

GLINES CANYON DAM ON THE ELWHA RIVER · WASHINGTON

Would you remove this dam?

YOUR LECTURER

Flavia Tromboni



Aquatic ecology and biogeochemistry

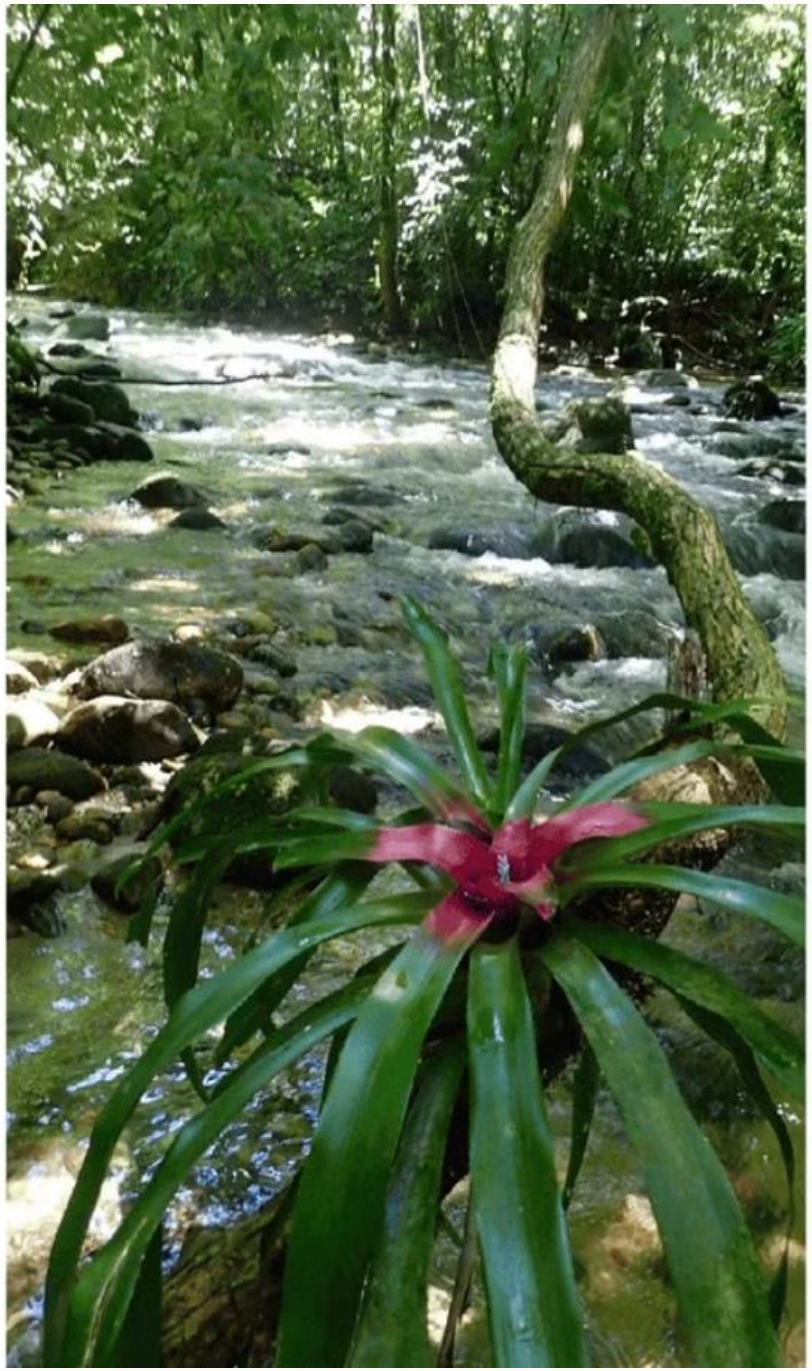
How environmental change alters communities and ecosystem processes

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The Contribution of Freshwater Ecosystems to the Global Carbon Cycle in a Changing World











Who is in the room?

1. Your name and background
2. A place you care about
3. A question you bring

Which biome interests you most?

1	FRESHWATER	Rivers, lakes and springs
2	FOREST OR MOUNTAIN	Terrestrial and high-elevation systems
3	URBAN	Built landscapes and everyday nature
4	WETLAND	Marshes, estuaries and transitional waters
5	MARINE AND COASTAL	Coasts, reefs and open water

What do you want to remain?

Think of the place you just named.

What would its loss actually mean?



What is conservation science?

What are we conserving, for whom, and in what future?

Distinguish objective, causes of damage and recognize that different values can bring to different decisions

Evaluate what an action could change

Defend a recommendation under both evidence and uncertainty

The problems we will investigate

30 Sep	Biodiversity and functioning	Do richness, carbon and human benefits agree?
05 Oct	Reference conditions	Which past should guide a future target?
07 Oct	Pressures and evidence	How do multiple stressors interact?
12 Oct	People and values	Whose priorities enter the decision?
14 Oct	Populations and climate	What allows persistence and adaptation?

The decisions we will test

21 Oct	Habitats and connectivity	When does connection help?
26 Oct	Protection and actions	What makes an intervention effective?
28 Oct	Invasions	When does community change cause harm?
02 Nov	Monitoring and adaptation	What evidence should change the plan?
04 Nov	Project presentations	Can someone else examine your reasoning?

Dates to keep in mind

30 September

First article discussion

Hua et al. (2022)

19 October

Field visit

Meeting and travel details on Moodle

4 November

Group presentations

Eight minutes, followed by questions

A guide to reading papers

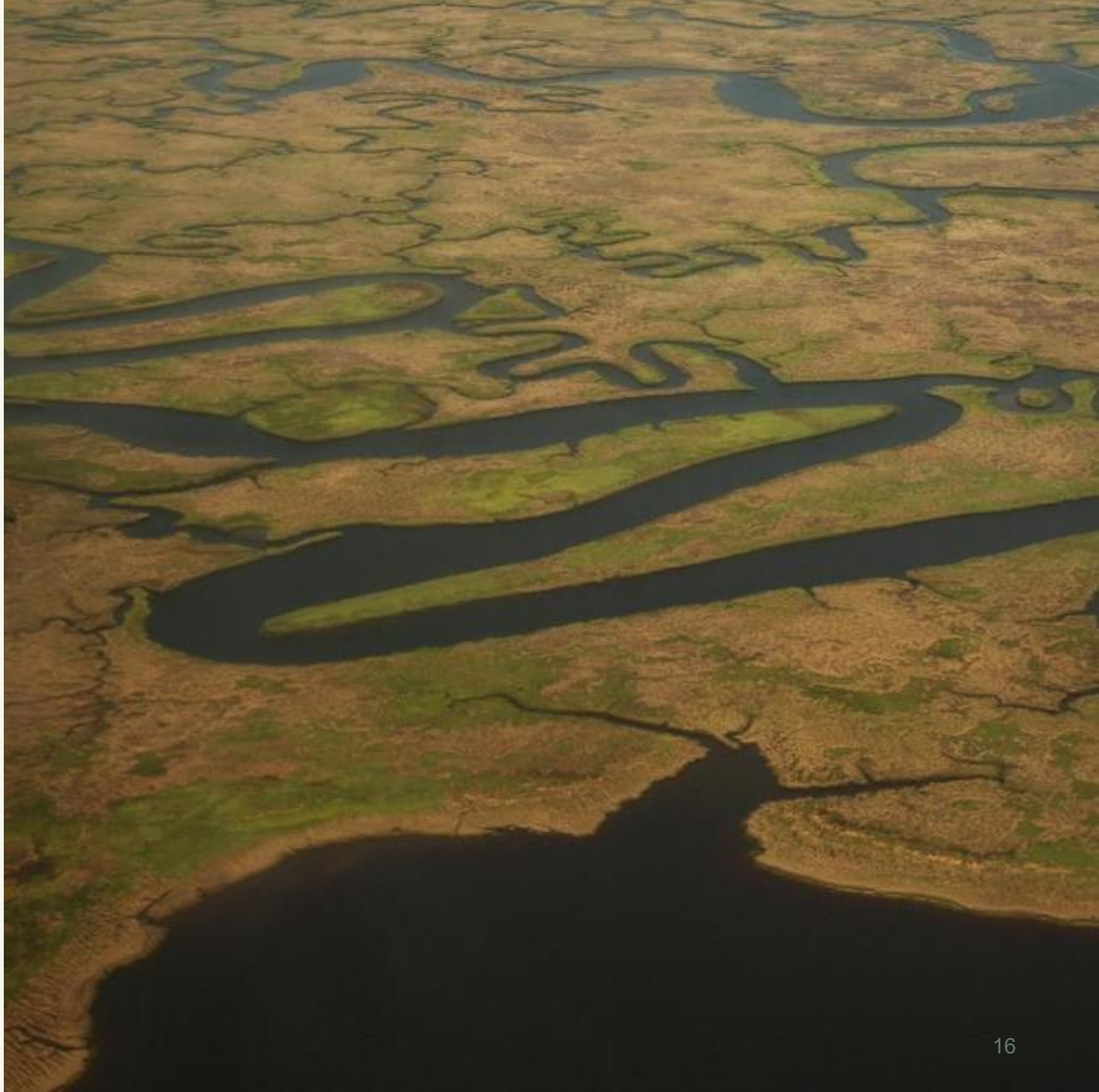
CLAIM	State the paper’s main argument in one sentence.
EVIDENCE	Identify the strongest support offered by the authors.
LIMITATION	Test one assumption, omission or transfer problem.
IMPLICATION	Name one conservation decision that could change.

GROUP PROJECT

One real conservation case

Conservation Management Plan

A recommendation a managing body could use



A target you can assess

Action	Restore a blocked connection
Desired outcome	A native population can reproduce and persist
Evidence to collect	Movement, recruitment and habitat conditions

Monitoring connects the action to the intended outcome

Authority and responsibility for the plan

A plan needs someone who can act.

Name the managing body

Identify the decisions within its authority

Explain who else must be involved

Ten years: expectation and ambition

The ecological outcome you aim to achieve

The outcome supported by the evidence



What your group will submit

Written plan

Case and pressures
Evidence and proposed strategy
Feasibility and ten-year outcomes
Monitoring, references and contributions

Eight-minute presentation

Explain and defend the plan
Then respond to questions

Possible cases: freshwater, forests and cities

1	FRESHWATER **Connectivity and ecological flows**	Fragmentation, barriers, flow alteration and climate change
2	FOREST OR MOUNTAIN **Climate vulnerability**	Refugia, range shifts, adaptive capacity and future targets
3	URBAN **Biodiversity and environmental equity**	Green and blue networks, disturbance, access and unequal benefits

Possible cases: wetlands and coasts



4 WETLANDS AND TRANSITIONAL WATERS

Functions under cumulative pressures

Hydrological alteration, nutrient inputs, salinisation, land use and sea-level rise



5 MARINE AND COASTAL

Ecological change and human uses

Warming, fishing, tourism, non-indigenous species and changing communities

A COMMON ANALYTICAL STRUCTURE

Questions for your investigation

01 Decision problem

02 Target and values

03 Causal diagnosis

04 Stakeholders

05 Future vulnerability

06 Management alternatives

07 Recommendation

08 Monitoring and revision

Every claim must separate evidence, assumptions and values.

Laguna Viva as a shared field laboratory



The visit provides:

- A real social-ecological system
- Visible pressures and management choices
- Contact with local knowledge and practice
- A test of what transfers across ecosystems

Field observation protocol

TARGET	What is being conserved?
SPACE	Which exchanges, barriers and boundaries matter?
PRESSURES	Which pressures are local and which arrive from outside?
PEOPLE	Who uses, manages and benefits from the system?
FUTURE	Which objectives may become unrealistic under climate change?

AFTER THE VISIT

Transferability and limits

Observation in the lagoon	What did we see?
General conservation principle	What does it teach?
Application to our case	What will we change?
Why transfer may fail	How is our biome different?

A first proposal

Our case is…

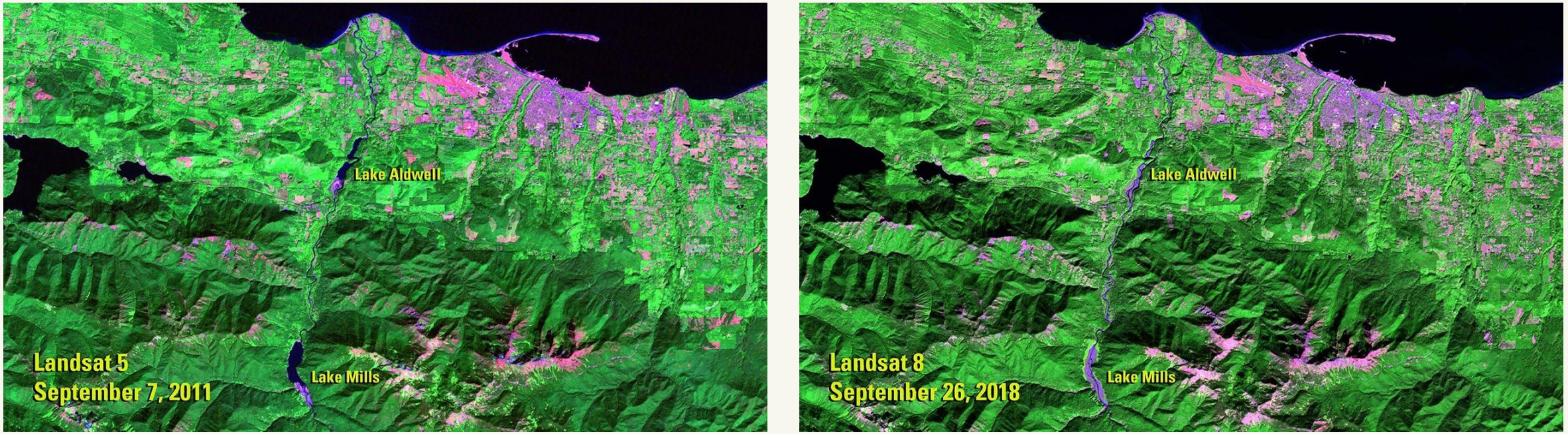
The ecological concern is…

The managing body is…

The evidence we need first is…

5 minutes in groups · brief proposals · feedback

The Elwha decision changed the landscape



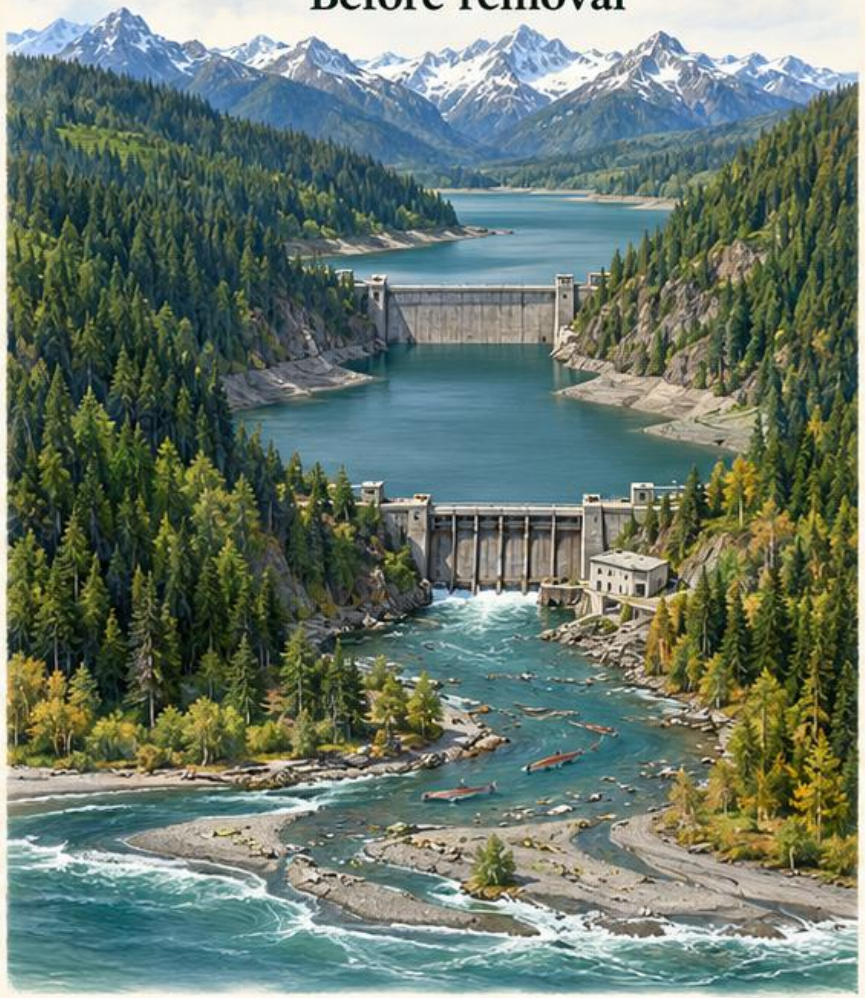
Dam removal initiates disturbance and recovery

NASA / USGS Landsat · Dam removal 2011–2014 · Morley et al. (2020)

Elwha River restoration

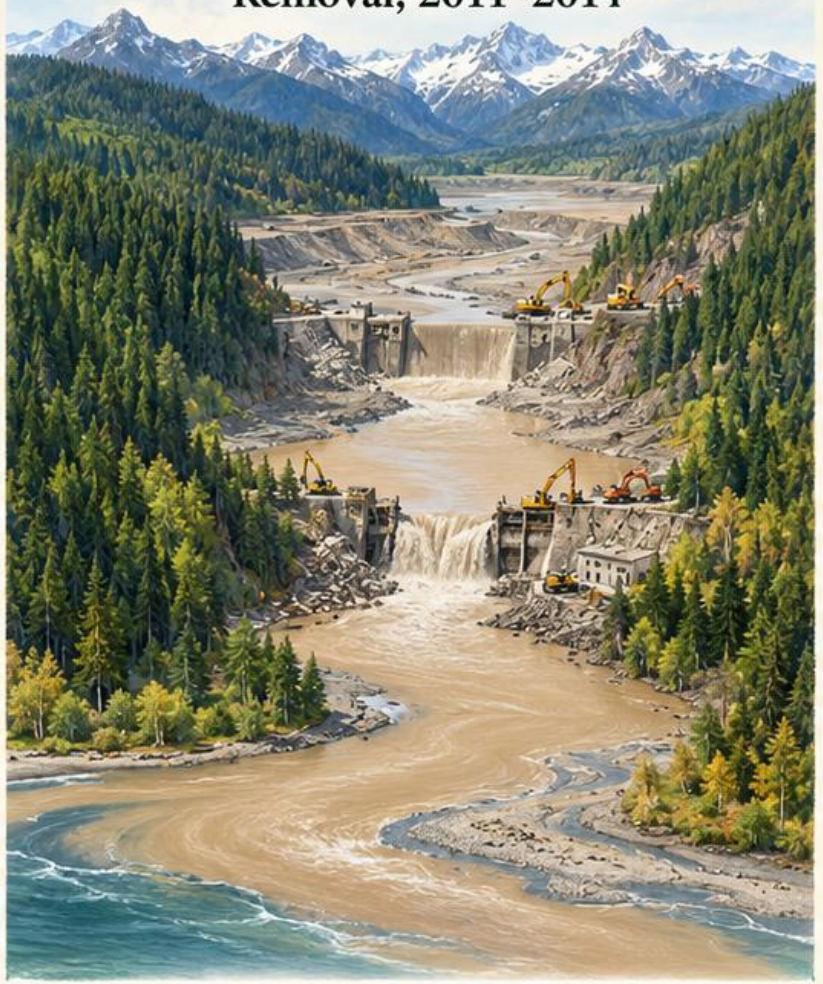
Two dams removed. A river reconnected.

Before removal



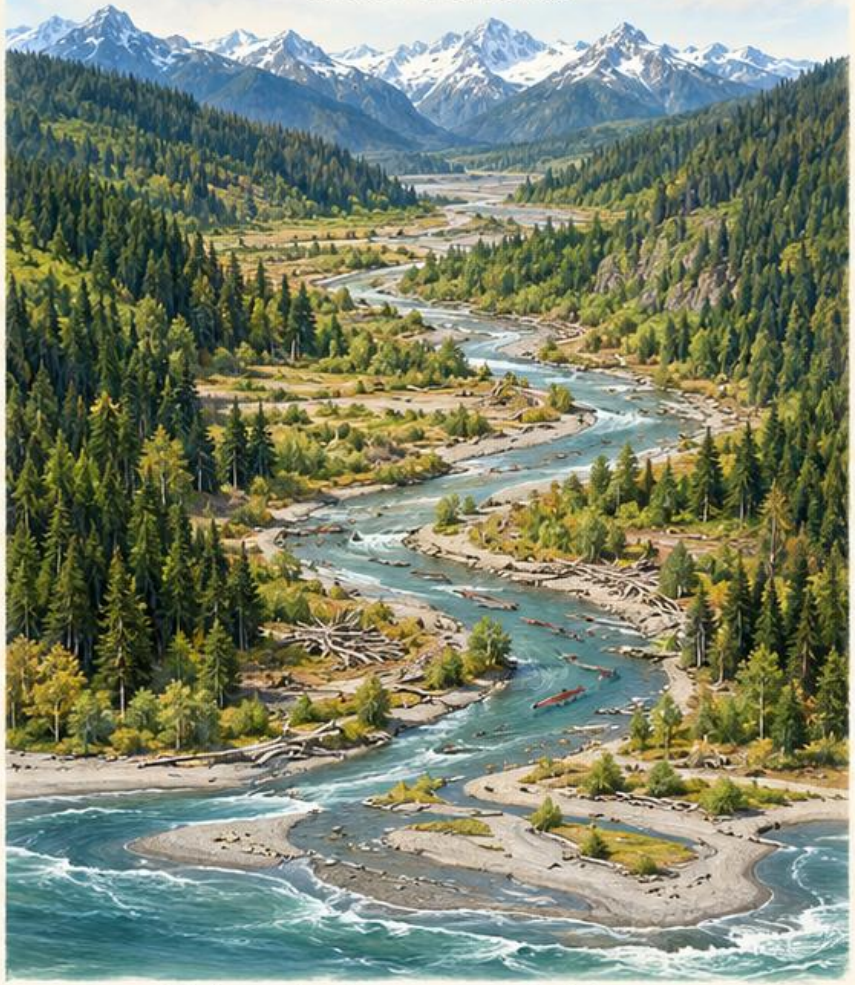
Fish passage blocked
Sediment trapped in reservoirs

Removal, 2011–2014



Stored sediment released
Temporary disturbance to habitats and food webs

After removal



Fish recolonise upstream habitats
Sediment transport resumes

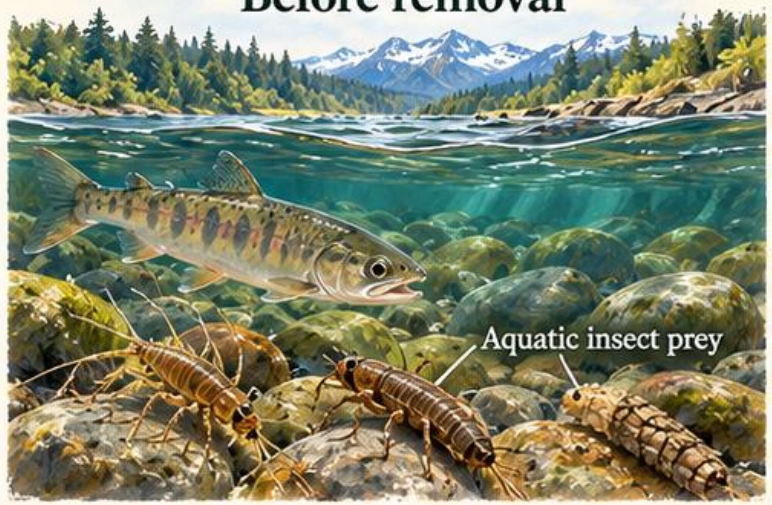
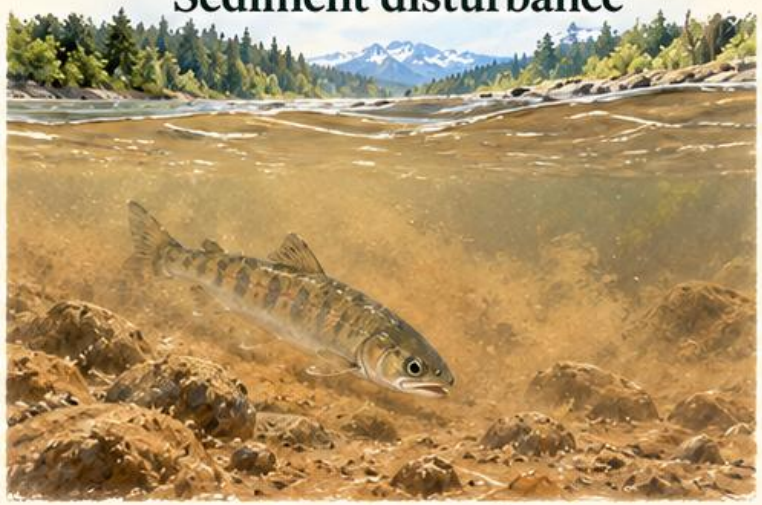
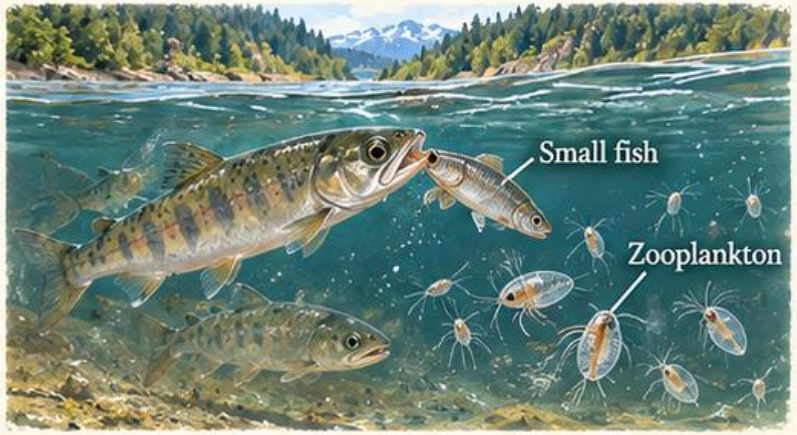
Reconnection enables recovery. Long-term monitoring shows how far it progresses.

A river of ecological and cultural importance to the Lower Elwha Klallam Tribe.

Conceptual illustration | Sources: National Park Service; Morley et al. (2020); Duda et al. (2021)

Elwha: how the food web changed

Observed responses before and during dam removal

	Before removal	Sediment disturbance	Changing diets
RIVER			
	Mayflies, stoneflies and caddisflies	Fewer aquatic invertebrates	More land insects, then sediment-tolerant prey
ESTUARY			
	Brackish-water invertebrate prey	Shift towards freshwater Loss of brackish-water prey	More fish and zooplankton in the diet

Diet shifts often maintained dietary energy, but river values fell in 2014.
By 2014, prey recovery was partial and differed among sites.

Conceptual illustration, organisms not to scale | Morley et al. (2020), PLOS ONE 15: e0239198

Recolonisation and population recovery differ



Observation: detections upstream of former dams

Supported: renewed access and recolonisation

Still to establish: sustained population recovery

Duda et al. (2021), Environmental DNA and Frontiers in Ecology and Evolution · Photograph: NPS

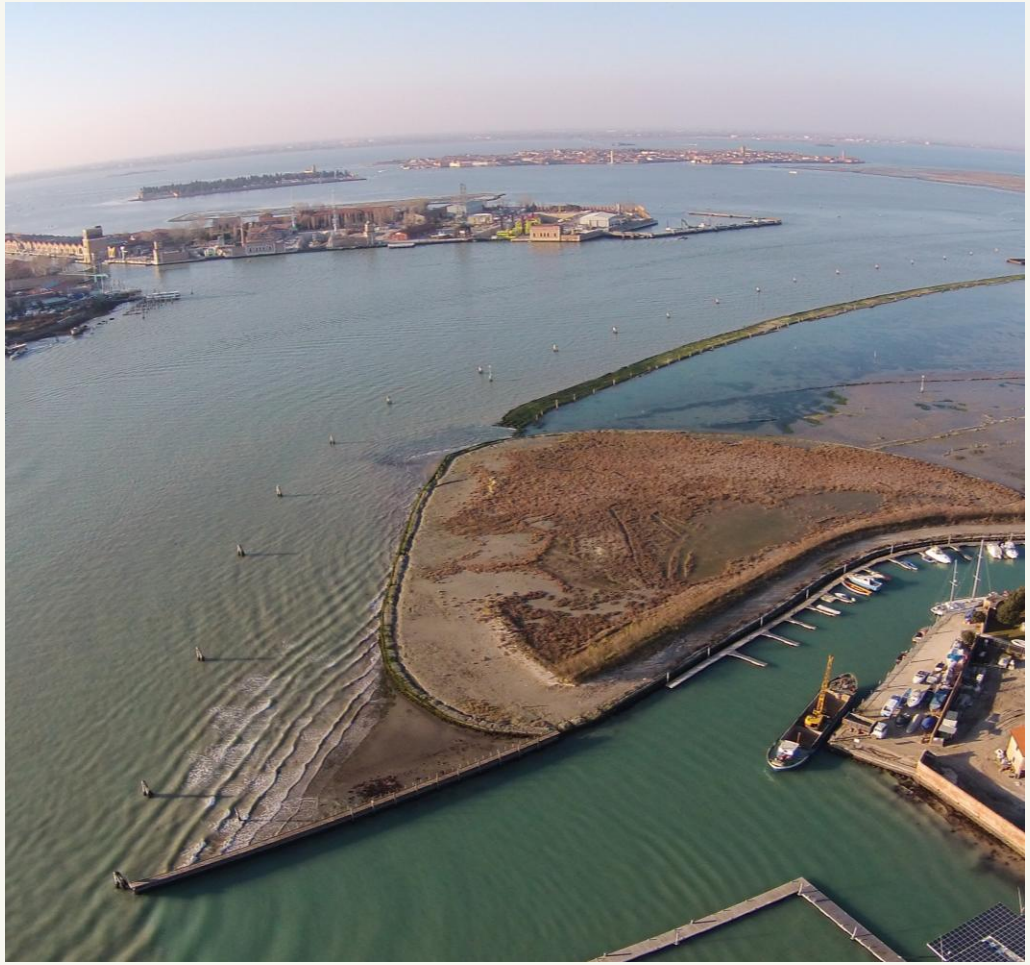
One landscape, many legitimate futures

A coastal wetland faces sea-level rise, tourism, aquaculture and habitat loss.

Possible conservation objectives

- A native species
- An ecological process
- A cultural landscape
- Benefits to people

The objective determines what we measure



Conservation science begins with a decision

A mission-driven field that uses evidence to sustain biodiversity, ecological processes and human relationships with nature under conditions of uncertainty.



It asks two different kinds of questions:

What is happening?

Evidence

What should we do?

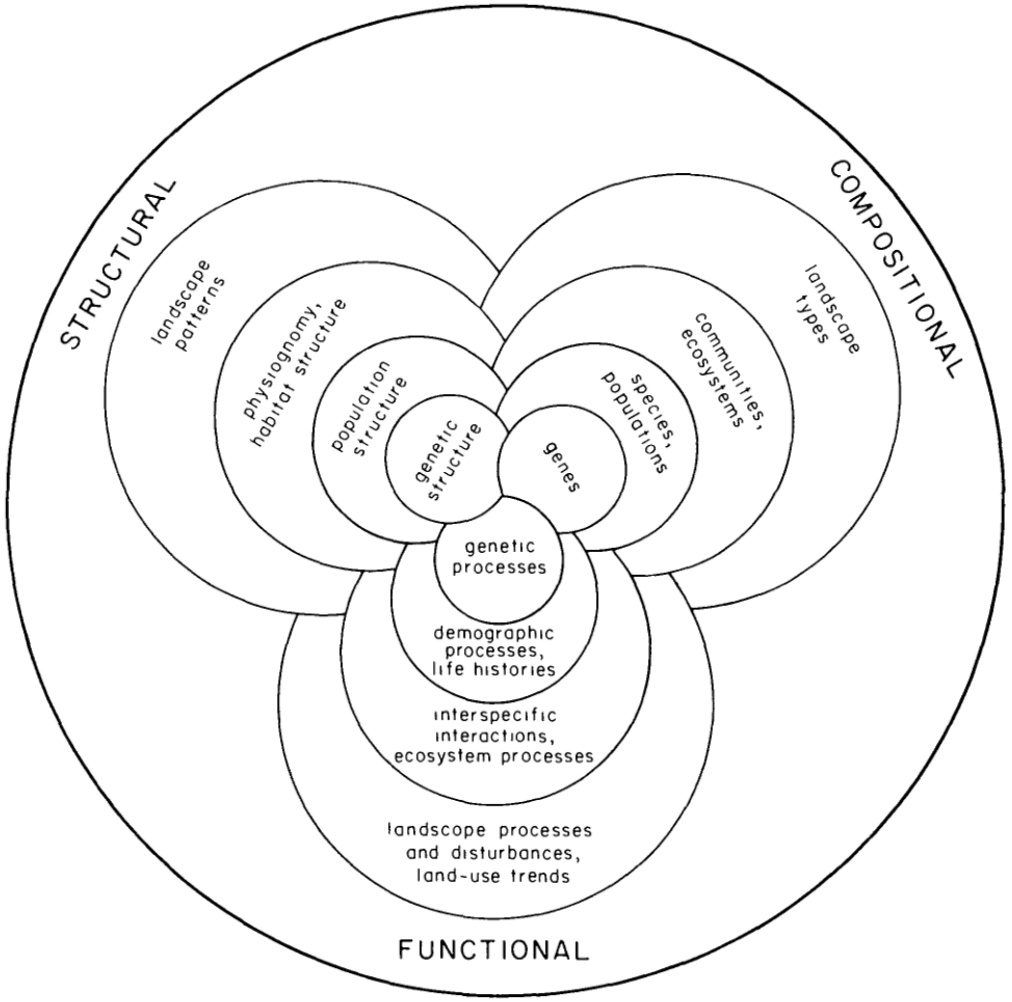
Decision under values and constraints

The field works across levels of biological organisation



Genes	Adaptive potential
Species	Persistence and extinction risk
Communities	Interactions and composition
Ecosystems	Functions and resilience
Landscapes	Connectivity and change

Biodiversity has composition, structure and function



Composition

Which genes, species and communities are present?

Structure

How are they organised within and across habitats?

Function

Which processes sustain the living system?

Noss (1990), Conservation Biology, Fig. 1. doi:10.1111/j.1523-1739.1990.tb00309.x

Mission-driven science makes its objective explicit

01

Knowledge

Describe patterns, causes and consequences

02

Judgement

Clarify goals, values and acceptable risk

03

Action

Compare feasible interventions and learn from outcomes

Good conservation keeps these tasks connected and visible.

Conservation science often acts before certainty

Urgency

Delay can make loss irreversible

Incomplete knowledge

Data rarely cover every species, place or future

Limited resources

Time, money and political attention constrain action

Consequences

Decisions affect both ecosystems and people

The goal is a defensible decision, not perfect prediction.

Conservation ideas changed as environmental problems changed

1800s

Preservation

Protect valued places

1930s

Resource management

Manage soils, forests and wildlife

1960s–80s

Pollution and extinction

Regulate harmful activities

1990s–today

Social-ecological systems

Work across nature, society and future change

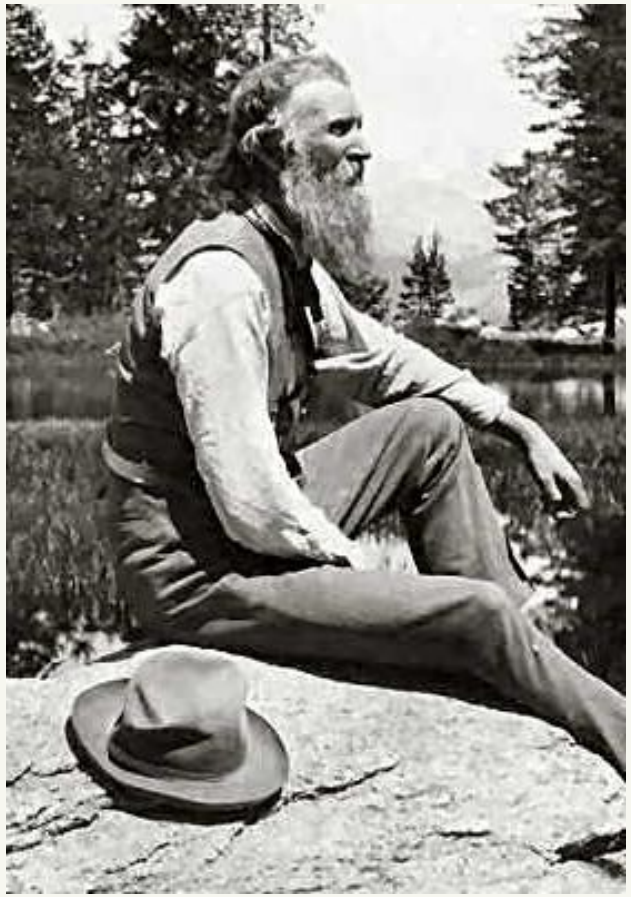
THREE RELATED TRADITIONS

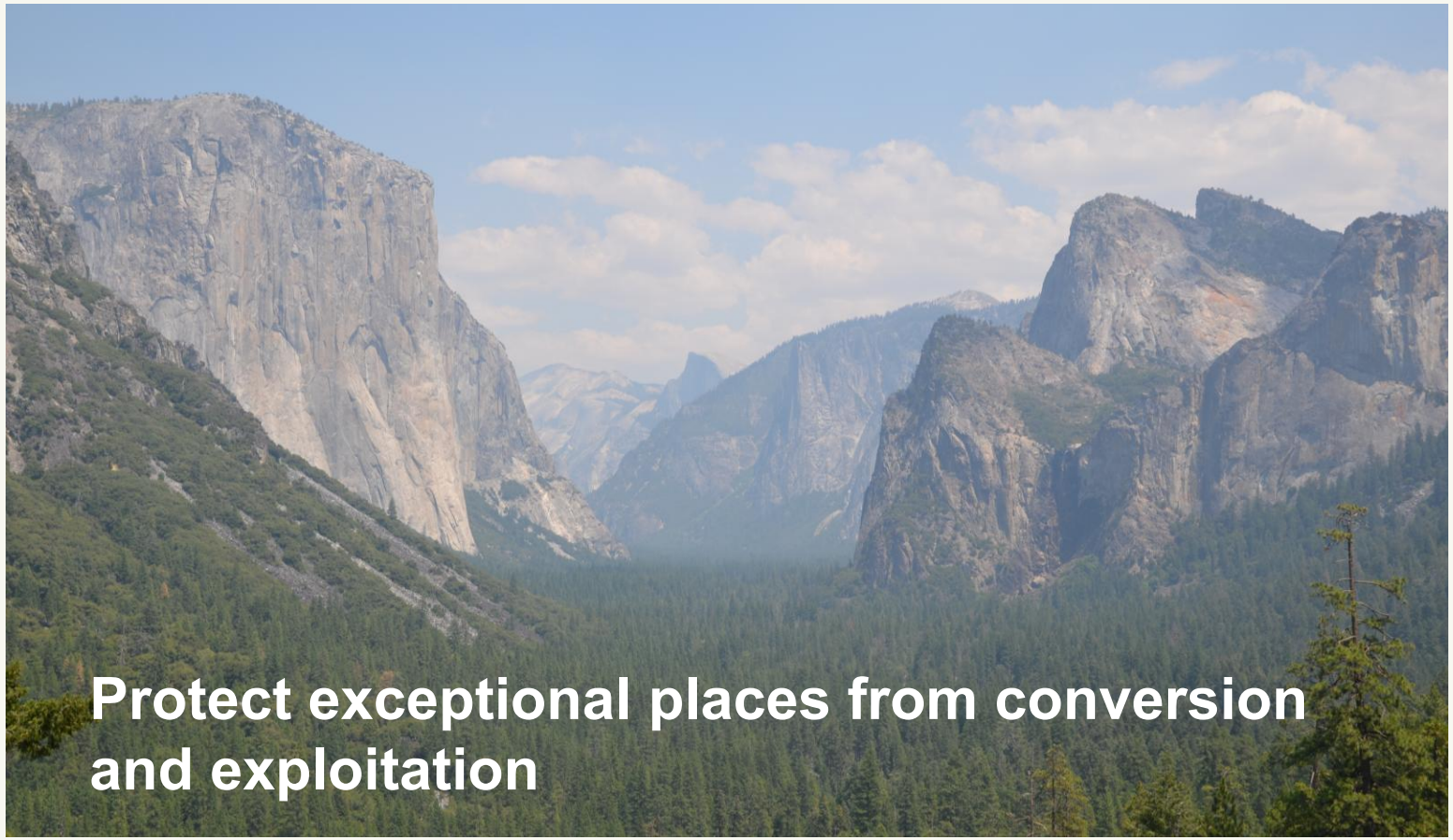
Preservation, conservation and sustainable use

PRESERVATION	Limit human use to protect valued places or entities
CONSERVATION	Maintain biodiversity, ecological processes and future options
SUSTAINABLE USE	Allow use within limits compatible with long-term persistence

A real policy can combine all three, but it should state which objective comes first.

Preservation made wild places politically visible







National Park Service · Raker Act, 19 December 1913

HETCH HETCHY · YOSEMITE

1913

Which public good comes first?

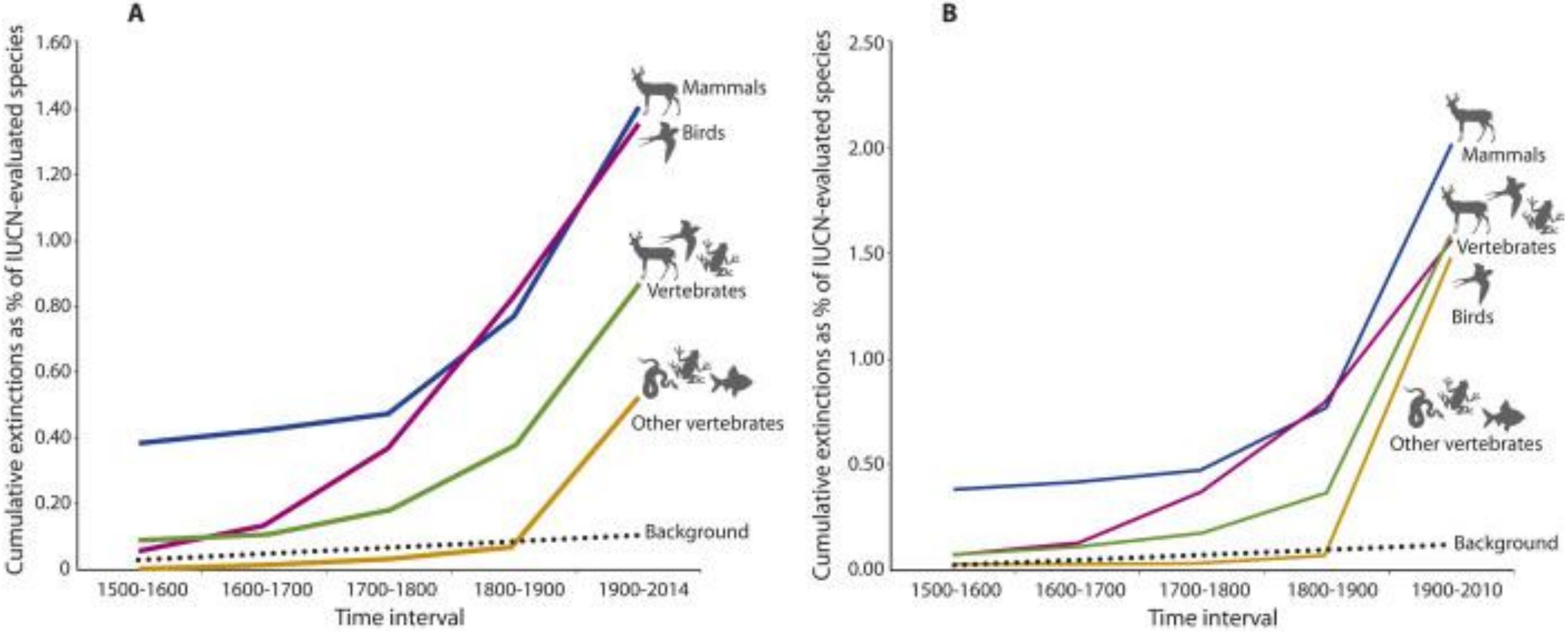
A protected landscape.
A reservoir for a city.

The biodiversity crisis expanded the object of concern

Extinction	Loss of unique evolutionary history
Population decline	Loss before extinction becomes visible
Functional change	Ecosystems can simplify while species remain
Homogenisation	Different places become increasingly similar



Modern extinction rates exceed the background rate



Historical evidence: vertebrates assessed by IUCN, with two sets of assumptions

Ceballos et al. (2015), Science Advances, Fig. 1. doi:10.1126/sciadv.1400253

1985: a science with an explicit mission

Conservation biology studies biodiversity loss and ways to prevent or reverse it.

A scientific claim needs evidence.
A conservation goal also expresses a value.

1935

Tansley: ecosystems

1949

Leopold: land ethic

1962

Carson: chemical impacts

Working synthesis of Soulé (1985) · Historical context: Meine, Soulé & Noss (2006)



15-minute break

Next: values, ecological change and conservation decisions

Must nature demonstrate its usefulness?

Kareiva & Marvier, 2012

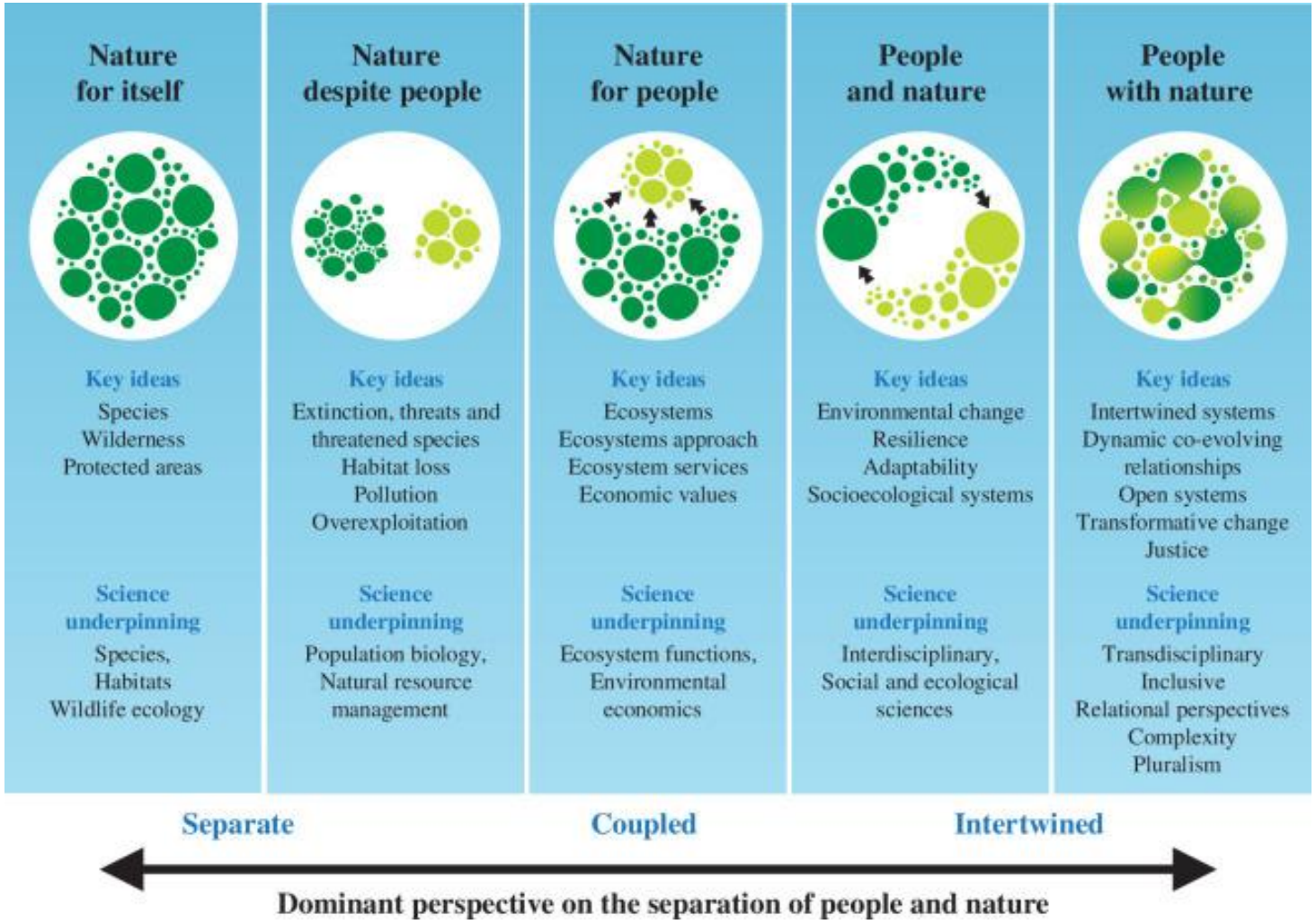
Conservation should address biodiversity and human well-being together.

Soulé, 2013

Protection should retain biodiversity as an end in itself.

An endemic species has no demonstrated human benefit. Protect it?

Conservation has broadened its purpose



These perspectives coexist

Reyers & Bennett (2025), Fig. 1, updating Mace (2014). doi:10.1098/rstb.2023.0320

The framing changes what we measure

Nature for itself	Persistence of species and habitats
Nature despite people	Reduction of damaging pressures
Nature for people	Benefits people receive from ecosystems
People and nature	Ecological outcomes and social relationships

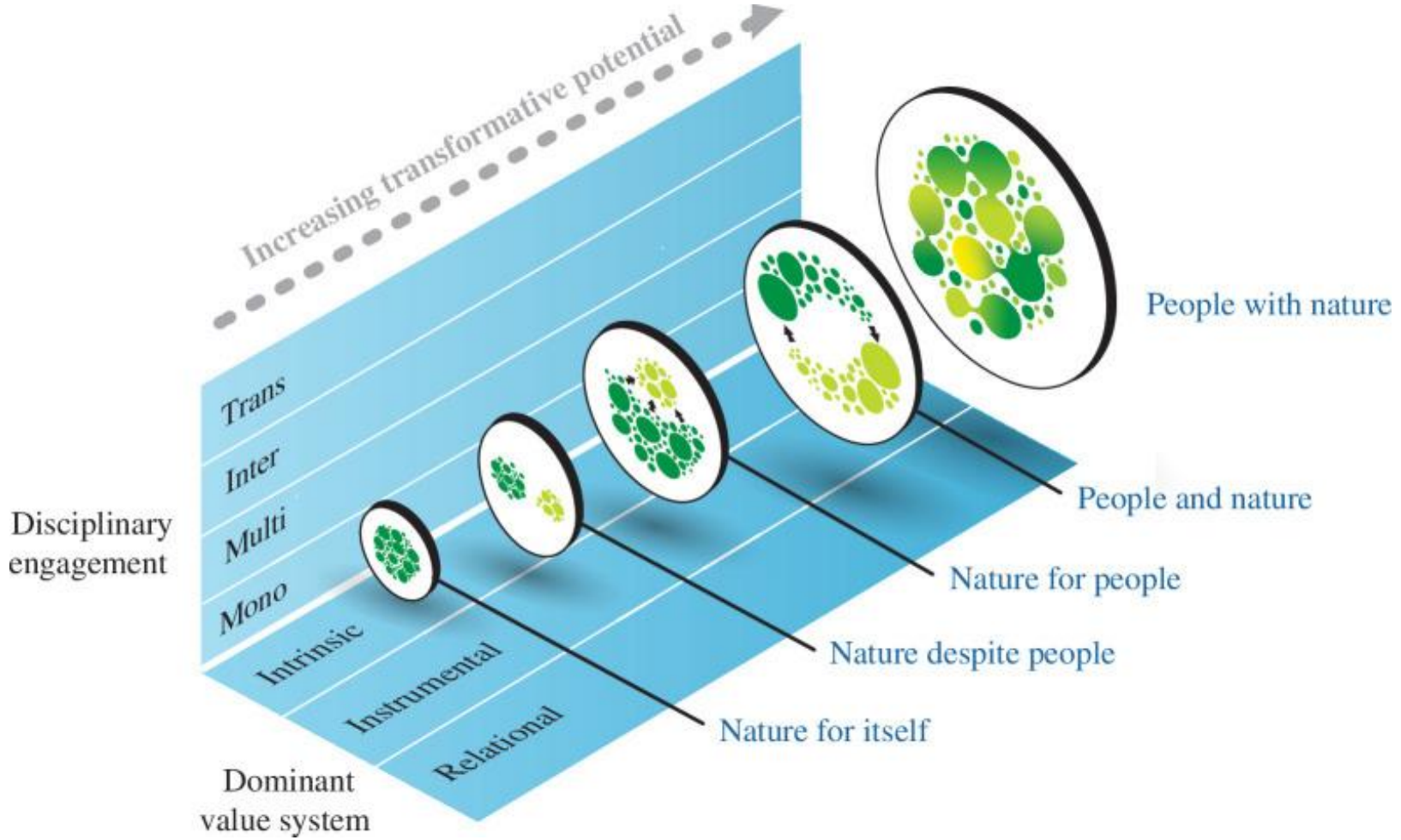
These perspectives coexist.

Nature matters in several ways

Intrinsic	Species and ecosystems have value in themselves
Instrumental	Nature supports material and non-material benefits
Relational	People value identities, responsibilities and relationships with nature

Disagreement about conservation often reflects different values, not different facts.

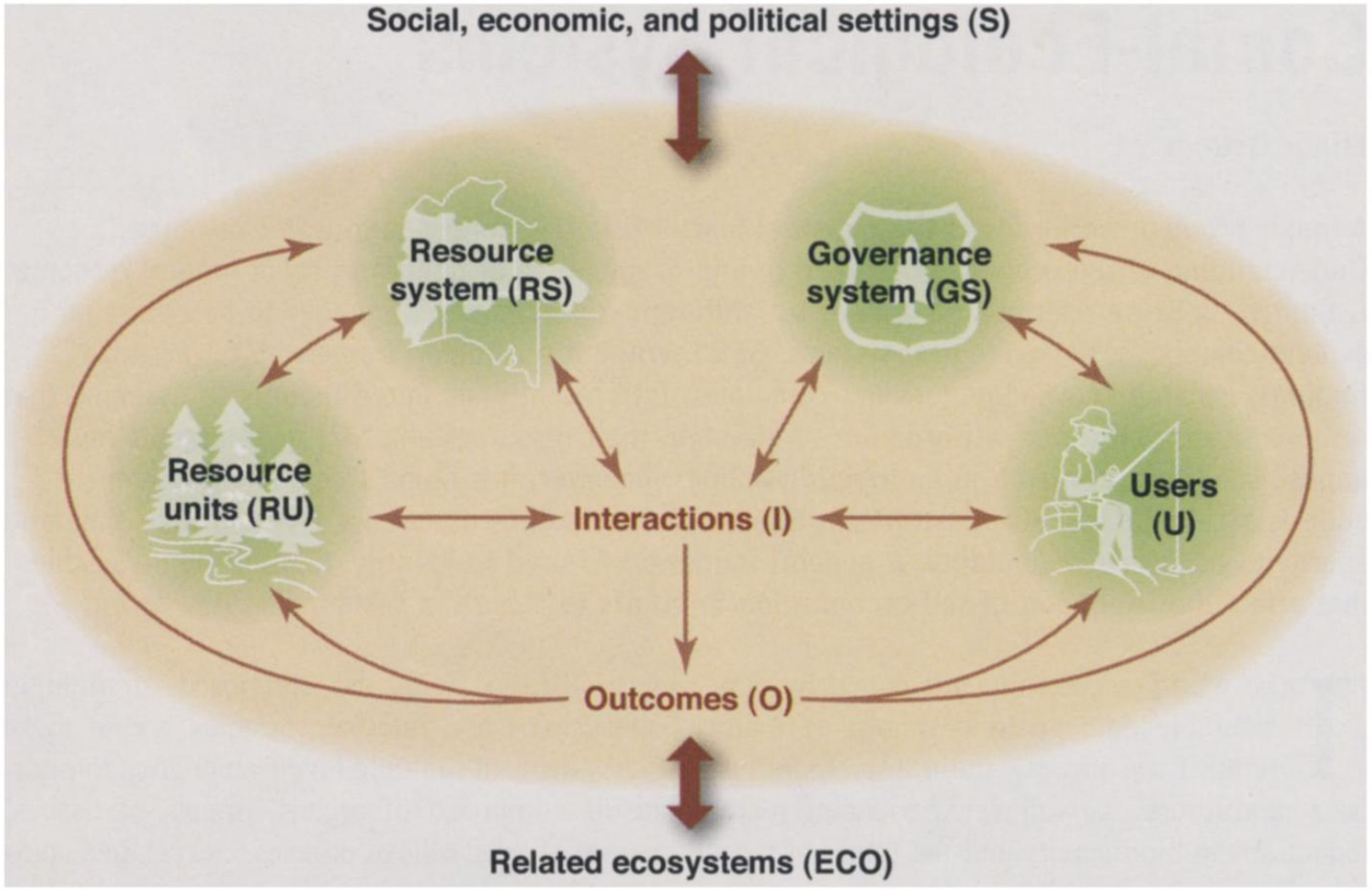
Values and knowledge shape conservation



Conceptual framework: values and disciplinary engagement

Reyers & Bennett (2025), Fig. 2. Graphics: Jive Media Africa. doi:10.1098/rstb.2023.0320

People and ecosystems form coupled systems



Resource system and resource units

Users and governance

Interactions create outcomes and feedbacks

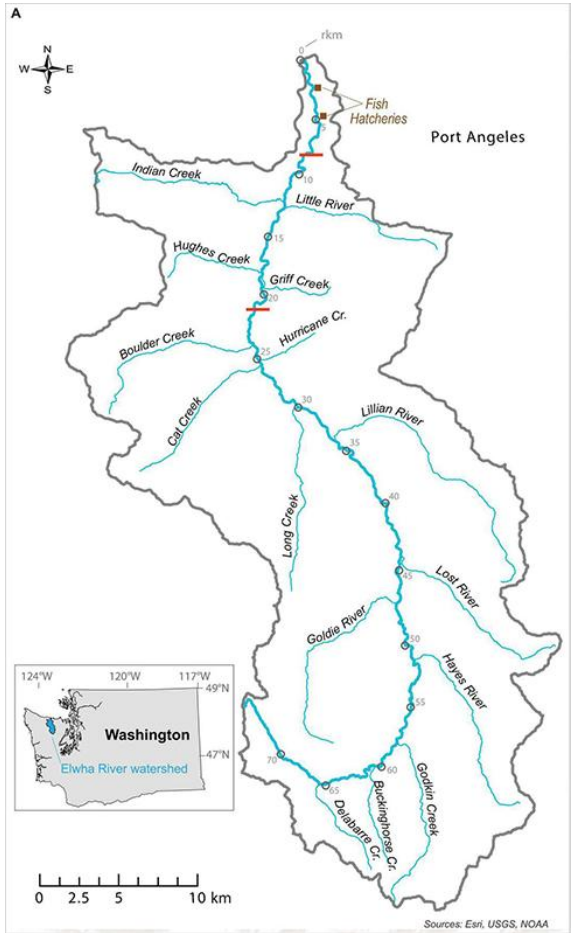
Ostrom (2009), Science, Fig. 1. doi:10.1126/science.1172133

Conservation decisions distribute benefits and costs

Decision maker	Has formal authority
Affected communities	Experience benefits, restrictions or displacement
Knowledge holders	Provide scientific, local or Indigenous knowledge
Future generations	Cannot participate directly

Representation influences which outcomes enter the decision

Recovery includes cultural relationships



Lower Elwha Klallam Tribe

A river can be habitat, livelihood and a continuing cultural relationship.

Duda et al. (2021), Fig. 1A · Lower Elwha Klallam Tribe · Bennett et al. (2017); Reyers & Bennett (2025)

The wilderness model has social and ecological limits

A protected place may still depend on:

- Water, organisms and nutrients arriving from outside
- Migration routes across working landscapes
- Institutions and communities beyond the boundary

Protection can also impose costs:

- Restricted access to land or resources
- Displacement and loss of cultural relationships
- Unequal influence over management

The contemporary question concerns how protected areas connect to ecological flows, rights and wider landscapes.

Protected areas need a complementary network



Representation

- Include biodiversity across the region
- Identify gaps in the existing network
- State explicit conservation targets

Complementarity and persistence

- Add what existing sites do not protect
- Maintain the processes that support it
- Plan across the surrounding landscape

Margules & Pressey (2000) · doi:10.1038/35012251

Conservation across different landscapes



Far from people

Protect ecological integrity with minimal direct disturbance.

Close to people

Conserve everyday nature and connect biodiversity with justice, health and livelihoods.

Both approaches depend on ecological connections and legitimate governance.

The range of conservation activities

IN SITU

EX SITU

Protect places

Strict reserves
National parks
Areas with regulated use

Recover species and habitats

Threat control
Restoration and corridors
Reintroductions

Keep living collections

Botanical gardens
Seed and gene banks
Conservation breeding

Long-term protection, varied rules

These activities can support the same conservation programme

CBD, Article 2 · Dudley / IUCN (2008) · Categories describe management objectives

Yellowstone: wolves return to the food web

1926

The last resident wolf pack is killed.

1995–1996

31 wolves are reintroduced from western Canada.

A missing predator returns, restoring an ecological interaction.



NPS, History of Wolf Management | Photo: NPS / Jim Peaco

How a trophic cascade can unfold

An indirect effect across feeding levels

Wolves → **Elk** → **Woody plants**

Predation on elk

Changes in abundance and browsing pressure

Less browsing can allow willow and aspen growth



Observed in parts of Yellowstone

Reduced browsing and recovery of woody vegetation.

The response depends on context

Water, other predators and hunting also influence the outcome.

Conservation can restore interactions as well as species.

Ripple & Beschta (2012); Hobbs et al. (2024); NPS | Photo: NPS / Jim Peaco

The Mekong brings the concepts together



300 kg stingray, tagged and released in Cambodia, June 2022

Photo and event: Wonders of the Mekong / University of Nevada, Reno

Biodiversity

A species and its population

Ecological processes

Habitat, flows and connections

People and values

Food, livelihoods
and cultural relationships

The Mekong: a conservation argument

Objective A native fish population persists

Action Reduce threats and protect habitat

People Work with fishers and managers

Evidence Survival, recruitment and population change



Persistence requires evidence over time.



Our memory sets a baseline

The conditions we first know can become our idea of normal.

Historical evidence extends our memory

Pauly (1995), Soga & Gaston (2018)

A catch viewed without historical context



2007

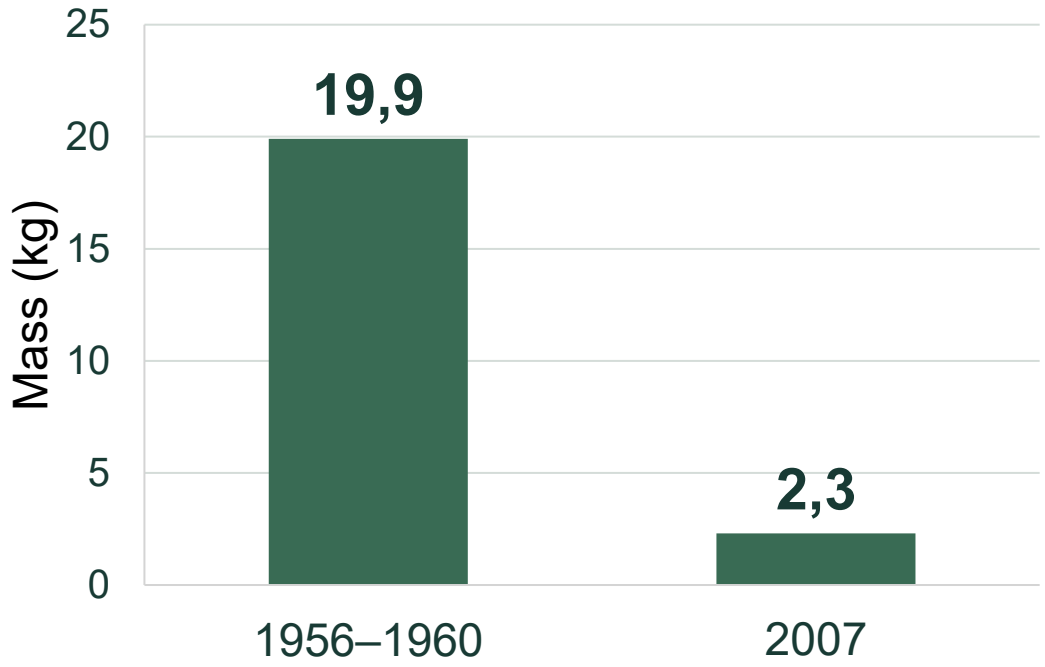
A snapshot needs a comparison

McClenachan (2009), Fig. 1C · Selected displayed catch

The historical comparison changes the question



Mean estimated mass of trophy fish



McClenachan (2009) · Endpoint means shown; SE = 1.5 and 0.3 kg · Not a random population sample

A baseline, a reference and a target

Baseline	The condition used to measure change
Reference	Evidence about a condition or trajectory we compare against
Target	The outcome we decide to pursue

A changing environment is different from a changing memory.

Pauly (1995); Milly et al. (2008); Heller & Zavaleta (2009); McLaughlin et al. (2022)

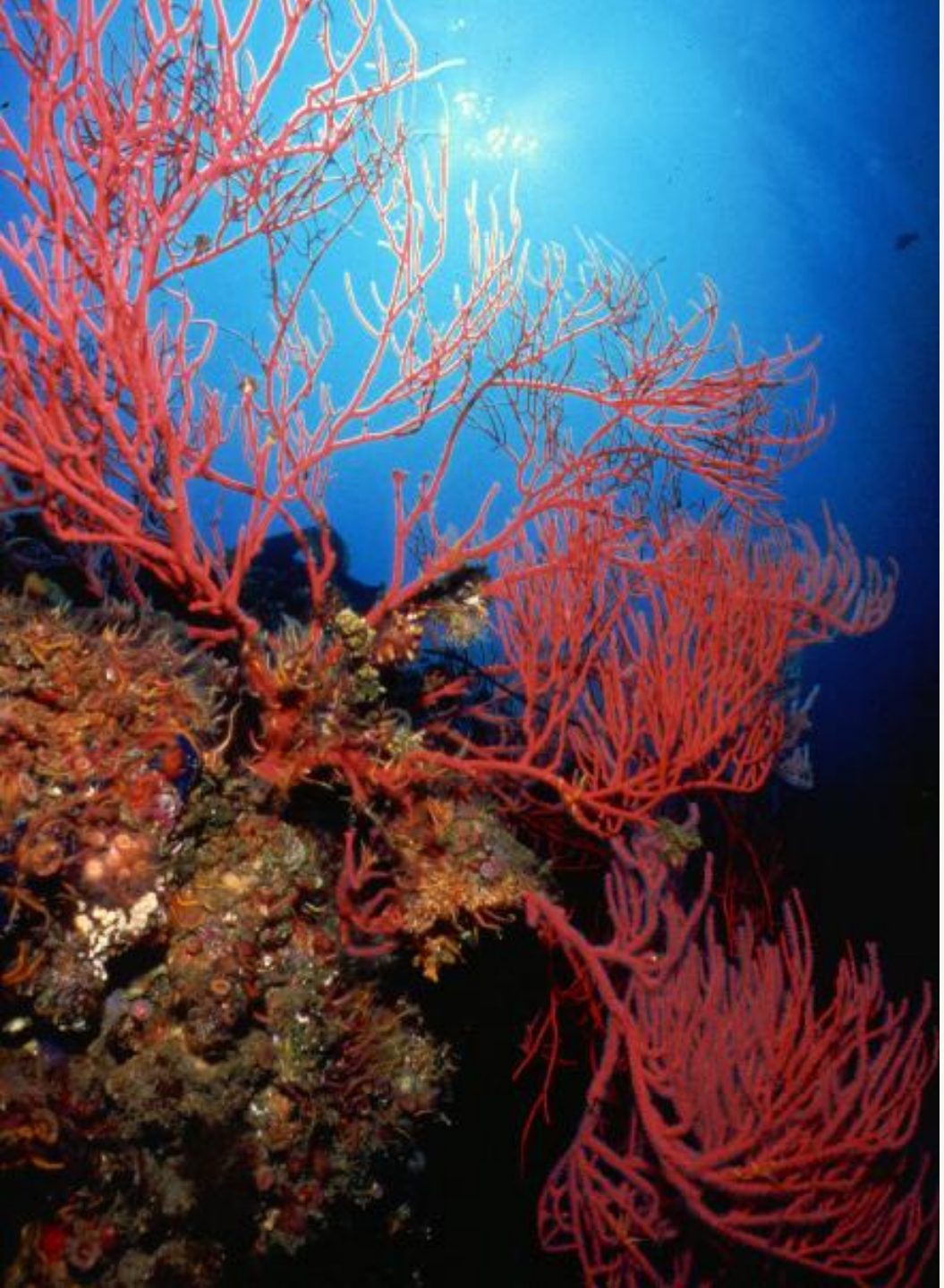
The Anthropocene changes the background conditions



Local decisions now operate inside global change.

- Climate shifts baselines and ranges
- Infrastructure fragments ecological flows
- Trade moves organisms and pressures
- Consumption separates benefits from impacts

Static targets become harder to defend.

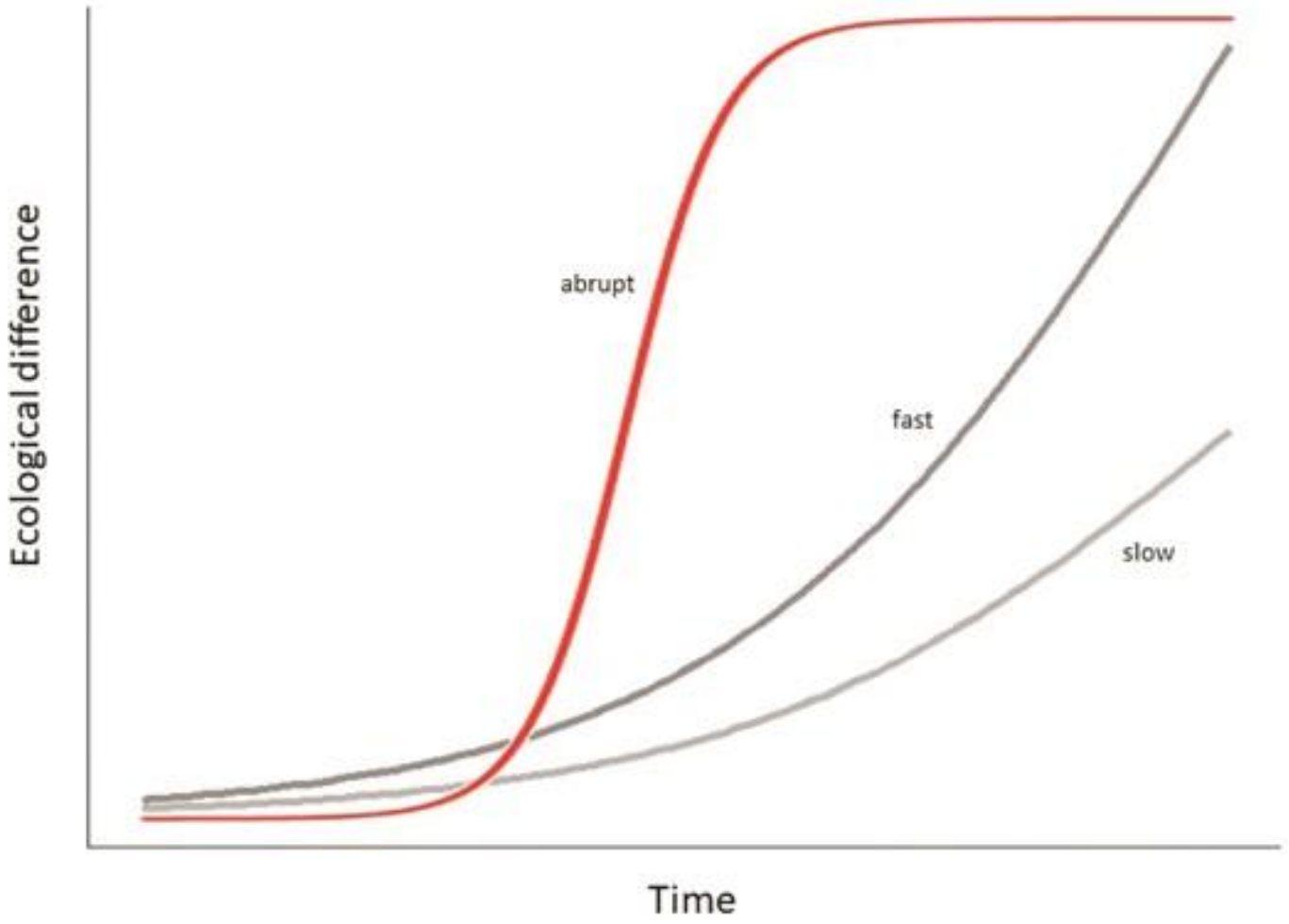


A boundary cannot exclude a heatwave.

Local action operates within changing global conditions.

Hughes et al. (2017) · McLaughlin et al. (2022)

Ecological responses can be gradual or abrupt



A changing climate does not imply a uniform ecological response

Conceptual trajectories

Schuurman et al. (2022), BioScience, Fig. 1. doi:10.1093/biosci/biab067

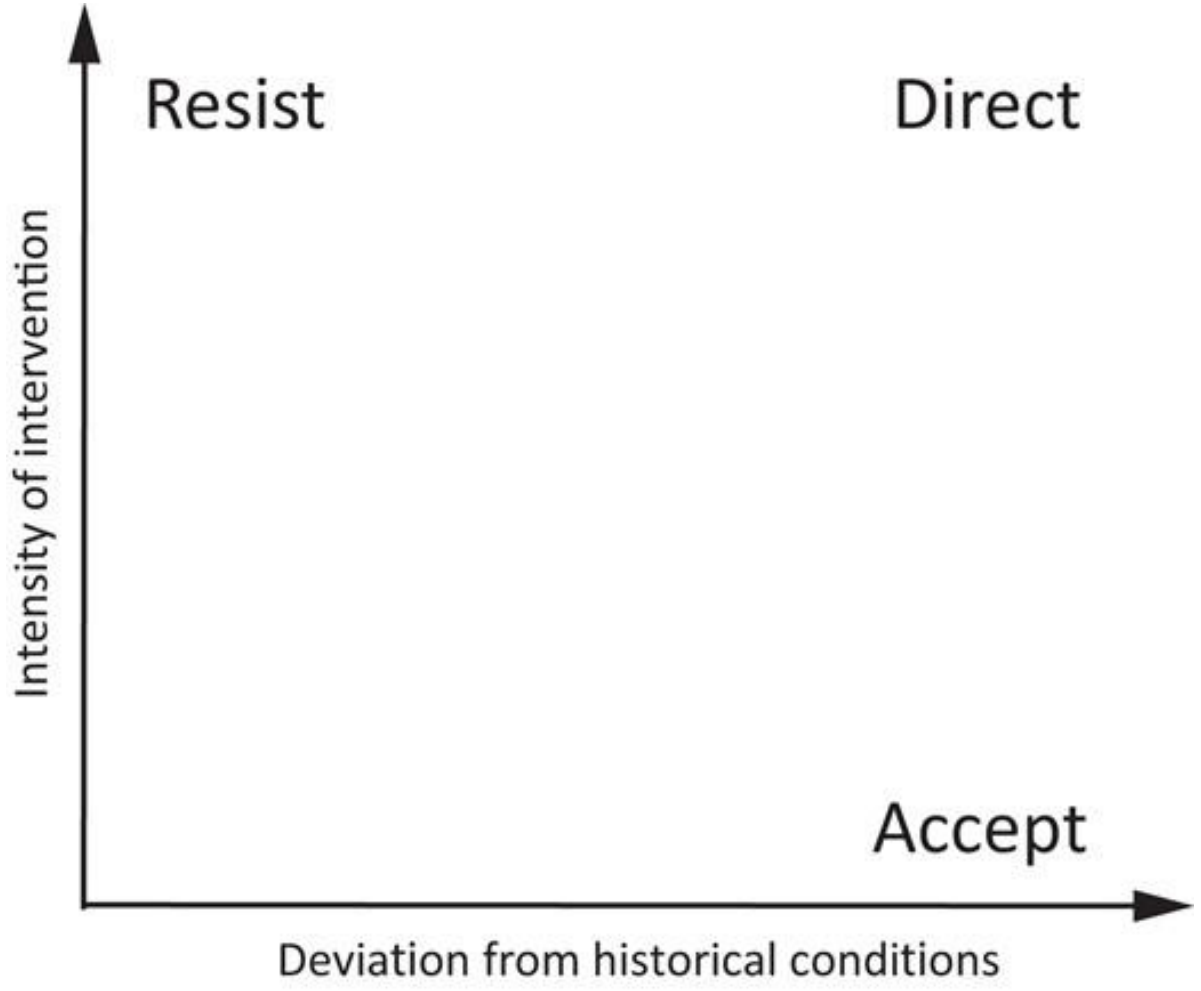
Three responses to ecological transformation

Resist–Accept–Direct (RAD)

Resist	Maintain desired conditions	Protect cold-water refuges
Accept	Allow ecological transition	Allow species composition to change
Direct	Guide the emerging ecosystem	Restore a climate-suited native assemblage

Goals depend on ecological feasibility and shared values

Adaptation involves choices about intervention



Intervention intensity

Distance from historical conditions

Different goals can require equally active management.

Schuurman et al. (2022), BioScience, Fig. 4. doi:10.1093/biosci/biab067

Uncertainty and judgement in conservation

Knowledge

Whether accessible habitat can support recruitment

Future conditions

Future changes in flow and temperature

Judgement

Acceptable losses and their distribution

Regan et al. (2002) · Values and acceptable losses also require deliberation

Three fields intervene at different points

CONSERVATION

Prevent loss and sustain ecological values

Protect habitat, manage use, maintain connectivity

RESTORATION

Assist recovery of a degraded ecosystem

Re-establish processes, structure or function

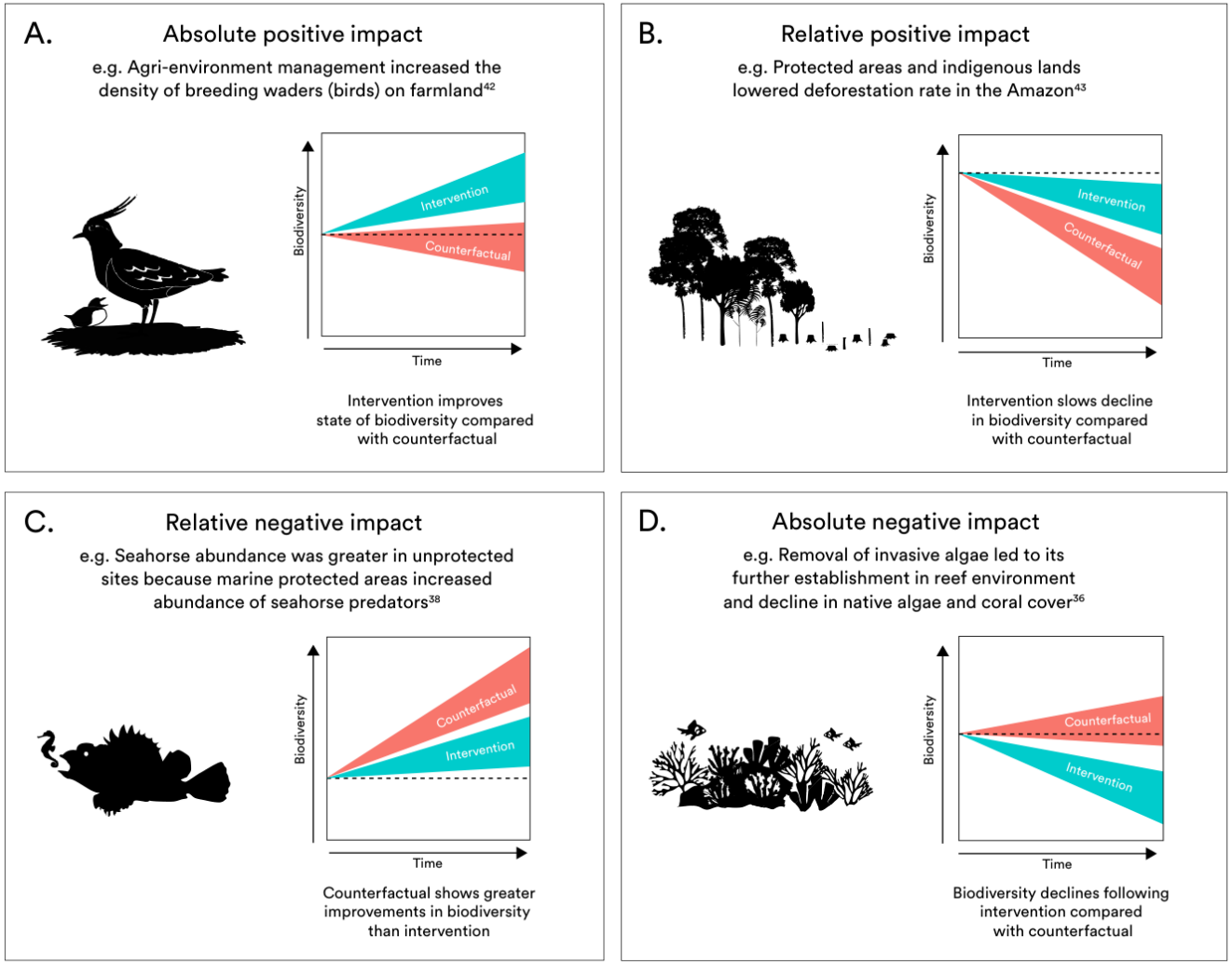
REMEDIATION

Reduce or remove contamination and hazard

Treat pollutants, soils, sediments or water

Real projects may combine them, but the objective must remain clear.

Success requires a comparison with no intervention



Conceptual comparison

Langhammer et al. (2024), Science, Fig. 1. doi:10.1126/science.adj6598

Monitoring needs a decision attached

Expectation

Passage improves access to suitable spawning habitat

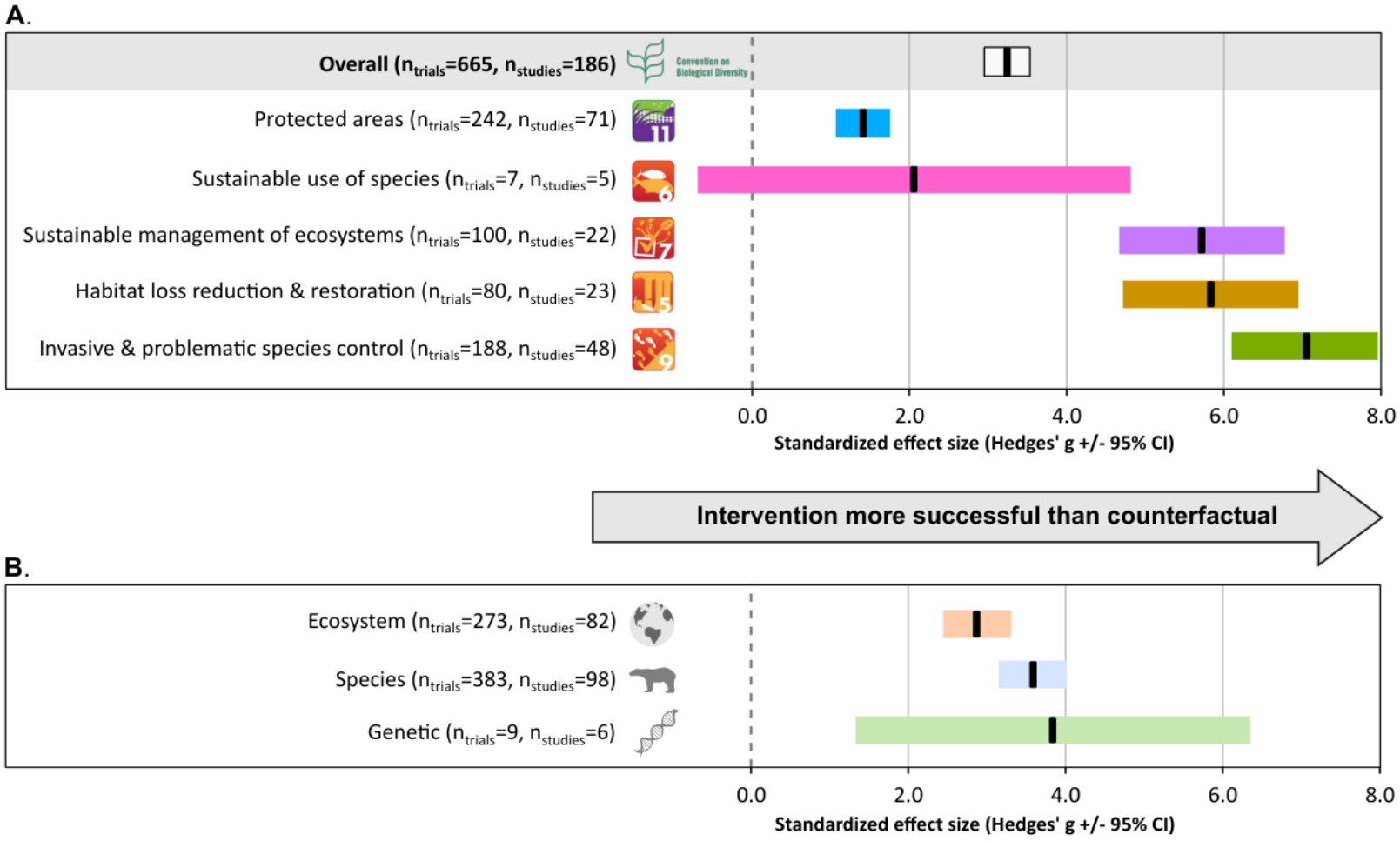
Observation

Fish arrive, but repeated recruitment remains low

Response

Test the limiting process and revise the intervention

Conservation interventions can improve outcomes



186 studies, 665 trials. Effect sizes compare action with a counterfactual.

Langhammer et al. (2024), Science, Fig. 2. doi:10.1126/science.adj6598

What will the next generation call normal?

Conservation shapes what future generations experience as normal



Photo: Suthep Kritsanavarin



Glines Canyon, September 2014 · USGS

RETURN TO YOUR FIRST ANSWER

What would you recommend now?

State a conservation objective

Name the strongest supporting evidence

Identify a condition that could change the action

Your first conservation argument

One goal worth pursuing

One claim we can test

One observation that would change the plan

NEXT CLASS · HUA ET AL. (2022)

Biodiversity and ecosystem services in forest restoration