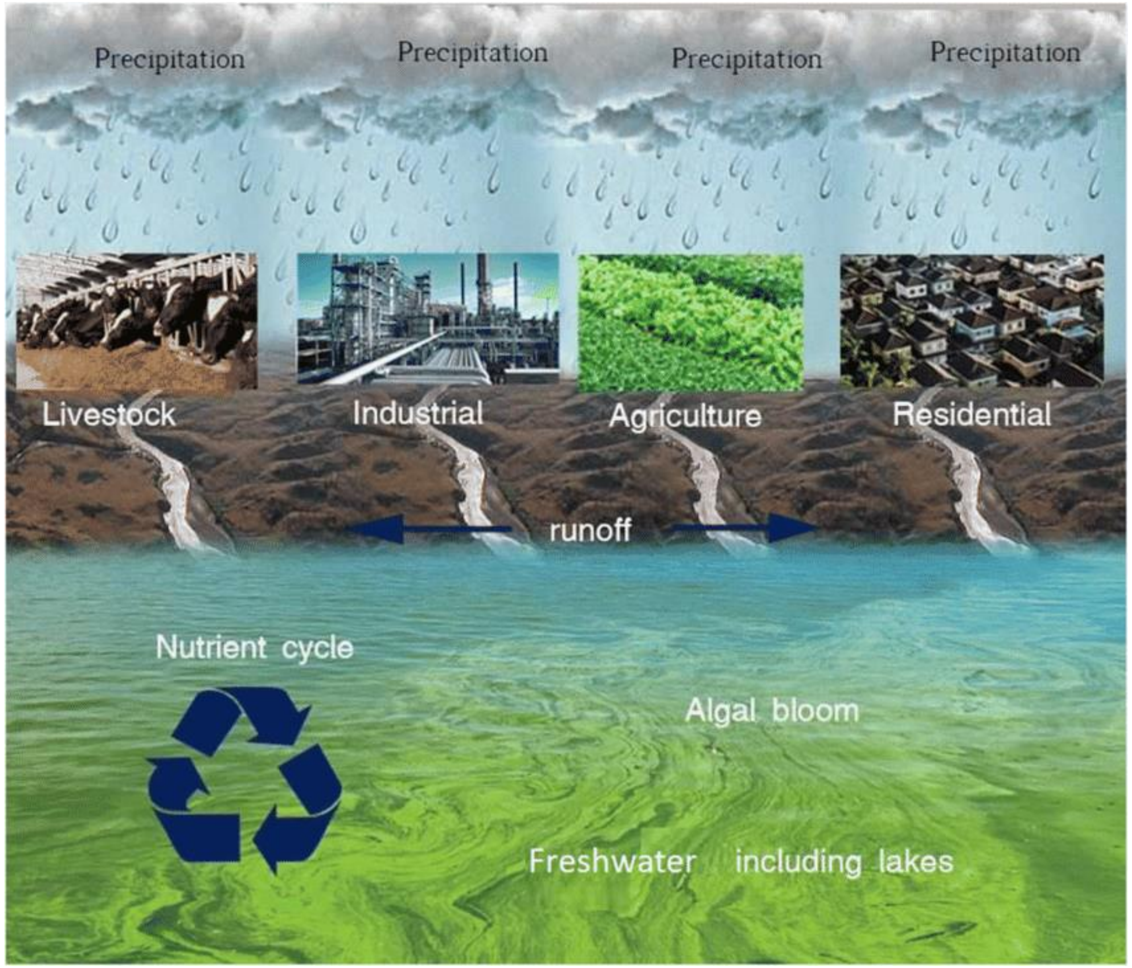


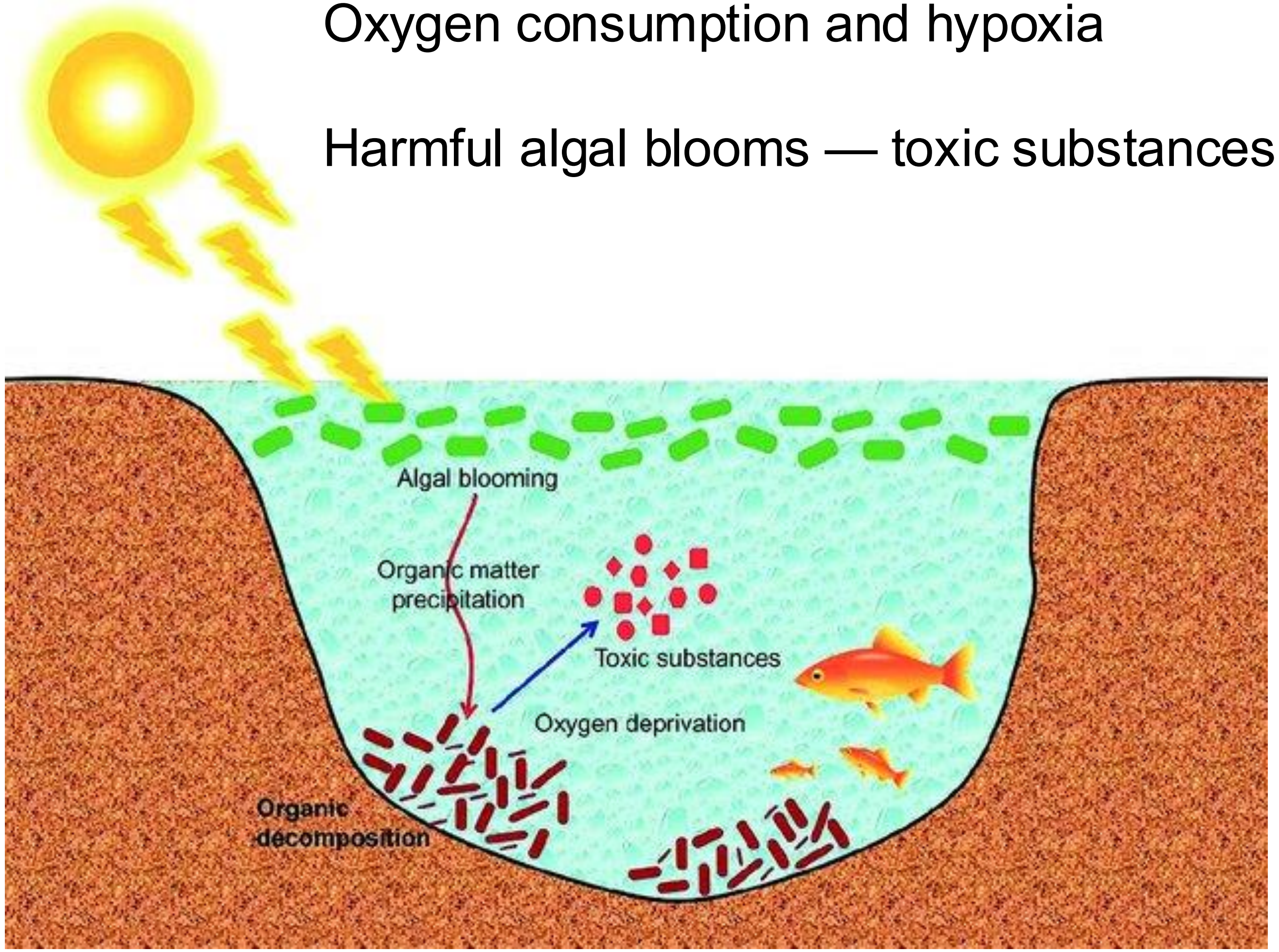
EPFL

Eutrophication of lakes and river

Build-up of algal biomass
Decay and microbial degradation
Oxygen consumption and hypoxia

Harmful algal blooms — toxic substances



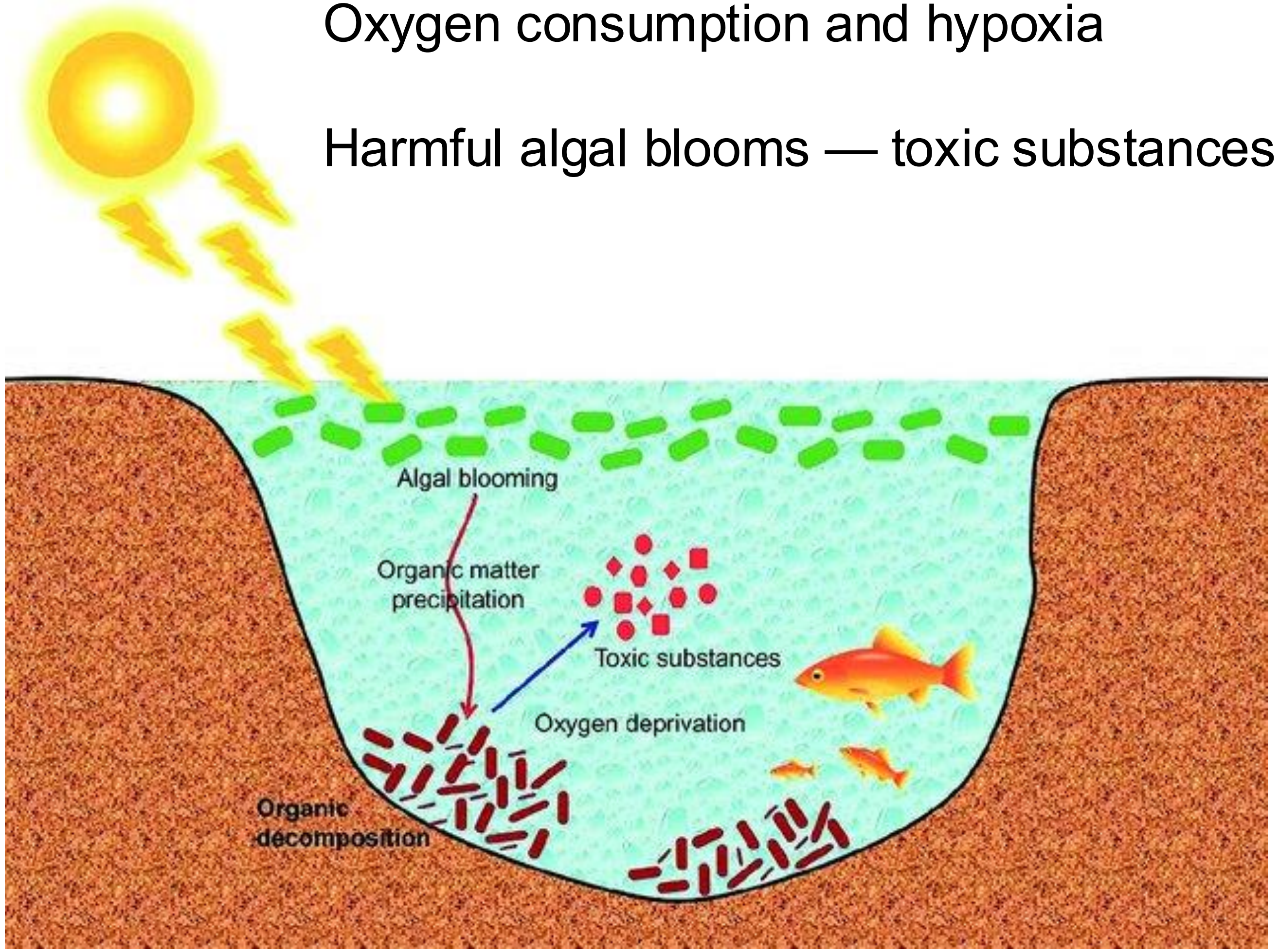


Eutrophication of lakes and river

Build-up of algal biomass
Decay and microbial degradation
Oxygen consumption and hypoxia

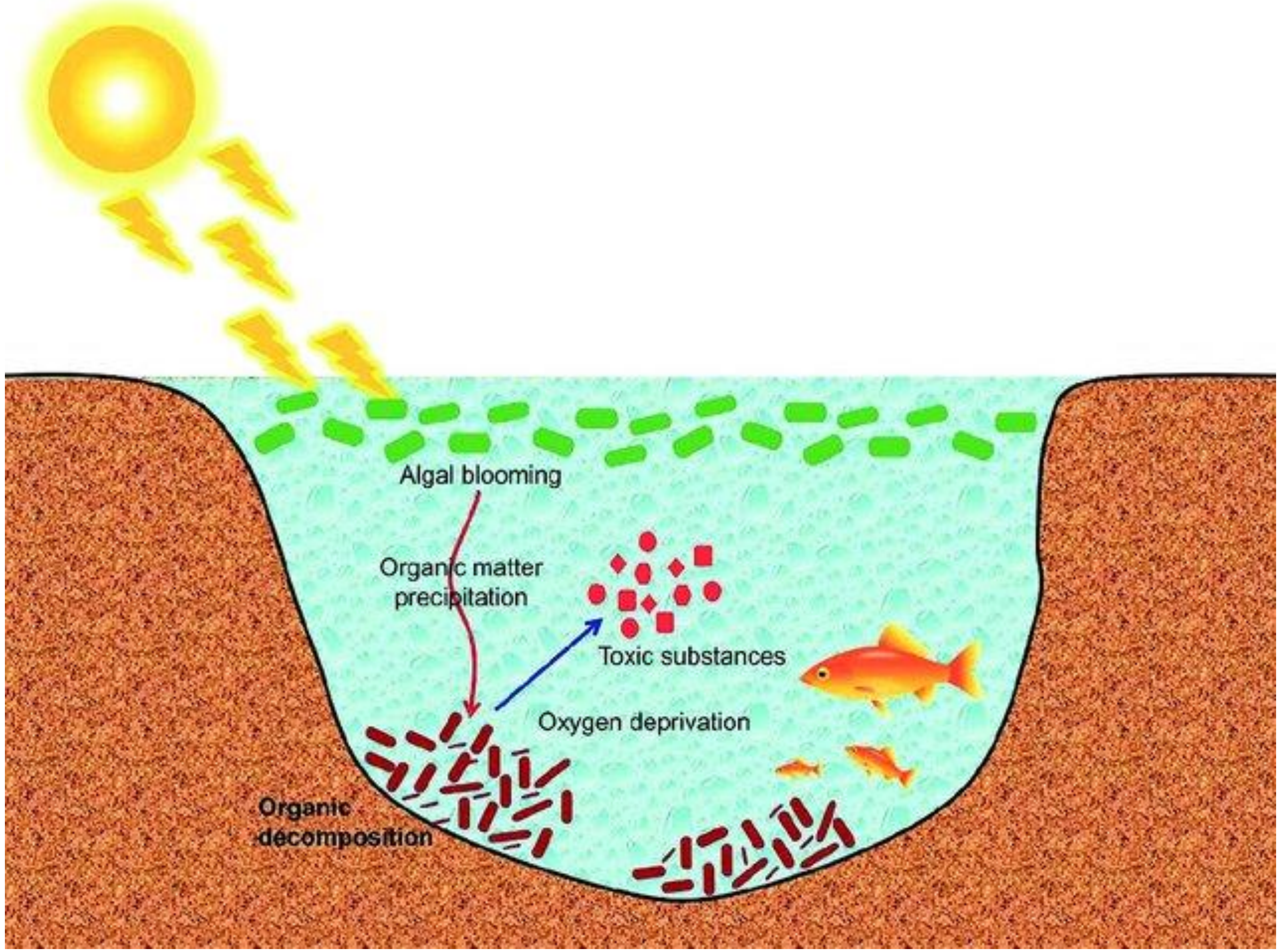
Harmful algal blooms — toxic substances

Figure 4
A dead African buffalo (*Syncerus caffer*) found in a reservoir with a dense bloom of the toxic cyanobacterium *Microcystis* at the Loskop Dam Nature Reserve in South Africa.



Eutrophication of lakes and river

- Biodiversity loss
- Compromised water resources



INLAND WATERS
2022, VOL. 12, NO. 2, 187–204
https://doi.org/10.1080/20442041.2022.2029317

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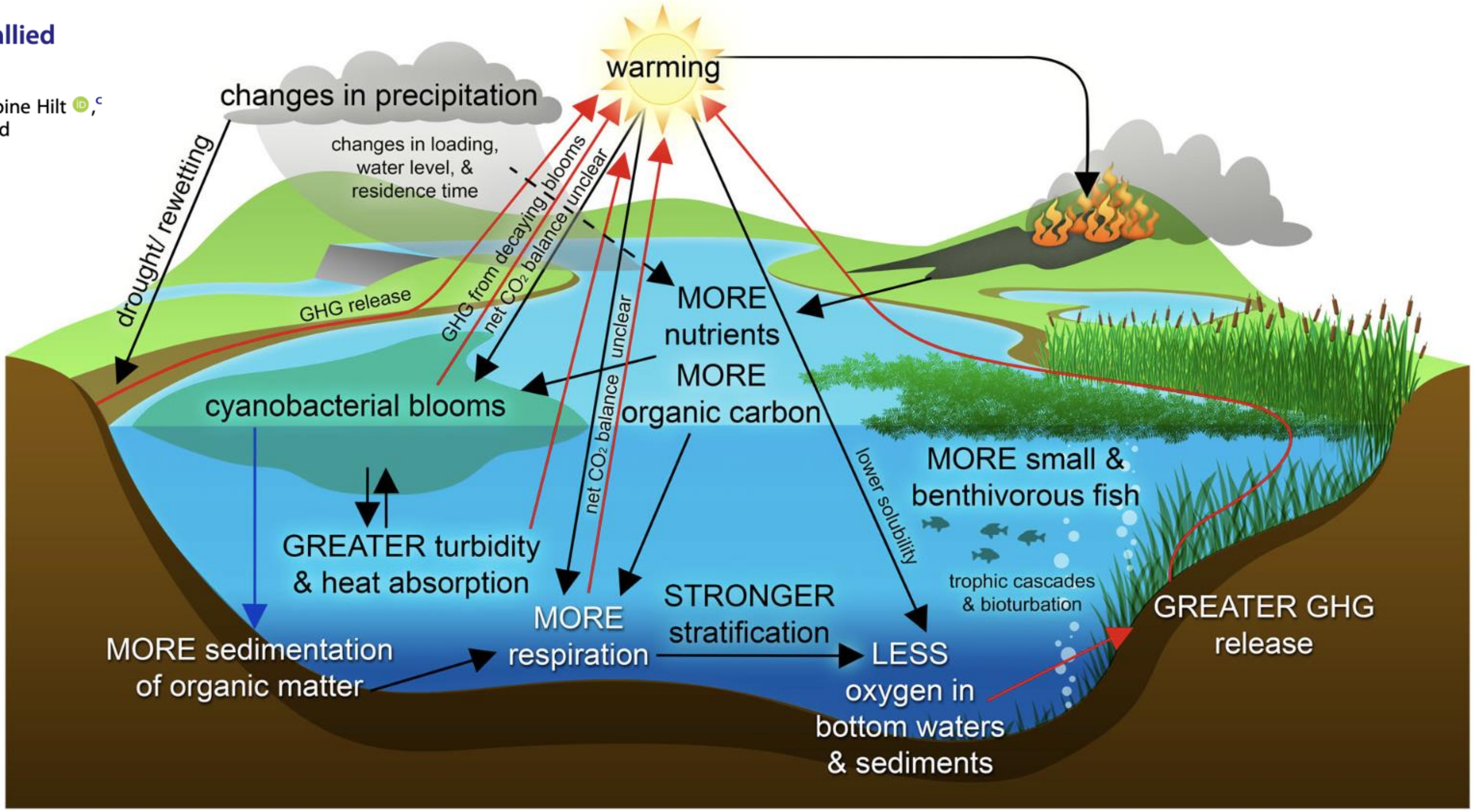
Check for updates

Feedback between climate change and eutrophication: revisiting the allied attack concept and how to strike back

Mariana Meerhoff [a,b], Joachim Audet [b], Thomas A. Davidson [b], Luc De Meester [c,d,e,f], Sabine Hilt [c], Sarian Kosten [g], Zhengwen Liu,[h,i,j] Néstor Mazzeo [a,k], Hans Paerl [l], Marten Scheffer [m] and Erik Jeppesen [b,h,n,o]

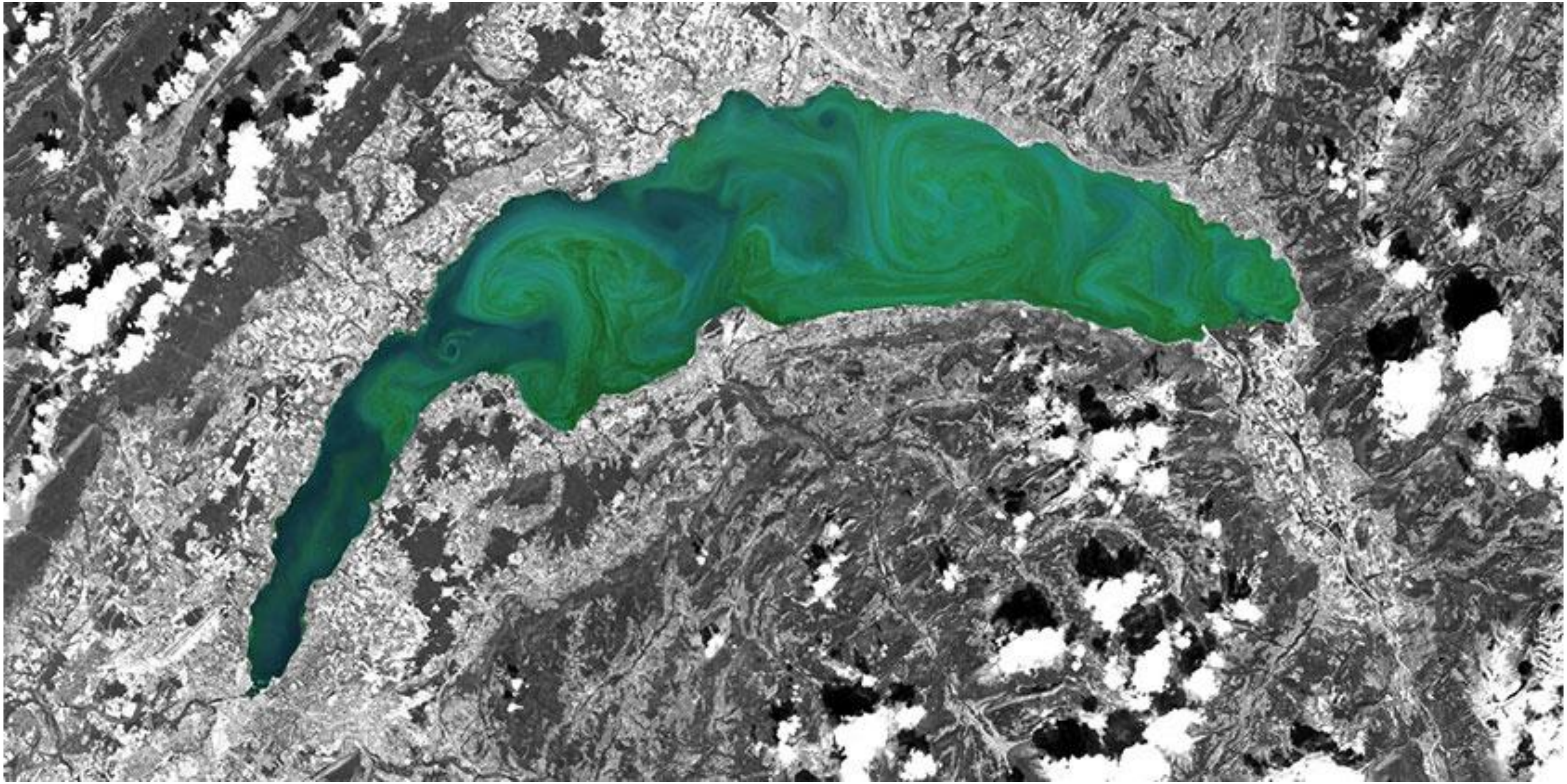


- Eutrophication promotes the prodcution of GHG (CO_2, CH_4, N_2O
- Potential feedback to the climate

Figure 3. Current understanding of main feedback effects of eutrophication on climate change. The blue arrow indicates carbon sequestration; red arrows indicate carbon emission routes; black arrows indicate other type of effects. The dashed line indicates that changes in precipitation regimes may either lead to higher or lower nutrient and organic carbon loading, depending on local and regional circumstances. Warming and eutrophication intensify water stratification and reduce oxygen concentrations. Direct and indirect changes in biotic interactions under eutrophic conditions promote cyanobacteria dominance, which has its own feedback with climate change. Warming and eutrophication may increase both CO_2 uptake and release, and thus net CO_2 balance is unclear, whereas potential effects on other GHG, particularly CH_4, are evident. Strong fluctuations in water level due to changes in precipitation may lead to cycles of drying–rewetting of sediments, promoting CO_2 release. GHG are produced and released by diffusion across different lake compartments, and CH_4 also by ebullition (bubbles). The role on GHG emissions of key communities, such as macrophytes, fish, and macroinvertebrates, is the subject of intense research. Drawing by Alan R. Joyner, based on Fig. 2 in Moss et al. (2011). Copyright © International Society of Limnology, with permission of Taylor & Francis Ltd.

EPFL

Also next door….



https://www.eawag.ch/en/department/surf/projects/primary-production-in-swiss-lakes/

Agricultural runoff fuels large phytoplankton blooms in vulnerable areas of the ocean

J. Michael Beman[1], Kevin R. Arrigo[2] & Pamela A. Matson[1,3]

NATURE | VOL 434 | 10 MARCH 2005 | www.nature.com/nature

Streams and rivers as biogeochemical connectors between land and ocean

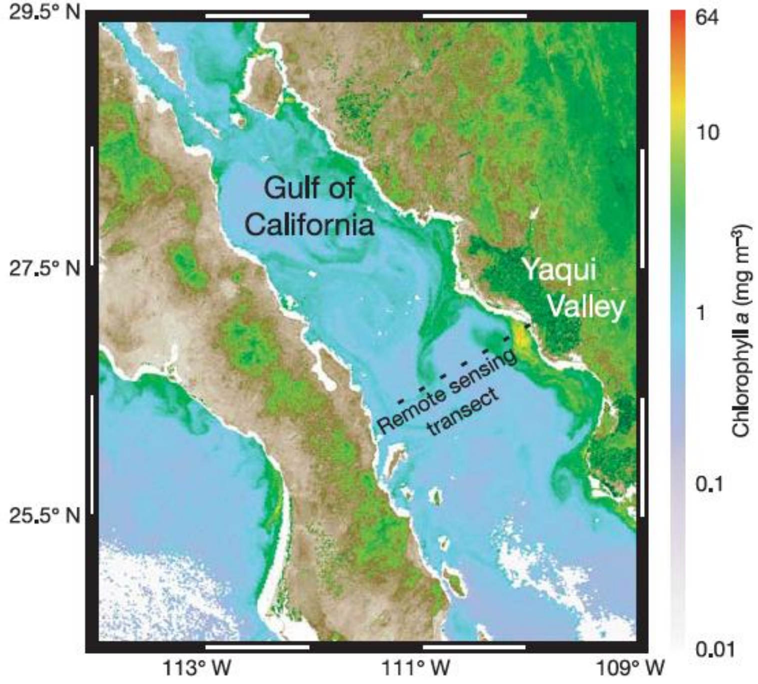


Figure 1 SeaWiFS image of chlorophyll *a* in the GOC from 6 April 1998, one day after peak irrigation. Location of remote sensing transect is shown crossing an intense phytoplankton bloom. As indicated by the colour scale, Chl concentrations in the bloom are significantly higher than elsewhere in the GOC. On land, the productive agricultural fields of the Yaqui Valley are clearly visible in a MODIS-Aqua vegetation image (NDVI) from 4 April 2003, overlaid on ocean colour data.

Agricultural runoff fuels large phytoplankton blooms in vulnerable areas of the ocean

J. Michael Beman[1], Kevin R. Arrigo[2] & Pamela A. Matson[1,3]

NATURE | VOL 434 | 10 MARCH 2005 | www.nature.com/nature

- Annually recurrent nitrogen loss from Yaqui Valley during irrigation of the fields; little retention and transformation capacity of nitrogen
- Nitrogen export sustains the phytoplankton bloom in the Gulf of California
- Streams and rivers are biogeochemical connectors between land and the ocean

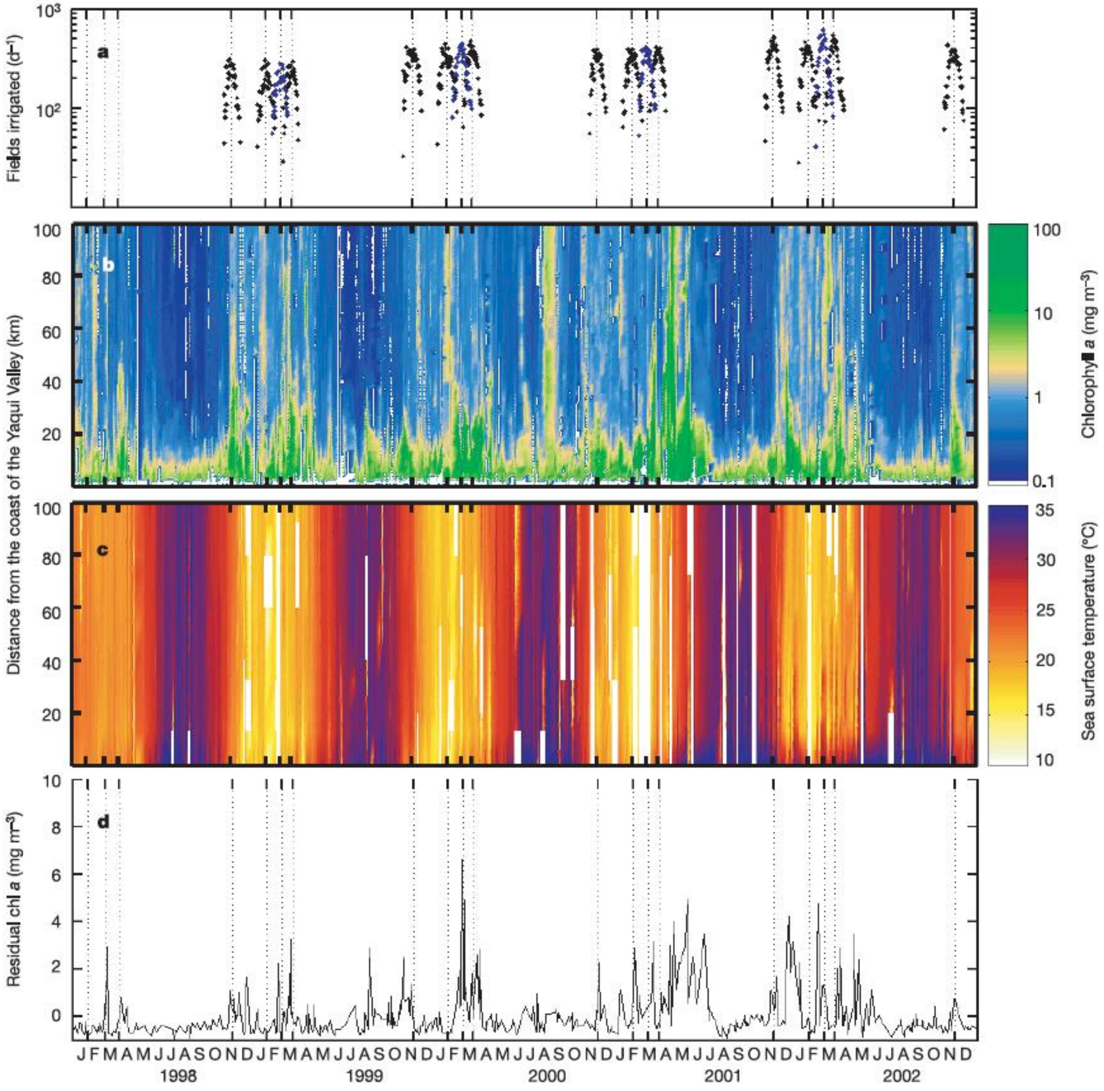


Figure 2 Five-year time series. **a**, Irrigation allotment data. **b**, SeaWiFS chlorophyll *a* data. **c**, AVHRR SST data. **d**, Residual Chl values from best-fit GLM. Horizontal axis represents time from 1998–2002; calculated peak irrigation periods are denoted by dotted lines and tick marks along the horizontal axis. Vertical axis in **b** and **c** represents distance across transect, colour bar on right shows corresponding Chl concentrations and SSTs.

article

Gulf of Mexico Hypoxia: Past, Present, and Future

Nancy N. Rabalais and R. Eugene Turner

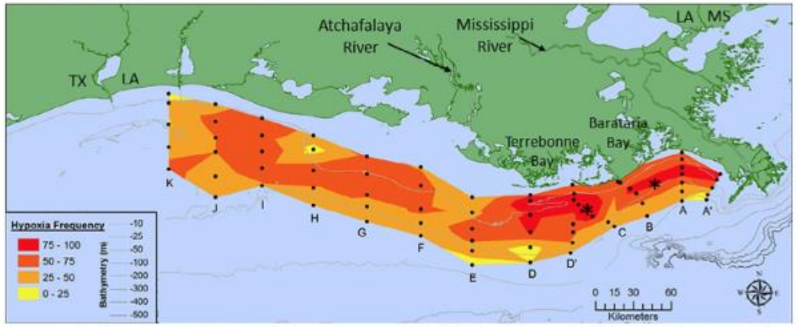


FIG. 1. The frequency of bottom-water hypoxia from shelf-wide hypoxia mapping (1985–2014) (updated from Rabalais et al. (2007b); frequency is determined from stations for which there are data for at least half of all cruises. Asterisks (*) indicate locations of near-bottom oxygen meters; transects C and F identified. Data source: N. N. Rabalais and R. E. Turner.

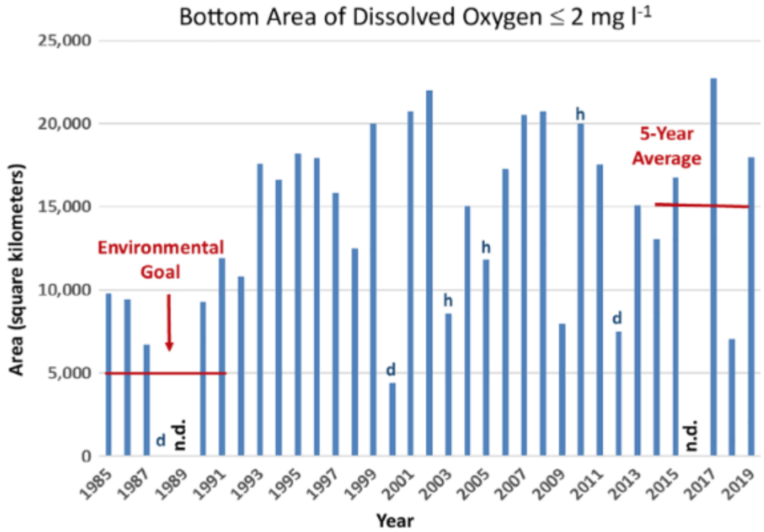
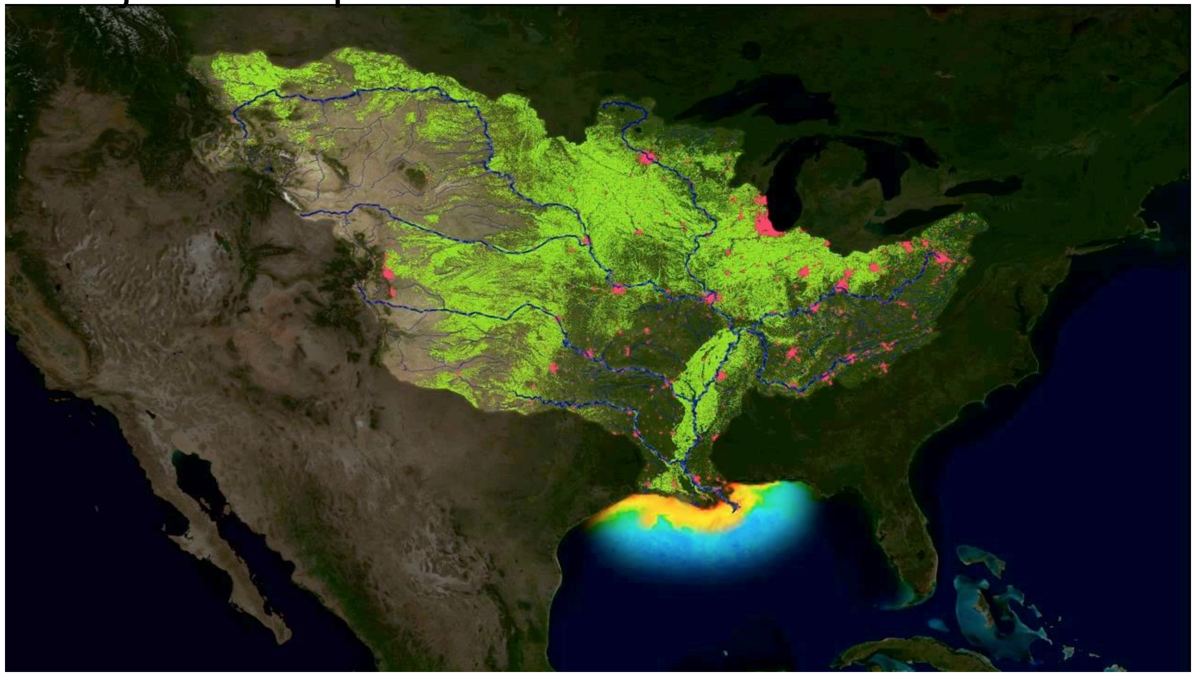


FIG. 2. Histogram of mid-summer bottom-area of dissolved oxygen ≤2 mg l^{-1} on the continental shelf west of the Mississippi River delta since 1985. Events that affect the size of the bottom area are d = drought, h = hurricane or tropical storm activity before or during the cruise to measure the area, w = winds from the west for an extended period before or during the cruise, and n.d. = no data. The only years not included are 1989 (lack of sufficient funding) and 2016 (lack of a suitable vessel).

- Annual exports of nitrogen cause eutrophication in the Gulf of Mexico
- The collapse of the algal bloom depletes oxygen concentration
- Induces large areas with hypoxic conditions — ‘dead zone’
- Major consequences for fisheries and local economics



http://www.mnn.com/earth-matters/translating-uncle-sam/stories/what-is-the-gulf-of-mexico-dead-zone

EPFL

Hydrology

LETTER
doi:10.1038/nature20584

High-resolution mapping of global surface water and its long-term changes

Jean-François Pekel[1], Andrew Cottam[1], Noel Gorelick[2] & Alan S. Belward[1]

- Uneven distribution of global surface waters
- And how they have changed between 1984 and 2014

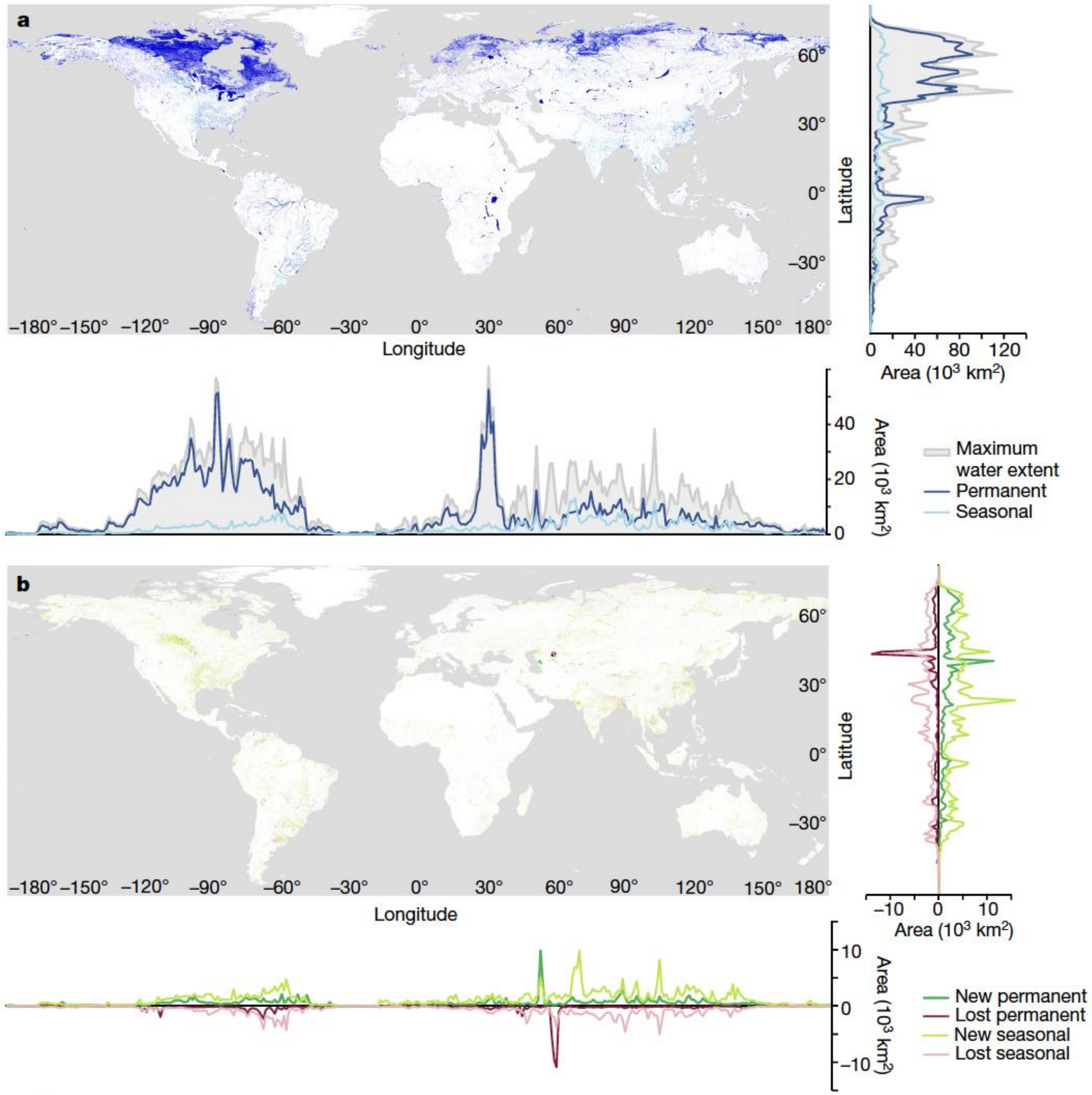


Figure 2 | Global surface water distribution and changes. Global maps, with 1° latitude/longitude summaries of surface water area shown on the right and underneath. **a**, Maximum water extent, permanent and seasonal surface water occurrence October 2014 to October 2015. **b**, Gains and loss in permanent and seasonal surface water area between 1984 and 2015. All measurements made from inland and coastal waters are defined only by the GADM reference layer (see Methods).

LETTER

doi:10.1038/nature20584

High-resolution mapping of global surface water and its long-term changes

Jean-François Pekel[1], Andrew Cottam[1], Noel Gorelick[2] & Alan S. Belward[1]

Strong regional differences in losses versus gains of surface waters

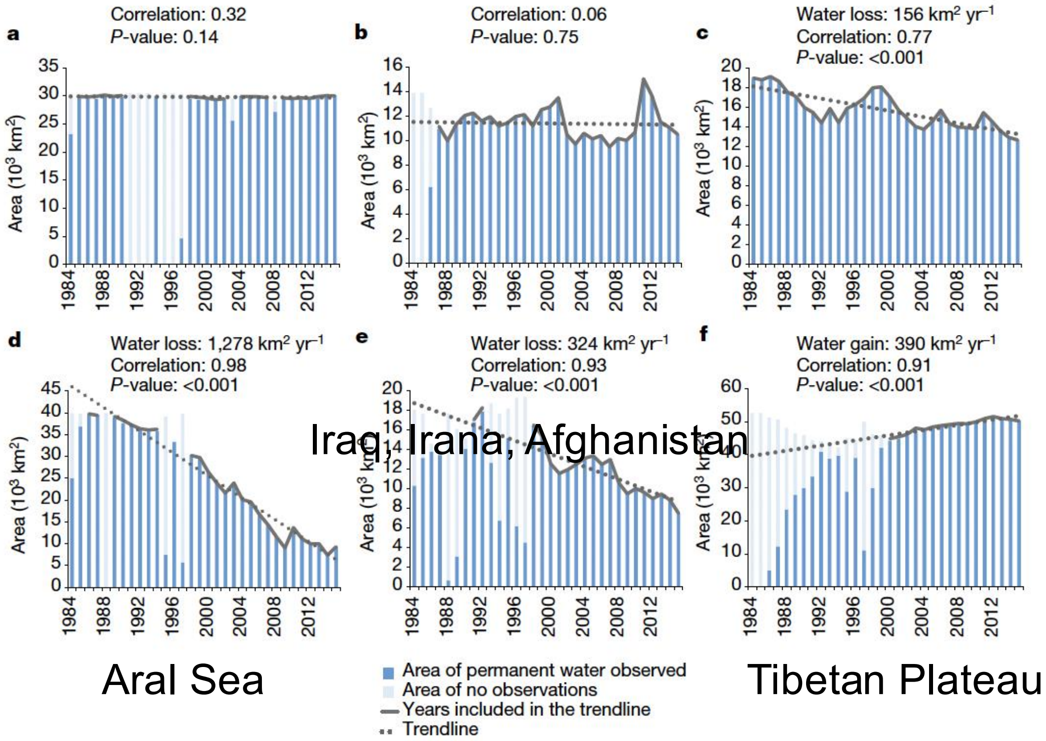
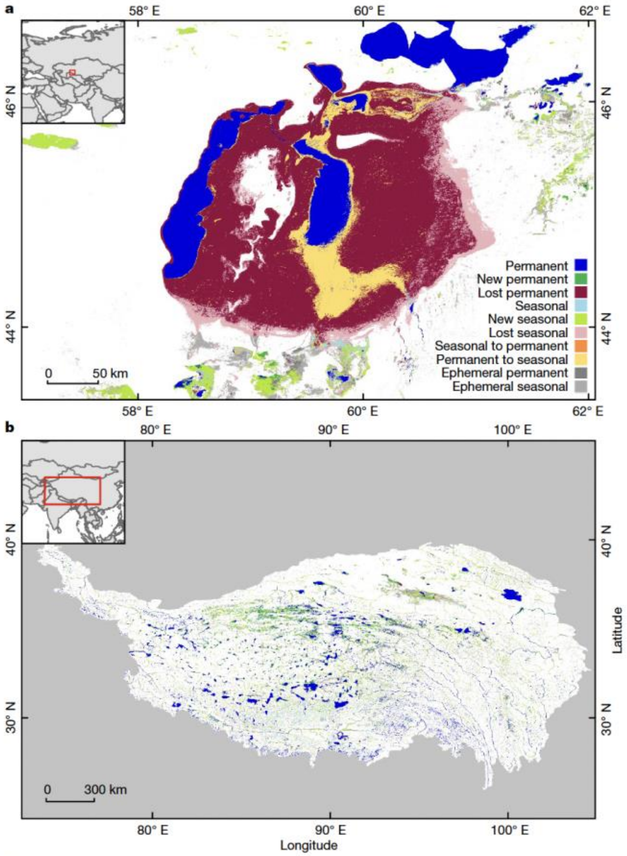


Figure 3 | Trends in annual permanent water surface area. **a**, Finland. **b**, New South Wales, Australia. **c**, Western states of the USA (Arizona, California, Idaho, Nevada, Oregon, Utah). **d**, Aral Sea (Kazakhstan, Uzbekistan). **e**, Iraq, Iran and Afghanistan. **f**, Tibetan plateau. Uncertainty is estimated from the unobserved component of the maximum permanent water extent. The true surface water area is within this range. Trend lines are provided from years where the unobserved component is less than 5%.



Aral Sea

Tibetan Plateau

Figure 4 | Surface water changes for the Aral Sea and Tibetan plateau. Transitions between the first year in which representative observations were acquired and the last year of observation. **a**, The Aral Sea. **b**, Tibetan plateau. The regional context for each location is shown in the insets. The 32-year trends in water surface area for these mapped regions are shown in Fig. 3d and f. The key to the seasonal classes applies to both panels.

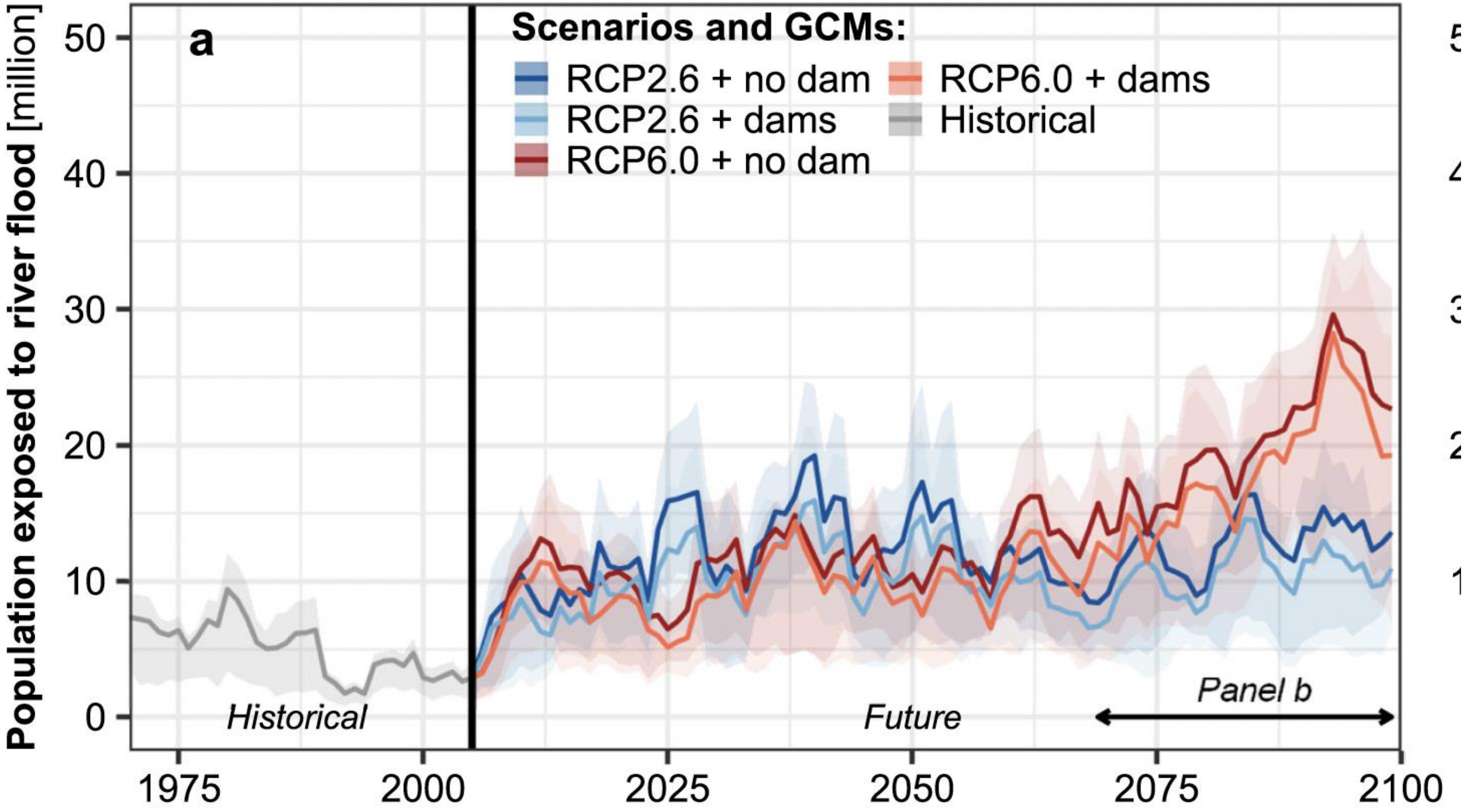
More disastrous floods ahead

ARTICLE

https://doi.org/10.1038/s41467-020-20704-0 OPEN

Role of dams in reducing global flood exposure under climate change

Julien Boulange[1✉], Naota Hanasaki[1], Dai Yamazaki[2] & Yadu Pokhrel[3]



More and less floods

LETTER

https://doi.org/10.1038/s41586-019-1495-6

Changing climate both increases and decreases European river floods

Günter Blöschl[1,37]*, Julia Hall[1,37], Alberto Viglione[1,2], Rui A. P. Perdigão[1], Juraj Parajka[1], Bruno Merz[3], David Lun[1], Berit Arheimer[4], Giuseppe T. Aronica[5], Ardian Bilibashi[6], Miloň Boháč[7], Ognjen Bonacci[8], Marco Borga[9], Ivan Čanjevac[10], Attilio Castellarin[11], Giovanni B. Chirico[12], Pierluigi Claps[2], Natalia Frolova[13], Daniele Ganora[2], Liudmyla Gorbachova[14], Ali Gül[15], Jamie Hannaford[16], Shaun Harrigan[17], Maria Kireeva[13], Andrea Kiss[1], Thomas R. Kjeldsen[18], Silvia Kohnová[19], Jarkko J. Koskela[20], Ondrej Ledvinka[7], Neil Macdonald[21,22], Maria Mavrova-Guirguinova[23], Luis Mediero[24], Ralf Merz[25], Peter Molnar[26], Alberto Montanari[11], Conor Murphy[27], Marzena Osuch[28], Valeryia Ovcharuk[29], Ivan Radevski[30], José L. Salinas[1], Eric Sauquet[31], Mojca Šraj[32], Jan Szolgay[19], Elena Volpi[33], Donna Wilson[34], Klodian Zaimi[35] & Nenad Živković[36]

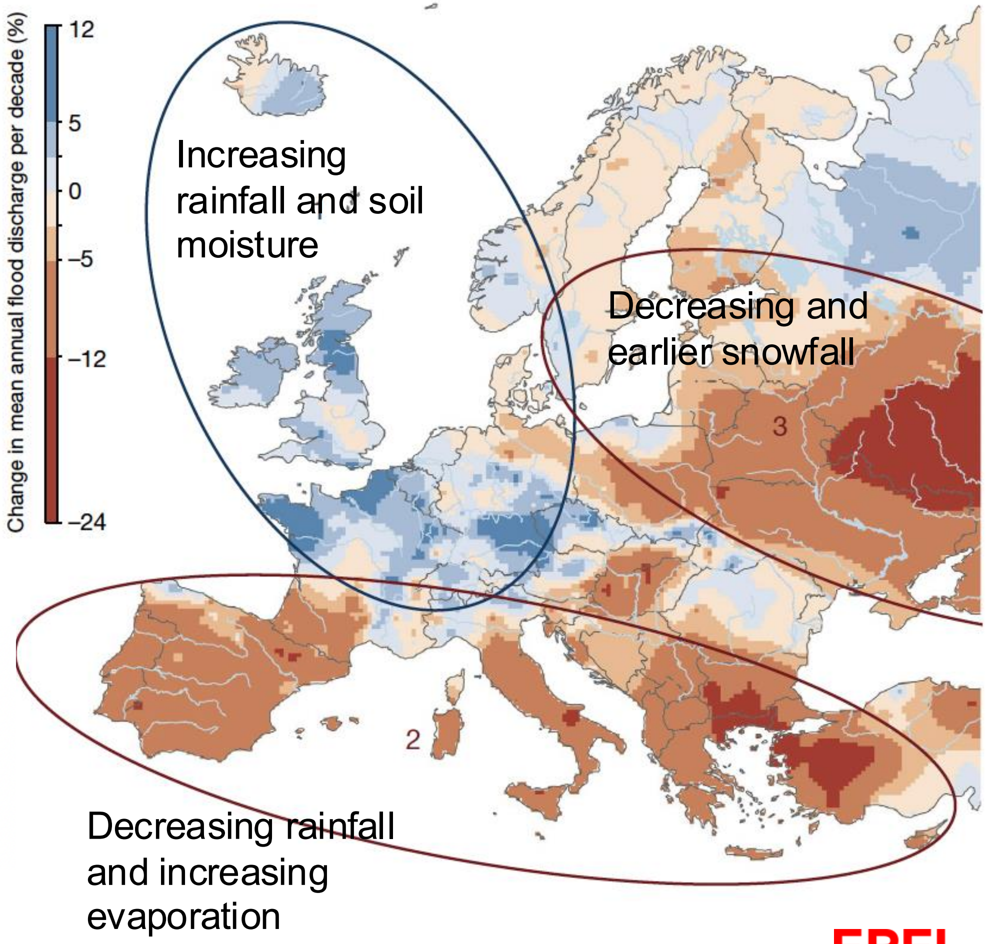


Fig. 1 | Observed regional trends of river flood discharges in Europe (1960–2010). Blue indicates increasing flood discharges and red denotes decreasing flood discharges (in per cent change of the mean annual flood discharge per decade). Numbers 1–3 indicate regions with distinct drivers. 1, Northwestern Europe: increasing rainfall and soil moisture. 2, Southern Europe: decreasing rainfall and increasing evaporation. 3, Eastern Europe: decreasing and earlier snowmelt. The trends are based on data from $n = 2,370$ hydrometric stations. For uncertainties see Extended Data Fig. 2b.

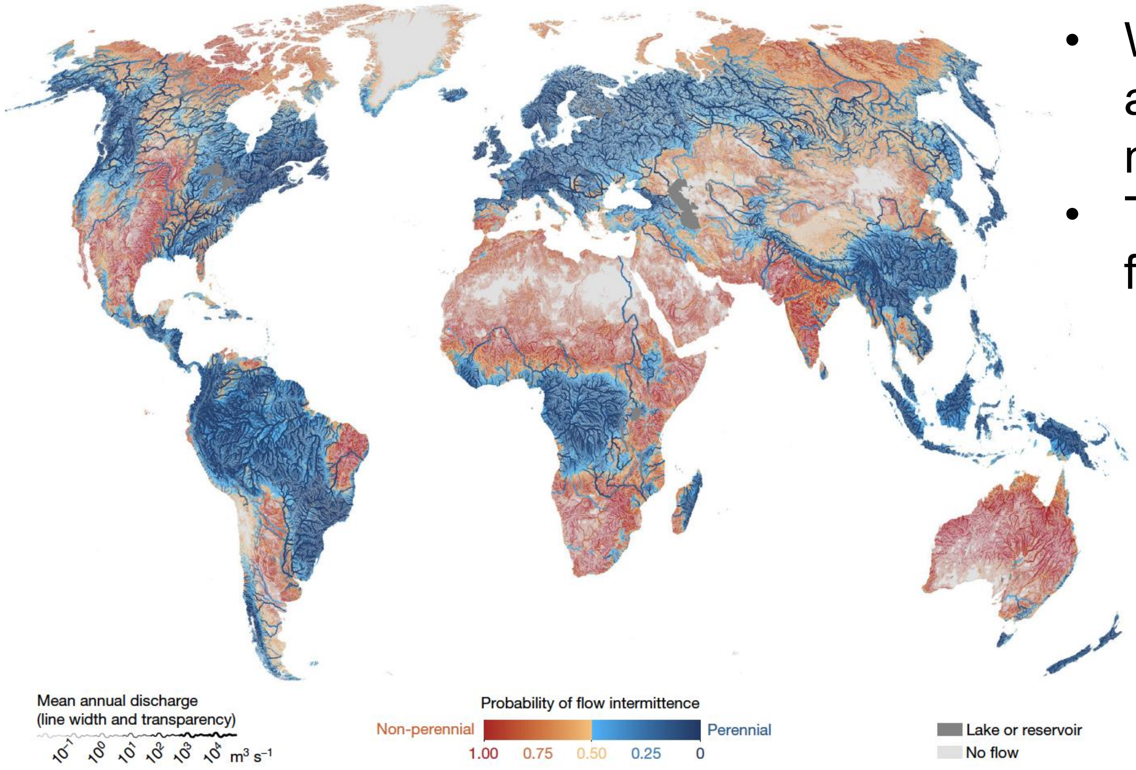
EPFL

Article

Global prevalence of non-perennial rivers and streams

https://doi.org/10.1038/s41586-021-03565-5
Received: 12 November 2020
Accepted: 19 April 2021

Mathis Loïc Messager[1,2]✉, Bernhard Lehner[1]✉, Charlotte Cockburn[1,7], Nicolas Lamouroux[2], Hervé Pella[2], Ton Snelder[3], Klement Tockner[4,5], Tim Trautmann[6], Caitlin Watt[1,8] & Thibault Datry[2]✉



- Worldwide, most river and stream systems have non-perennial flow
- They experience zero-flow days (intermittency)

EPFL

Article

Global prevalence of non-perennial rivers and streams

https://doi.org/10.1038/s41586-021-03565-5
Received: 12 November 2020
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Mathis Loïc Messager[1,2✉], Bernhard Lehner[1✉], Charlotte Cockburn[1,7], Nicolas Lamouroux[2], Hervé Pella[2], Ton Snelder[3], Klement Tockner[4,5], Tim Trautmann[6], Caitlin Watt[1,8] & Thibault Datry[2✉]

Variables related to climate, soil water content and hydrology are the best predictors of flow intermittency

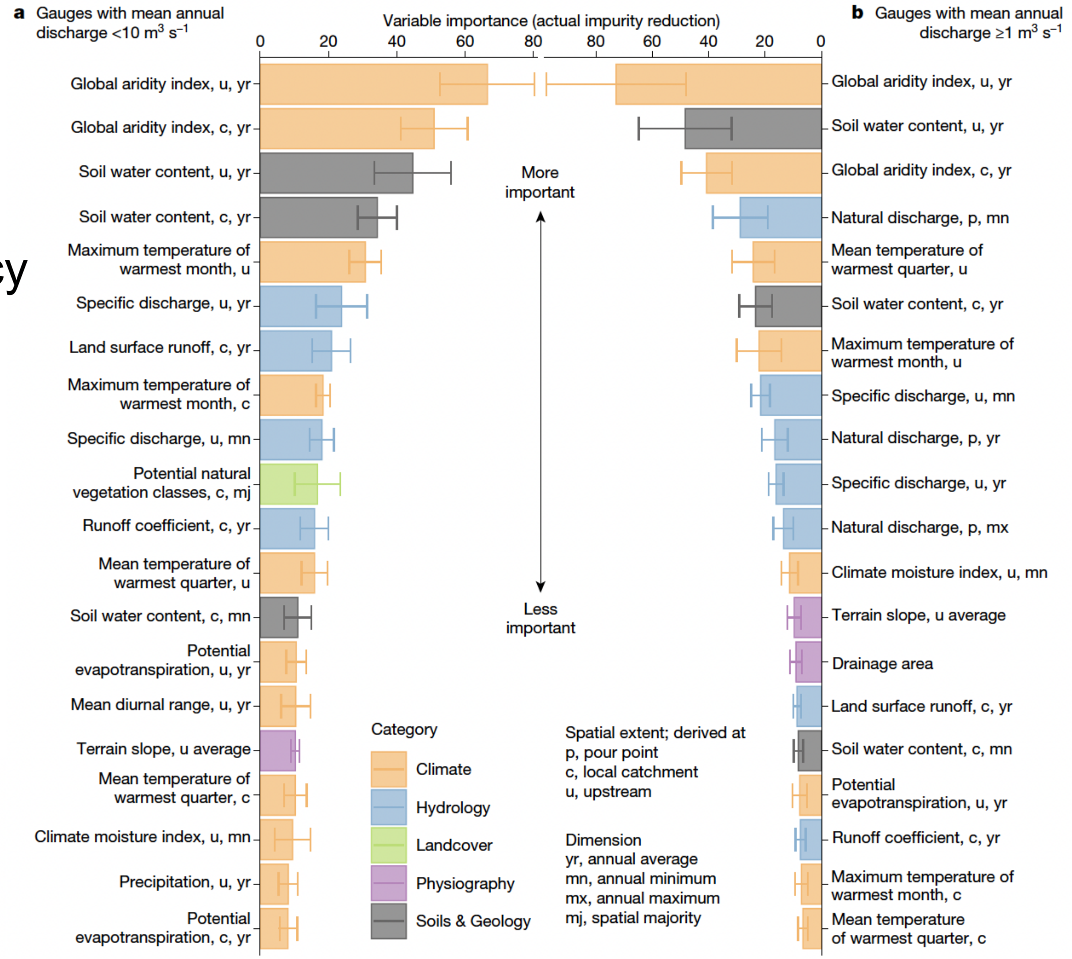


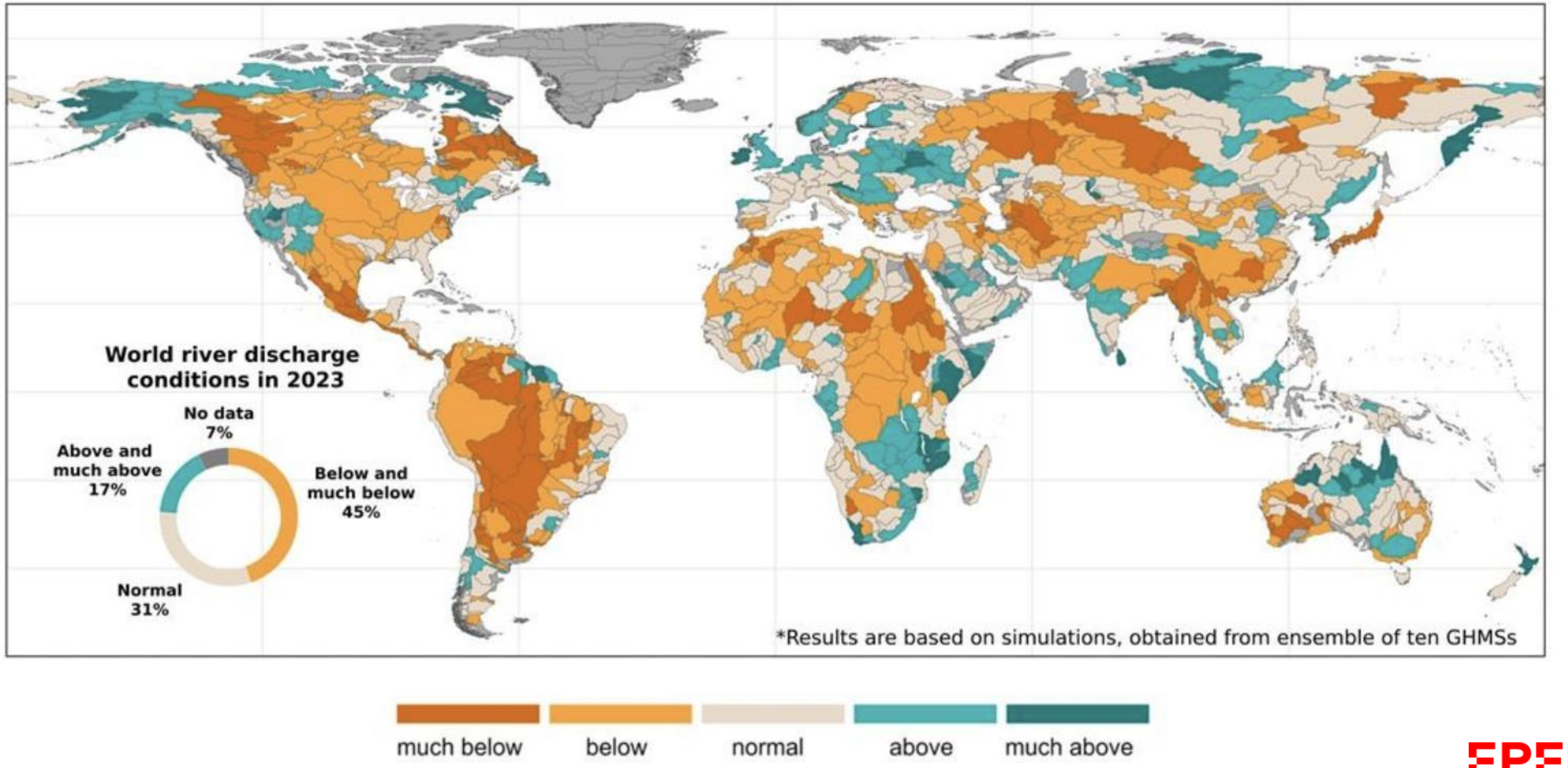
Fig. 2 | Climate-induced aridity and hydrologic variables are the main predictors of global flow intermittence. a, b, The two sets of ranked predictor variables represent results from a split random forest model trained on gauges with a mean annual naturalized flow <10 $m^3 s^{-1}$ (**a**) and gauges with a mean annual naturalized flow ≥1 $m^3 s^{-1}$ (**b**). See Methods section 'Machine learning models' for details on model structure and implementation. Rectangular bars show the balanced accuracy-weighted average of actual impurity reduction[49] (AIR) across non-spatial cross-validation folds and repetitions. The longer the bar (that is, the higher the AIR), the more important the variable in predicting flow intermittence. Error brackets show ± one weighted standard deviation of AIR. After the variables' names, the first abbreviation denotes each variable's spatial extent: p (derived at the pour point of the river reach), c (derived within the local catchment that drains directly into the reach), or u (derived within the total drainage area upstream of the reach pour point). The second abbreviation denotes each variable's dimension: yr (annual average), mn (annual minimum), mx (annual maximum), or mj (spatial majority). See Methods and Extended Data Table 2 for data sources of variables.

EPFL

WMO report highlights growing shortfalls and stress in global water resources

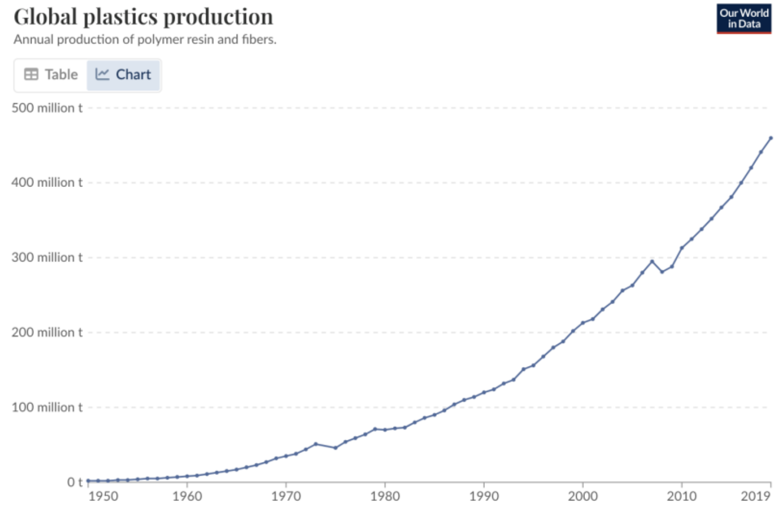
PRESS RELEASE

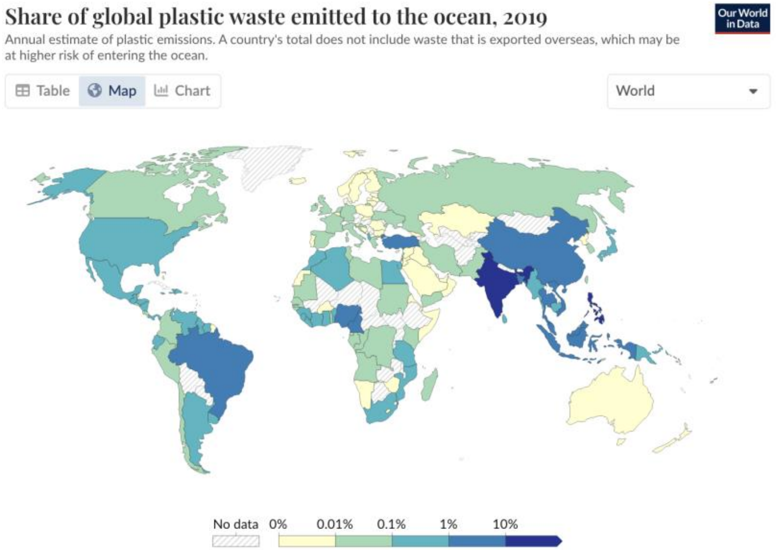
- Owing to a warm summer with little precipitation, many of the world's rivers had water flows significantly below average
- A widespread drought



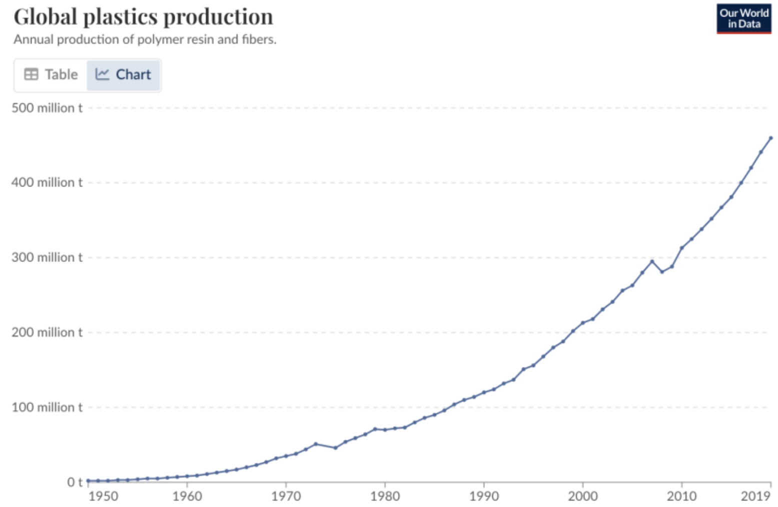
(Micro)plastics

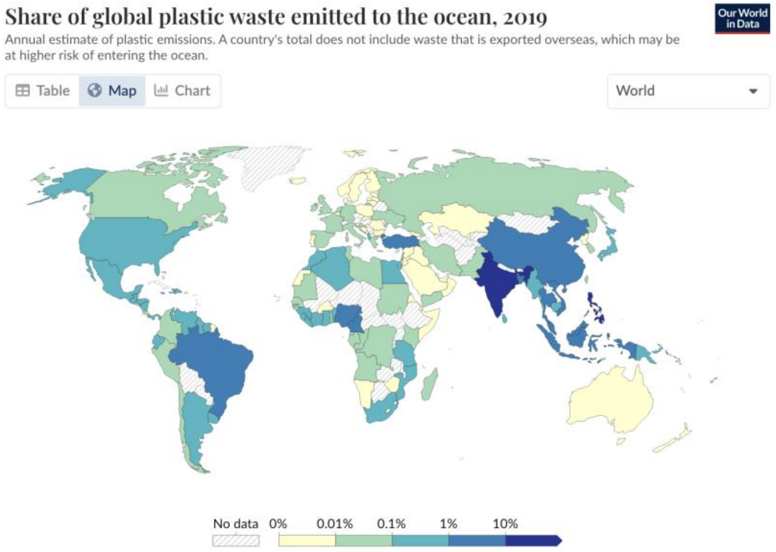
(Micro)plastics



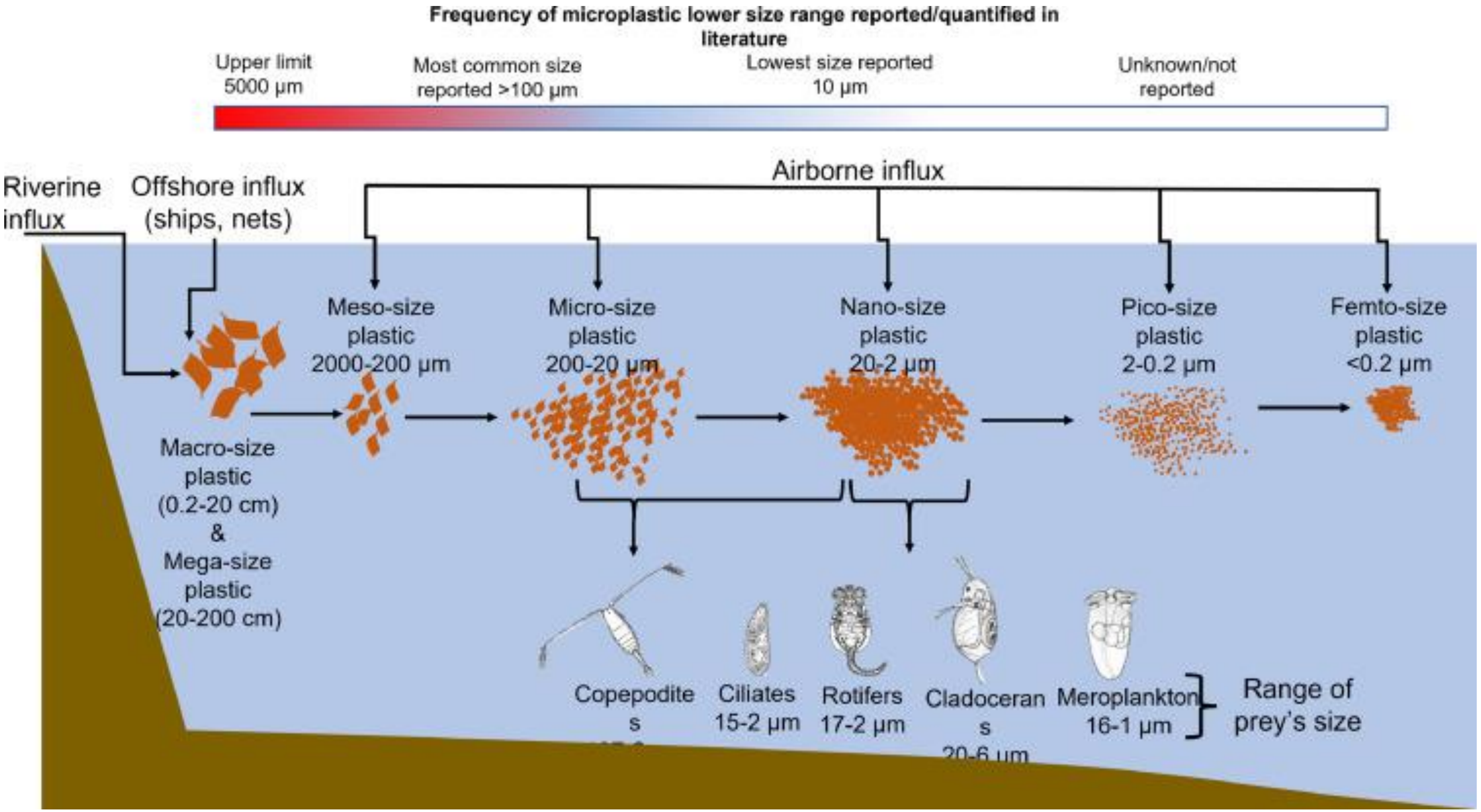


(Micro)plastics





(Micro)plastics



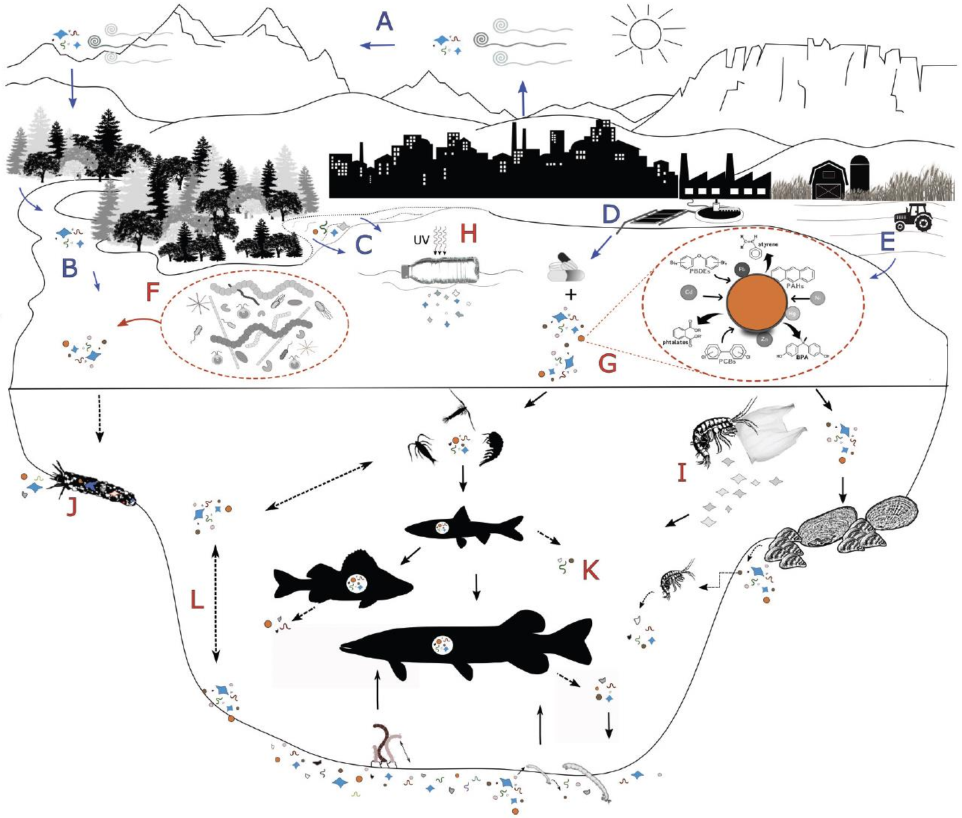
- A full size range of plastics
- Each size with its own impacts

Canadian Science Publishing
REVIEW

Microplastics in lakes and rivers: an issue of emerging significance to limnology

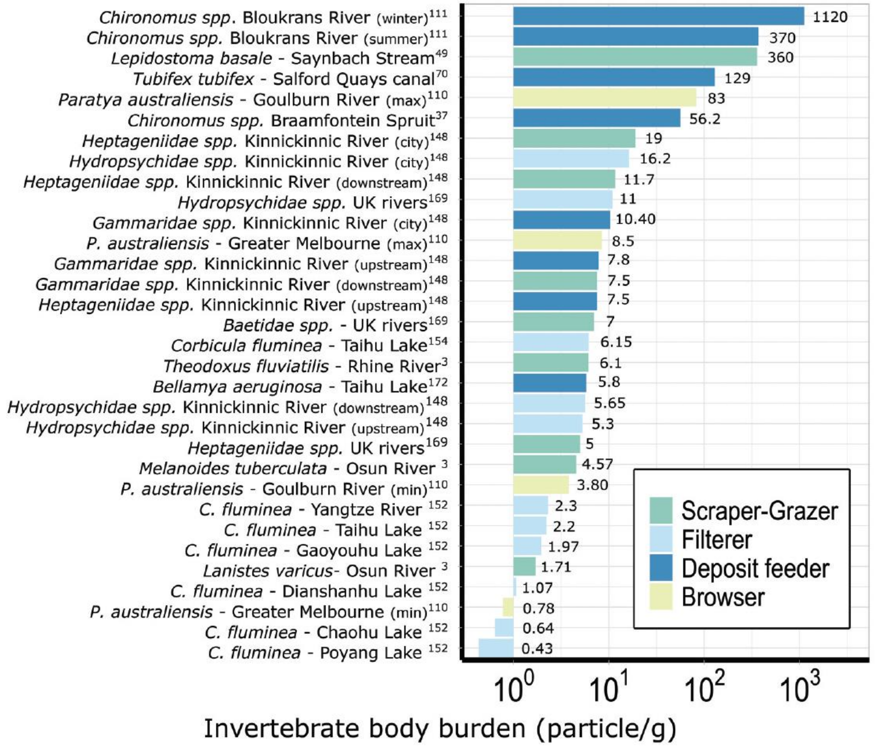
Genevieve D'Avignon, Irene Gregory-Eaves, and Anthony Ricciardi

Fig. 1. The biogeochemical cycle of plastics in inland waters. Blue letters represent microplastic transport pathways to aquatic systems. Microplastics are transported (A) via aerial transport and deposition (winds) or (B) by tributaries throughout the watershed. Terrestrial plastic waste and debris are carried by water via (C) flooding, (D) wastewater and stormwater effluents, or (E) runoff (e.g., urban, agricultural applications of contaminated sludge or biowaste, dredge piles). Red letters illustrate processes within aquatic environments: (F) biofilm formation via colonization by microbial organisms; (G) the sorption of associated contaminants (heavy metals, organic pollutants, pharmaceuticals) onto the surface of plastic particles (orange sphere represents a microbead); the fragmentation of plastics by (H) physical processes (exposure to UV light, mechanical or chemical erosion) or by (I) their interaction with organisms; (J) incorporation of microplastics in larval cases or shelters of aquatic insects; (K) introduction and circulation of microplastics in aquatic food webs; and (L) vertical movement of microplastics (e.g., changes in buoyancy, deposition, re-suspension, burial). Drawn using license-free clipart images and the Inkscape vector graphics editor.



- Numerous sources and fates of plastics in aquatic ecosystems
- UV-radiation, temperature, physical abrasion, biodegradation
- Enters food web and biomagnification

Fig. 5. Comparison of the body burden (microplastic particle per gram of tissue) of freshwater invertebrates found along rivers. Only organisms that incorporated microplastics (particles ≤ 5 mm) into their body via ingestion or essential structures (e.g., the larval case of *Lepidostoma basale*) were used for this figure. Colours represent different functional groups. Species are listed individually with the locations sampled and the reference number. Original data and complete references are available in the Supplementary data, Table S3[1].



EPFL

Trends in Analytical Chemistry 112 (2019) 66–74

Contents lists available at ScienceDirect

Trends in Analytical Chemistry

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

(Micro) plastic fluxes and stocks in Lake Geneva basin

Julien Boucher [a, b, *], Florian Faure [c], Olivier Pompini [c], Zara Plummer [a], Olivier Wieser [c], Luiz Felippe de Alencastro [c]

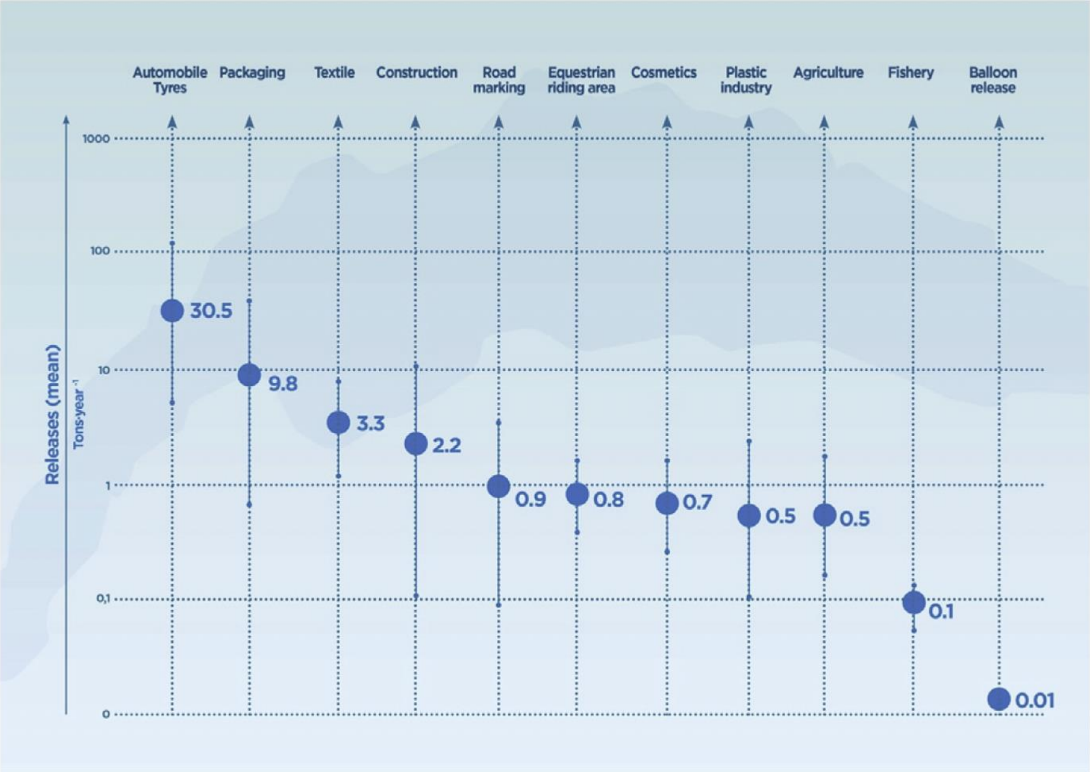
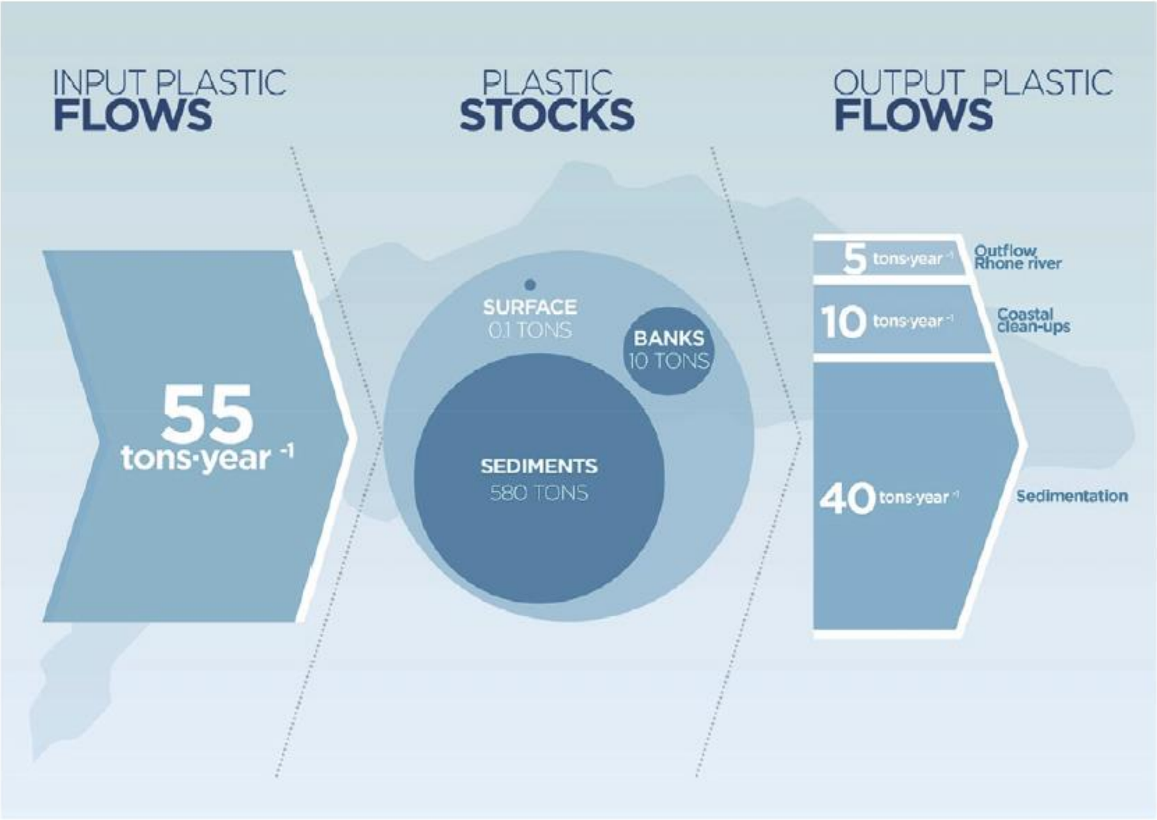


Fig. 4. RELEASES of plastic to the Lake Geneva; contribution of the different sources (log10 scale).



- Lake Geneva as a major sink for microplastics
- Automobile tyres wear as a major contributor

Other pollutants

Environmental Science and Pollution Research (2023) 30:90595–90614
https://doi.org/10.1007/s11356-023-28802-4

REVIEW ARTICLE

Occurrence, environmental impact and fate of pharmaceuticals in groundwater and surface water: a critical review

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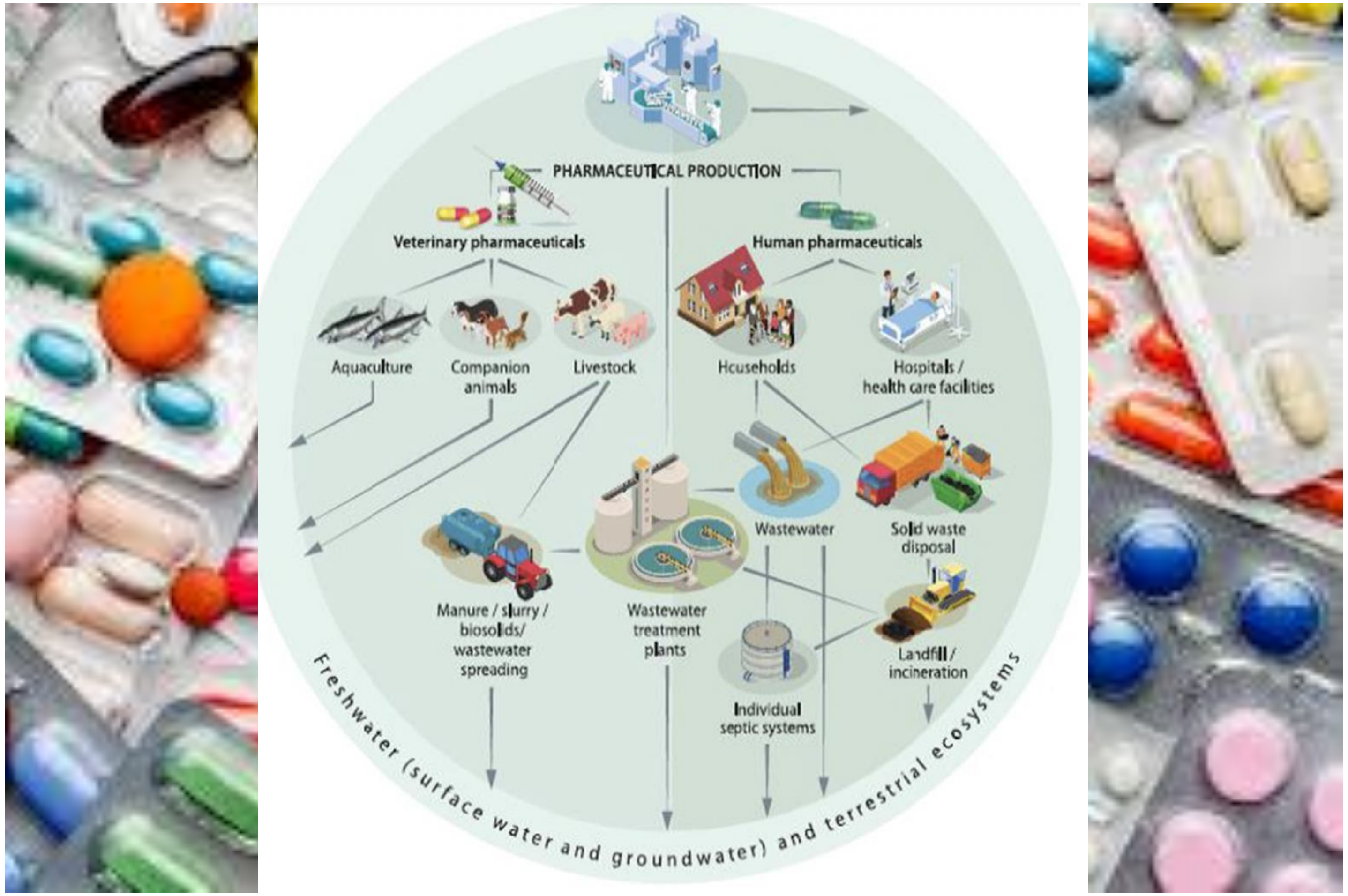

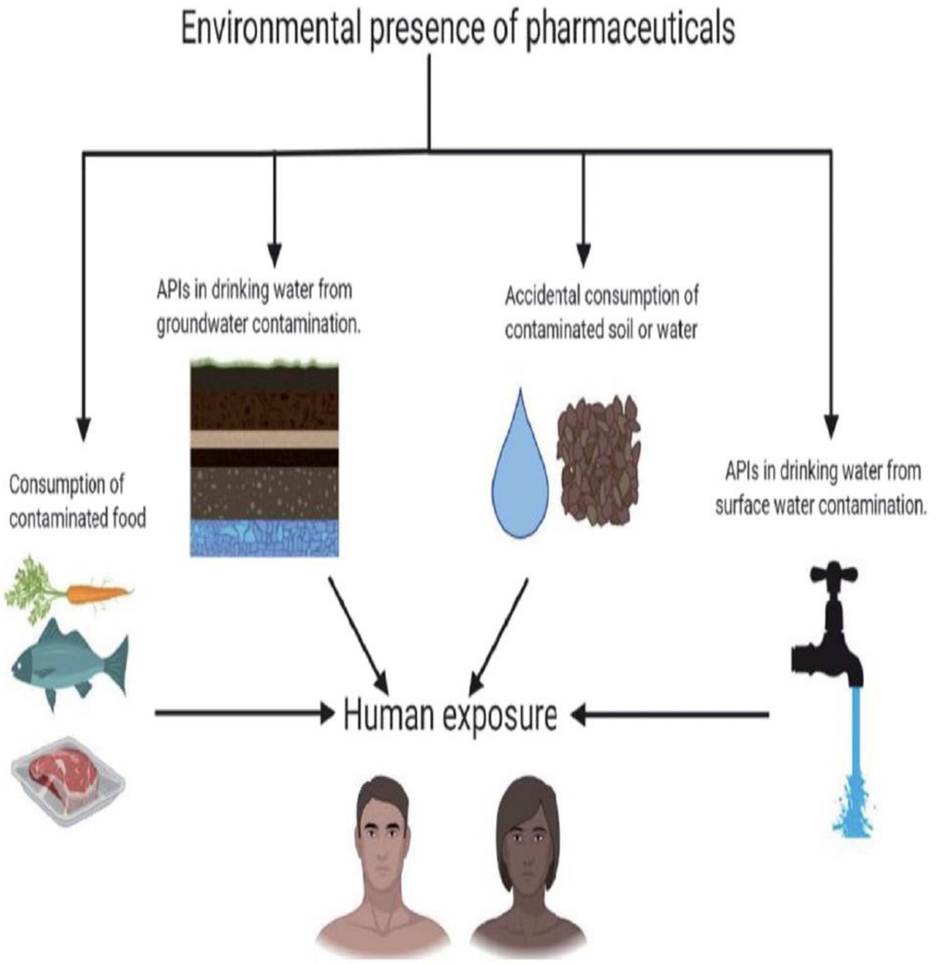

API: Active Pharmaceutical Ingredients


Pharmaceutical pollution of the world's rivers

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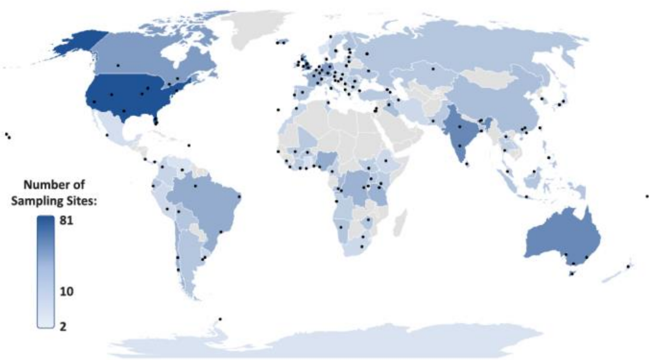
ENVIRONMENTAL SCIENCES



- Active pharmaceutical ingredients (API) detected in all rivers
- A large diversity of API in the world's major river systems – different concentrations

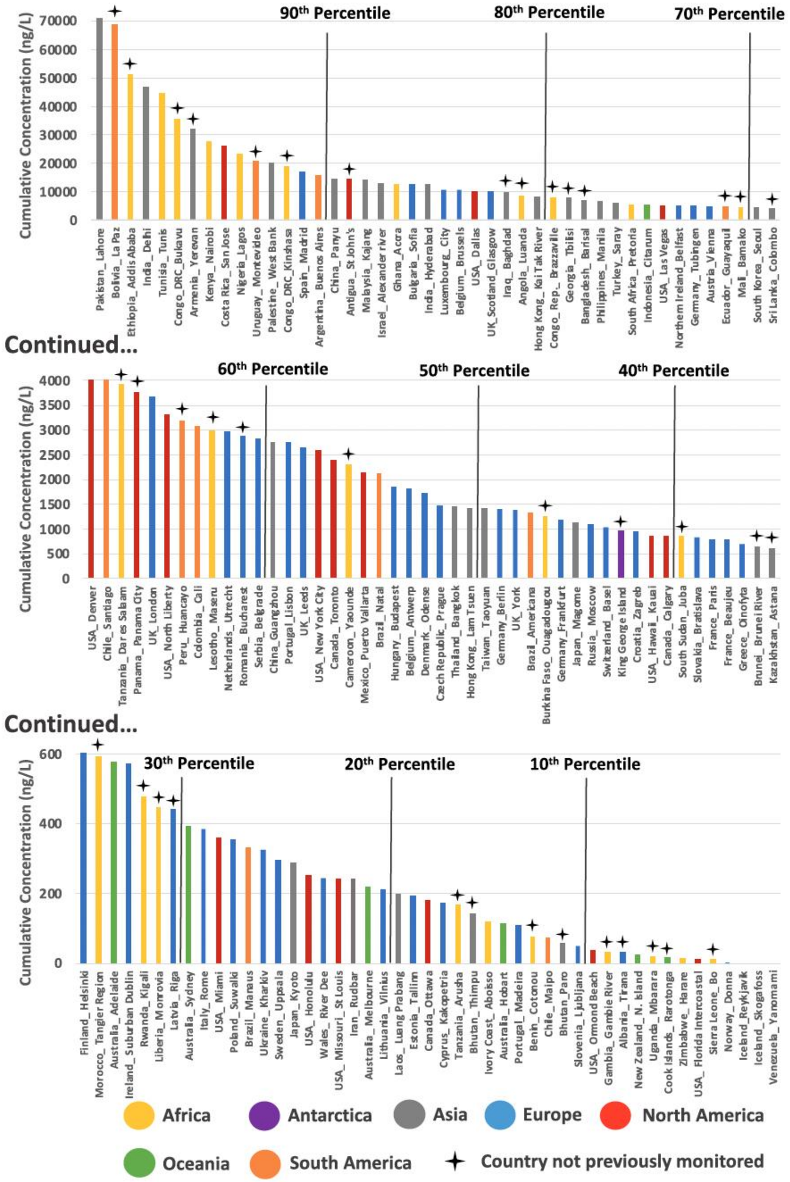


Fig. 2. Cumulative API concentrations quantified across 137 studied river catchments (Dataset S6) organized by descending cumulative concentration (ng/L). Percentiles are marked by black lines and countries not previously monitored by crosses above the plot. The cumulative concentrations reported here are calculated as the average of the sum concentration of all quantifiable API residues at each sampling site within respective river catchments.

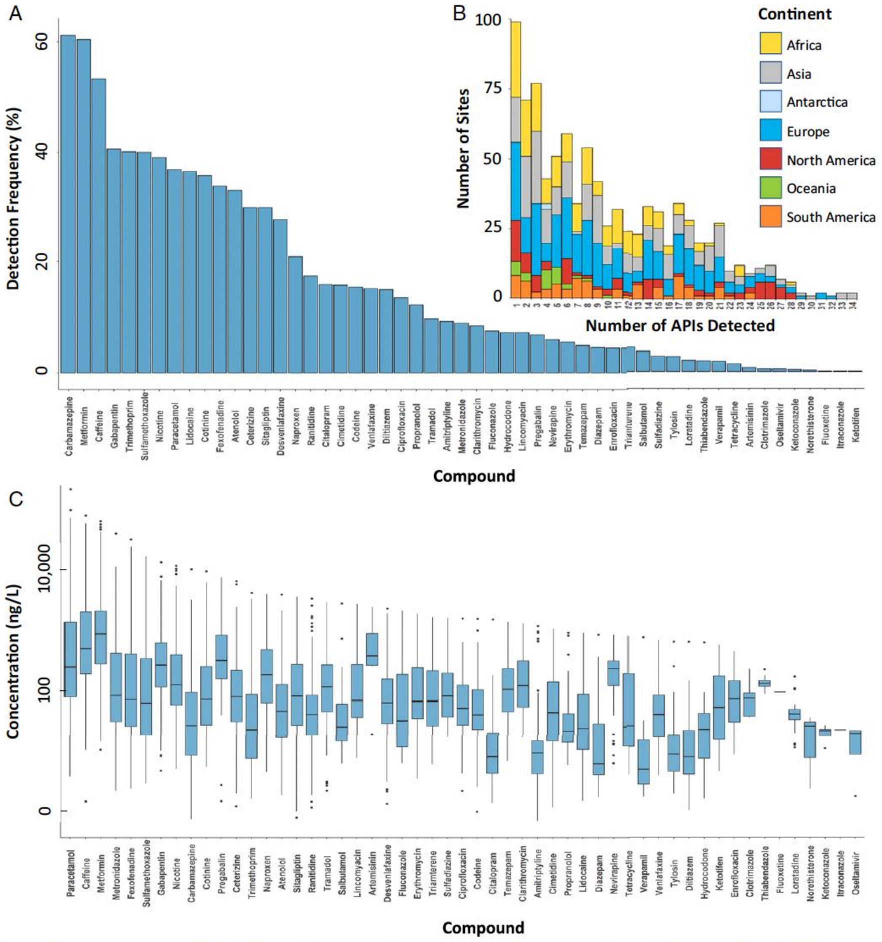


Fig. 3. (A) Detection frequencies (Dataset S5) and (B) number of APIs detected at sampling sites in the global monitoring study (Dataset S4), excluding sites without the detection of any API, and (C) box-and-whisker plots of concentrations (ng/L) of individual APIs (Dataset S4), indicating the mean, minimum, maximum, and upper and lower quartile concentrations for each API globally.

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ARTICLE

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A diverse suite of pharmaceuticals contaminates stream and riparian food webs

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- Numerous pharmaceuticals detected in aquatic insect larvae
- Platypus and trout highly enriched in antidepressants

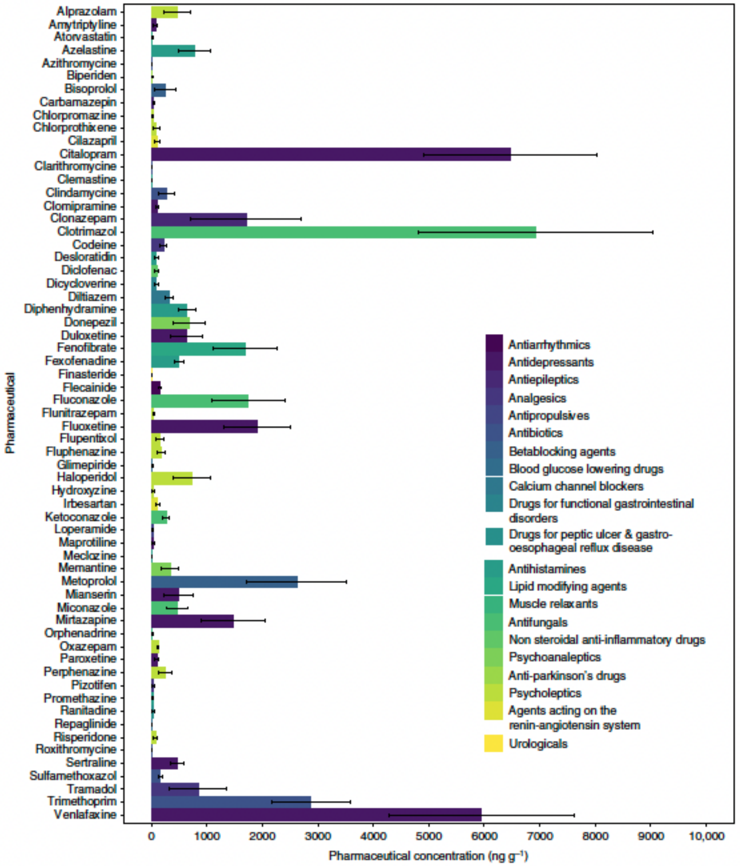


Fig. 1 Pharmaceutical concentrations in caddisfly larvae. Mean pharmaceutical concentrations (ng g^{-1} dry weight ±1 SE) in caddisfly larvae (Hydropsychidae) ($n = 6$) at wastewater-influenced Brushy Creek. Each bar represents the mean concentration of a pharmaceutical compound in the six individuals collected over two sampling dates. Colours represent therapeutic drug classes

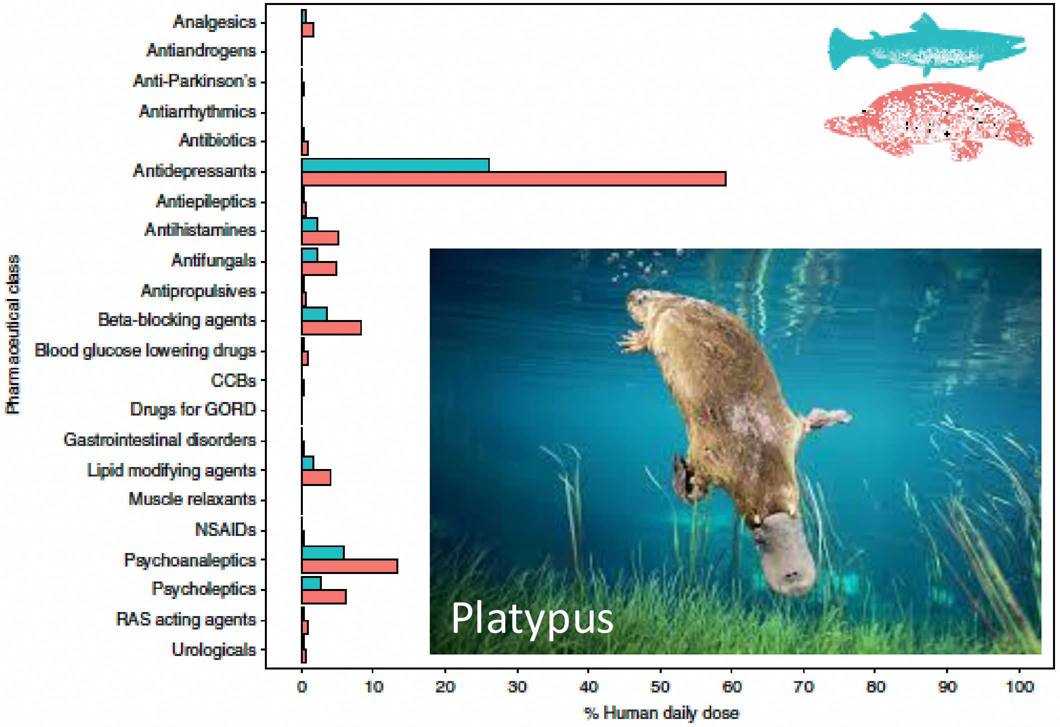
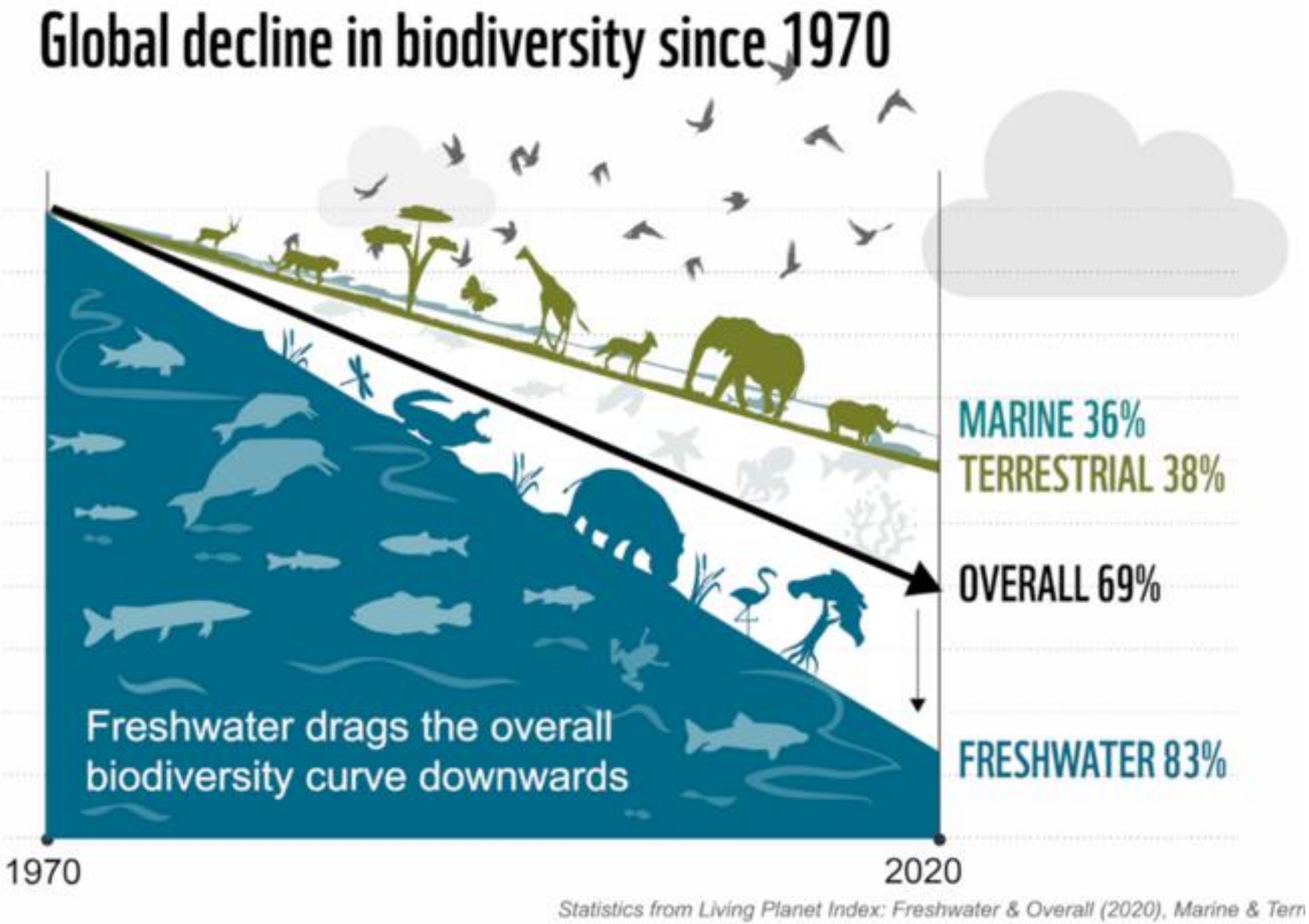


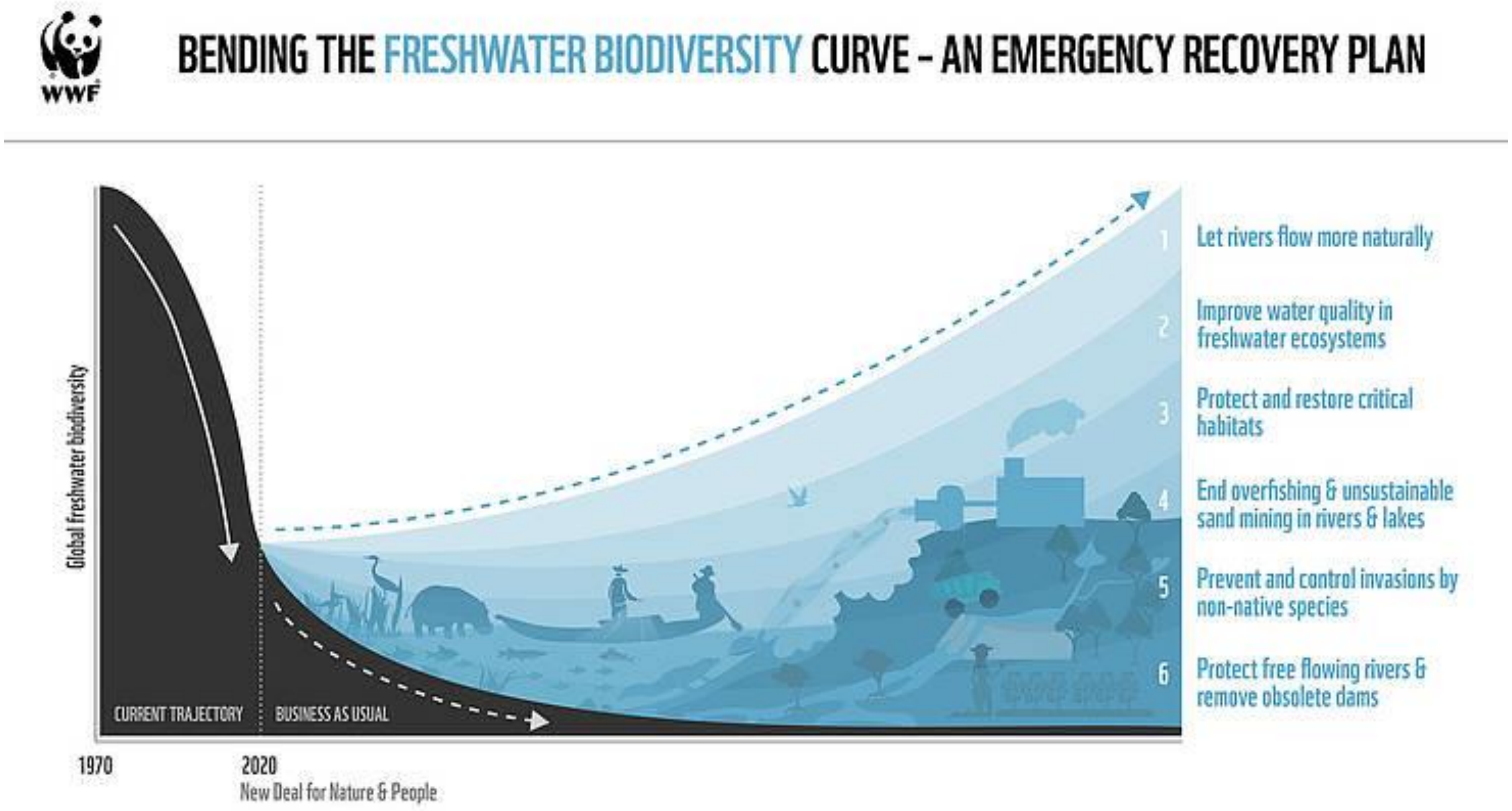
Fig. 4 Estimated dietary intake of pharmaceuticals by two representative invertebrate predators compared to recommended human pharmaceutical doses. Dietary intake rates as a percentage of recommended human pharmaceutical daily doses by therapeutic class for platypus (pink) and brown trout (blue) in Brushy Creek. (CCBs calcium channel blockers, GORD gastroesophageal reflux disease, NSAID non-steroidal anti-inflammatory drugs, RAS renin angiotensin system). Calculations appear in Methods section (equations 2-5). The trout and platypus images in this figure were adapted from Harter, Jim. 'Animals 1419 copyright-free illustrations of mammals, birds, fish, insects, etc. A pictorial archive from Nineteenth century sources' Mineola, New York. Copyright Dover Publication Inc. (1979). All rights reserved

Biodiversity



Highest biodiversity loss in freshwater ecosystems, particularly streams and rivers

What would have to be done to counteract the biodiversity l



What would have to be done to counteract the biodiversity l

And why it does not work!

BIOLOGICAL REVIEWS
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Bending the curve of global freshwater biodiversity loss: what are the prospects?

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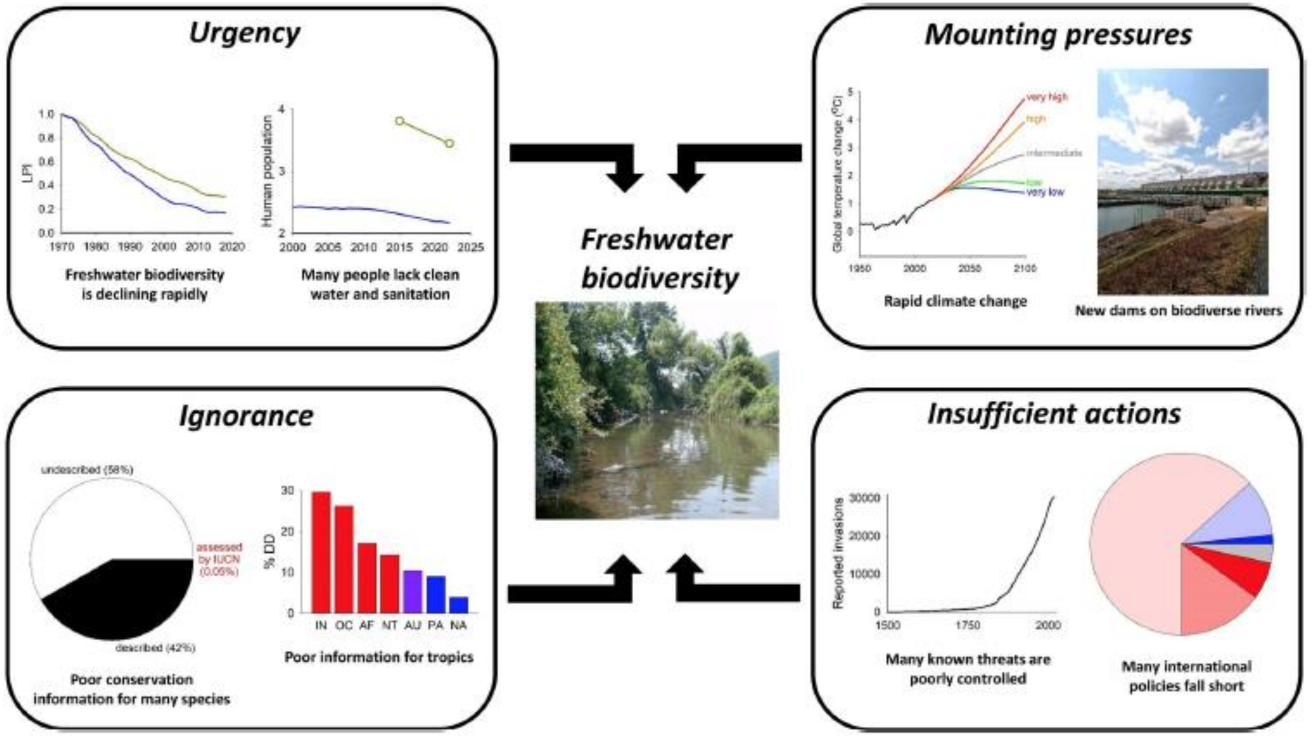
Urgency: freshwater biodiversity is declining rapidly, where the blue and green lines denote freshwater and terrestrial animals respectively, while much of the global human population (shown here in billions of people) still lack safely managed water (blue line) and sanitation (green line)

Ignorance: the conservation status and even basic biology of many freshwater species is poorly known, especially in the tropics, frustrating traditional species-based conservation programs.



Mounting pressures: the climate is changing rapidly, and will continue to do so, depending on how well emissions of greenhouse gases are controlled, and new, large dams continue to be planned and built on great biodiverse rivers

Insufficient actions: the number of biological invasions continues to accelerate (left panel), showing that existing controls are inadequate and international conservation policies often fail to meet their goals

Ecosystem functioning

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RESEARCH ARTICLE

Global Change Biology WILEY

A global synthesis of human impacts on the multifunctionality of streams and rivers

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- Most stream and river ecosystem functions compormised by anthropogenic stressors
- Leaf litter decomposition rates reduced by wastewater, flow regulation and urbanisation; accelerated by nutrient enrichment (see class on N immobilisation and remineralisation)

Definition of stressors

Stressor	Definition
Agriculture	Compound stressor with various individual impacts that often act simultaneously and in opposite directions, for example, pesticide and nutrient inputs, fine sediment inputs, hydromorphological degradation, removal of riparian vegetation
Urbanization	Compound stressor associated with urban development with various individual and often interacting impacts, for example, diffuse inputs from impervious surface areas, high temperatures, riparian clearcutting, hydromorphological degradation, and flashy hydrology
Flow regulation	Encompasses modification of the natural hydrological regime by dams and weirs for hydropower and shipping but also irrigation
Habitat loss	Loss of in-stream habitats such as submerged macrophytes and large woody debris or the replacement of coarse by fine substrates following sedimentation are often associated with human interventions. Studies dealing with stream restoration measures were assigned to this category by treating restored sites as reference and unrestored sites as impact
Nutrient enrichment	Nutrient enrichment refers to increases in dissolved inorganic nitrogen and phosphorus concentrations. Studies on the effects of artificially increased N and/or P concentrations were assigned to this category
Wastewater	Point-source pollution of potentially harmful substances (e.g., pharmaceuticals) and organic and inorganic nutrients and organic carbon from wastewater treatment plants

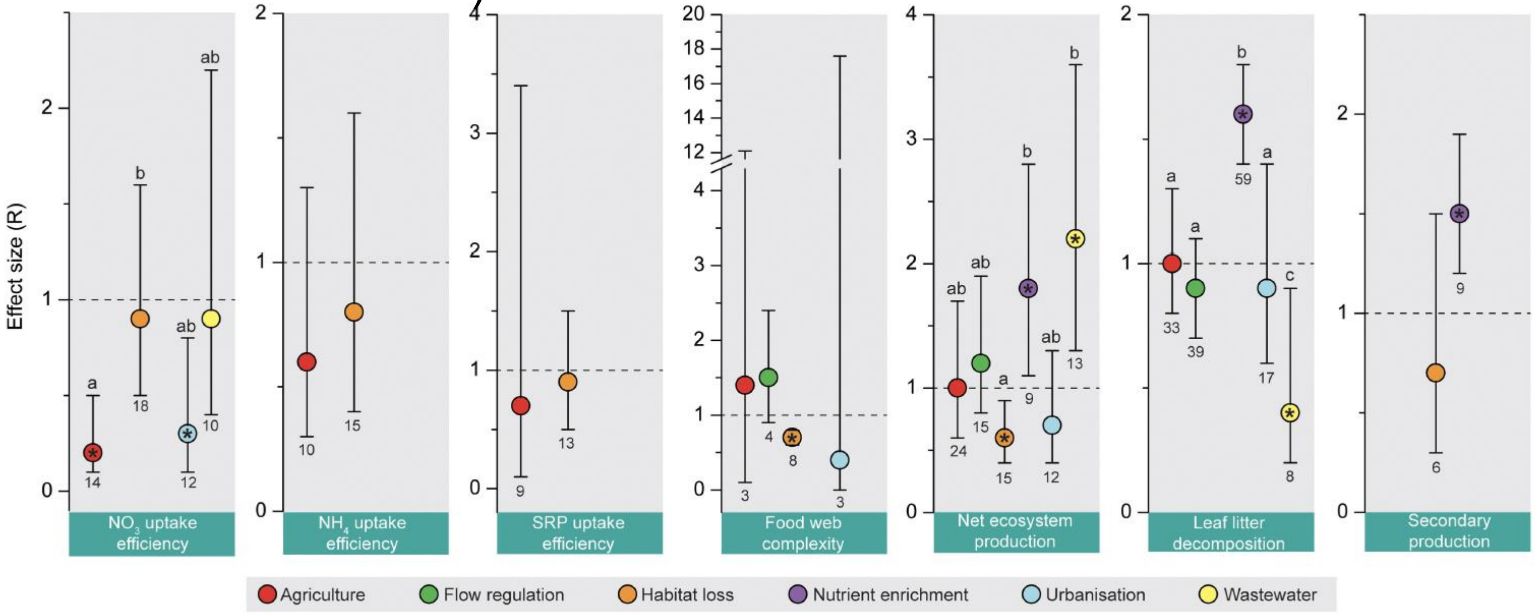

FIGURE 2 Individual responses of ecosystem functions to human stressors. *R* is the effect size calculated as the ratio between impacted and reference streams and presented as means and 95% confidence intervals. The dashed lines ($R = 1$) indicate no response, while $R < 1$ and $R > 1$ indicate that ecosystem functions are lower or higher in impacted than in reference streams, respectively. Asterisks indicate effect sizes significantly different from zero (95% CI does not overlap 1). Different letters indicate significant differences among stressors within ecosystem functions (Tukey honestly significant difference test, $p < .05$), and numbers indicate sample sizes. See Table S3 for the underlying random-effects meta-analyses and Table S4 for pairwise comparisons of effect sizes

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Next week

Restoration ecology