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Evidence charts the future of freshwater biodiversity conservation

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ABSTRACT

Evidence is essential for promoting freshwater conservation and selecting appropriate conservation actions. This article examines the importance of evidence for freshwater conservation, available sources, how evidence is used, geographical coverage, and the challenges in obtaining evidence. Two databases containing published evidence, namely, Conservation Evidence (CE) and the Collaboration for Environmental Evidence (CEE), were systematically searched and evaluated. Evidence in CE is geographically skewed, with most studies coming from North America and Europe. The IUCN Red List requires evidence to assign species to threat categories, but is limited in its ability to track conservation success. IUCN Green Status can be used to assess the impact of conservation actions on species recovery, but suffers from some of the limitations of Red List assessments. Evidence is also required to select freshwater areas for protection, and for monitoring their condition over time, accompanied by an increasing recognition of the value of using evidence from Indigenous communities to support international agreements. Persistent barriers to the use of evidence for promoting freshwater conservation include weak baselines, short monitoring horizons, mismatched spatial scales, reliance on subjective opinion when analysing evidence, and under-reporting of failures. These and other barriers are addressed in several concluding recommendations.

Keywords: conservation actions, data repositories, expert opinion, Indigenous communities, international policy, IUCN, monitoring, protected areas.

Introduction

The principle of using evidence to support policy and practice has spread from its use in medicine in the 19th Century (Ratnani *et al.* 2023) to other areas such as education and social policy (Baron 2018). There are now academic journals dedicated to publishing work on evidence-based practices. Among these are the Open Access *Conservation Evidence Journal* and *Environmental Evidence*, both of which share systematic information about the effectiveness of conservation actions. Despite this, the application of evidence-based decision-making in conservation is inconsistent.

This article, written by members of the Freshwater Conservation Committee of IUCN's Species Survival Commission examines one specific environmental application, namely the use of evidence in freshwater biodiversity conservation. Here, the word 'biodiversity' conforms to the broad definition of the Convention on Biological Diversity (CBD) that includes both the diversity of living organisms and ecosystems. This article considers 'evidence' to be a comprehensive collection of relevant information on a specific question or topic, collected and synthesized following a defined systematic protocol and accompanied by an assessment of the validity or confidence in that evidence that can be used to inform decision-making. Our aim is not to make a comprehensive review of the details of the many *sources* of information (e.g. primary ecological data, scientific literature, individual systematic reviews and meta-analyses, expert judgment, traditional ecological knowledge (TEK), institutional assessment frameworks) or to present a comprehensive synthesis of the effects and effectiveness of conservation for freshwater ecosystems. In fact, that is the function of the Conservation Evidence databases that we have reviewed and is further investigated in recent publications that are based on extensive reviews of scientific papers

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that discuss conservation actions and their outcomes (Cutts *et al.* 2024; Thornton *et al.* 2025; Taylor *et al.* 2026). Instead, our approach is to discuss more generally why conservation evidence is important, where and how it might be applied to decision-making in freshwater policy and practice, and some of the associated challenges and solutions. This study addresses the following four central questions:

i. What sources of conservation evidence are available?
ii. How is evidence used to measure the success of a conservation project, practice or policy?
iii. Where are freshwater conservation efforts located geographically?
iv. Why is evidence often so difficult to obtain?

The incentive to ensure that conservation is based on evidence takes many forms and covers a range of disciplines. In many countries there are statutory requirements to report on the condition of habitats and species populations. For example, in Europe, EU Member States must report to the European Commission every 6 years on the conservation status of Special Areas of Conservation (SACs) established under the Habitats Directive (see https://environment.ec.europa.eu/topics/nature-and-biodiversity/habitats-directive_en). The United States and Canada report on instruments such as the Endangered Species Act and the Species at Risk Act. Multilateral environmental agreements, such as the CBD's Kunming to Montreal Global Biodiversity Framework (GBF) (International Union for Conservation of Nature and Natural Resources 2023), and the Ramsar Convention on Wetlands of International Importance also require countries to report on the status of species and ecosystems (i.e. National Biodiversity Action Plans and National Reports respectively). These frameworks illustrate the importance of evidence-based reporting for accountability and for priority setting.

Using Canada as a case study, Reid *et al.* (2022) described the development of scoring methods to assess 259 syntheses of evidence for the effectiveness of 50 freshwater management actions for addressing threats to freshwater biodiversity. Examining action plans, such as those used for species in the Canadian Species at Risk Act, they reported that actions such as habitat creation, invasive species removal and revegetation were found to have reliable evidence syntheses, enabling them to be used to guide conservation and management actions.

Freshwater conservation requires trans-disciplinary approaches (e.g. biology, ecology, hydrology, social sciences) to understand ecological processes and human drivers of change, and to solve complex problems. The need for an evidence-based approach to freshwater conservation must not only be supported by scientific research but should stimulate a quest for new methods of improving conservation success and for measuring it more effectively. For example, over the past 30 years, the emphasis on restoring the conservation value of rivers has begun to shift from one based on deliberately altering river form and flow to one that encourages process-based restoration (Addy *et al.* 2016). This change in emphasis, although by no means universal, has come about largely through evidence derived from fluvial geomorphological research (Piégay *et al.* 2023). In addition, studies have begun to demonstrate the need to restore connectivity between terrestrial and freshwater ecosystems (Dala-Corte *et al.* 2020), and the opportunities for including local community engagement and citizen science (Metcalfe *et al.* 2022; Adhya *et al.* 2024; von Gönner *et al.* 2024; Moberg *et al.* 2025) in research and action aiming to protect freshwater biodiversity.

The significant decline in the state of freshwater biodiversity has highlighted the urgent need for well-focused conservation actions. Freshwater vertebrate populations worldwide have declined on average by 85% according to the Living Planet Index (World Wide Fund for Nature 2024), and the IUCN Red List shows that 25% of assessed freshwater species are threatened with extinction (Sayer *et al.* 2025). Environmental threats known to be responsible for the declines in freshwater species include dam construction, water abstraction, organic and inorganic pollution, habitat loss, and the spread of invasive alien species, with climate change already affecting species survival and distribution either directly through temperature increases or indirectly through its effect on hydrological patterns. The cost, both in terms of time and money, required to address these threats and mitigate the declines, provides another major incentive for gathering evidence to demonstrate its effectiveness. Although some freshwater conservation measures may cost little (e.g. replanting riparian zones), others are extremely expensive. For example, a cost–benefit analysis of a long-term plan for restoring 400 km of rivers in Switzerland, based on biodiversity and ecosystem services, has estimated that this will cost CHF1,200,000 (€1,305,000; US$1,534,000) per kilometre (Logar *et al.* 2019). Financial and political pressures often result in conservation being given low priority by governments, especially for fresh waters (van Rees *et al.* 2025), and funding from other bodies such as non-governmental organizations is severely limited. This creates a pressure to identify funding priorities that make the most efficient use of resources and emphasizes the importance of having evidence that demonstrates the success of specific conservation measures when requesting funding for conservation projects (Al-Fulaij *et al.* 2025).

The recent explicit application of an evidence-based approach to environmental decision-making has been reviewed by Cooke *et al.* (2023), who concluded that 'there is an urgent need for research involving methods from social science, behavioural sciences, and public policy to understand the basis for patterns and trends in environmental evidence use' (p. 1). This holistic approach to conservation was summarized by Mace (2014) who traced the evolution of conservation thinking from 'Nature for itself', to 'Nature despite people', to 'Nature for people', and finally to 'People and nature', reflecting an interdisciplinary approach that integrates ecological and social sciences and involves the critical role that humans play within ecosystems. Assessing success in such integrated models is complex (Ghoddousi *et al.* 2022) but increasingly important (Serra-Llobet *et al.* 2022). Understanding and integrating socio-ecological aspects such as water-use rights, indigenous management systems, freshwater biodiversity use, and governance for equitable sharing of benefits, is essential for evaluating the long-term sustainability of conservation actions.

Many individuals and organizations advocate a greater awareness of the need for freshwater conservation by developing education programmes that address fresh waters as complex ecosystems and guide their conservation and management beyond water security (Barouillet *et al.* 2024). One way of doing this has been to encourage the application of scientific research in the production and use of educational resources (Boon and Baxter 2021). However, whether through formal or informal education, conservation awareness is unlikely to yield results without evidence showing that conservation works and represents a benefit for society. Of equal, or greater, importance is whether people's attitudes and actions towards conservation, or to the importance of freshwater habitats and species, can be changed by raising awareness. Gathering robust data on this is challenging (Ardoin *et al.* 2020), but there are clear indications that awareness alone is not enough to drive positive conservation decisions (Simaika and Samways 2018).

Locating and using evidence on the effectiveness of freshwater conservation actions

Evidence repositories

Freshwater conservation actions rely on diverse evidence sources. Given the exponential increase in scientific literature in recent years, it is increasingly difficult for practitioners to find and apply information contained in individual scientific studies (Larsen and von Ins 2010). Thornton *et al.* (2025) described the very complex methods that were necessary for evaluation of conservation evidence for freshwater fishes derived from extensive literature reviews. Evidence syntheses (e.g. systematic maps and reviews, often including meta-analysis) support decision-making by using systematic methods to critically evaluate and combine findings across a comprehensive collection of literature on a particular topic (Cooke *et al.* 2023).

Repositories of evidence further increase the accessibility of such syntheses to practitioners, but these have been available only comparatively recently. In a study on decision-making in conservation, Pullin *et al.* (2004) concluded that the majority of conservation actions remained experience-based, and although some evidence existed, much was not readily accessible in a suitable form. This led to a proposal for web-based systems for storing and analysing conservation evidence (Sutherland *et al.* 2004; Pullin and Knight 2009) and eventually to the two primary repositories of evidence that contain syntheses of the effectiveness of freshwater conservation interventions, namely the Conservation Evidence (CE) database (Sutherland *et al.* 2019, accessed from https://conservationevidence.com/) and the Collaboration for Environmental Evidence (see https://environmentalevidence.org/).

Here, we describe the format of these repositories, methods used to generate them, effective ways to find relevant evidence, and analysed the scope of the actions they contain with regard to action type, effectiveness and geographical coverage. We acknowledge that further useful information can be found by searching the primary scientific literature or repositories of data (as was undertaken, for example, by Cutts *et al.* 2024, Thornton *et al.* 2025 and Taylor *et al.* 2026); however, the focus here is on repositories of evidence that can be used directly by practitioners.

Overview of the sources of freshwater conservation evidence

The CE database summarizes the available evidence on the effectiveness of conservation actions. The CE team gathers information using systematic searches of scientific journals as well as reports and unpublished literature. This information is presented as summaries of 'studies', 'actions' or 'synopses' (see https://conservationevidence.com/). 'Studies' describe the context, action/intervention(s) tested, and the consequences described in a single document (e.g. a journal article). An action is an intervention with a synthesis of evidence for its effectiveness based on all available studies. 'Synopses' collect and summarize all evidence on a particular topic, such as a taxonomic group (e.g. 'Amphibian Conservation', 'Reptile Conservation', and 'Marine and Freshwater Mammal Conservation'), habitat (e.g. 'Marsh and Swamp Conservation') or conservation challenge (e.g. 'Control of Freshwater Invasive Species' and 'Sustainable Aquaculture'). As of November 2025, the open-access website contained 8867 studies, 3891 actions and 27 synopses.

The CEE aims to 'promote and deliver evidence syntheses on issues of greatest concern to environmental policy and practice as a public service' (see https://environmentalevidence.org/). It maintains several open-access searchable repositories of evidence relevant to biodiversity conservation. The CEE Evidence Synthesis Library (CEEESL) presents summaries of all CEE-approved evidence syntheses. The CEE Database of Evidence Reviews (CEEDER) is targeted at policy makers, managers, funders and the public, and summarizes reviews against CEE methodological standards. The flagship journal of CEE, i.e. *Environmental Evidence*, publishes systematic maps and systematic reviews including meta-analyses. The journal scope encompasses any environmental topic, within which freshwater biodiversity conservation firmly sits. In addition, CEE has seven evidence centres around the world, which often list research outputs on their institutional website (e.g. Canadian Centre for Evidence-Based Conservation; see https://canadiancebc.com/).

Methods of searching repositories for freshwater conservation evidence

We used different search strategies across the two sources (Table 1). To get an overview of available evidence, we restricted the results to those that were specific to freshwater systems ('freshwater-specific'), excluding interventions that were relevant to freshwater systems but also applicable to terrestrial and marine systems. This was completed by a single reviewer and was intended to provide a rough overview rather than an application of systematic review. In the case of CE, we also restricted actions to those supported by at least four studies, acknowledging that assessments of effectiveness on the basis of fewer than four studies can inform decisions and represent a large quantity of available information. For example, using the keyword 'freshwater' to search, CE returned 541 results (not only freshwater-specific) that were supported by three studies or fewer and 309 potential actions that were not supported by any studies.

The most comprehensive method of searching CE was using the keyword 'freshwater', which returned the largest number of overall results (749 actions, Table 1), the most freshwater-specific results (135 actions) and the most novel actions of those that were most relevant (i.e. those not found by the other searches, 14 actions). In total, 157 freshwater-specific actions were found on the CE database, of which 96 (61%) were returned by all three search methods and each search method returned some novel actions.

Searching the CEE repositories was less efficient, with larger numbers of irrelevant results from the initial search owing to the broad scope (Table 1). Freshwater-specific results from CEE sources were also restricted to systematic reviews or maps of the effectiveness of freshwater conservation interventions, or summaries thereof. The multiple CEE repositories collectively returned 58 relevant reviews or summaries. Many actions retrieved through the CEEDER or CEEESL corresponded to a few systematic reviews or maps in the CEE journal.

The scope of the two sources differed with a greater focus on removal of pollutants from freshwater systems in CEE repositories. For example, 51 (88%) of the relevant actions on CEE considered constructed wetlands for the removal of various types of pollutants, including their effects on biodiversity. Some actions overlapped between CE and CEE repositories, such as restoration of wet meadows, vegetated strips/buffers around agricultural land, grazing/mowing, adding lime to water bodies, and freshwater restoration generally.

The scope of available evidence

In CE, 74 actions in the existing synopses considered the potential benefit to the habitat, primarily freshwater or brackish–saline wetlands. Conservation actions for the potential benefit to species tended to focus on amphibians, birds, and to a lesser extent on mammals. The potential benefits to some amphibian and bird groups were considered in more detail, including frogs, toads, salamanders (including newts), wading birds, divers, loons, coots, rails and cranes. A small number of actions considered species-specific effectiveness, although more would be expected among actions supported by fewer than four studies. No actions were found that considered the potential benefit to invertebrates or fish, but these synopses are planned or under way. Some evidence for

Table 1. Methods of searching for evidence on the effectiveness of actions to conserve freshwater habitats and associated species: Conservation Evidence (CE); Collaboration for Environmental Evidence (CEE); CEE Evidence Synthesis Library (CEESL); CEE Database of Evidence Reviews (CEEDER); *Environmental Evidence* (CEE Journal).

Source	Search method	Search details	Total number of results	Freshwater-specific conservation actions
CE	Filters applied	Categories: amphibians, invasive species control, marine or freshwater mammals, marsh or swamp, sustainable aquaculture Habitats: rivers, streams, wetlands	265	116
CE	Keyword search	'freshwater'	749	135
CE	Keyword search	'wetland'	623	133
CEESL	Keyword search	'freshwater'	13	5
CEESL	Keyword search	'wetland'	5	3
CEEDER	Filters and keyword search	Review type: evidence overview Field to search: title, abstract or keywords Query: 'freshwater OR wetland' (2018–25)	40	16
CEEDER	Filters and keyword search	Review type: evidence review Field to search: title, abstract or keywords Query: 'freshwater OR wetland' (2018–25)	141	29
CEE Journal	Keyword search	'freshwater OR wetland'	136	12

actions to conserve invertebrates and fishes was found in CEE repositories, including spring restoration, liming lakes, and positioning instream structures and large wood for trout and salmon. Ten actions were found that considered the effectiveness of invasive species removal, which may benefit multiple species groups and habitats.

The geographical bias in the CE database overall (Christie *et al.* 2021) was also observed for freshwater conservation evidence (Fig. 1). In total, 130 (83%) of the 157 freshwater conservation actions retrieved were supported by at least one study from North America, followed by 106 from Europe (68%) and 48 from Australia and New Zealand (31%). This geographical imbalance could be the combined product of the distribution of available literature and the geographical locations of experts involved. The amphibian conservation panel had 28 members from 13 countries, 15 of which were from the UK or USA (see https://conservationevidence.com/). Information on the geographical locations of included studies is available for CEE reviews but is not reported as explicitly.

A value of 100 indicates that 100 freshwater conservation actions were found, and the assessment of effectiveness of these included at least one study from the region. Regions are defined according to the M49 standard subregions (UN Statistics Division 2025). European subregions are grouped together, and Melanesia, Micronesia and Polynesia are grouped together as Pacific Islands.

How is effectiveness assessed?

For CE summaries, lists of potential actions are created and evidence is assessed by a panel of experts. Actions are included whether or not evidence is currently available. The expert panels assign actions to one of six categories regarding their overall effectiveness, including 'Beneficial', 'Likely to be beneficial', 'Trade-offs between benefits and harms', 'Unknown effectiveness (limited evidence)', 'Unlikely to be beneficial' and 'Likely to be ineffective or harmful'. These are derived from assessments of percentage scores across three aspects, namely effectiveness, certainty and harm. For example, to be classed as 'Beneficial', the thresholds for these three scores are >60, >60 and <20% respectively.

The methods used in CEE reviews for assessing effectiveness differ among syntheses. For example, in reviewing the evidence on the effect of beavers (as a species of interest for habitat restoration) on aquatic macroinvertebrates, Washko *et al.* (2022) synthesized the findings of 23 studies and reported how many observed responses in aquatic macroinvertebrate richness, density, biomass, and functional composition, compared with unaffected lotic habitats nearby. The evaluation of review quality presented on CEEDER flagged that it is unclear why this study did not synthesize the collective results analytically (such as using a meta-analysis). By contrast, Cheng and Ma (2023) used a meta-analysis to collate analytically the data collected across multiple studies and analyse the overall effect of artificial (*v.* natural) wetlands on breeding bird performance, which included testing the effect of conservation interventions and nest locations.

Most of the freshwater-specific actions found in CE were assessed as 'Likely to be beneficial' (86 actions), followed by 'Trade-off between benefits and harms' (33 actions) and 'Beneficial' (23 actions, Fig. 2). Examples of actions that were assessed as 'Beneficial' were directly planting trees or shrubs for brackish or saline wetlands, creating ponds for amphibians, and restoring or creating wetlands for amphibian species and wetland habitats.

An example of an action with Trade-offs was the widely used pesticide 'rotenone' to remove or control fish for amphibian conservation, in which three studies and one review observed

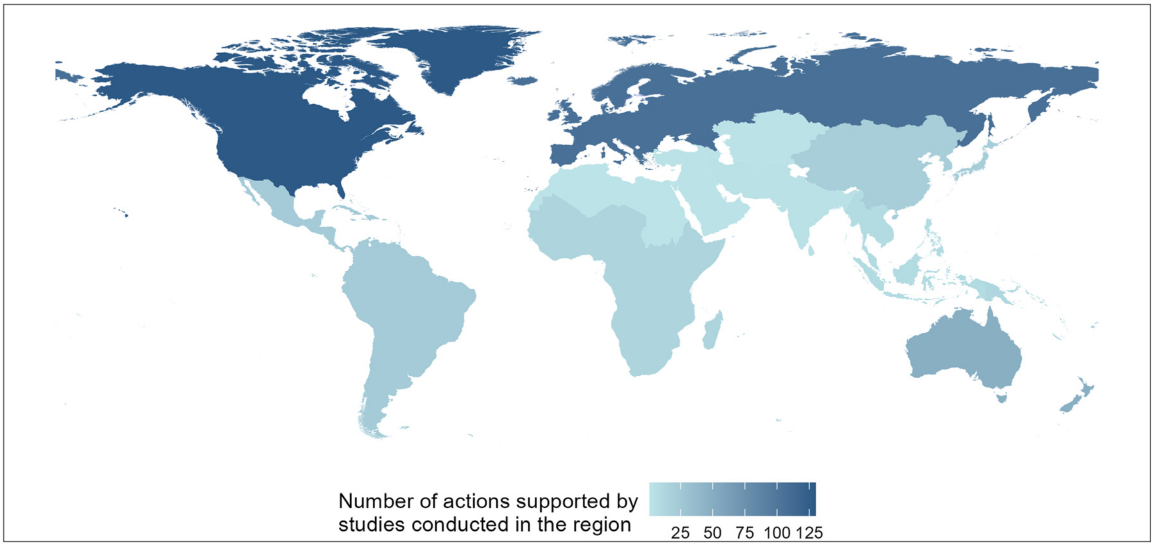

Fig. 1. The number of freshwater conservation actions retrieved from https://conservationevidence.com/ that were supported by studies in each geographical region.

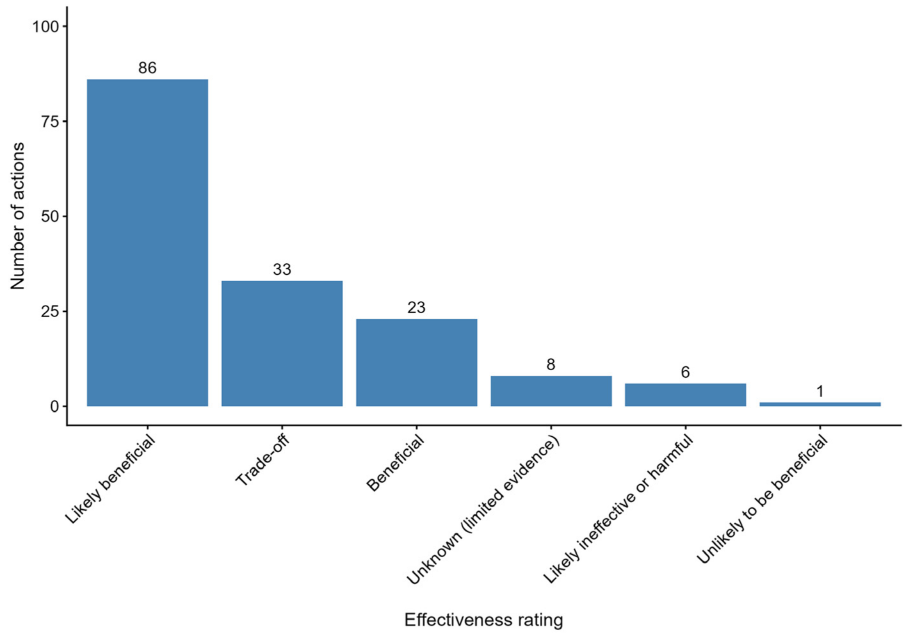

Fig. 2. The number of freshwater actions in Conservation Evidence classified in each of the six categories of effectiveness (see https://conservationevidence.com/).

increases in abundance and reproduction, but two replicated studies observed negative side-effects including increased mortality (Haque 1971). Other actions assessed as Trade-offs included raising water levels to restore degraded marshes, culverts or tunnels as road crossings, captive breeding and releasing toads, and translocating frogs.

Both CE and CEE provide valuable and complementary resources for informing the conservation of freshwater habitats and their associated species. The CE database represents an efficient action-oriented approach, especially where targeted management interventions are already covered by existing synopses. By contrast, CEE repositories are particularly useful when addressing wide-scale threats such as pollution or when seeking systematic reviews on species and habitats not yet included in one of the synopses of CE.

Other sources of biological information to support freshwater conservation

IUCN Red List of Threatened Species

The IUCN Red List of Threatened Species (hereafter 'Red List') is the most comprehensive dataset on the extinction risk, trends, and threats of the world's taxa. The Red List currently holds information for nearly 173,000 species, of which just over 41,000 are found in fresh water (International Union for Conservation of Nature and Natural Resources 2025). The Red List categorizes extinction risk along a scale ranging from the lowest risk categories of 'Least Concern' and 'Near Threatened' to the threatened categories of 'Vulnerable', 'Endangered' and 'Critically Endangered', and reaching to 'Extinct in the Wild', and 'Extinct' (International Union for Conservation of Nature and Natural Resources 2012).

To assign a species to a particular threat category on the Red List, the following five different criteria are used that encapsulate different 'symptoms' of extinction risk (Collen *et al.* 2016): (A) population size reduction; (B) geographical range in the form of 'extent of occurrence' (EOO) or 'area of occupancy' (AOO); (C) small population size and decline; (D) very small or restricted population; and (E) probability of extinction (International Union for Conservation of Nature and Natural Resources 2012). In addition, the IUCN Red List holds supporting information on population status and trends, distribution, habitat and ecology, threats, and existing or needed conservation actions. Consequently, the Red List provides a robust framework and often the best information available on the conservation of a particular species and allows tracking of conservation success.

The Red List can provide information on why species become downlisted from a higher to a lower Red List threat category owing to genuine improvements in conservation status. Such data have been used previously to determine the success of conservation interventions (Hayward 2011), although detecting genuine positive changes within the Red List can be slow by design. Note that the Red List also includes non-genuine improvements in classification status; for example, improvements owing to new and improved information, previous use of incorrect data or misinterpretation of criteria, or taxonomic revisions (IUCN Standards and Petitions Committee 2024), that do not reflect conservation success. Only genuine improvements in a species' Red List category can point to effective conservation actions.

However, there are some limitations in using it as a tool to track the effectiveness of specific conservation actions. The Red List assessment of the conservation status of a species may focus on conservation actions that were intended to or have led to improvement, but ultimately relies only on the metrics that relate to the Red List criteria; for example, slowing or reversal of population declines; increases in range (leading to larger EOO or AOO); or growth in population sizes, without a required link to specific interventions (although these may often be given in the supporting information by the assessors). Second, although the Red List does include a section for describing conservation actions in place or needed, this information is optional (International Union for Conservation of Nature and Natural Resources 2013) and thus is not consistent across Red List assessments. Third, the conservation actions section may refer to management or conservation actions that result in unquantified improvements in the species' conservation status. Indeed, the Conservation Actions Classification Scheme is very broad and unless more details are given within the Red List text, it is difficult to infer the effectiveness of specific conservation actions. Last, for widely distributed taxa, Red List assessment data often lack the resolution to clearly attribute conservation actions to outcomes in particular regions or locations, thus obscuring local or regional successes or failures. Applying the IUCN Red List Categories and Criteria at the regional level, such resolution may improve results, but assessments still vary in quality and are not always easily accessible.

With recent improvements in the coverage of freshwater species on the Red List (Sayer *et al.* 2025), the volume of data on genuine changes is also increasing. For example, *Acanthobrama telavivensis* (Yarkon bream), native to coastal streams in Israel, became Extinct in the Wild in 1999 because of drought, but was downlisted to Vulnerable in 2013 after a successful *ex situ* breeding and reintroduction programme (Goren 2014). *Ex situ* breeding and subsequent conservation translocations are probably among the easier conservation interventions to track in the Red List, because follow-up monitoring of translocations can provide population size data (for Criteria C and D), population time series data (for Criterion A), and, depending on where translocations occur, may increase the range metrics of a species (expand EOO or AOO for Criterion B).

There are only a few examples of genuine improvements for freshwater invertebrates, and none could be found for freshwater plants, and documentation of what caused the status change is absent. For example, there has been a genuine improvement reported in fat pocketbook mussel (*Potamilus capax*), with no mention of conservation measures or reason for change (Cordeiro and Cummings 2012). However, as species are being reassessed in the wake of the first Global Freshwater Fauna Assessment (Sayer *et al.* 2025) and documentation standards improve and capture details of the most effective conservation interventions, the Red List has the potential to become a source for conservation evidence for freshwater species.

IUCN Green Status of Species

The IUCN Green Status of Species was launched in 2021 as a standardized tool for assessing the impact of conservation actions and species recovery (Grace *et al.* 2021). Specifically, it assesses four components, one of which, 'Conservation Legacy', uses counterfactuals to assess the impact that past conservation interventions have had on maintaining or improving a species' current Red List status. Conservation Legacy is thus the main Green Status data source on conservation evidence, whereas the other Green Status metrics of 'Conservation Dependence', 'Conservation Gain' and 'Recovery Potential' are short-term and long-term future projections of conservation impact and potential. Because Green Status assessments are broken down into spatial units, i.e. subdivisions of the species' range in which the state of the species is assessed (IUCN Green Status of Species Working Group 2024), they can capture more spatially detailed information about conservation impacts than Red List assessments. However, the coding of conservation actions that has led to the predicted change in species status in each spatial unit is currently recommended, not required (IUCN Green Status of Species Working Group 2024) and again follows the same broad Conservation Actions Classification Scheme as the Red List, so that additional documentation may be needed to define a conservation intervention accurately.

A total of 39 Green Status assessments (of a total of 157) have been published for species in freshwater systems (4 birds, 5 mammals, 3 reptiles, 13 amphibians, 3 fishes, 3 decapods, 1 dragonfly, 5 mussels and 2 liliopsid plants; International Union for Conservation of Nature and Natural Resources 2025). For these, Conservation Legacy was zero in some cases, either because no conservation actions were in place; or actions started too recently for any visible impact; or no actions were needed.

Medium or high Conservation Legacy is linked to the impacts of national or regional legislation (e.g. Philippine crocodile, *Crocodylus mindorensis*; van Weerd and Gatan-Balbas 2021), protected areas (e.g. blue crane, *Anthropoides paradiseus*; Craig *et al.* 2021), or improved trapping regulations (e.g. North American beaver, *Castor canadensis*; Snyderman *et al.* 2025). Most assessments give limited additional detail on the conservation actions that led to Conservation Legacy scores (beyond the Conservation Actions Classification Scheme).

Using evidence for assessing the condition of freshwater protected areas

There are many regional or international agreements, conventions and statutes whose principal objectives are to create protected areas of land or water for the benefit of habitats and species. There is general agreement that the process of selecting these and monitoring their condition over time should be based on evidence, but there are different approaches to the way this is achieved. The following five sections provide some examples of sources of evidence or tools for assessing evidence. For a wider geographical perspective, see the IUCN report by Moberg *et al.* (2024).

European Habitats Directive

At a European level, the overall aim of the Habitats Directive is to achieve 'favourable conservation status' for the habitats and species listed in its annexes. However, there are few published attempts at assessing conservation success for freshwater habitats and species included in the Directive. One example is a study on threats to freshwater habitats in Poland (Grzybowski and Glińska-Lewczuk 2019). Only 25.7% of the 72,673-km^2 total area of freshwater habitat covered by SACs in Poland was classified as favourable in the period 2013–18, whereas 68.7% was classified as unfavourable–inadequate or unfavourable–bad status.

How do individual EU Member States assess and report on the condition of the habitats and species within SACs, and what supporting evidence is needed? Data on SACs are managed by the European Environment Information and Observation Network (Eionet), which is a partnership network of the European Environment Agency (EEA, see https://www.eea.europa.eu/en) and its 38 member and cooperating countries. EEA and Eionet gather and develop data, knowledge, and advice to policymakers about Europe's environment (see https://www.eionet.europa.eu/). As part of this, Eionet provides guidance on how EU Member States should submit data on SACs to the European Commission (see https://cdr.eionet.europa.eu/help/natura2000). The reporting form includes definitions of the terms used for 'degree of conservation' for habitats and species, and for the conservation objectives for habitats and species. The degree of conservation for habitats should be described as 'Complete' (i.e. 'Complete survey or statistically robust estimate in hectares; for example, taken from mapping in management plans)', 'Limited' ('Based mainly on extrapolation from a limited amount of data (expert judgement))', 'Very limited' ('Based mainly on expert opinion with very limited data (based on partial mapping data))' or 'Unknown' ('Insufficient or no data available'). Similar non-specific terms define the degree of conservation for species as follows: 'Excellent', 'Good', 'Reduced' and 'Unknown'.

Wild and Scenic Rivers Act (USA)

Other national jurisdictions for managing and protecting freshwater ecosystems, and particularly river corridors, were discussed by Pittock *et al.* (2018) and Perry *et al.* (2021), and include the Wild and Scenic Rivers Act (WSRA) in the USA, established in 1968. The WSRA recognizes selected rivers and their riparian regions that possess 'outstandingly remarkable values' (ORVs; comparable to ecosystem services) that should be preserved in free-flowing condition (Moberg *et al.* 2024). Once a river has been designated, a comprehensive river management plan (CRMP) must be created. However, there are no standardized guidelines for defining the geographical areas over which the ORVs are monitored, creating inconsistent application (Perry 2017). Also, limited resources and funding may mean that CRMPs are not updated to meet changing ecological, climate, and management priorities for the river, and restrict the ability to undertake river quality monitoring (McDonagh 2020). Nevertheless, Field-Juma and Roberts-Lawler (2021) showed how, for rivers in New Jersey, the WSRA has helped create the necessary partnerships between government and local communities to implement river conservation plans, and thereby measure the benefits derived.

UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)

UNEP-WCMC is mandated by the CBD to collect information on protected area management effectiveness (PAME) and a 'framework for assessing management effectiveness of protected areas' has been published (Hockings *et al.* 2006). A Global Database on PAME also exists, but Juffe-Bignoli *et al.* (2016) noted that PAME tools need to be updated to ensure that 'they assess effectiveness across all components of aquatic integrity and address climate change adaptation for freshwater protected areas' (p. 138). Best known among the various tools is the Management Effectiveness Tracking Tool (METT) that was initially focused only on aspects of management, but has subsequently been developed to assess social and environmental outcomes (Stolton *et al.* 2021).

Ramsar Convention

A derivative of METT is the Ramsar Site Management Effectiveness Tracking Tool (R-METT) (Ramsar 2015). This tool provides a series of questions to assist Ramsar site managers in assessing the threats to the sites (ranked from low to high), many of which are comparable to the categories of threats used to assess species conservation status in the IUCN Red List. The tool also includes questions on management techniques and outcomes (i.e. evidence of success), ranked from 'Poor' to 'Excellent'. The tool allows the description of the ecological characteristics of the Ramsar site (but without any pre-defined definitions of those characteristics) and the assessment of the current state and trends in change of those characteristics, rated as 'Good', 'Low Concern', 'High Concern', 'Critical' and 'Data Deficient'. The lack of specific criteria to assess conservation outcomes and success means that R-METT may not be consistently applied to different Ramar sites. Parr *et al.* (2011) raised several concerns about the effectiveness of wetland management approaches and discussed several areas where they felt Ramsar management recommendations were ineffective.

Green List of Protected Areas

The Green List of Protected Areas (International Union for Conservation of Nature and World Commission on Protected Areas 2017) is another mechanism for reporting evidence of management effectiveness. Based on a Global Standard of Components and Criteria, supported by indicators, it measures how well protected and conserved areas are achieving conservation outcomes. The Components include one on 'Successful Conservation Outcomes' which has three criteria. The area must demonstrate:

- conservation of major natural value
- conservation of major associated ecosystem services, and
- conservation of major cultural values

Generally, these are assessed by science-based threshold values established through quantitative monitoring programs for the site, or expert scientific opinion and traditional ecological knowledge (see also box 6.1 in Moberg *et al.* 2024). Natural values are based on condition of intact ecosystems (ecological integrity); specific species; specific ecological communities or habitats; ecological features; ecological processes; geological features; and palaeontological features. The Green List assesses these values as being in 'Good', 'Fair' or 'Poor' condition. Further discussion of the process is provided by International Union for Conservation of Nature and World Commission on Protected Areas (2017) and the 'Components, Criteria and Indicators' section of the Green List website (see https://iucngreenlist.org/standard/components-criteria/).

Evidence of societal benefits and their contribution to conservation

Conservation of freshwater ecosystems also supplies measurable social and economic benefits that are evidence of success. Community-based knowledge and actions are often essential for this success and Speed *et al.* (2026) provided an overview of the types of societal benefits gained from freshwater restoration. Notably, there are few metrics for assessing these societal gains; below we outline one tool and review the importance of integrating community knowledge into assessing freshwater conservation success.

Protected area benefits assessment

The Protected Areas Benefits Assessment Tool+ (PA-BAT+) measures stakeholders' perceptions of the benefits derived from conservation and protection in protected areas (Ivanić *et al.* 2020). It provides a valuation (not necessarily quantitative) of the economic benefit of the ecosystem services resulting from ecosystem conservation. It has been applied in a few freshwater cases; for example, measuring ecosystem services generated by management of the Otun catchment in Colombia. However, this tool may be measuring benefits that are tangential to habitat and species change.

Traditional ecological knowledge

Traditional ecological knowledge (TEK; which incorporates Indigenous Knowledge) represents the cumulative knowledge, practices and beliefs regarding the relationship between organisms and their environment passed down through generations (Berkes 2017). International conventions and guidelines have started to recognize the worth of TEK as a valuable basis for biodiversity conservation. The CBD acknowledges TEK as central to conserving, restoring, and sustainably using biodiversity, emphasizing the critical role of Indigenous and local communities' knowledge and practices (Mekonen 2017). In addition, the importance of TEK in improving biodiversity conservation, assessment and monitoring, and in achieving UN Sustainable Development Goals has been recognized by the Millennium Ecosystem Assessment (MEA), reflected in the Aichi and GBF targets and supported by the Global Assessment of the Intergovernmental Science–Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Reid *et al.* 2005; McElwee *et al.* 2020). Notably, Indigenous People and Local Community (IPLC) territories represent 25–28% of the world's land area and encompass ~40% of all terrestrial protected areas and ecologically intact landscapes (Garnett *et al.* 2018).

The contribution by TEK to biodiversity assessment, monitoring and conservation in freshwater systems has been particularly relevant for fishes, covering aspects such as basic biology, abundance, and temporal and spatial patterns of distribution (de Sousa *et al.* 2022). TEK is being more explicitly incorporated into IUCN Red List assessments for freshwater fishes, starting with the completion of the Lake Tanganyika freshwater fish reassessments in 2025, where TEK was included from the riparian countries surrounding the lake (as reported at the 2025 IUCN World Conservation Congress, see https://iucncongress2025.org/programme/incorporating-traditional-knowledge-iucn-red-list-freshwater-perspective-lake-tanganyika). One of the most prominent aspects of TEK is its ability to detect phenomena over an extended timescale, thus compensating for the spatial and temporal limitations of scientific knowledge. This is of great importance in transboundary river basins that are exposed to increasing fragmentation by dams and inhabited by migratory species (Garavello *et al.* 2010). However, TEK may be more relevant when it comes to assessing evidence of biodiversity changes associated with species having socio-economic value, as is often the case for fisheries. In the Amazon Basin, for instance, the giant species *Arapaima gigas* (pirarucu) has represented up to 40% of fishing activity for local people (Queiroz and Sardinha 1999). With their participation, the abundance of pirarucu in the floodplain lakes was increased by incorporating the fishermen's fish counts, and their ability to identify adults and juveniles on the basis of subtle visual and acoustic cues. This allowed the definition of new catch quotas and the recovery of pirarucu in managed areas through revised fishing strategies (Castello 2023). Furthermore, TEK may be valuable for understanding baseline conditions of freshwater ecosystems. For instance, a TEK-based study helped identify 18 ecosystem services in a wetland situated in the Lower Gangetic floodplains, which had no prior ecological assessment (Adhya and Banerjee 2022). Moberg *et al.* (2025) published several case studies highlighting where the connectivity and protection of rivers have been secured through community-based knowledge and action.

However, TEK has its limitations in detecting changes in the biodiversity of freshwater ecosystems, or evidence of improvement, particularly in biologically complex systems such as large floodplain rivers. These ecosystems experience significant hydrological fluctuations that alter aquatic habitats, complicating the evaluation of conservation interventions (Baigún *et al.* 2025). Although local communities may accurately perceive changes in the abundance of large, iconic or economically important species such as large fishes, aquatic mammals, and reptiles, their knowledge is often limited regarding less visible taxa with no direct use value, such as plankton, benthic invertebrates and amphibians, which are nonetheless integral to aquatic biodiversity and ecological integrity. Fishermen may also exhibit a cognitive bias regarding trends in species abundance (Daw 2010), which can mask real evidence of changes in biodiversity. This occurs particularly when there is an intergenerational 'shifting baseline syndrome' as suggested by Pauly (1995), which can distort stakeholders' perceptions when they are asked to assess population trends (Papworth *et al.* 2009). Nevertheless, long-term TEK observations can help reconstruct the temporal and spatial patterns of species distribution, reducing retrospective biases in assessing species conservation status (O'Donnell *et al.* 2010).

Why is evidence often so hard to obtain?

Despite growing recognition of the need for evidence-based conservation, obtaining robust evidence remains challenging because of methodological constraints (e.g. inconsistent baselines and indicators, sparse temporal and spatial data, weak designs) and operational constraints (e.g. limited funding and technical capacities, access to technology, poor data-sharing systems).

Monitoring methods lacking sufficient complexity

Measuring changes in biodiversity, and, hence, evidence of conservation success, requires monitoring multiple variables, including genetic composition, species populations, species traits, community composition, ecosystem structure, and ecosystem functioning, as outlined in the categorization by the Group on Earth Observations Biodiversity Observation Network of 'Essential Biodiversity Variables' (Turak *et al.* 2017). Previously, monitoring these variables was limited by underdeveloped data, tools and standardized methodologies. However, improved or innovative technologies and the development of extensive integrated data systems have alleviated some of those problems (Turak *et al.* 2017). Yet, challenges remain in monitoring the effectiveness of interventions and presenting meaningful results. This includes finding control sites for comparison and implementing before–after study designs (Acreman *et al.* 2020; dos Reis Oliveira *et al.* 2020). Birnie-Gauvin *et al.* (2020) gave an example of where 'before–after–control–impact' (BACI) studies of freshwater habitats provide evidence that restoring connectivity for a river in Denmark improved fish population demographics. Nevertheless, adequate monitoring of the effectiveness of conservation actions (hence evidence of success) is often lacking (dos Reis Oliveira *et al.* 2020). A review of French river restoration projects showed that monitoring and evaluations were often not suitably robust, using insufficient numbers of sites or frequency of sampling before restoration, leading to inaccurately positive conclusions (Morandi *et al.* 2014). Similarly, an analysis of the effect of dam removal on fish populations in Spain indicated that systematic or organized fish population monitoring was not performed after the dam had been removed (Rodeles *et al.* 2017). Ecosystem structure and function variables, such as food webs, remain poorly documented, partly owing to system complexity and interacting variables. For example, large floodplain rivers have significant hydrological fluctuations that influence the habitats of aquatic and semi-aquatic organisms (Arrington and Winemiller 2006; Jiang *et al.* 2021; Hamer *et al.* 2023). This can make it difficult to assess the conservation success of an intervention. Also, conservation actions must often be balanced with social benefits that are hard to quantify. Nevertheless, there are documented examples of conservation and restoration success that have been based on complex socio-ecological systems (Finlayson 2020).

Poorly designed data management systems

In a review of biodiversity monitoring and evaluation, Dixon *et al.* (2019) identified major shortcomings, attributed mainly to the way the data are managed. More recent analyses, too, have shown that effective evaluation of conservation outcomes depends on robust data management and the integration of datasets (Binley *et al.* 2024). Evaluation strategies should be designed early in project planning and be based on clearly defined objectives (Morandi *et al.* 2014; dos Reis Oliveira *et al.* 2020). Downey *et al.* (2022) further emphasized that transparency, reproducibility and long-term data interoperability are fundamental to generating reliable, evidence-based guidance. It is also important to identify thresholds for biodiversity status and ecological end points, derived from integrated ecological, social and regulatory-based information that will help direct appropriate conservation actions (Morandi *et al*. 2014; Dixon *et al*. 2019). The increasing availability and dissemination of more detailed, linked datasets, and the development of appropriate policy targets (e.g. National Biodiversity Strategies and Action Plans) have the potential to strengthen these efforts.

Monitoring at inappropriate spatial and temporal scales

The scales at which conservation actions are implemented can also create challenges for effective monitoring of evidence of success. This is emphasized in a new European standard on river restoration (British Standards Institution 2025), which stresses the importance of understanding a river at the catchment scale before embarking on restoration, even when specific actions are undertaken at smaller scales. This is illustrated by the restoration of Eddleston Water, a stream that falls within the EU Special Area of Conservation (SAC) for the River Tweed catchment (Fig. 3). The project aimed at gathering evidence on the effectiveness of natural flood management techniques and habitat restoration measures at a catchment scale. An extensive monitoring network covering hydrology, river morphology and ecology was set up to assess the impact of restoration. Monitoring is still continuing more than 10 years after restoration. So far, results have shown reduced peak water levels downstream during heavy rain and a recovery in the diversity and numbers of aquatic invertebrates (Spray *et al*. 2022).

A study of more than 40 years of lowland stream restoration in the Netherlands also demonstrated that restoration practices are often restricted to small scales, even though it is necessary to track multiple stressors acting over large scales to obtain meaningful evidence of success or failure (dos Reis Oliveira *et al*. 2020). Moreover, studies are often in areas of reasonable environmental condition, where success is more likely and more easily achieved, rather than for highly modified streams where evidence of success will be dependent on higher investment in restoration. Increased and sustained funding is essential for strengthening the frameworks for monitoring and evaluation, and for supporting the necessary human resources of expertise and time (Dixon *et al*. 2019).

Monitoring for outcomes must be conducted over a prolonged period (e.g. years to decades) to detect genuine trends over short-term anomalies. For example, species populations often fluctuate within and among years, owing to factors such as temperature. The Smithsonian Tropical Research Institute (STRI) has been monitoring ecosystems in Panama for a century, exemplifying the benefits of research and data assimilation that extend across decades owing to multiple investigators working across generations (Wright 2020). The results of STRI's research have been reported in more than 16,000 scientific publications (Smithsonian Tropical Research Institute 2024). However, this prolonged monitoring can be expensive and difficult to sustain, even in developed countries (Acreman *et al*. 2020, citing Hockings *et al*. 2006). For example, the STRI, with ~25 resident staff scientists, 370 employees, and about 1400 visiting researchers, has an operating budget of about US$30 million (Smithsonian Tropical Research Institute 2024), directed at documenting important, long-term changes in ecosystem health. However, STRI may be an anomaly; available funding is usually short-term for most programmes, prioritizing novelty and quick returns on investment over sustained efforts (Cooke *et al*. 2024; Cracknell *et al*. 2024). Thus, monitoring may not be implemented over the long ecological timeframes required, but is often restricted within the timeframes of projects (1–3 years) or political, financial or policy cycles (4–5 years). Even in the latter cases, practitioners or policymakers often require faster insights than ecological research can provide (Dixon *et al*. 2019). Consequently, monitoring may not happen at

Fig. 3. (*a*) Re-meandering of a 3.5-km straightened stretch of the Eddleston Water, south-east Scotland; (*b*) Re-connecting the river and its floodplain. Figures reproduced by permission of Tweed Forum.

all, and there may be geographical biases in data availability (see the 'Improving data quality and equity' section), making it impossible to evaluate conservation success or failure.

The challenge of using evidence for promoting freshwater conservation

Having described some of the barriers that hinder the effective collection, assessment, and use of freshwater conservation data, the challenge remains to find ways to make evidence-based conservation a reality. This is consistent with the aim of the Alliance for Freshwater Life (Darwall *et al.* 2018), which is 'to engage with conservation professionals, civil society, government and policymakers, and to place freshwater species and their associated ecosystems on the global agenda as legitimate targets for conservation action' (p. 1018).

Improving the quantity and quality of available evidence

Looking more broadly at protected and conserved areas globally, several tools have been used for measuring management effectiveness, on the basis of specific criteria, and documenting evidence of success. Moberg *et al.* (2024) discussed some of the general characteristics of freshwater ecosystems that should be monitored to obtain evidence for assessing management effectiveness. These include the hydrological regime (magnitude, frequency, duration and timing of flow events), connectivity of aquatic ecosystems; water quality, and instream and riparian habitat structure and biotic composition. Moberg *et al.* (2024, table 6.4) also discussed the key features for indicators that should be used to monitor the characteristics of ecosystems, and their change under conservation management. For example, they recommended that the indicators should:

- have a predictable and verifiable relationship to the element being measured;
- be sensitive to change, so they give evidence that management actions have an effect;
- assess impacts of known pressures and detect new pressures; and
- reflect changes that have direct implications for management from an ecological and social perspective (demographics of key species, agreed fishing levels); and reflect changes over scales and periods that are relevant to management.

These key features are directed at management effectiveness; however, in most cases, this also measures conservation effectiveness and success. Several of these key features are closely related, but indicate the rigorous processes required to assess and report on biodiversity responses and outcomes of conservation action (Acreman *et al.* 2020).

Various suggestions for improving the process and criteria for assessing conservation effectiveness were set out by Acreman *et al.* (2020). They recommended new metrics for assessing spatial and temporal variations in ecological processes and their responses to stressors, and noted that invertebrates, plants and algae, which are abundant and important components of ecosystem functions, are often under-surveyed. Similarly, they emphasized the need to monitor environmental factors such as climate, geology, soils, vegetation and water flows that affect biodiversity, and hence conservation outcomes. The geographical location of analysis also plays an important role in evaluating conservation evidence. For instance, most of the best available information comes from temperate areas where biodiversity is much lower than in tropical and subtropical regions, where information is much scarcer.

Evidence where conservation actions fail, not only where they succeed

Evidence of where conservation action has failed, and the reasons behind those failures, is equally as important as evidence of success. However, such information and the lessons learned for avoiding similar mistakes in the future, are rarely published (Catalano *et al.* 2019). This was confirmed by two initial bibliographic searches conducted for this study, targeting freshwater conservation-, protection- or restoration-related articles, from 2000 to the present, including keyword title terms such as 'fail', 'hinder' and 'lessons learned'. The searches produced 351 and 413 articles respectively, which is a surprsingly low number for such a potentially broad topic. However, it is also possible that project failures might be discussed in the full text of an article but are not its main focus; hence, information will be hard to retrieve through literature searches. A key barrier to reporting failures is the institutional disincentive to disclose unsuccessful outcomes, often driven by concerns over reputation, funding continuity or perceived inefficiency (Catalano *et al.* 2019). Promoting a culture of learning and adaptive management is essential for improving transparency and iterative conservation planning. This is illustrated by a study of river restoration in Germany (Jähnig *et al.* 2011), which concluded that restoration 'success' is often a matter of perspective. As well as comparing the conclusions using objective or subjective measures, the authors also suggested that in some cases self-evaluation by water managers may lead them to attribute success to a restoration scheme with flimsy evidence in an effort to show that progress is being made towards meeting the targets of the EU Water Framework Directive. Similarly, Palmer *et al.* (2010) suggested that there is often an acceptance that certain types of restoration activities are the right ones, on the basis of assuming links between specific physical drivers of change and necessary physical responses.

Understanding where and why previous conservation efforts have been successful or have failed has been identified as one of the '25 essential research questions to inform the protection and restoration of freshwater biodiversity' (Harper *et al.* 2021, p. 2641). It may also directly inform several of the other essential questions they identified; for example, 'how can we improve monitoring metrics and resources to guide restoration, conservation and sustainable management of freshwater biodiversity?'

Balancing ecological and social needs

As the conservation community continues to build information on conservation success, it will be important to ensure that this is grounded on integrating the ecological and social dimensions of the ecosystems being managed and conserved. This interdisciplinary approach is necessary to track progress towards the policy targets of several international agreements. For example, the GBF is focused on reducing threats to biodiversity, and meeting people's needs through sustainable use and equitable benefit-sharing. The Ramsar Convention on Wetlands calls for maintaining the ecological character of wetlands, 'achieved through the implementation of ecosystem approaches, within the context of sustainable development'. The complexities of these socio-ecological approaches have been noted above. Nevertheless, there are case studies on river, floodplain and wetland restoration programmes both in the global south and north that have jointly achieved components of habitat restoration and provision of ecosystem services, thereby benefitting both biodiversity and human societies (Mohanty and Panda 2020; Serra-Llobet *et al.* 2022; Moberg *et al.* 2025).

Subjectivity in the analysis of evidence

In this article, we have set out why it is important to obtain evidence on whether or not specific conservation actions are effective. Yet, some of the case studies described in this article suggest that subjectivity may often influence the analysis of evidence. For example, Annex III of the EU Habitats Directive sets out criteria for Sites of Community Importance (which are the precursors of SACs) that illustrate the difficulty of applying these using objective evidence. One of these criteria is 'Degree of conservation of the structure and functions of the natural habitat type concerned and restoration possibilities', but guidance on the type of evidence needed to assess 'Degree of conservation' (see https://www.eionet.europa.eu/) raises more questions than answers. In addition, the EU Habitats Directive uses qualitative categories ('Excellent', 'Good', etc.) to rate the conservation status of species, an approach that leaves room for subjective interpretation.

The definitions of these terms illustrate the fundamental problem of removing, or at least reducing, subjectivity in determining conservation success or failure. Who decides what 'excellent' or 'good' means in the context of conservation, and how? The word 'evidence' appears in a guidance document on *Proposing the removal of habitats and species from the subjects of protection of a Natura 2000 site* (Sub-Expert Group on the Birds and Habitats Directives 2021). This explains that proposing such removals constitutes an 'exceptional' action and must be justified using sound and conclusive scientific evidence. The types of evidence required to enable the European Commission to make a decision are presented in a series of questions, such as:

- What is the quality of available data?
- What protection and conservation, including restoration, measures have been established and implemented for the habitat or species proposed for deletion in the site?

However, there is scant guidance on what would constitute acceptable evidence, which is critically important for evidence-based conservation.

Transferring and applying evidence

Even when conservation evidence is available, its transfer among conservation researchers, practitioners and policymakers remains challenging (Sutherland *et al.* 2019). Acreman *et al.* (2020) found that quantitative evidence of the effectiveness (positive, negative or neutral) of freshwater protected areas was provided in fewer than 2% of the 2586 publications returned through their systematic review of the published information. When presented, conservation evidence must be accessible, comprehensible, and unambiguous (Barouillet *et al.* 2024). In practice, locating such information can be time-consuming (e.g. see the methods used by Thornton *et al.* 2025), the information may be inaccessible (e.g. set behind paywalls) or be presented in a language different from that of the practitioners who need it to implement their own conservation efforts (Sutherland *et al.* 2019). In addition, the information is often presented in a way in which the conservation application is assumed rather than clearly described (Boon and Baxter 2021).

These barriers are compounded when there is poor communication between scientists and managers, which can result in misaligned priorities; scientists produce research that is not easily applied (and at most can only make recommendations), and managers make decisions often without considering available evidence (Dixon *et al.* 2019; Farwig *et al.* 2025). Arthington (2021) similarly noted that conservation and management activities have tended to operate in silos, and that effective freshwater conservation requires 'collaboration across stakeholders with indigenous, societal, and scientific knowledge, technical expertise, and credentials at all levels of governance' (p. 4). As noted in the 'Poorly designed data management systems' section, this integration of Indigenous and community expert knowledge brings an essential source of information to project implementation and monitoring (e.g. in the restoration of the Senegal River; Hamerlynck and Duvail 2003), and improves the relevance and acceptance of conservation actions. Expert community knowledge has been shown to be especially important where monitoring of ecosystem status and conservation action can be developed using more qualitative rather than quantitative data (Esselman and Opperman 2010). The importance of communication in the field of conservation has been well summarized by Hoesen and Lemieux (2026), who stressed the need for 'strategic, evidence-based communication approaches that balance optimism with realism, integrate diverse knowledge systems, and resonate across audiences'.

Recommendations

On the basis of our analysis, the following recommendations are made to help improve the effectiveness of evidence-based freshwater conservation:

Improving data quality and equity

a. Improve geographical equity by increasing the quantity and quality of data on biodiversity, threats and impacts in the Global South, particularly in subtropical and tropical areas, and create or reinforce regional platforms to collate freshwater evidence.
b. Incorporate evidence on socio-ecological aspects, including inputs from Indigenous and local communities.
c. Define terms used in evaluations to describe conservation status (e.g. for Habitats Directive) and explain how they have been derived.
d. Develop improved systems for classifying conservation actions and ensure that these are reflected in databases used for storing the results.

Enhancing cost-effectiveness

a. Understand that information gathered over time should never be considered as an unnecessary expense, but rather an investment that provides more robust evidence of biodiversity changes to support conservation planning.
b. Encourage the use of evidence-based indicators in the requirements of major funding agencies (e.g. World Bank) and national biodiversity strategies to improve the cost-effectiveness of conservation programmes.

Strengthening monitoring design

a. Ensure that conservation monitoring programmes are fit for purpose, both in the variables included and at the spatial and temporal scales applied, and report the results of conservation interventions that have been unsuccessful as well as those that have succeeded.
b. Apply robust sampling designs by collecting data before conservation actions are implemented and conduct sufficient post-action monitoring to improve the reliability of evidence used for determining the degree of success.
c. Reconsider regularly the evidence on established conservation interventions and consider alternatives where there is evidence of negative trade-offs.
d. As well as applying scientific methods to obtain evidence, draw on local and traditional knowledge and the expertise of users who are familiar with the water bodies and make use of their resources.
e. Increase investment by government organizations, NGOs, universities, and others in building local capacity to facilitate long-term freshwater monitoring, especially in least developed countries.

Improving evidence transfer

a. Communicate transparently the way that evidence on conservation actions has been analysed, especially explaining the role of expert opinion and subjectivity and whether or not this might have contributed to the conclusions.
b. Improve the transfer of evidence appraisals of conservation actions and make the results freely accessible in ways that are designed to meet the needs of a range of stakeholders.
c. Expand educational opportunities for using evidence to demonstrate conservation actions that are effective as well as those that are not.

Implications for policy development

a. Ensure compatibility among the methods used by different countries for analysing evidence for reporting under the same international policy commitments (e.g. Ramsar Convention, EU Habitats Directive).
b. Encourage evidence-based policy rather than seeking to gather policy-based evidence, and to treat evidence as a learning process to allow adaptive management, rather than a static output.

References

Acreman M, Hughes KA, Arthington AH, *et al.* (2020) Protected areas and freshwater biodiversity: a novel systematic review distils eight lessons for effective conservation. *Conservation Letters* **13**, e12684. doi:10.1111/conl.12684

Addy S, Cooksley S, Dodd N, *et al.* (2016) River restoration and biodiversity: nature-based solutions for restoring rivers in the UK and Republic of Ireland. CRW2014/10. (International Union for the Conservation of Nature National Committee UK: Rhosesmor, Wales; and Scotland's Centre of Expertise for Waters: Aberdeen, Scotland) Available at https://iucn-nc.uk/wp-content/uploads/2017/05/low-res-river-restoration-and-biodiversity_web.pdf

Adhya T, Banerjee S (2022) Impact of wetland development and degradation on the livelihoods of wetland-dependent communities: a case study from the Lower Gangetic Floodplains. *Wetlands* **42**(7), 65. doi:10.1007/s13157-022-01588-w

Adhya T, Banerjee S, Dey P, *et al.* (2024) Density estimation of the globally threatened fishing cat *Prionailurus viverrinus* through a participatory science approach in the Chilika lagoon, eastern India. *Endangered Species Research* **54**, 1–13. doi:10.3354/esr01322

Al-Fulaij N, Abbott P, Bowmer A, *et al.* (2025) Approaches for integrating evidence of the effectiveness of actions in conservation funding to inspire more effective practice. *Ecological Solutions and Evidence* **6**(1), e12404. doi:10.1002/2688-8319.12404

Ardoin NM, Bowers AW, Gaillard E (2020) Environmental education outcomes for conservation: a systematic review. *Biological Conservation* **241**, 108224. doi:10.1016/j.biocon.2019.108224

Arrington DA, Winemiller KO (2006) Habitat affinity, the seasonal flood pulse, and community assembly in the littoral zone of a Neotropical floodplain river. *Journal of the North American Benthological Society* **25**(1), 126–141. doi:10.1899/0887-3593(2006)25[126:HATSFP]2.0.CO;2

Arthington AH (2021) Grand challenges to support the freshwater biodiversity Emergency Recovery Plan. *Frontiers in Environmental Science* **9**, 664313. doi:10.3389/fenvs.2021.664313

Baigún C, Lechuga Sánchez JF, Himes-Cornell A (2025) Global perspective on the potential application of the concept of other effective area conservation measures in inland fisheries. In 'Exploring the role of inland fisheries area-based management in conserving freshwater biodiversity'. (Eds JF Lechuga Sánchez, A Himes-Cornell) FAO Fisheries and Aquaculture Technical Paper number 733, pp. 11–56. (Food and Agriculture Organization of the United Nations: Rome, Italy) doi:10.4060/cd4881en

Baron J (2018) A brief history of evidence-based policy. *The ANNALS of the American Academy of Political and Social Science* **678**(1), 40–50. doi:10.1177/0002716218763128

Barouillet C, González-Trujillo JD, Geist J, *et al.* (2024) Freshwater conservation: lost in limnology? *Aquatic Conservation: Marine and Freshwater Ecosystems* **34**(1), e4049. doi:10.1002/aqc.4049

Berkes F (2017) 'Sacred ecology: traditional ecological knowledge and resource management', 4th edn. (Routledge: New York, NY, USA) doi:10.4324/9781315114644

Binley AD, Vincent JG, Rytwinski T, *et al.* (2024) Making the most of existing data in conservation research. *Perspectives in Ecology and Conservation* **22**, 122–128. doi:10.1016/j.pecon.2023.11.004

Birnie-Gauvin K, Nielsen J, Frandsen SB, *et al.* (2020) Catchment-scale effects of river fragmentation: a case study on restoring connectivity. *Journal of Environmental Management* **264**, 110408. doi:10.1016/j.jenvman.2020.110408

Boon PJ, Baxter JM (2021) Editorial: putting the conservation into *Aquatic Conservation*. *Aquatic Conservation: Marine and Freshwater Ecosystems* **31**(8), 1927–1928. doi:10.1002/aqc.3630

British Standards Institution (2025) Guidance standard on a strategic approach to river restoration. BS EN 18025:2025. (BSI: London, UK) Preview available at https://knowledge.bsigroup.com/products/water-quality-guidance-standard-on-a-strategic-approach-to-river-restoration

Castello L (2023) Filling global gaps in monitoring data with local knowledge. *Aquatic Conservation: Marine and Freshwater Ecosystems* **33**, 423–430. doi:10.1002/aqc.3937

Catalano AS, Lyons-White J, Mills MM, Knight AT (2019) Learning from published project failures in conservation. *Biological Conservation* **238**, 108223. doi:10.1016/j.biocon.2019.108223

Cheng C, Ma Z (2023) Conservation interventions are required to improve bird breeding performance in artificial wetlands. *Biological Conservation* **278**, 109872. doi:10.1016/j.biocon.2022.109872

Christie AP, Amano T, Martin PA, *et al.* (2021) The challenge of biased evidence in conservation. *Conservation Biology* **35**(1), 249–262. doi:10.1111/cobi.13577

Collen B, Dulvy NK, Gaston KJ, *et al.* (2016) Clarifying misconceptions of extinction risk assessment with the IUCN Red List. *Biology Letters* **12**(4), 20150843. doi:10.1098/rsbl.2015.0843

Cooke SJ, Cook CN, Nguyen VM, *et al.* (2023) Environmental evidence in action: on the science and practice of evidence synthesis and evidence-based decision-making. *Environmental Evidence* **12**, 10. doi:10.1186/s13750-023-00302-5

Cooke S, Kinsley E, Armstrong O, *et al.* (2024) Increasing the effectiveness of environmental funder-fundraiser relationships. (Environmental Funders Network) Available at https://www.greenfunders.org/resources/increasing-the-effectiveness-of-environmental-funder-fundraiser-relationships/

Cordeiro J, Cummings K (2012) Fat pocketbook *Potamilus capax*. In 'The IUCN Red List of Threatened Species 2012'. e.T18091A1677819. (International Union for Conservation of Nature and Natural Resources) Available at https://www.iucnredlist.org/species/18091/1677819

Cracknell J, Miller F, Cremona P, Godwin H (2024) Where the green grants went 9. Patterns of UK Funding for Environmental Work. (Environmental Funders Network) Available at https://www.greenfunders.org/resources/where-the-green-grants-went-9/

Craig CA, Scott A, Scott M (2021) Blue crane *Anthropoides paradiseus*. In 'The IUCN Red List of Threatened Species 2021'. e.T22692109A2269210920261. (International Union for Conservation of Nature and Natural Resources) Available at https://www.iucnredlist.org/species/22692109/177514877 [Green Status assessment]

Cutts V, Berthinussen A, Reynolds SA, *et al.* (2024) Conservation evidence series synopses. University of Cambridge, Cambridge, UK. Available at https://www.conservationevidence.com/synopsis/pdf/39

Dala-Corte RB, Melo AS, Siqueira T, *et al.* (2020) Thresholds of freshwater biodiversity in response to riparian vegetation loss in the Neotropical region. *Journal of Applied Ecology* **57**(7), 1391–1402. doi:10.1111/1365-2664.13657

Darwall W, Bremerich V, De Wever A, *et al.* (2018) The *Alliance for Freshwater Life*: a global call to unite efforts for freshwater biodiversity science and conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems* **28**(4), 1015–1022. doi:10.1002/aqc.2958

Daw TM (2010) Shifting baselines and memory illusions: what should we worry about when inferring trends from resource user interviews? *Animal Conservation* **13**, 534–535. doi:10.1111/j.1469-1795.2010.00418.x

de Sousa WL, Zacardi DM, Vieira TA (2022) Traditional ecological knowledge of fishermen: people contributing towards environmental preservation. *Sustainability* **14**, 4899. doi:10.3390/su14094899

Dixon KM, Cary GJ, Worboys GL, *et al.* (2019) Features associated with effective biodiversity monitoring and evaluation. *Biological Conservation* **238**, 108221. doi:10.1016/j.biocon.2019.108221

dos Reis Oliveira PC, van der Geest HG, Kraak MHS, *et al.* (2020) Over forty years of lowland stream restoration: lessons learned? *Journal of Environmental Management* **264**, 110417. doi:10.1016/j.jenvman.2020.110417

Downey H, Bretagnolle V, Brick C, *et al.* (2022) Principles for the production of evidence-based guidance for conservation actions. *Conservation Science and Practice* **4**(5), e12663. doi:10.1111/csp2.12663

Esselman PC, Opperman JJ (2010) Overcoming information limitations for the prescription of an environmental flow regime for a Central American river. *Ecology and Society* **15**(1), 6. doi:10.5751/ES-03058-150106

Farwig N, Sprenger P, Baur B (2025) Identifying major factors for success and failure of conservation programs in Europe. *Environmental Management* **75**, 425–443. doi:10.1007/s00267-024-02086-x

Field-Juma A, Roberts-Lawler N (2021) Using partnerships and community science to protect wild and scenic rivers in the eastern United States. *Sustainability* **13**, 2102. doi:10.3390/su13042102

Finlayson CM (2020) An overview of the restoration and management of Chilika Lagoon: successful application of the Ramsar wise use guidelines. In 'Ecology, conservation, and restoration of Chilika Lagoon, India'. (Eds C Finlayson, G Rastogi, D Mishra, A Pattnaik) *Wetlands: Ecology, Conservation and Management*, vol. 6, pp. 7–21. (Springer: Cham, Switzerland) doi:10.1007/978-3-030-33424-6_2

Garavello JC, Garavello JP, Oliveira AK (2010) Ichthyofauna, fish supply and fishermen activities on the mid-Tocantins River, Maranhão State, Brazil. *Brazilian Journal of Biology* **70**, 575–585. doi:10.1590/s1519-69842010000300014

Garnett ST, Burgess ND, Fa JE, *et al.* (2018) A spatial overview of the global importance of Indigenous lands for conservation. *Nature Sustainability* **1**, 369–374. doi:10.1038/s41893-018-0100-6

Ghoddousi A, Loos J, Kuemmerle T (2022) An outcome-oriented, social–ecological framework for assessing protected area effectiveness. *BioScience* **72**(2), 201–212. doi:10.1093/biosci/biab114

Goren M (2014) Yarkon bream *Acanthobrama telavivensis*. In 'The IUCN Red List of Threatened Species 2014'. e.T61249A19009597. (International Union for Conservation of Nature and Natural Resources) Available at https://www.iucnredlist.org/species/61249/19009597

Grace MK, Bennett EL, Akçakaya HR (2021) IUCN launches Green Status of Species: a new standard for species recovery. *Oryx* **55**(5), 651–652. doi:10.1017/S0030605321000880

Grzybowski M, Glińska-Lewczuk K (2019) Principal threats to the conservation of freshwater habitats in the continental biogeographical region of Central Europe. *Biodiversity and Conservation* **28**, 4065–4097. doi:10.1007/s10531-019-01865-x

Hamer AJ, Czeglédi I, Gál B, *et al.* (2023) Hydrology is a major influence on amphibian abundance in a large European floodplain. *Freshwater Biology* **68**(8), 1303–1318. doi:10.1111/fwb.14104

Hamerlynck O, Duvail S (2003) The rehabilitation of the Delta of the Senegal River in Mauritania. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland, and Cambridge, UK) Available at https://portals.iucn.org/library/sites/library/files/documents/WTL-029.pdf

Haque KA (1971) Rotenone and its use in eradication of undesirable fish from ponds. *Pakistan Journal of Scientific and Industrial Research* **14**, 385–387.

Harper M, Mejbel HS, Longert D, *et al.* (2021) Twenty-five essential research questions to inform the protection and restoration of freshwater biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems* **31**(9), 2632–2653. doi:10.1002/aqc.3634

Hayward MW (2011) Using the IUCN Red List to determine effective conservation strategies. *Biodiversity and Conservation* **20**, 2563–2573. doi:10.1007/s10531-011-0091-3

Hockings M, Stolton S, Leverington F, *et al.* (2006) 'Evaluating effectiveness: a framework for assessing management effectiveness of protected areas', 2nd edn. (IUCN: Gland, Switzerland)

Hoesen J, Lemieux CJ (2026) Communicating conservation effectiveness: balancing optimism, tradeoffs and realism in conservation success narratives. *PARKS* **32**(1), 97–107. doi:10.2305/JUGF4326

International Union for Conservation of Nature and Natural Resources (2012) 'IUCN Red List categories and criteria: version 3.1', 2nd edn. (IUCN: Gland, Switzerland)

International Union for Conservation of Nature and Natural Resources (2013) Documentation standards and consistency checks for IUCN Red List assessments and species accounts. Version 2. Adopted by the IUCN Red List Committee and IUCN SSC Steering Committee. (IUCN) Available at https://nc.iucnredlist.org/redlist/resources/files/1530703338-RL_Standards_Consistency.pdf

International Union for Conservation of Nature and Natural Resources (2023) Global species action plan: supporting implementation of the Kunming Montreal Global Biodiversity Framework. (IUCN: Gland, Switzerland) Available at https://portals.iucn.org/library/sites/library/files/documents/2023-029-En.pdf

International Union for Conservation of Nature and Natural Resources (2025) The IUCN Red List of Threatened Species. Version 2025-2. (IUCN) Available at https://www.iucnredlist.org

International Union for Conservation of Nature and World Commission on Protected Areas (2017) IUCN Green List of Protected and Conserved Areas: Standard, Version 1.1. (IUCN: Gland, Switzerland) Available at https://portals.iucn.org/library/sites/library/files/resrecrepattach/IUCN%20Green%20List%20Standard%20Version%201.1%20-%2025%20September%202018%20update.pdf

IUCN Green Status of Species Working Group (2024) Background and Guidelines for the IUCN Green Status of Species. Version 2.0. (IUCN) Available at https://nc.iucnredlist.org/redlist/content/attachment_files/GSS_Background_and_Guidelines_Version_2_August_2024.pdf

IUCN Standards and Petitions Committee (2024) Guidelines for Using the IUCN Red List Categories and Criteria. Version 16. (International Union for Conservation of Nature) Available at https://www.iucnredlist.org/documents/RedListGuidelines.pdf

Ivanić K-Z, Stolton S, Figueroa Arango C, Dudley N (2020) Protected Areas Benefits Assessment Tool + (PA-BAT+): a tool to assess local stakeholder perceptions of the flow of benefits from protected areas. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland) Available at https://portals.iucn.org/library/sites/library/files/documents/PATRS-004-En.pdf

Jähnig SC, Lorenz AW, Hering D, *et al.* (2011) River restoration success: a question of perception. *Ecological Applications* **21**(6), 2007–2015. doi:10.1890/10-0618.1

Jiang X, Zheng P, Cao L, Pan B (2021) Effects of long-term floodplain disconnection on multiple facets of lake fish biodiversity: decline of alpha diversity leads to a regional differentiation through time. *Science of The Total Environment* **763**, 144177. doi:10.1016/j.scitotenv.2020.144177

Juffe-Bignoli D, Harrison I, Butchart SHM, *et al.* (2016) Achieving Aichi Biodiversity Target 11 to improve the performance of protected areas and conserve freshwater biodiversity. *Aquatic Conservation: Marine and Freshwater Ecosystems* **26**(S1), 133–151. doi:10.1002/aqc.2638

Larsen PO, von Ins M (2010) The rate of growth in scientific publication and the decline in coverage provided by Science Citation Index. *Scientometrics* **84**(3), 575–603. doi:10.1007/s11192-010-0202-z

Logar I, Brouwer R, Paillex A (2019) Do the societal benefits of river restoration outweigh their costs? A cost–benefit analysis. *Journal of Environmental Management* **232**, 1075–1085. doi:10.1016/j.jenvman.2018.11.098

Mace GM (2014) Whose conservation? *Science* **345**, 1558–1560. doi:10.1126/science.1254704

McDonagh A (2020) Wild and scenic rivers management plan implementation. A river level perspective. (Interagency Wild and Scenic Rivers Coordinating Council) Available at https://www.river-management.org/assets/WildandScenic/2020/CRMPFinalReport.pdf

McElwee P, Fernandez-Llamazares Á, Aumeeruddy-Thomas Y, *et al.* (2020) Working with Indigenous and local knowledge (ILK) in large-scale ecological assessments: reviewing the experience of the IPBES Global Assessment. *Journal of Applied Ecology* **57**, 1666–1676. doi:10.1111/1365-2664.13705

Mekonen S (2017) Roles of traditional ecological knowledge for biodiversity conservation. *Journal of Natural Sciences Research* **7**(15), 21–27. https://api.semanticscholar.org/CorpusID:59381156

Metcalfe AN, Kennedy TA, Mendez GA, Muehlbauer JD (2022) Applied citizen science in freshwater research. *WIREs Water* **9**(2), e1578. doi:10.1002/wat2.1578

Moberg T, Abell R, Dudley N, *et al.* (2024) Designing and managing protected and conserved areas to support inland water ecosystems and biodiversity. IUCN WCPA Technical Report Series Number 8. (International Union for Conservation of Nature and Natural Resources: Gland, Switzerland) Available at https://portals.iucn.org/library/sites/library/files/documents/PATRS-008-En.pdf

Moberg T, Shahbol N, Fitzsimons J, *et al.* (2025) Designing protected and conserved areas to support free-flowing rivers: environmental flows, connectivity and communities. *PARKS* **31**(2), 47–58. doi:10.2305/VIGB3354

Mohanty SK, Panda D (2020) Fish and fisheries of Chilika: post-restoration scenario. In 'Ecology, conservation, and restoration of Chilika Lagoon, India'. (Eds C Finlayson, G Rastogi, D Mishra, A Pattnaik) *Wetlands: Ecology, Conservation and Management*, vol. 6, pp. 295–333. (Springer: Cham, Switzerland) doi:10.1007/978-3-030-33424-6_12

Morandi B, Piégay H, Lamouroux N, Vaudor L (2014) How is success or failure in river restoration projects evaluated? Feedback from French restoration projects. *Journal of Environmental Management* **137**, 178–188. doi:10.1016/j.jenvman.2014.02.010

O'Donnell KP, Pajaro MG, Vincent ACJ (2010) How does the accuracy of fisher knowledge affect seahorse conservation status? *Animal Conservation* **13**, 526–533. doi:10.1111/j.1469-1795.2010.00377.x

Palmer MA, Menninger HL, Bernhardt E (2010) River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice? *Freshwater Biology* **55**(s1), 205–222. doi:10.1111/j.1365-2427.2009.02372.x

Papworth SK, Rist J, Coad L, Milner-Gulland EJ (2009) Evidence for shifting baseline syndrome in conservation. *Conservation Letters* **2**(2), 93–100. doi:10.1111/j.1755-263X.2009.00049.x

Parr JWK, Sricharoen Y, Pichaisiri A, *et al.* (2011) Community-based wetland management at Goot Ting marshes, northeast Thailand: implications for policy and practice. *International Journal of Environment and Sustainable Development* **10**(1), 96–118. doi:10.1504/IJESD.2011.037693

Pauly D (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution* **10**(10), 430. doi:10.1016/S0169-5347(00)89171-5

Perry D (2017) Reframing the Wild and Scenic Rivers Act: ecosystem-based resilience and adaptation. *International Journal of Wilderness* **23**(2), 41–48.

Perry D, Harrison I, Fernandes S, *et al.* (2021) Global analysis of durable policies for free-flowing river protections. *Sustainability* **13**, 2347. doi:10.3390/su13042347

Piégay H, Arnaud F, Belletti B, *et al.* (2023) Why consider geomorphology in river rehabilitation? *Land* **12**(8), 1491. doi:10.3390/land12081491

Pittock J, Thieme M, Blom E, Willems D (2018) Freshwater protected area corridors. In 'Freshwater ecosystems in protected areas: conservation and management'. (Eds CM Finlayson, AH Arthington, J Pittock) pp. 177–189. (Routledge, Taylor & Francis: London, UK; and New York, NY, USA) doi:10.4324/9781315226385

Pullin AS, Knight TM (2009) Doing more good than harm – building an evidence-base for conservation and environmental management. *Biological Conservation* **142**(5), 931–934. doi:10.1016/j.biocon.2009.01.010

Pullin AS, Knight TM, Stone DA, Charman K (2004) Do conservation managers use scientific evidence to support their decision-making? *Biological Conservation* **119**(2), 245–252. doi:10.1016/j.biocon.2003.11.007

Queiroz HL, Sardinha AD (1999) A preservação e o uso sustentado dos pirarucus (*Arapaima gigas*, Osteoglossidae) em Mamirauá. In 'Estratégias para manejo dos recursos pesqueiros em Mamirauá'. (Eds HL Queiroz, WGR Crampton) pp. 108–141. (SCM, CNPq/MCT: Brasília, Brazil) [In Portuguese]

Ramsar (2015) Resolution XII.15 Evaluation of the management and conservation effectiveness of Ramsar Sites. In '12th Meeting of the Conference of the Parties to the Convention on Wetlands (Ramsar, Iran, 1971)', 1–9 June 2015, Punta del Este, Uruguay. (Convention on Wetlands Secretariat: Gland, Switzerland) Available at https://www.ramsar.org/sites/default/files/documents/library/cop12_res15_management_effectiveness_e.pdf

Ratnani I, Fatima S, Abid MM, *et al.* (2023) Evidence-based medicine: history, review, criticisms, and pitfalls. *Cureus* **15**(2), e35266. doi:10.7759/cureus.35266

Reid MW, Mooney HA, Cropper A, *et al.* (2005) 'Ecosystems and Human Well-being: Synthesis.' A Report of the Millennium Ecosystem Assessment. (Island Press: Washington DC, USA) Available at https://www.millenniumassessment.org/documents/document.356.aspx.pdf

Reid JL, Bergman JN, Kadykalo AN, *et al.* (2022) Developing a national level evidence-based toolbox for addressing freshwater biodiversity threats. *Biological Conservation* **269**, 109533. doi:10.1016/j.biocon.2022.109533

Rodeles AA, Galicia D, Miranda R (2017) Recommendations for monitoring freshwater fishes in river restoration plans: a wasted opportunity for assessing impact. *Aquatic Conservation: Marine and Freshwater Ecosystems* **27**(4), 880–885. doi:10.1002/aqc.2753.

Sayer CA, Fernando E, Jimenez RR, *et al.* (2025) One-quarter of freshwater fauna threatened with extinction. *Nature* **638**, 138–145. doi:10.1038/s41586-024-08375-z

Serra-Llobet A, Jähnig SC, Geist J, *et al.* (2022) Restoring rivers and floodplains for habitat and flood risk reduction: experiences in multi-benefit floodplain management from California and Germany. *Frontiers in Environmental Science* **9**, 778568. doi:10.3389/fenvs.2021.778568

Simaika JP, Samways MJ (2018) Insect conservation psychology. *Journal of Insect Conservation* **22**, 635–642. doi:10.1007/s10841-018-0047-y

Smithsonian Tropical Research Institute (2024) Smithsonian Tropical Research Institute: Media Fact Sheet February 22, 2024. (The Smithsonian Institution) Available at https://www.si.edu/newsdesk/factsheets/smithsonian-tropical-research-institute

Snyderman LS, Mychajliw A, Hofman CA (2025) North American beaver *Castor canadensis*. In 'The IUCN Red List of Threatened Species 2025'. e.T4003A400320261. (International Union for Conservation of Nature and Natural Resources) Available at https://www.iucnredlist.org/species/4003/22187946 [Green Status assessment]

Speed R, Gippel C, Vollmer D, *et al.* (2026) Societal benefits of large-scale river and wetland restoration. WWF-UK, Woking, UK. Available at https://dmscdn.vuelio.co.uk/publicitem/2916676e-7b28-496b-b7d7-6bfd3d6e39c9

Spray C, Black A, Bradley D, *et al.* (2022) Strategic design and delivery of integrated catchment restoration monitoring: emerging lessons from a 12-year study in the UK. *Water* **14**, 2305. doi:10.3390/w14152305

Stolton S, Dudley N, Hockings M (2021) METT handbook: a guide to using the Management Effectiveness Tracking Tool (METT). Second edition guidance for using METT-4. (World Wide Fund for Nature: Gland, Switzerland) Available at https://wdpa.s3.eu-west-1.amazonaws.com/PAME/METT/METT_4_Handbook.pdf

Sub-Expert Group on the Birds and Habitats Directives (2021) Finalised note on removal of habitats and species from the subject of protection in Natura 2000 sites – conditions & justifications. (NADEG) Available at https://www.natura2000.nl/sites/default/files/Bibliotheek/Europa/Doc%20NADEG%2021-12-05-04%20removing%20habitats%20and%20species%20from%20protection.pdf

Sutherland WJ, Pullin AS, Dolman PM, Knight TM (2004) The need for evidence-based conservation. *Trends in Ecology & Evolution* **19**(6), 305–308. doi:10.1016/j.tree.2004.03.018

Sutherland WJ, Taylor NG, MacFarlane D, *et al.* (2019) Building a tool to overcome barriers in research-implementation spaces: the Conservation Evidence database. *Biological Conservation* **238**, 108199. doi:10.1016/j.biocon.2019.108199

Taylor NG, Cutts V, Sutherland WJ, *et al.* (2026) 'Vegetation conservation in inland aquatic habitats: global evidence for the effects of interventions.' Conservation Evidence Series Synopses. (University of Cambridge: Cambridge, UK) Available at https://conservationevidencejournal.com/synopsis/pdf/38

Thornton A, Cutts V, Morgan WH, *et al.* (2025) 'Fish conservation in inland habitats: global evidence for the effects of selected actions to conserve freshwater fishes.' Conservation Evidence Series Synopsis. (University of Cambridge: Cambridge, UK) Available at https://www.conservationevidence.com/synopsis/pdf40

Turak E, Harrison I, Dudgeon D, *et al.* (2017) Essential biodiversity variables for measuring change in global freshwater biodiversity. *Biological Conservation* **213**(B), 272–279. doi:10.1016/j.biocon.2016.09.005

UN Statistics Division (2025) Standard country or area codes for statistical use (M49). (United Nations: New York, NY, USA) Available at https://unstats.un.org/unsd/methodology/m49/

van Rees CB, Geist J, Arthington AH (2025) Grasping at water: a gap-oriented approach to bridging shortfalls in freshwater biodiversity conservation. *Biological Reviews* **100**(5), 1970–1993. doi:10.1111/brv.70030

van Weerd M, Gatan-Balbas M (2021) Philippine crocodile *Crocodylus mindorensis*. In 'The IUCN Red List of Threatened Species 2021'. e.T5672A567220261. (International Union for Conservation of Nature and Natural Resources) Available at https://www.iucnredlist.org/species/5672/3048281 [Green Status assessment]

von Gönner J, Masson T, Köhler S, *et al.* (2024) Citizen science promotes knowledge, skills and collective action to monitor and protect freshwater streams. *People and Nature* **6**(6), 2357–2373. doi:10.1002/pan3.10714

Washko S, Willby N, Law A (2022) How beavers affect riverine aquatic macroinvertebrates: a review. *PeerJ* **10**, e13180. doi:10.7717/peerj.13180

World Wide Fund for Nature (2024) Living Planet Report 2024 – a system in Peril. (WWF: Gland, Switzerland) Available at https://www.wwf.org.uk/sites/default/files/2024-10/living-planet-report-2024.pdf

Wright SJ (2020) The Smithsonian Tropical Research Institute: a century of ecological and applied research. *Biological Conservation* **252**, 108858. doi:10.1016/j.biocon.2020.108858

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