Restoration ecology

Can we repair some of the damage humans have done to ecosystems and biodiversity?

Ecological restoration seeks to do just that, and restoration ecology is the science that underpins it.

https://www.nature.com/scitable/knowledge/library/restoration-ecology-13239069/

Restoration projects differ in their objectives and methods. Many restoration projects aim to

- establish ecosystems composed of a native species
- improve or create particular ecosystem functions (e.g., pollination or erosion control).

Species conservation *versus* ecosystem/habitat preservation and management.

Revegetation: The establishment of vegetation on sites where it has been previously lost, often with erosion control as the primary goal. For example, vegetated buffers are strips of vegetation that protect water quality in riparian ecosystems from urban or agricultural runoff.

Habitat enhancement: The process of increasing the suitability of a site as habitat for some desired species.

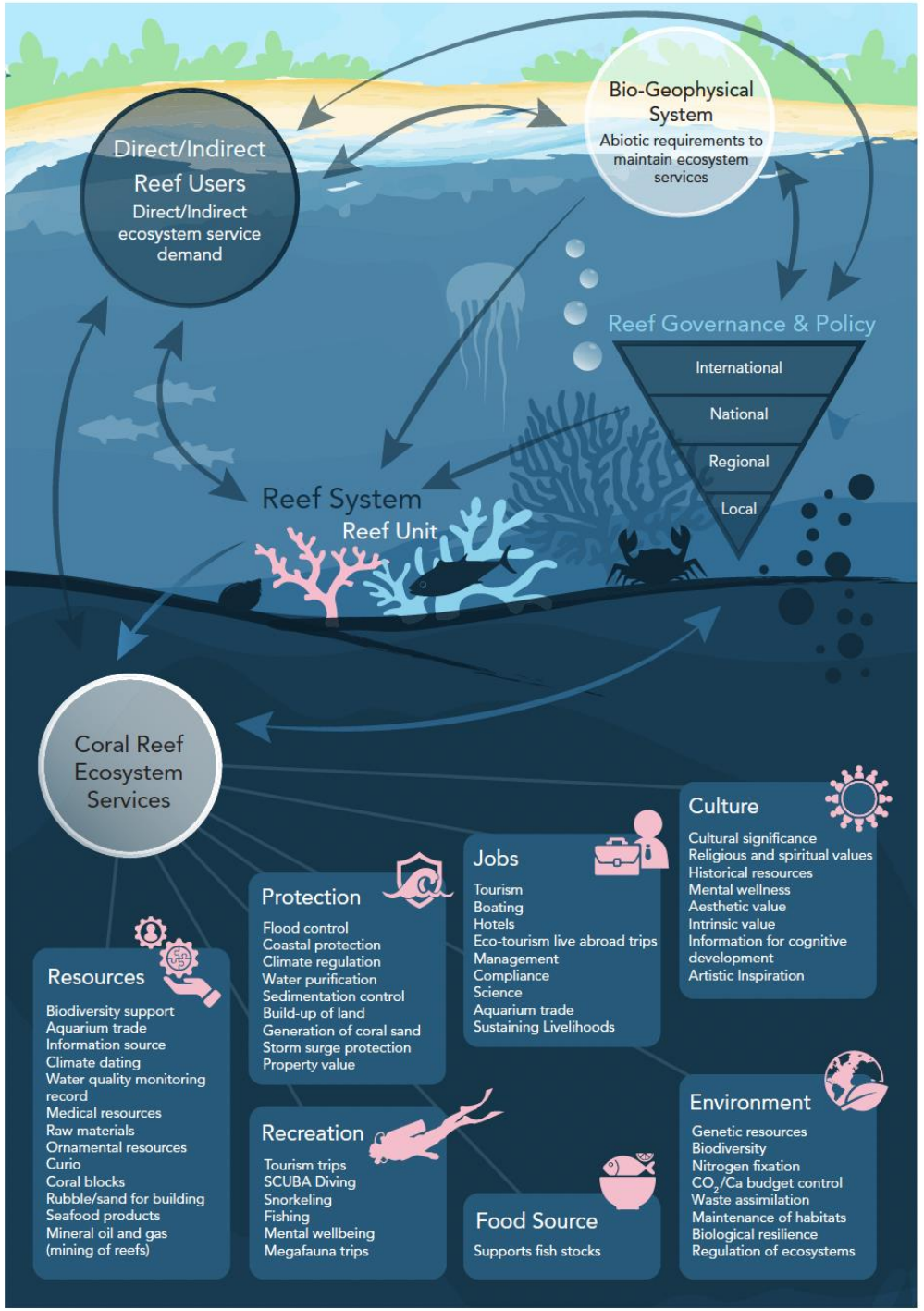
Remediation: Improving an existing ecosystem or creating a new one with the aim of replacing another that has deteriorated or been destroyed.

https://www.nature.com/scitable/knowledge/library/restoration-ecology-13339059/

Coral reefs

Coral reefs

Ecosystem services



CellPress

One Earth

Perspective

An integrative framework for sustainable coral reef restoration

David J. Suggett,[1,2,6,*] Melissa Edwards,[3] Deborah Cotton,[3] Margaux Hein,[4,5] and Emma F. Camp[1]

EPFL

Coral reef

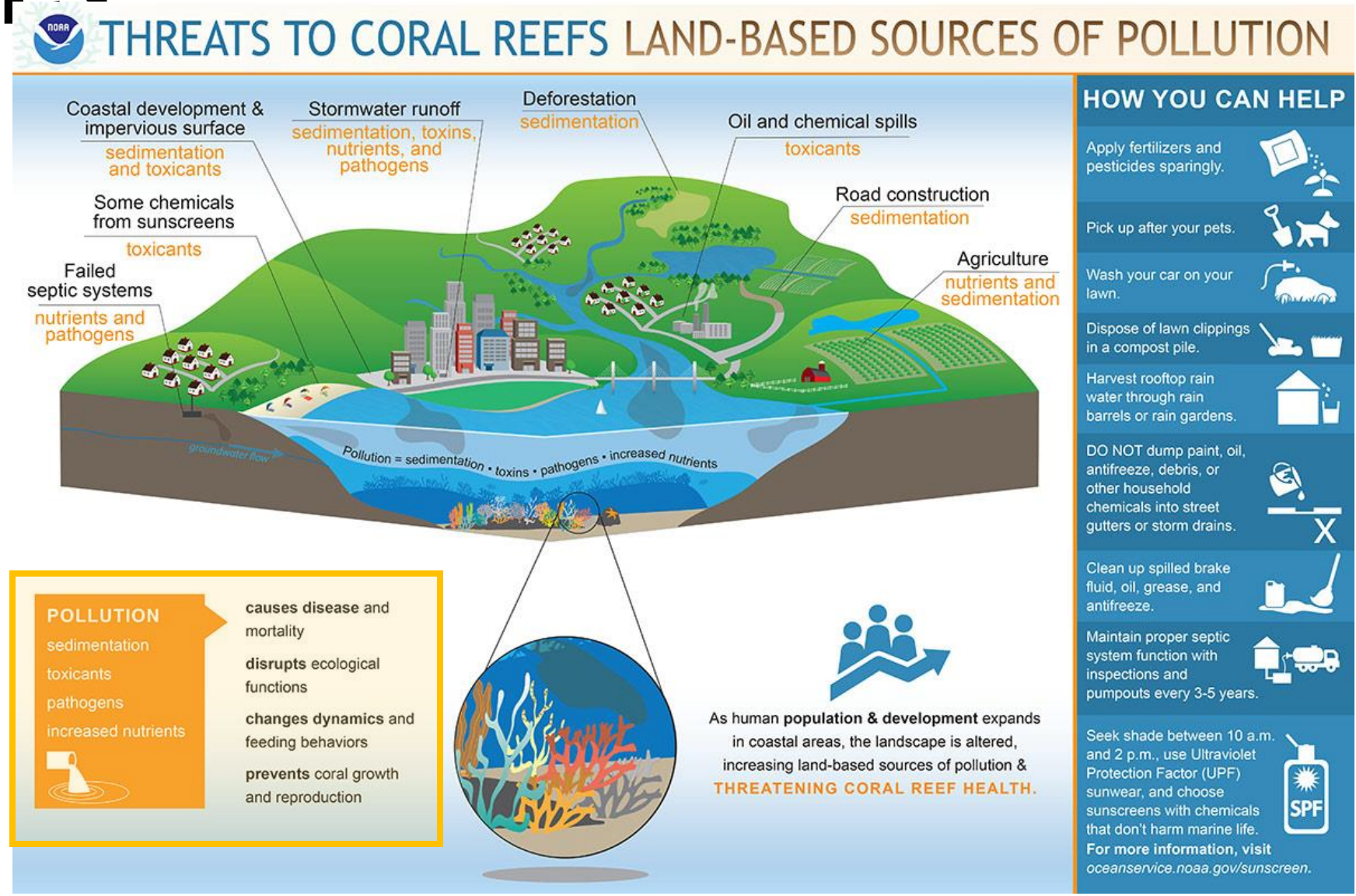
Threats

- Warming
- Acidification

Coral reefs

Threats

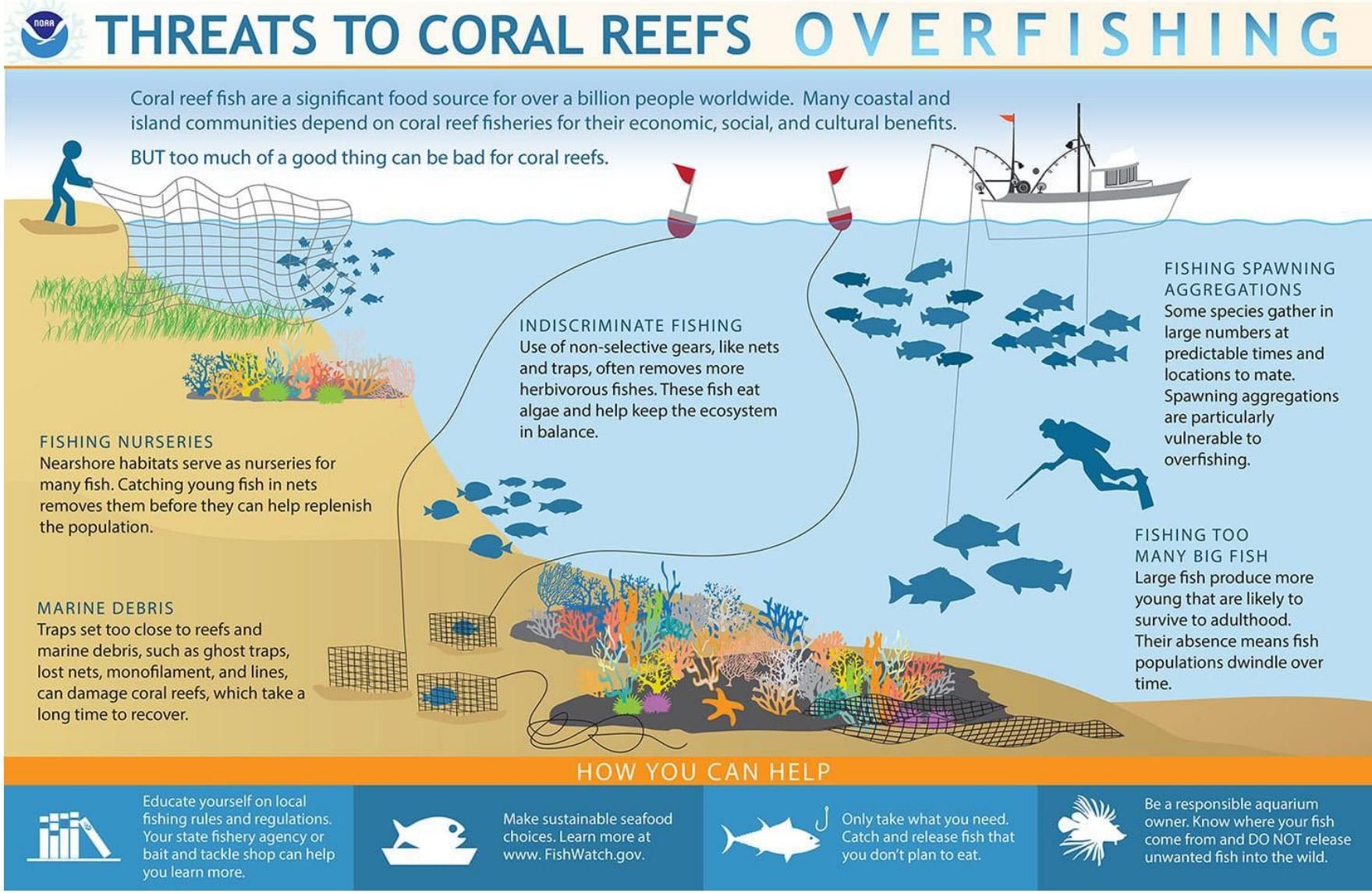
- Warming
- Acidification
- Pollution
- Overfishing



Coral reefs

Threats

- Warming
- Acidification
- Pollution
- Overfishing



- Removing keystone species
- Disturbing community and food web structure
- Altering nutrient and organic matter fluxes

Coral reefs

From threats to restoration

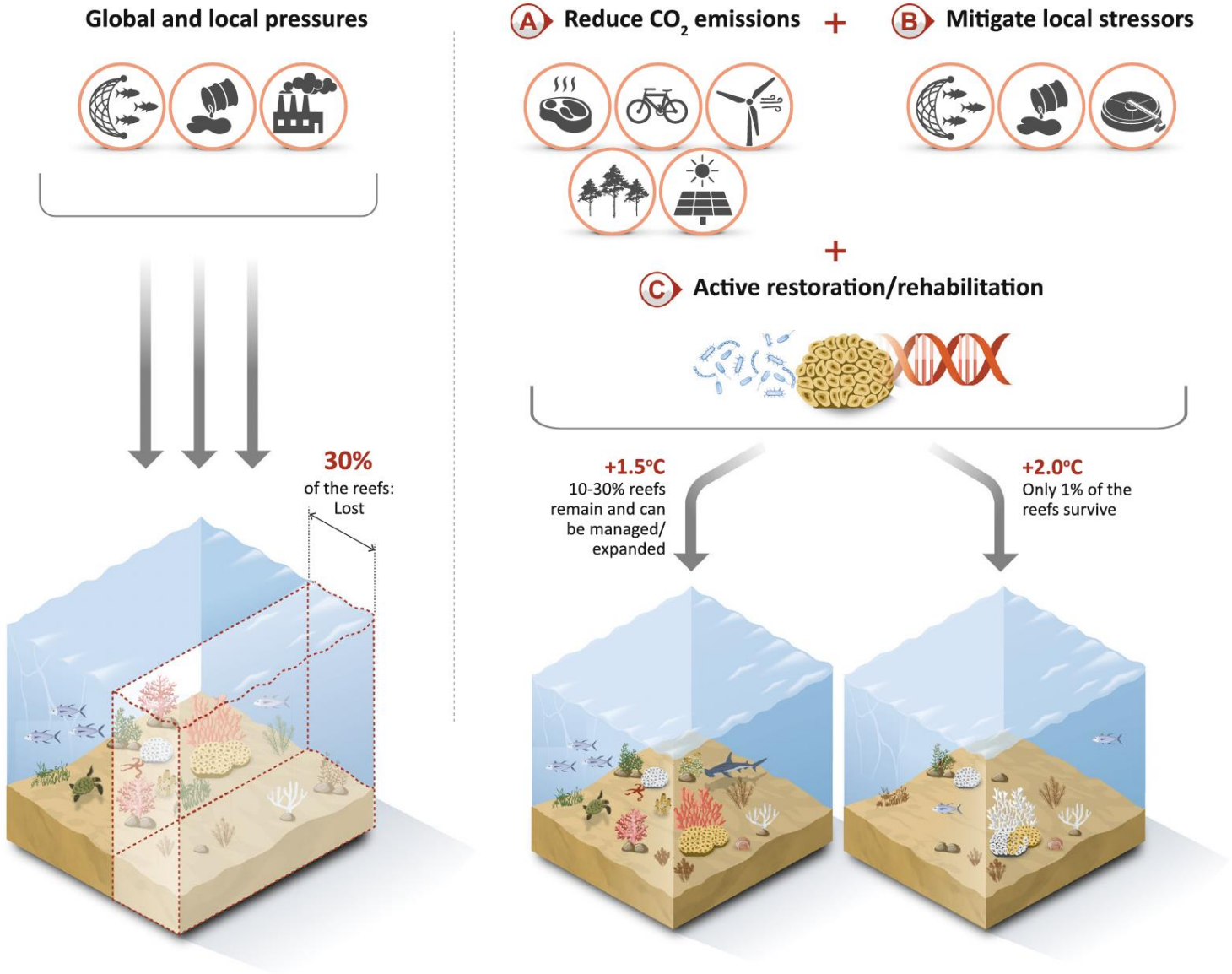


Figure 2. Global and local pressures have led to the loss of 30% of global reef cover (left). The International Coral Reef Society (ICRS) has proposed three pillars for restoring coral reefs and mitigating their further loss (right): (A) reduce CO_2 emissions; (B) mitigate local stressors (e.g., by managing fish stocks or improving water quality); and (C) active restoration/rehabilitation. It is important to note that without reducing CO_2 emissions to curb global warming to below 2°C and eventually becoming carbon neutral, we will still lose the majority of coral reefs (C, right-hand side).

Science & Society

TRANSPARENT PROCESS OPEN ACCESS EMBO *reports*

Mitigating the ecological collapse of coral reef ecosystems

Effective strategies to preserve coral reef ecosystems

Christian R Voolstra[1,*], Raquel S Peixoto[2,**] & Christine Ferrier-Pagès[3,***]

EPFL

Coral reefs

From threats to restoration

Coral restoration – A systematic review of current methods, successes, failures and future directions

Lisa Boström-Einarsson, Russell C. Babcock, Elisa Bayraktarov, Daniela Ceccarelli, Nathan Cook, Sebastian C. A. Ferse, Boze Hancock, Peter Harrison, Margaux Hein, Elizabeth Shaver, Adam Smith, David Suggett, Phoebe J. Stewart-Sinclair, Tali Vardi, Ian M. McLeod

Published: January 30, 2020 • https://doi.org/10.1371/journal.pone.0226631

Table 1. The terms for restoration methods used in the review, their definitions and other common terms. Categories are not mutually exclusive as some methods are often combined.

Method	Definition	Other common terms
ASEXUAL PROPAGATION METHODS		
Direct transplantation	*Transplanting coral colonies or fragments without intermediate nursery phase*	Coral tipping, post-disturbance repair
Coral gardening	*Transplanting coral fragments after an intermediate nursery phase*	Population enhancement, asexual propagation, *
Coral gardening—Nursery phase	*Transplanting coral fragments with an intermediate nursery phase (used to describe case studies that only detail the nursery phase). Nurseries can be in situ (on the reef) or ex situ (flow through aquaria). Note that following the above definition of restoration, a coral nursery does not constitute restoration, until outplanting has occurred.*	
Coral gardening—Transplantation phase	*Transplanting coral fragments with an intermediate nursery phase, including outplanting juveniles raised in the nursery (used to describe case studies that only detail the transplantation phase)*	Outplanting
Coral gardening—Micro-fragmentation	*Transplanting micro-fragments from corals, with an intermediate nursery phase*	Re-skinning
SEXUAL PROPAGATION METHODS		
Larval enhancement	*Using sexually derived coral larvae to release or outplant at restoration site, after intermediate holding phase which can be in- or ex-situ*	Larval propagation, sexual propagation, larval seeding, assisted breeding
SUBSTRATUM ENHANCEMENT METHODS		
Substratum addition—Artificial reef	*Adding artificial structures for purposes of coral reef restoration*	Engineered/artificial structures, various brand names (e.g. BioRock, EcoReef, ReefBall, Mars Spiders)
Substratum stabilisation	*Stabilising substratum to facilitate coral recruitment or recovery (often combined with artificial reefs and transplantation of coral fragments)*	
Substratum enhancement—electric	*Enhancing artificial substrata with an electrical field or direct current*	Electrochemically formed structures, mineral accretion, BioRock
Substratum enhancement—Algae removal	*Enhancing substrata by removing macroalgae*	

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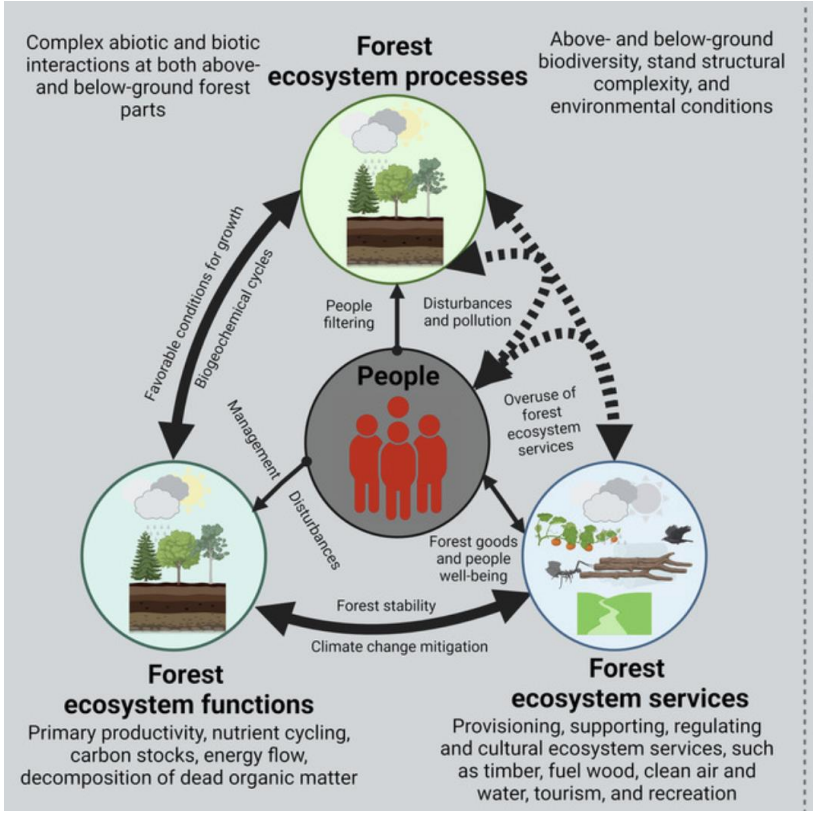
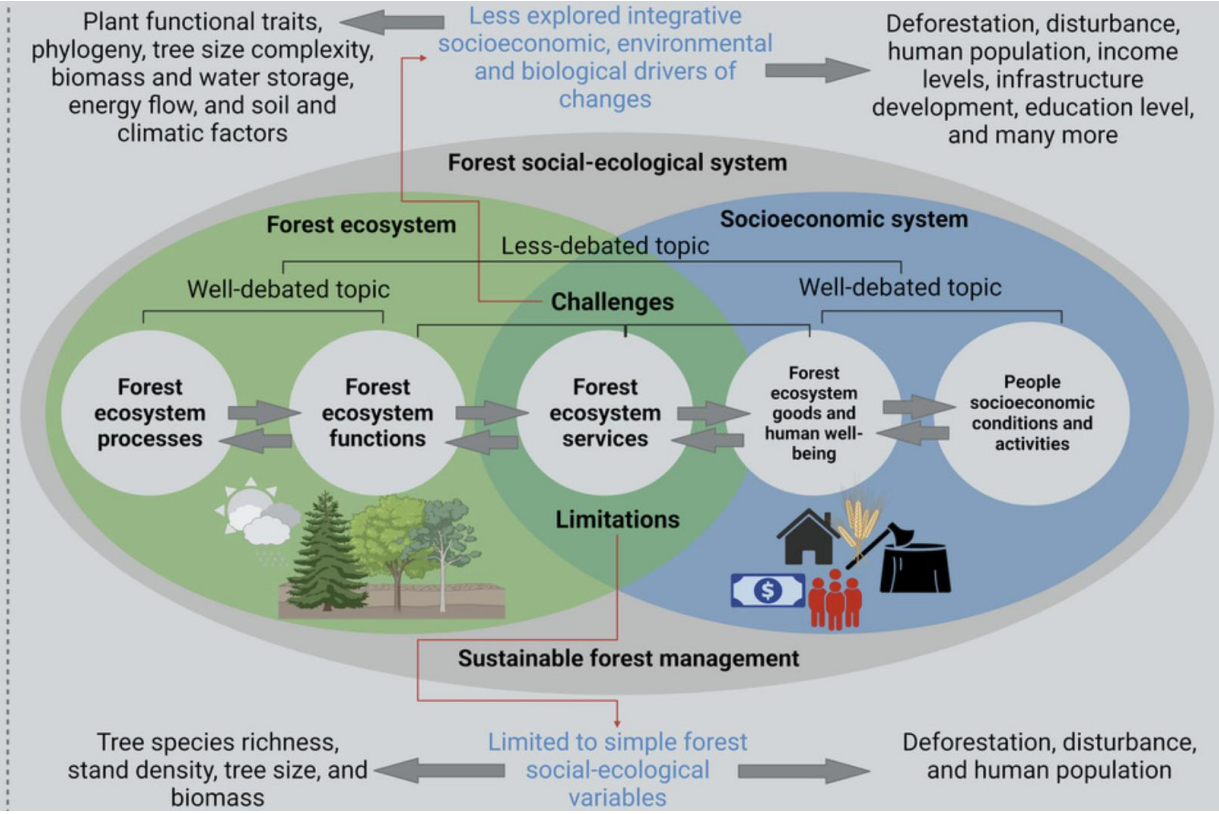
Forests

Forests

Ecosystem services





ELSEVIER

Science of The Total Environment

Volume 892, 20 September 2023, 164768

Linking forest ecosystem processes, functions and services under integrative social–ecological research agenda: current knowledge and perspectives

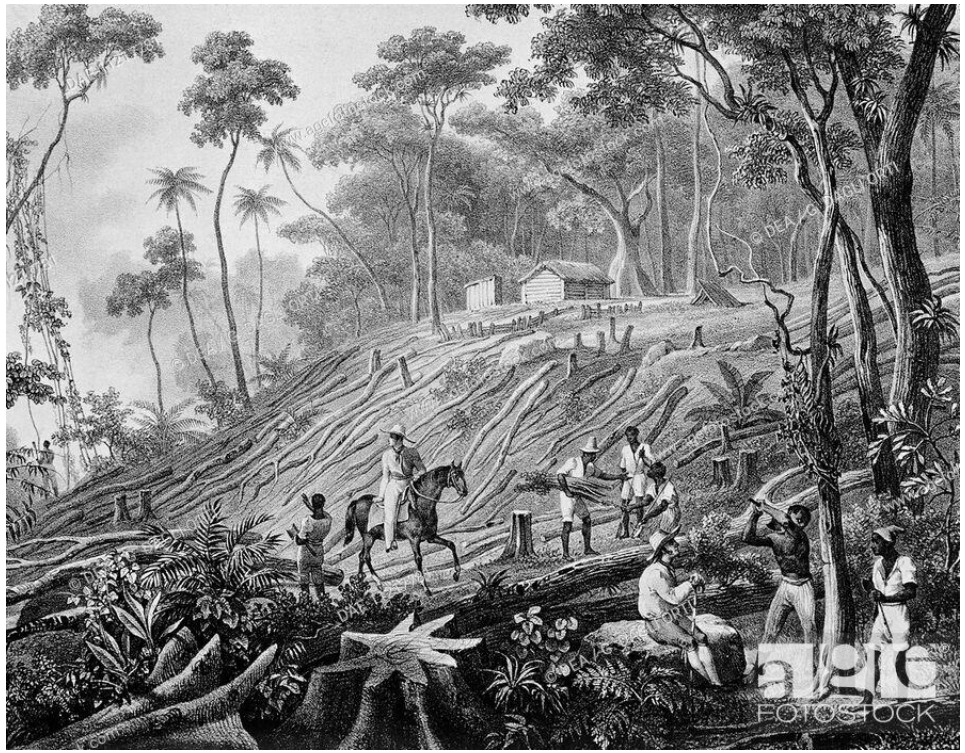
Arshad Ali ✉

EPFL

Forests

Deforestation

- Construction material
- Fuel
- Land conversion



Forests

Deforestation

Land conversion

- Crops
- Palm oil plantation
- Timber

Forests

Climate change

- Droughts
- Wildfires
- Pest

Forests

Restoration

Forests

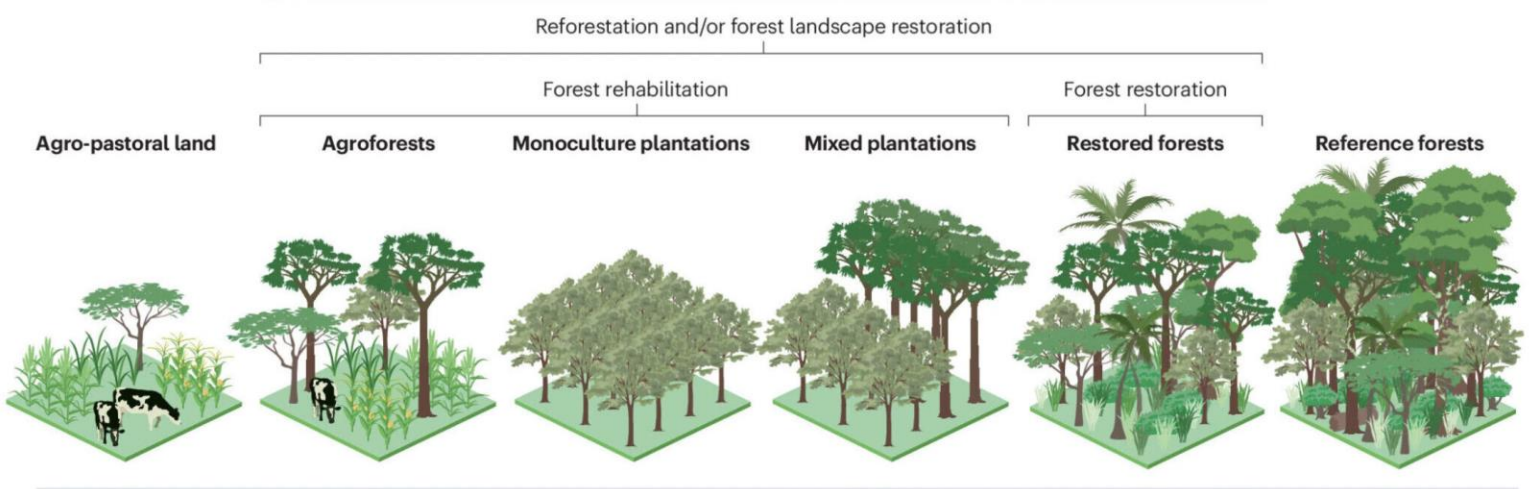
Various actions

Term	Definition (source)
Afforestation	"Establishment of forest through planting and/or deliberate seeding on land that, until then, was not classified as forest" (FAO, 2012).
Reforestation	"Re-establishment of forest through planting and/or deliberate seeding on land classified as forest" (FAO, 2012).
Ecological restoration	"the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (Clewell et al., 2004).
Natural regeneration	"a gradual process of recovery of the structure, function, and composition of the pre-disturbance ecosystem" (Chazdon and Guariguata, 2016).
Plantation forest	"Planted forests that have been established and are (intensively) managed for commercial production of wood and non-wood forest products, or to provide a specific environmental service (e.g. erosion control, landslide stabilisation, windbreaks, etc.)" (Carle and Holmgren, 2003).
Rehabilitation	"emphasizes the reparation of ecosystem processes, productivity and services" (Clewell et al., 2004).
Forest landscape restoration	"a planned process that aims to regain ecological integrity and enhance human wellbeing in deforested or degraded landscapes" (WWF and IUCN, 2000).

Adapted from: Mansourian, 2018

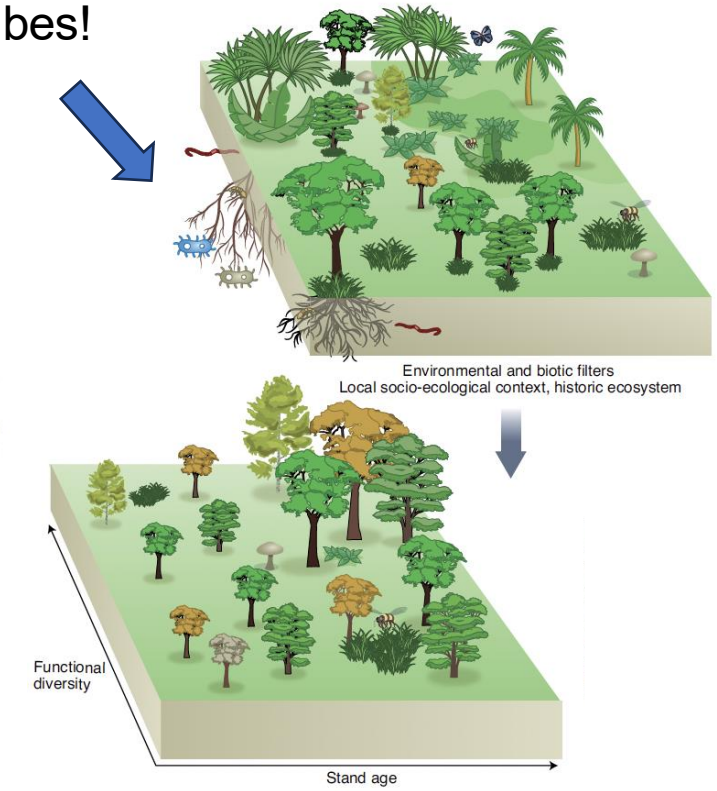
Forests

Restoration



	Agro-pastoral land	Agroforests	Monoculture plantations	Mixed plantations	Restored forests	Reference forests
Biodiversity	Low	Low	Low	Moderate	High	High
Water quality	Low	Moderate	Moderate	Moderate	High	High
Carbon	Low	Moderate	High	High	High	High
Timber	Low	Moderate	High	High	Low	Moderate
Food	High	High	Low	Low	Low	Moderate

Microbes!



- Back to a reference forest
- Environmental and biotic filters – including the soil microbiome
- Historical and socio-economic context

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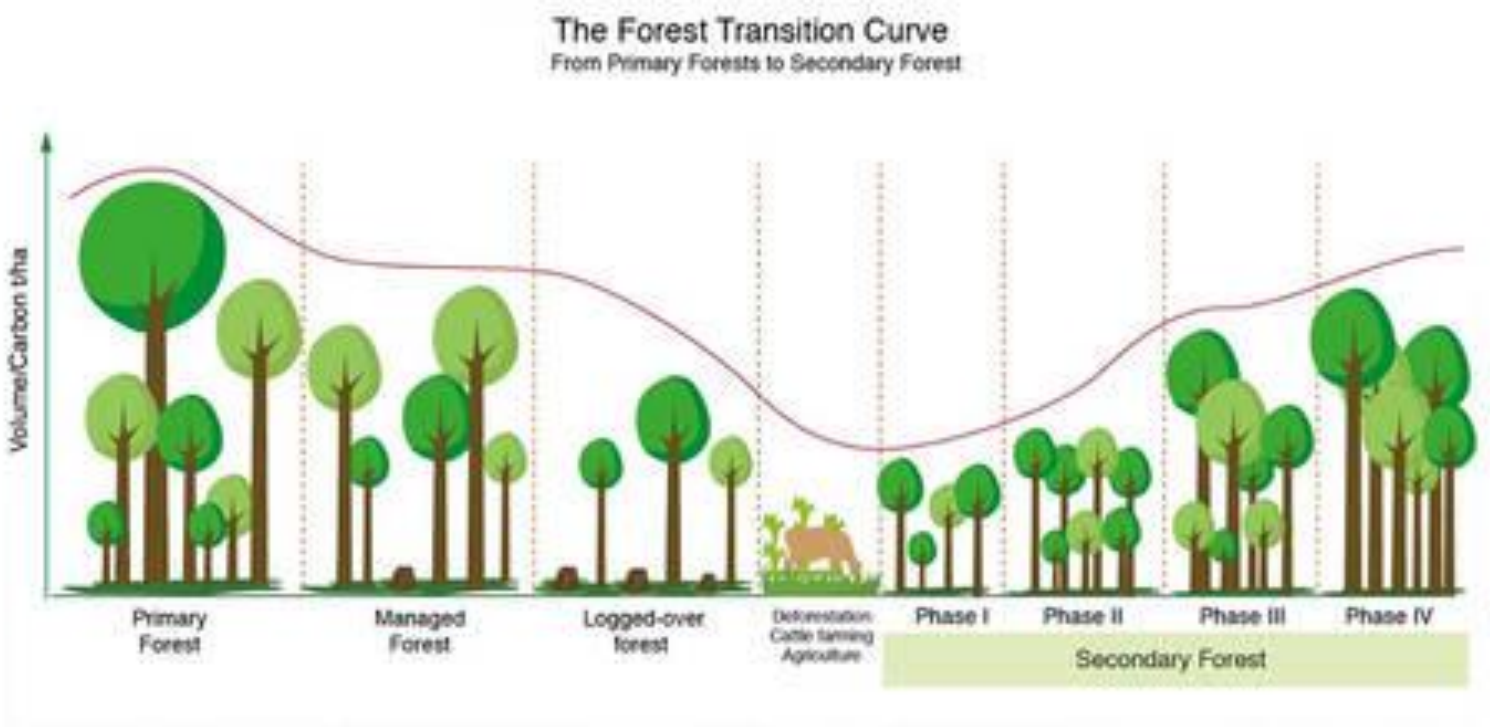
Forests

Restoration

- Land that is ecologically suitable for forest often transitions from primary forest to an unproductive forest state or a non-forest state due to exploitative management.
- Forest restoration can accelerate a transition back to a productive forest state

Succession ecology!



Forests

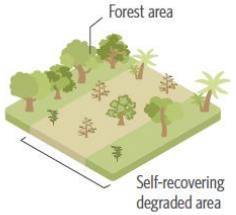
Restoration

- Forest restoration often has a social and socioeconomic context
- What are the needs of local communities?

ECOLOGICAL RESTORATION

Environmental restoration with the purpose of recovering degraded ecosystems, restoring the environmental balance of the area. For this, it is necessary to assess the ecological characteristics of the original vegetation to try to replicate it.

Ecological restoration techniques:



I. Spontaneous Natural Regeneration (RNE)
Natural regeneration process of trees and forests, with little or no human intervention. It has greater potential in degraded areas near forests and lower costs.

II. Assisted Natural Regeneration (ANR)
Combination of active planting with natural regeneration; there is intervention to assist trees and native vegetation in natural regeneration, eliminating barriers and threats to development.

III. Active Restoration
Recovery of degraded areas through the direct planting of seedlings of native species.

NATIVE VEGETATION SILVICULTURE

Planting native tree species for economic purposes, for the harvest and commercialization of wood and/or non-timber forest products. The type of management applied and the commercialization of non-timber forest products contribute to short-term revenue generation.

Silviculture techniques:

I. Diverse Economic Planting (Native)
Planting of different native species, arranged according to a spatial design, defined based on the ecological conditions of each species. The planting is usually done in an intercalated manner.

II. Economic Monoculture Planting (Native)
Cultivation of a single species, usually planted in rows. It can occur with native or exotic species, such as eucalyptus and pine, but for restoration purposes, only the planting of native species is considered.

Mixed Planting (Native and Exotic)
Planting with native and exotic species. Allows for short-term revenue from exotic species and long-term revenue from native species.

FOREST AND LANDSCAPE RESTORATION (FLR)

Long-term process that aims to restore the ecological functionality of forests and promote the well-being of communities at the landscape level. It may involve different restoration methods, including natural regeneration, silviculture of native and exotic species, and productive arrangements such as AFS and pasture recovery.

Restoration Models FLR:

I. ECOLOGICAL RESTORATION

II. NATIVE VEGETATION SILVICULTURE

III. Agroforesty Systems (AFS)
Planting managed trees together with agricultural or forage crops, promoting both environmental improvement and the production of food and forest products in the same area.

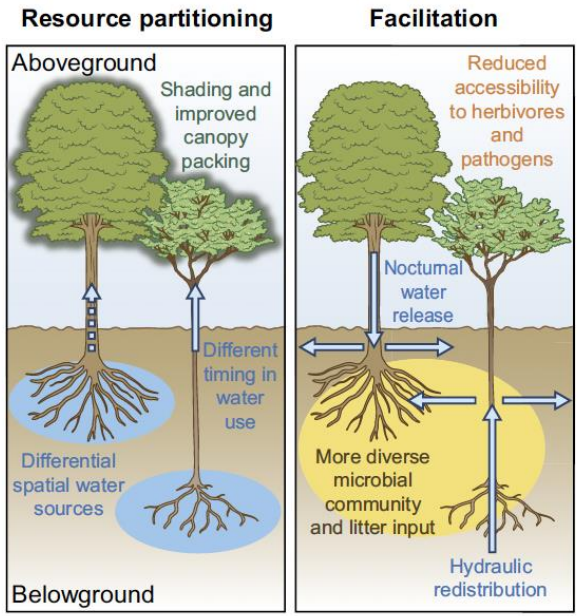
IV. Crop-Cattle-Forest Integration (CCFI)
Also known as Silvopastoral System, it is a form of sustainable production that integrates cattle, agricultural, and forestry activities, seeking synergy between strategies and combining increased efficiency with the conservation of natural resources. Integration can occur in the same area simultaneously or successively, and it involves different combinations of forest, agriculture, and cattle.

Source: *CPI/PUC-Rio adapted from WRI (ndb), 2024*

Forests

Restoration against drought effects

- Naturally adapted drought-resistant trees could form the backbone of future resilient forests
- Requires in-depth knowledge of plant ecology and physiology



New Phytologist

Tansley insight

Having the right neighbors: how tree species diversity modulates drought impacts on forests

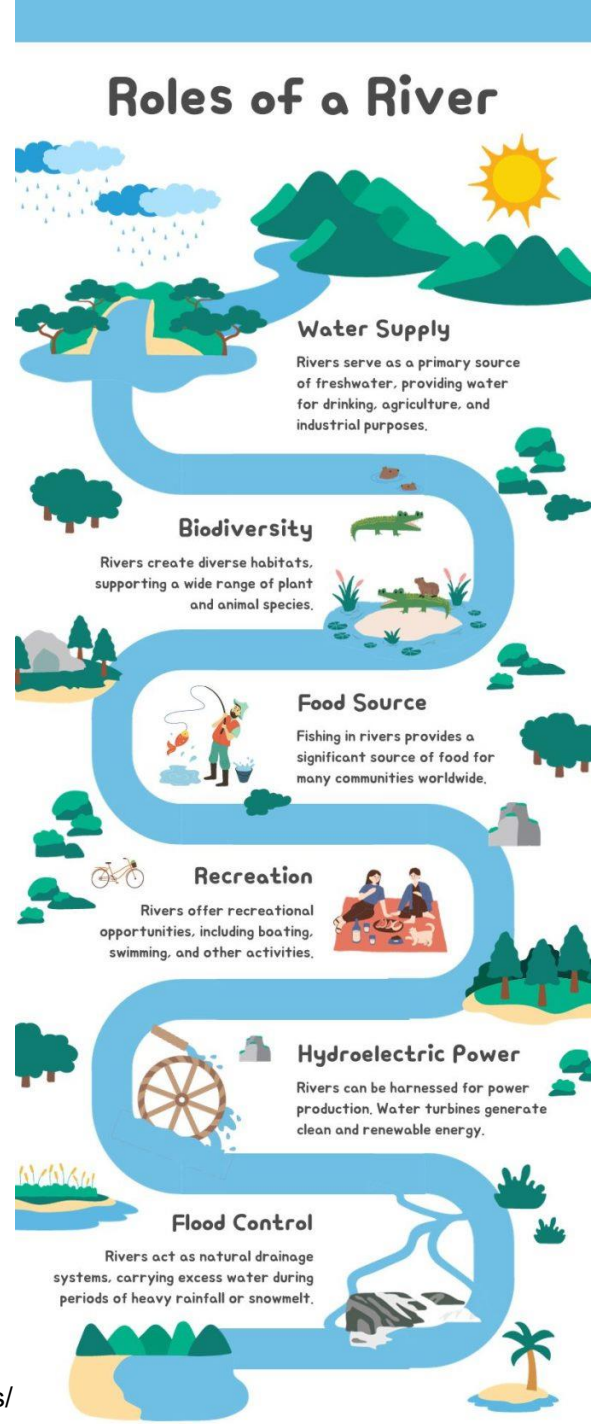
Charlotte Grossiord

EPFL

Rivers

Rivers

Ecosystem services



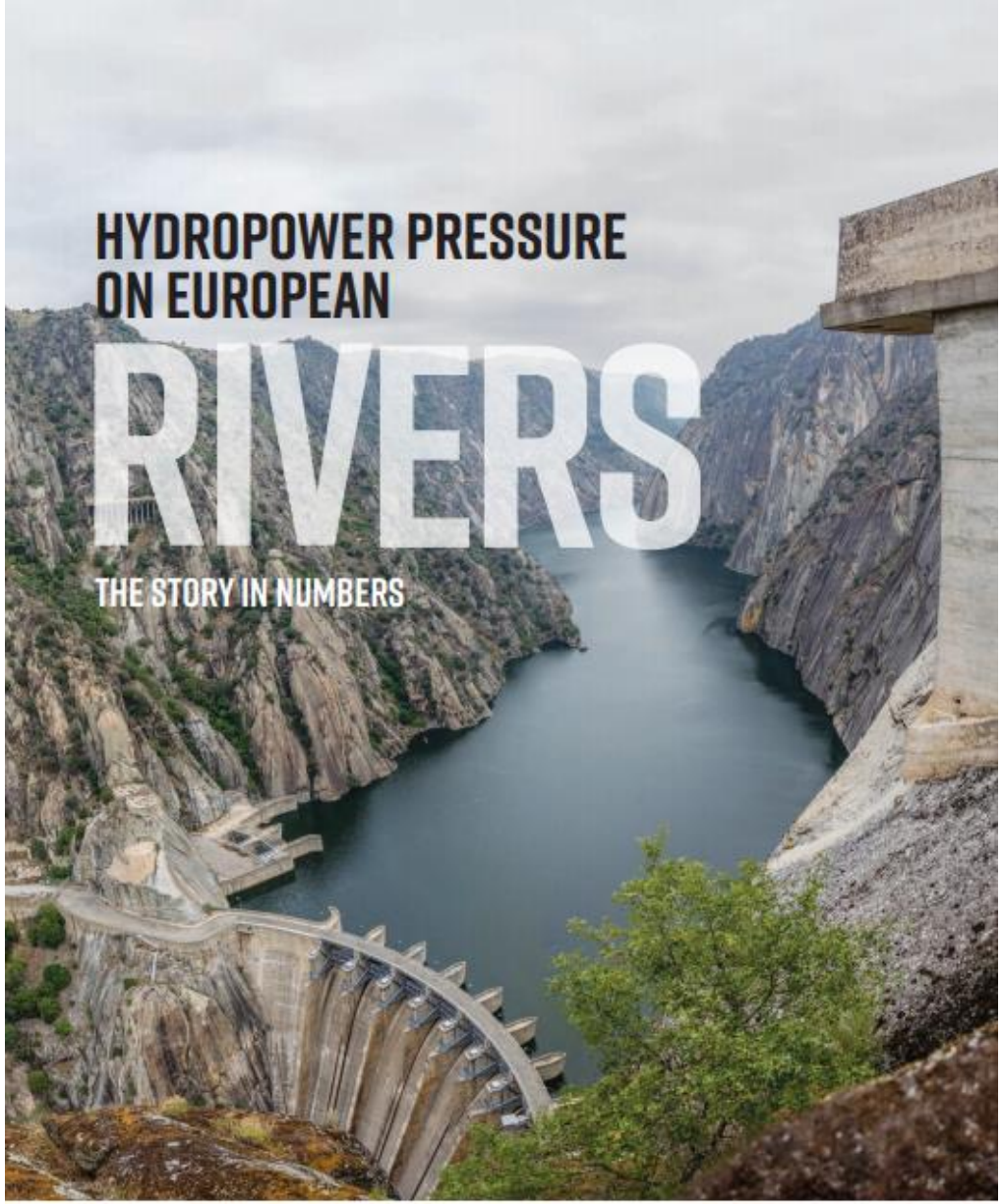
https://earthhow.com/river-roles/

Rivers

Threats

Damming, inter-basin diversion and hydropower

- Fragmentation of flow
- Biodiversity
- Retention of sediments, nutrients and organic matter
- Greenhouse gas emssions



WWF geota RiverWatch euronatur

EPFL

Rivers

Threats

Damming, inter-basin diversion and hydropower

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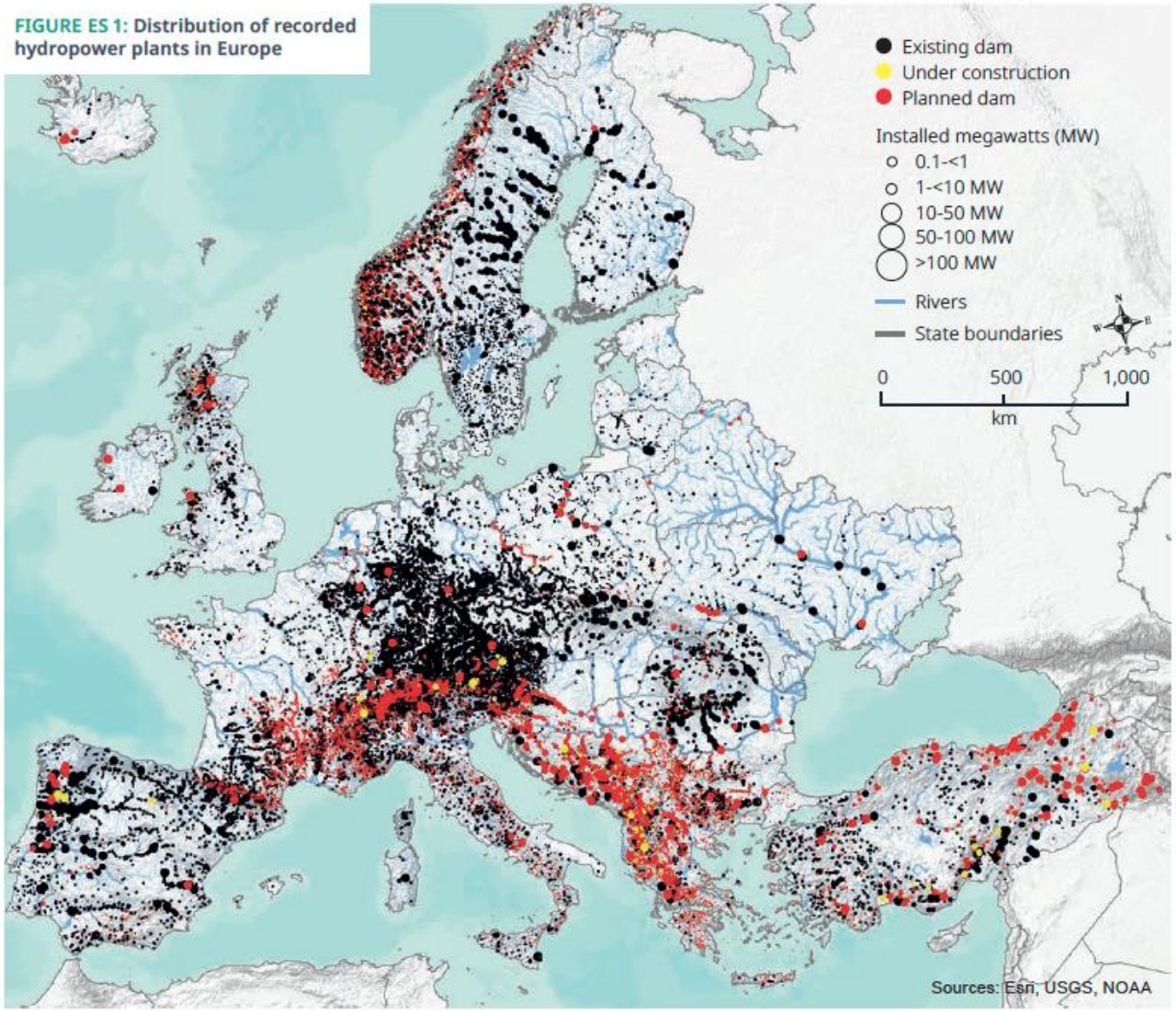
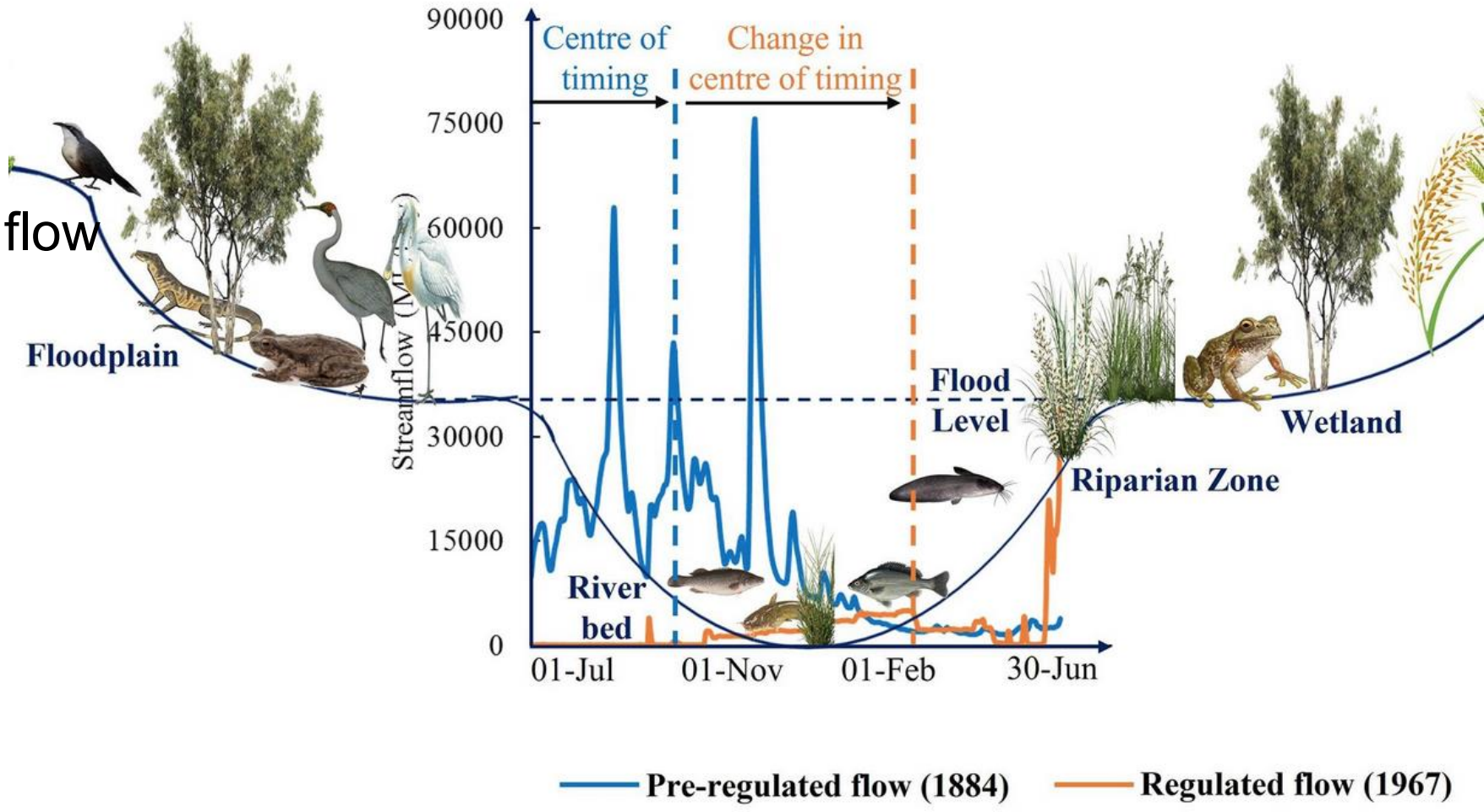


Rivers

Threats

- Flow regulation
- Hydropeaking
- Minimal environmental flow



ELSEVIER

Ecological Indicators
Volume 153, September 2023, 110444

Change in centre of timing of streamflow and its implications for environmental water allocation and river ecosystem management

Rupesh Patil [a b], Yongping Wei [a], James Shulmeister [a c]

EPFL

Rivers

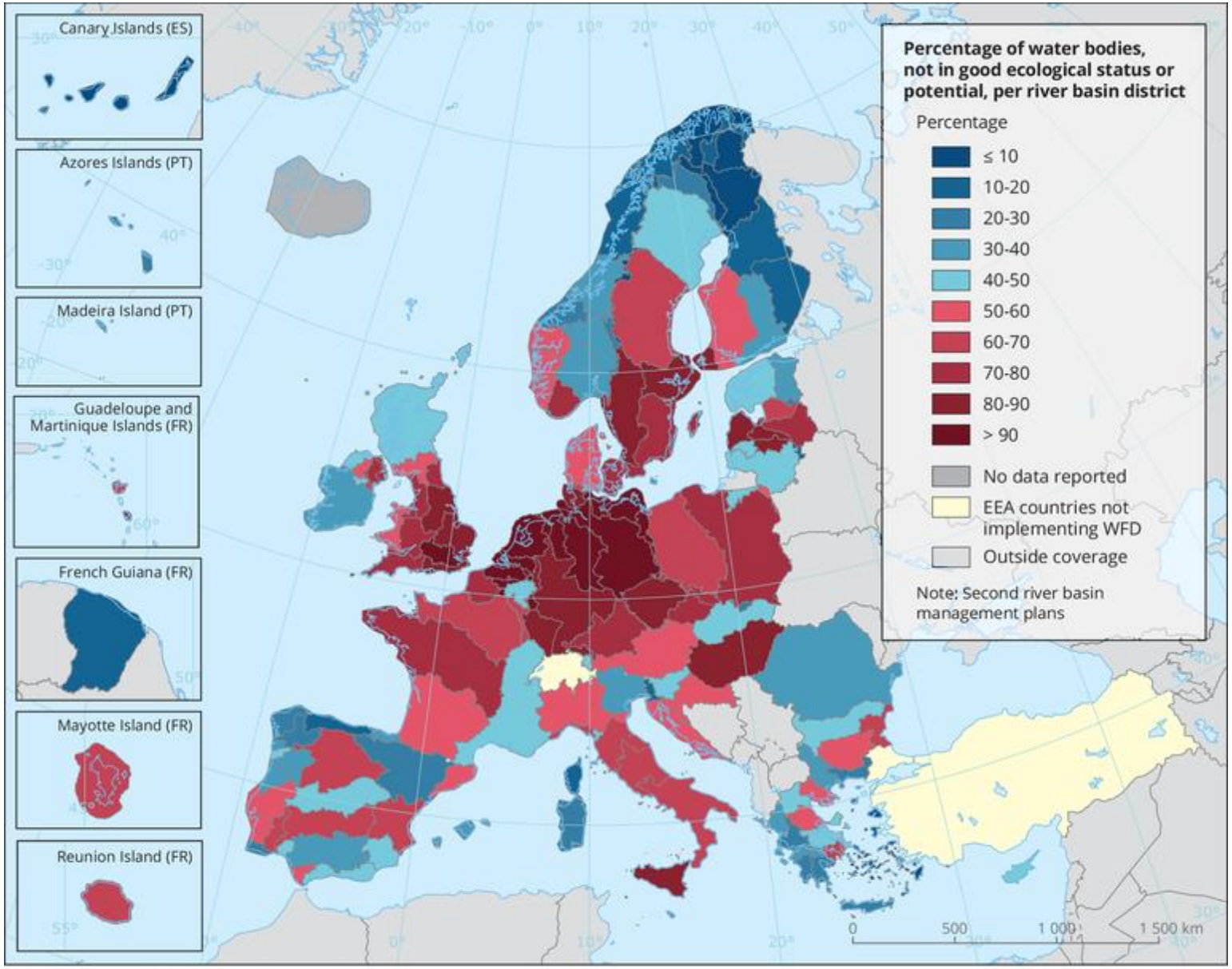
Threats

Pollution

- Nutrients and eutrophication
- Plastics
- Pharmaceuticals
- Etc…

Rivers

Bad ecologcial status of European streams and rivers

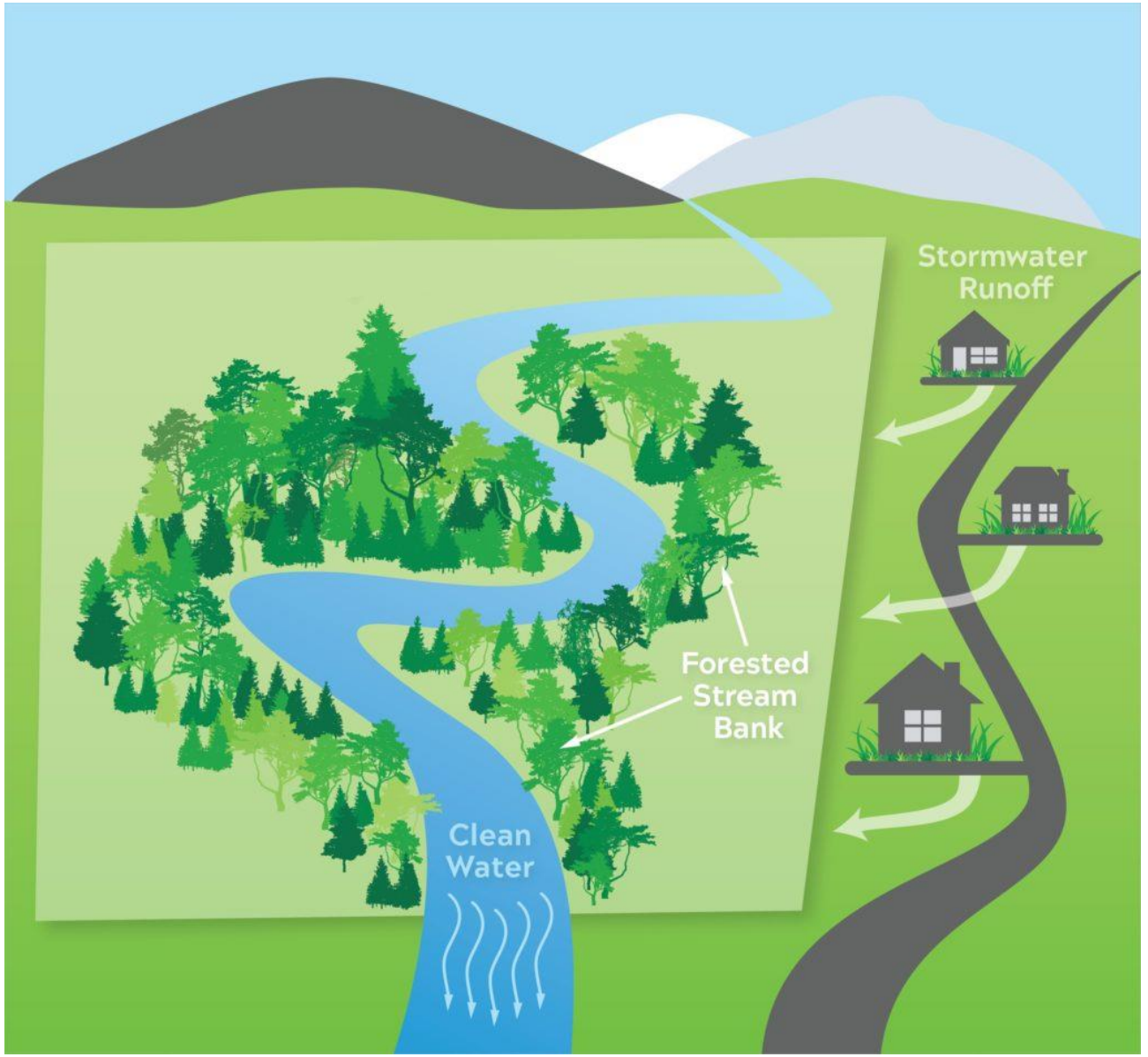


Rivers

Restoration

Fight eutrophication

- Less fertilizer application
- Riparian buffer
- Increase oxygenation



Rivers

Restoration

- Fight flow regulation
- Increase hydrological connectivity and environmental heterogeneity

Muhar, S., Sendzimir, J., Jungwirth, M., Hohensinner, S. (2018). Restoration in Integrated River Basin Management. In: Schmutz, S., Sendzimir, J. (eds) Riverine Ecosystem Management. Aquatic Ecology Series, vol 8. Springer, Cham. https://doi.org/10.1007/978-3-319-73250-3_15

Rivers

Restoration

- Fish passages
- Connectivity and biodiversity

Rivers

Restoration

Towards process based approaches

- Restore flow regimes and hydrological connectivity
- Reinstall ecosystem integrity, including ecosystem structure, processes and biota

REVIEW

HYDROLOGY

Linkages between flow regime, biota, and ecosystem processes: Implications for river restoration

Margaret Palmer[1]*† and Albert Ruhi[2]*

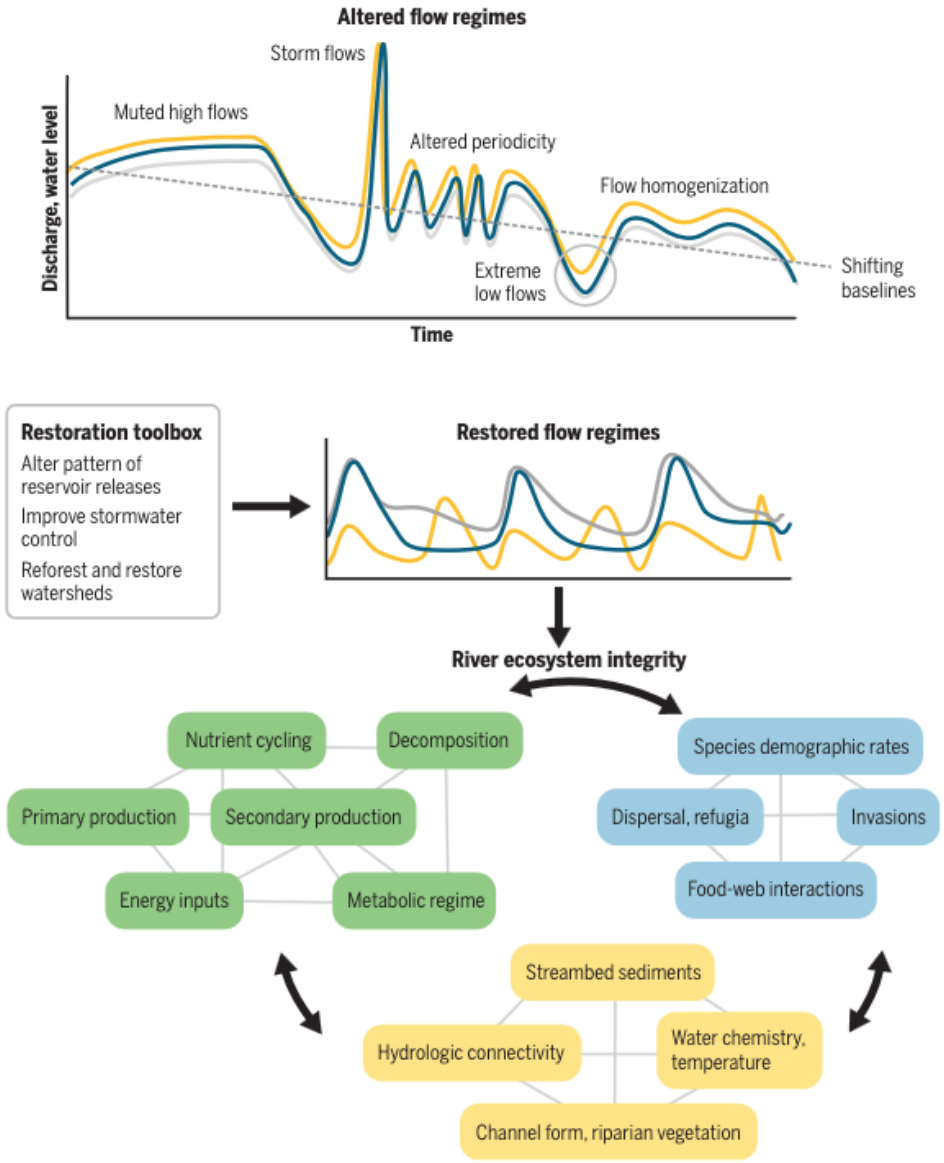


Fig. 2. Process-based restoration posits that actions must target processes, not patterns, that have been degraded. River ecosystems are sustained by a host of environmental conditions, or ecosystem structure (gold rectangles), which in turn influence ecosystem processes (green rectangles) and biotic processes (blue rectangles). These processes, as well as ecosystem structure, are all controlled by the flow regime. Thus, correcting facets of flow regime alteration may enhance river ecosystem integrity in both direct and indirect ways.

EPFL

Why you need basic knowledeg in ecology to restore a reef, a forest or a river

Ecological restoration and ecology

Disturbance

Disturbance events can occur at many scales and different levels of severity, and some are natural parts of every ecosystem. Disturbance events can alter species composition, nutrient cycling, and soil properties. Natural disturbances include severe weather damage, fire, flooding, treefalls and even volcanic eruptions. Anthropogenic (human-caused) disturbances can alter or destroy natural habitat (like clearing land for agriculture) and/or ecological functions (like damming rivers for flood control).

Genetics

Restoration projects also typically include genetic considerations. Plants (or animals) from local sources are more likely to be well adapted to the target ecosystem. Therefore, using animals or plant materials (like seeds or cuttings) collected from local sources may increase the chance of successful establishment.

Succession

Ecological succession is the process by which biological community composition- the number and proportion of different species in an ecosystem- recover over time following a disturbance event. Passive restoration means simply allowing natural succession to occur in an ecosystem after removing a source of disturbance.

Why you need basic knowledeg in ecology to restore a reef, a forest or a river

Community assembly theory

Community assembly theory suggests that similar sites can develop different biological communities depending on order of arrival of different species. In the context of restoration, sites may not always recover toward a desired or anticipated group of species or ecosystem functions.

Landscape ecology

Restoration draws on several concepts from landscape ecology. Restored areas are often relatively small and isolated, which makes them especially sensitive to problems associated with habitat fragmentation. Habitat fragmentation occurs when continuous areas of habitat become disconnected by natural or human causes. Fragmentation generally leads to small, isolated patches of hospitable habitat.

Ecological restoration and ecology

In-depth undertanding of ecology required

- From species conservation to process-based restoration and management
- Integrative approaches — environment, processes and biota
- Interdisciplinary in nature, including socioeconomic aspects