

HOW-TO GUIDE

Hydropower Biodiversity and Invasive Species



A guide for hydropower project developers and operators on delivering good international industry practice



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Rescued Tapir near the Itaipu project on the border between Brazil and Paraguay
Photo Credit: Joerg Hartmann

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Acronyms

BAP	Biodiversity Action Plan
BMP	Biodiversity Management Plan
CABI	Commonwealth Agricultural Bureaux International
CBD	Convention on Biological Diversity
CI	Conservation International
CIA	Cumulative Impact Assessment
CITES	Convention on International Trade in Endangered Species
CMS	Convention on Migratory Species
CSO	Civil Society Organisation
ESIA	Environmental and Social Impact Assessment
ESMMP	Environmental and Social Management and Monitoring Plan
FFI	Flora and Fauna International
GISP	Global Invasive Species Database
HPP	Hydropower plants
HSAP	Hydropower Sustainability Assessment Protocol
IBAT	Integrated Biodiversity Assessment Tool
IFC	International Finance Corporation
IUCN	International Union for Conservation of Nature
ISP	Invasive Species Plan
KBA	Key Biodiversity Area
NBSAP	National Biodiversity Strategies and Action Plan
NGOs	Non-Governmental Organisations
PA	Protected Area
SEA	Strategic Environmental Assessment
TNC	The Nature Conservancy
ToR	Terms of Reference
VEC	Valued Environmental Component
WCMC	World Conservation Monitoring Centre
WCS	Wildlife Conservation Society
WWF	World Wide Fund for Nature

Glossary

Avoid	Measures are taken to avoid creating impacts from the outset, such as careful spatial or temporal placement of infrastructure, or timing of disturbance.
Aquatic	Refers to processes or biodiversity features that occur in water (as opposed to terrestrial, below).
Anadromous	A species that migrates from the sea to freshwater to breed.
Area of influence	The geographical area in which impacts of a project will be felt. Separate Areas of Influence are often defined, for the infrastructure footprint, upstream and downstream, or direct and indirect impacts.
Biodiversity corridors	Narrower pathways of habitat that allow species to travel between larger areas of habitat.
Biodiversity	The measure of the number, variety and variability of living organisms. It includes diversity within species, between species, and among ecosystems.
Biodiversity features	Specifically identified species, habitats, ecosystems, or biological processes that are identified in a project's area of influence during assessment or monitoring.
Catadromous	A species that migrates from a freshwater ecosystem to the sea to breed.
Catchment	The drainage area, or basin; the area of land bounded by watersheds draining into a river, basin or reservoir.
Compensate	Measures taken to compensate for any residual adverse impacts, after full implementation of the previous three steps of the mitigation hierarchy. They seek to create or restore habitats that support populations of threatened species beyond the project boundaries. Also known as 'offsets'.
Conformance/ Compliance	The main difference between compliance and conformance is the source of the implementation of whichever guideline or standard is in question. Adherence to legal requirements, policies and public commitments is a matter of compliance. Conformance addresses the level to which implementation measures conform to the most up-to-date project related plans.
Congregatory species	Those that concentrate in large groups, often during the non-breeding season.
Connectivity	Habitat connectivity is the degree to which separate patches of suitable habitat are connected. Greater habitat connectivity means animals are able to travel between these patches. It is important because this connectivity enables gene exchange and seasonal migrations.
Critical habitat	Any area of the planet with high biodiversity conservation significance, based on the existence of habitat of significant importance to critically endangered or endangered species, restricted-range or endemic species, globally significant concentrations of migratory and/or congregatory species, highly threatened and/or unique ecosystems, and key evolutionary processes.
Cumulative impact assessment	The assessment of the combined impacts of a number of identified existing and planned developments.
Drawdown zone	The area around the edge of the reservoir, or other body of water, that is frequently exposed to the air due to changes in water level.
Ecosystem	A community or group of living organisms that live in and interact with each other in a specific environment.

Endemic species	An organism that is native to one particular geographic locality.
Ecosystem services	The benefits people obtain from ecosystems. Services include nutrient and water cycling, soil formation and retention, provisioning services (e.g. food, fuel and fibre), pollination of plants, regulation of climate, as well as pest and pollution control.
E-Flows	An Environmental Flow is the quantity, quality and timing of freshwater flows and levels necessary to sustain aquatic ecosystems which, in turn, support human cultures, economies, sustainable livelihoods, and well-being (some jurisdictions use related terms such as 'ecological', 'compensation' or 'minimum' flows).
Equator Principles Financial Institutions	Private banks that have voluntarily adopted the Equator Principles; this is a risk-management framework for determining, assessing and managing environmental and social risk in project finance, including the application of the International Finance Corporation's (IFC) Performance Standards on Environmental and Social Sustainability.
Habitat	The place or type of site where an organism or population naturally occurs.
Hydropower Sustainability Tools	Tools and guidance developed by the Hydropower Sustainability Assessment Council to assist the development of sustainable hydropower.
Invasive species	An alien species is a species introduced to an area outside its natural past or present distribution; if this species becomes problematic, it is termed an invasive alien species.
IUCN Red List of Threatened Species	The world's most comprehensive inventory of the global conservation status of plant and animal species. It uses a set of quantitative criteria to evaluate the extinction risk of thousands of species. These criteria are relevant to most species and all regions of the world. With its strong scientific base, the IUCN Red List is recognised as the most authoritative guide to the status of biological diversity.
Key Biodiversity Areas	Sites contributing significantly to the global persistence of biodiversity in terrestrial, freshwater and marine ecosystems.
Keystone species	An organism that helps to define an entire ecosystem, having a disproportionately large effect on its natural environment relative to its abundance. Without its keystone species, the ecosystem would be dramatically different or cease to exist altogether.
Lacustrine/lentic	Static or non-flowing water, as in a lake or pond.
Lotic/riverine	Flowing water, as in a river.
Macrophytes	Aquatic plants growing in or near water. They may be either emergent (i.e. with upright portions above the water surface), submerged or floating.
Macro-invertebrates	The group of larger invertebrates that that can be caught in a sieve or net with a mesh of 500 microns.
Migratory species	Species that, during their lifecycles, perform regular movements between separate areas, usually linked to seasonal changes.
Mitigation Hierarchy	An approach to environmental management which involves the sequential application of measures to avoid, minimise, restore or rehabilitate; and compensate for adverse impacts. Measures to avoid or prevent negative or adverse impacts are always prioritised, and where avoidance is not practicable, then minimisation of adverse impacts is sought. Where avoidance and minimisation are not practicable, then mitigation and compensation measures are identified and undertaken commensurate with the project's risks and impacts.
Minimise	Measures taken to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided.

Mitigate/Restore or rehabilitate	Measures taken to improve degraded or removed ecosystems, following exposure to impacts that cannot be completely avoided or minimised. Restoration tries to return an area to the original ecosystem that occurred before impacts, whereas rehabilitation only aims to restore some basic ecological functions and/or ecosystem services (e.g. through planting trees to stabilise bare soil).
Net Gain	A project improves the biodiversity values of threatened species or critical habitats during its lifetime.
No Net Loss	A project replaces lost biodiversity values of threatened species or critical habitats through like-for-like management activities.
Nutrient levels	The quantities of nitrogen and phosphate-based chemicals in water that promote the growth of algae and plants.
Offset	A synonym of 'compensate' or 'compensation' in the context of the mitigation hierarchy. Biodiversity offsets are major investments that require long-term management.
Primary production	The use of carbon dioxide and sunlight by plants to create vegetable biomass.
Ramsar sites	Wetlands of international importance that have been officially designated under the criteria of the Ramsar Convention on Wetlands, for containing representative, rare or unique wetland types, or for their importance in conserving biological diversity.
Residual impact	Those predicted adverse impacts which remain after avoidance and minimisation measures have been applied.
Restricted-range species	Species with a geographically restricted area of distribution. For terrestrial vertebrates and plants, restricted-range species are defined as those species that have an extent of occurrence less than 50,000 square kilometres (km ²). For coastal, riverine, and other aquatic species in habitats that do not exceed 200 km in width at any point (for example, rivers), restricted range is defined as having a global range of less than or equal to 500 km linear geographic span (i.e. the distance between occupied locations furthest apart).
Stratification	The layering of water in a lake or reservoir, with dense cold water at the bottom and lighter warm water on the surface.
Terrestrial	Refers to processes or biodiversity features that occur on land (as opposed to aquatic, above).
Threatened species	Species included in the Critically Endangered (CR), Endangered (EN) or Vulnerable (VU) categories of the IUCN Red List.
Valued environmental component	Any environmental or social receptor that is considered important by the proponent, stakeholders, community, and environmental and social specialists involved in the assessment process.
Wetlands	Areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt; including areas of marine water the depth of which at low tide does not exceed six metres (Ramsar Convention)





Renace project in Guatemala
Photo Credit: CMI Energia

An aerial photograph of a river winding through a dense, green forest. The river is light brown and flows from the top left towards the bottom left. The forest is a vibrant green, with some areas appearing slightly hazy or misty. A large teal-colored geometric shape, resembling a triangle, is overlaid on the top right corner of the image. The number '1' is written in white on this teal shape.

1

Introduction



Introduction

Construction of a hydropower project inevitably has impacts on the **ecosystem** in which it is built; some of these can occur many miles downstream. Identifying and managing these impacts responsibly is now an essential step in sustainable hydropower development.

Biodiversity is important throughout the world, and human activity is causing many species to decline, affecting the integrity and viability of ecosystems worldwide. In some places, certain species are also emblematic to local cultures: for example, salmon in North America or manatees in West Africa. At the same time, some river systems harbour fisheries that may provide significant economic or nutritional benefits to communities. While every site and every basin presents different challenges, a good knowledge and understanding of biodiversity issues at an early stage in project planning can allow many of the negative impacts, for which hydropower projects have been extensively criticised in the past, to be **avoided** or **minimised**.



Guanaco near the planned
Aysén project in Chile
Photo credit: Joerg Hartmann

Invasive species are also rising in prominence as river systems become increasingly man-modified, and globalisation is allowing inter-continental transfer of alien species that may become ‘invasive’ when introduced to areas outside their native range. In some cases, these species compete directly with native and **threatened species**, while in others they may cause significant economic harm and need to be actively managed.

1.1 This How-to Guide

1.1.1 Aim

This How-to Guide sets out to assist project developers to avoid and minimise the negative impacts of hydropower projects on biodiversity, and to address the risks posed by invasive species. It contributes to increasing knowledge and understanding of the practical measures that can be undertaken to meet good international industry practice, as assessed using the Hydropower Sustainability Tools (Figure 1). This suite of sustainability tools seeks to enhance the understanding of, and promote sustainability in hydropower.

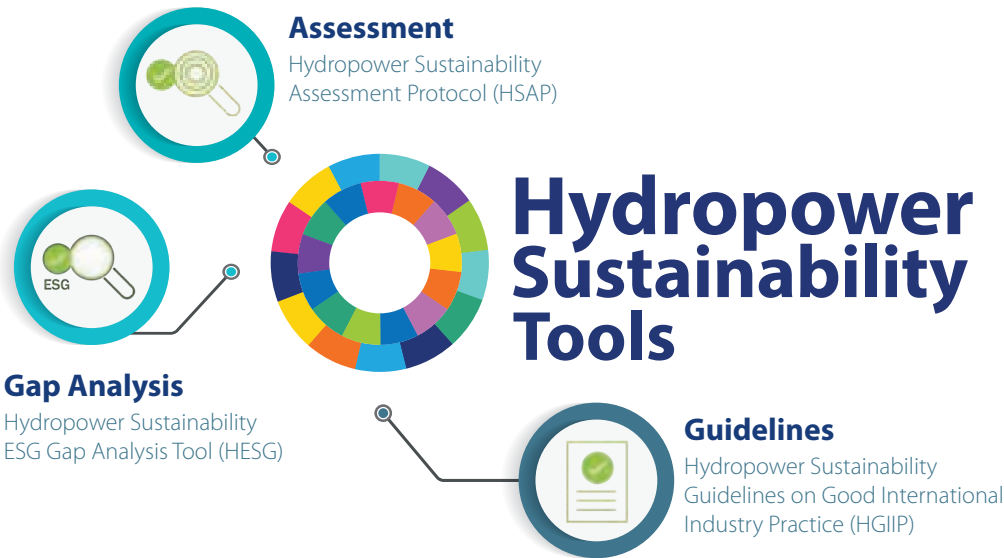
This guide expands upon the Hydropower Sustainability Guidelines on Good International Industry Practice (HGIIIP). It helps hydropower

projects to identify possible biodiversity impacts early in the project cycle, to assess the most significant risks, and then to design both infrastructure proposals that avoid or minimise adverse impacts, and management programmes that manage the remaining risks. It is designed to provide practical support to developers, their consultants, lenders, government and local stakeholders, in identifying and managing the biodiversity and invasive species impacts arising from hydropower development.

The Biodiversity and Invasive Species topic addresses the assessment and management of threatened biodiversity; **ecosystem values and services**; species affecting human health, as well as potential impacts arising from invasive species associated with the planned project. The intent of this topic is that there are healthy, functional and viable **aquatic** and **terrestrial** ecosystems in the project-affected area, and that these are sustainable over the long term, following proactive biodiversity assessment and management during project design and implementation.

1.1.2 Approach and structure

A wide range of good-practice materials are available on this topic. The approaches adopted here draw on a range of processes, many of



The Hydropower Sustainability Tools are governed by the Hydropower Sustainability Assessment Council, a multi-stakeholder group of industry, government, financial institutions, and social and environmental NGOs. The tools are supported by the International Hydropower Association (IHA), the council's management body.

Sustainability guidelines

The Hydropower Sustainability Guidelines on Good International Industry Practice define expected sustainability performance for the sector across a range of environmental, social, technical and governance topics. Released in 2018, the 26 guidelines present definitions of the processes and outcomes related to good practice in project planning, operation and implementation. As a compendium, the guidelines are a reference document for meeting the expectations of lenders, regulators and consumers. Compliance with each guideline can be specified in commercial contracts between financiers and developers, and between developers and contractors. The guidelines are based on the performance framework of the Hydropower Sustainability Assessment Protocol.



Biodiversity and Invasive Species

The Biodiversity and Invasive Species good practice guideline addresses the management of biodiversity and invasive species issues with the hydropower project or operating facility. Adherence with this guideline is measured using the HSAP and the HESG.

Further information

Visit [Hydrosustainability.org](https://hydrosustainability.org)

Assessment protocol

The Hydropower Sustainability Assessment Protocol offers a framework for objective assessments of hydropower project performance. It was developed between 2007 and 2010 following a review of the World Commission on Dams' recommendations, the Equator Principles, the World Bank Safeguard Policies and IFC Performance Standards, and IHA's own previous sustainability tools. Assessments are delivered by independent accredited assessors and can examine different stages of a project's life cycle. Evidence collected during an assessment is used to create a sustainability profile and benchmark performance against both good and best proven practice. The assessment protocol was updated in 2018 with a new topic covering hydropower's carbon footprint and resilience to climate change.

Gap analysis tool

The Hydropower Sustainability ESG Gap Analysis Tool enables hydropower project proponents and investors to identify and address gaps against international good practice. Launched in 2018, the tool is based on the assessment framework of the HSAP's environmental, social and governance topics.

It provides a gap management action plan to help a project team address any gaps and is divided into 12 sections that are compatible with both the IFC Environmental and Social Performance Standards and the World Bank's Environmental and Social Framework.

them tried and tested through the project development approaches and safeguards adopted by international lenders, complemented by innovative good practice developed by individual developers and managers, or by international NGOs.

The greatest challenge in developing this guide was how to propose general approaches when every dam has a set of very specific individual challenges associated with it. It is not possible to address every technical dimension of biodiversity management in such a guide. Measures to manage a threatened population of orang-utans that may be flooded by a reservoir will be very different from those required to maintain a productive downstream fishery that depends on the hydrological cycle, or measures to protect a threatened species of toad, for example.

This guide therefore seeks to highlight the most important steps, and to help developers focus on what is significant for their project and its impacts throughout the project life cycle – from the Early Stage, through to Preparation, Implementation and Operation stages, as outlined in the HSAP.

The How-to Guide is presented in five chapters and two annexes:

- **Chapter 1** – Introduction
- **Chapter 2** – Understanding biodiversity and invasive species in hydropower
- **Chapter 3** – Achieving good international industry practice
- **Chapter 4** – Methodologies and technologies
- **Chapter 5** – Conclusions
- **Annex 1** – Bibliography
- **Annex 2** – Project examples

Terms shown in bold in the text on their first occurrence are defined in the Glossary. Annex 1 lists all source materials and references used for this guide. Responsible parties for a hydropower biodiversity management plan or biodiversity action plan are encouraged to read more broadly on the subject, and to review case studies of any similar projects or in the same country or context as the hydropower project under consideration. Annex 2 provides examples of good practice drawn from published HSAP assessments.

1.2 Biodiversity and invasive species in the Hydropower Sustainability Tools

IHA has developed a suite of sustainability tools to harmonise the understanding of sustainability in hydropower. The topic of Biodiversity and Invasive Species is included in three of the main HSAP tools that correspond to the project life cycle stages – Preparation, Implementation, and Operation. In the HSAP, this topic is addressed in P-19 for the Preparation stage, I-15 for the Implementation stage and O-15 for the Operation stage. In the Early Stage, biodiversity issues are an important part of ES-8 Environmental Issues and Risks. In the Hydropower Sustainability ESG Gap Analysis Tool (HESG), this topic is addressed in Section 6. These provide an approach to measuring good international industry practice in the management of biodiversity and invasive species, in relation to criteria on Assessment, Management and Conformance/Compliance.

The intent of the Biodiversity and Invasive Species topic is that:

- aquatic and terrestrial ecosystems in the project-affected area are healthy, functional, viable and sustainable over the long term;
- biodiversity impacts arising from project activities are managed responsibly; and
- commitments to implement biodiversity and invasive species measures are fulfilled.

1.2.1 Objectives of this How-to Guide

The guide:

- sets out the many considerations for planning, assessing and managing biodiversity and invasive species in hydropower projects;
- highlights the biodiversity and invasive species risks that need to be identified, avoided and mitigated in a timely manner; and
- outlines important methodological steps and practical strategies to achieve good international industry practice.

1.2.2 Scope and limitations

The scope of the guide is relevant for all types of hydropower projects, and covers:

- the basic good practice requirements for the management of biodiversity and invasive species set out in the HSAP and associated tools; and
- all stages of a project's life cycle, from the Early Stage through Preparation, Implementation and Operation.

The guide gives some background on biodiversity issues and the significance of different biodiversity-related issues; it also describes the steps to identify and manage significant biodiversity risks. The guide blends a range of approaches – including presentation of theoretical background, project examples, and questions that developers should be able to answer at different stages – and describes how decision-makers can strategically approach this complex issue.

This guide is only one of a range of relevant tools developed by IHA to support the delivery of the HGIIIP. There are clear linkages with other How-to Guides, including:

- Erosion and Sedimentation: the transport of sediment downstream of a dam impacts not only water quality, but also creates **habitats** for biodiversity: for example, sandbanks or mud deposits in floodplains and deltas, which are of value to biodiversity. Ultimately, outflow of sediments to the sea sustains marine life.
- Downstream Flow Regimes: these are an essential tool for hydropower developers, and this guide addresses the consequences and management of changes to hydrology downstream of dams. The aquatic habitats and biodiversity downstream are determined by these environmental flow (**E-Flow**) regimes, and any changes in flows will impact them. This is therefore complementary to the current guide, and they should be read together.

An aerial photograph showing a vast, dense forest with a thick canopy of green trees. The perspective is from directly above, looking down on the forest floor. The trees are packed closely together, creating a textured, green surface. Some darker patches are visible, possibly indicating shadows or different tree species.

Nam Theun watershed is a national
protected area and Lao PDR's largest
biodiversity area with endemic animals and
plants to Southeast Asia
Photo Credit: Asian Development Bank



2

Understanding biodiversity and invasive species in hydropower

Understanding biodiversity and invasive species in hydropower

This chapter provides the context for biodiversity management associated with hydropower projects. It highlights some of the risks for the hydropower developer if biodiversity impacts are not managed effectively. The range of potential impacts on biodiversity and invasive species when a hydropower project is implemented and operated are summarised.





Beaver signs upstream of the
Semla project in Sweden
Photo Credit: Joerg Hartmann

2.1 Why are biodiversity and invasive species important?

Hydropower projects are frequently built in the upper parts of river basins, which often have more intact ecosystems than the lowland areas that are more highly populated and extensively developed. Nevertheless, hydropower projects often have significant impacts upon downstream riverine ecosystems and their biodiversity, even down to the maritime deltas, which can have significant biodiversity value. The impacts of hydropower upon both upstream and downstream biodiversity pose significant risks and opportunities for the sustainable implementation of a hydropower project. In addressing these risks and opportunities, it is pivotal to understand why biodiversity is important and how it can be impacted by hydropower development, before designing the mitigation and management approaches explored in Chapters 3 and 4. Box 1 expands on the recognised definition of biodiversity, and describes how the key terms are used in this guide.

2.1.1 Threatened biodiversity

The dramatic rate of biodiversity loss in recent decades is becoming well recognised, with habitat loss and pressure upon natural resources as major

driving forces. Inland waters and freshwater ecosystems show some of the highest rates of decline: indeed, 85 per cent of the world's wetlands have already been lost. The average abundance of native species in most major terrestrial biomes has fallen by at least 20 per cent; this is potentially affecting ecosystem processes, and hence nature's contributions to people. This decline has mostly taken place since 1900, and may be accelerating. In areas of high endemism, native biodiversity has often been severely impacted by invasive alien species. The IUCN Red List website notes that 27 per cent of the species (32,000 species) that have been Red List assessed are threatened with extinction.

Biodiversity is threatened by the ever-increasing pressure of human activities. This can take the form of habitat loss or change, due to agricultural expansion and intensification, or urban and industrial developments; change in the quality of land, air and water, due to solid waste and plastics disposal, air and water pollution; as well as over- and illegal use of natural resources, fishing, hunting, and the wildlife trade. Hydropower development is one of many sources of pressure upon biodiversity, but its specific pressures – especially loss of habitat, connectivity and changes in the flow regime of rivers – can be cumulative when combined with other pressures, leading to increased impacts on species.

Box 1 What is biodiversity and how is this term applied in this guide?

The Convention on Biological Diversity (CBD) defines 'biological diversity' as meaning the variability among living organisms from all sources, including terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems.

Within this complex, all-encompassing definition, the basic principle is that if something can be described as 'living', then it is part of biodiversity. Livestock, garden plants and agricultural crops, for example, are all part of biodiversity in the same way as tigers, orchids and mosquitoes. Hydropower development potentially concerns five particular aspects of biodiversity which will be the focus for this guide, and which are addressed during the ESIA process. These comprise:

- **Threatened species** These species represent the intrinsic biodiversity conservation values of an area. Within a hydropower project, biodiversity impacts on threatened species are managed through a Biodiversity Management Plan or Action Plan (BMP or BAP).
- **Species and habitats providing food, fibre and fuel**, etc., for consumption or sale by local communities. These are called Provisioning Ecosystem Services, and are often important for national and local cultures and livelihoods. They can have measurable economic value and need to be assessed in the ESIA. Negotiations on losses, compensation, restoration and/or management should be undertaken with local communities who depend on them.
- **Species affecting human health.** These are the species that are hosts or vectors for human diseases. They may be introduced or their populations increased due to the changes in habitat caused by hydropower projects. They are managed through health plans and vector control measures.
- **Invasive alien species.** These are the species that have been introduced from other regions of the world, either accidentally or purposefully, and which proliferate under the new environmental conditions created following hydropower development. They can cause operational and economic problems, as well as being one of the threats to native species. They are managed through an Invasive Species Plan (ISP).
- **Indicator species** are those used specifically for general environmental monitoring of the performance of a hydropower project. Typically, these would include those species that are common and easily measured. Fish, zooplankton, diatoms and macro-invertebrate species are examples of species selected as indicators of general aquatic ecosystem health. These are defined in the Environmental and Social Monitoring Plan.

Some plants and animals are becoming increasingly rare, and are threatened with extinction both locally and globally – these are the **threatened species** whose populations and distribution are decreasing. The International Union for Conservation of Nature (IUCN) convenes expert working groups to assess the status of species throughout the world, according to a set of well-defined categories. This is known as the **IUCN Red List**, continually

developed over the last 30 years, and intended to be an easily and widely understood reference standard for classifying species at high risk of global extinction. Table 1 shows the IUCN Red List categories and criteria for defining a threatened species. Some of the areas where hydropower projects are located also contain **endemic** species that are only found in a very restricted area or range, and are therefore more at risk of extinction.

To achieve good international industry practice, developers should ensure that there is **no net loss** of threatened biodiversity, and that these species are subject to appropriate conservation measures. The presence of endangered or critically endangered species in project sites is also likely to trigger additional safeguards when projects are financed by multilateral donors or Equator Principles financial institutions.

For the remainder of this Guide, the IUCN definition of ‘threatened’ species is used, referring to all species appearing in the IUCN Red List of Threatened Species in the categories of Critically Endangered (CR), Endangered (EN), or Vulnerable (VU), as shown in Table 1.

Table 1 The IUCN Red List categories and main criteria

Source: Adapted from IUCN Red List categories and criteria (2012)

Red List category		Population reduction rate	Geographic range Extent of occurrence Area of occupancy		Population size	Population restrictions	Extinction probability (in the wild)
Not Evaluated (NE)		A species for which a systematic Red List evaluation has NOT yet been carried out					
Data Deficient (DD)		A species for which there is insufficient information to establish its threatened status					
Least Concern (LC)		A species that has a widespread and abundant population					
Near Threatened (NT)		A species that is likely to qualify for a threatened character in the near future					
Vulnerable (VU)	Threatened species	30–50% population decline	<20,000 km²	<2,000 km²	<10,000 mature individuals	<1,000 mature individuals or area of occupancy of <20 km²	At least 10% within 100 years
Endangered (EN)		50–70 % population decline	<5,000 km²	<500 km²	<2,500 mature individuals	<250 mature individuals	At least 20% within 20 years or five generations
Critically Endangered (CR)		>80–90% population decline	<100 km²	<10 km²	<250 mature individuals	<50 mature individuals	At least 50% within 10 years or three generations
Extinct in the Wild (EW)		Only survives in cultivation (plants), in captivity (animals), or as a population well outside its established range					
Extinct (EX)		No remaining individuals of the species survive					

The importance of habitats and species biodiversity has been generally recognised through the designation of protected areas, national parks and wildlife sanctuaries (see Box 2). The category level generally indicates the level of protection and the importance of the biodiversity within the protected area. Hydropower projects that impact a Category I protected area may require more significant biodiversity impact assessment than those affecting a Category VI protected area. In many countries, the largest officially protected areas are located in the upland areas – exactly the same areas where hydropower plants have greatest potential.

Criteria for the designation of such protected areas include representativeness of the ecosystem type and its rarity, the ranges of threatened species that the PA is trying to protect, and the connectedness (**biodiversity corridors**) with other ecosystems and PAs.

Other areas of significant biodiversity may be identified from the listed species of other international conventions, such as the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species (CITES) and the Convention on Migratory Species (CMS). The CBD has developed principles and tools for the protection of biodiversity, including requirements for National Biodiversity Strategies and Action Plans (NBSAP), and setting of national biodiversity targets in line with agreed international biodiversity conservation strategies. Sites of international importance have been designated by the International Convention on Wetlands of International Importance (Ramsar), and UNESCO World Heritage sites and Man and Biosphere sites. Considering the impact of dams on water flows and **wetlands**, the Ramsar Convention is especially significant.

Where listed sites or species occur within a hydropower project's area of influence, there may be a specific compliance requirement to protect the biodiversity. If a dam project threatens the maintenance of the ecosystem values for which a particular site has been designated, then measures to declassify that site may trigger intergovernmental mechanisms agreed under each convention.

The emphasis on protecting habitats is very important for biodiversity, because without key feeding and breeding sites, species cannot persist; and the supporting ecosystem services – such as maintaining soils structure and fertility, pollination of crops, and natural pest control – cannot be sustained. Some areas outside the protected area system are also important for biodiversity, and these are being recognised through a developing system of **Key Biodiversity Areas** (KBAs); these may also lie within a hydropower project's area of influence of, and indicate the presence of significant biodiversity.

2.1.2 Provisioning Ecosystem Services

Ecosystems are made up of both physical components (air, soil, water, etc.), and their associated biodiversity. Following the categories of the Millennium Ecosystem Assessment, river ecosystems provide four types of broad ecosystem services to humanity, namely:

- Provisioning (e.g. fish and other aquatic organisms for food, wood for fuel/construction, grass for grazing, etc.).
- Regulating (e.g. flood regulation, erosion control, water purification).
- Cultural (e.g. recreational, tourism, aesthetic, spiritual).
- Supporting, which back up the production of all other services (e.g. primary biological productivity, nutrient cycling on floodplains, habitat for biodiversity).

Of these four services, the first, the value of **Provisioning Ecosystem Services**, has a direct link to biodiversity wherever individual species provide direct benefits to communities. The focus of this guide includes consideration of the use of natural resources in the river basin, such as:

- trees from forests or woodlands used for timber, construction and fuelwood;
- non-timber forest products – plants, fungi, fruits, tubers, insects and other wildlife used for food and natural medicines;

Box 2 IUCN Protected Areas categories

The presence of a protected area within or near the area of influence of a hydropower project is indicative of significant biodiversity. The categories are dependent upon national legislation, and are generally listed below in decreasing biodiversity significance.

- I. **Strict Nature Reserve:** Category I are strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphic features; where human visitation, use and impacts are strictly controlled and limited, to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
- II. **National Park:** Category II protected areas are large natural or near-natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems that are characteristic of the area. These areas also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities.
- III. **Natural Monument or Feature:** Category III protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, a geological feature such as a cave, or even a living feature such as an ancient grove. They are generally quite small protected areas, and often have high visitor value.
- IV. **Habitat/Species Management Area:** Category IV protected areas aim to protect certain species or habitats, and management reflects this priority. Many Category IV protected areas will need regular, active interventions to address the requirements of certain species or to maintain habitats, but this is not a requirement of the category.
- V. **Protected Landscape/Seascape:** Category V protected areas, where the interaction of people and nature over time has produced an area of distinct character, with significant ecological, biological, cultural and scenic value. Safeguarding the integrity of this interaction is vital for protecting and sustaining the area, and for its associated nature conservation and other values.
- VI. **Protected area with sustainable use of natural resources:** Category VI protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition; a proportion of the area is under sustainable natural resource management; and low-level non-industrial use of natural resources, as is compatible with nature conservation, is seen as one of the main aims of the area.

- fish, waterfowl, frogs and snails caught for food in the rivers and wetlands; and
- the use of floodplains for grazing sheep and cattle (especially in the dry season).

such as cardamom, command high prices and can bring a significant income for some rural communities. Provisioning Ecosystem Services are often the easiest biodiversity benefits to quantify, in terms of direct monetary value.

In many parts of the world, especially in less economically developed regions, local communities may depend on wild foods for up to a third of their nutrition requirements. Some wild foods, such as fungi, and natural medicines,

2.1.3 Invasive alien species

Invasive species are both a significant driver of biodiversity loss and have direct economic impacts on human activities. Invasive alien species of plants and animals are those that have been brought in or spread from other parts of the world. Because they may have few natural enemies in the new region, their populations are able to grow unhindered without the natural controls they had at their place of origin; they can threaten or overcome the native species, or become pests and damage crops. Aquatic invasive plants, such as water hyacinth, can block channels and navigation, and damage infrastructure. Invasive species are often negative keystone species, because they dominate and change the aquatic habitats adversely.

2.1.4 Species affecting human health

The conversion of flowing-water to still-water habitats provides conditions where aquatic animals that are vectors for human diseases can flourish. Mosquito larvae prefer to live in still water, and are vectors for malaria and dengue fever; dam construction sites and the development of reservoirs have been associated with increase in these diseases amongst communities living on the reservoir banks. Similarly, snails that are hosts for the parasitic worms or flukes that cause bilharzia (schistosomiasis) can flourish in the still waters of a reservoir, or in rivers where flow regimes have been stabilised by dams. In the Senegal River delta, for example, 57 per cent of children under the age of 14 were found to be infected with intestinal schistosomiasis, and 22 per cent with urinary schistosomiasis, despite mass treatment campaigns from 2009 to 2011. Modified river flows and less salt-water intrusion as a consequence of the Manantali dam, completed in 1988, allowed the snail vectors to proliferate.

2.1.5 Indicator species for river ecosystem health

Hydropower construction activities and operation change the environmental conditions in the river, both downstream and in the reservoir. Groups of aquatic flora and fauna are often monitored to assess these impacts, as well as the status of

the river ecosystem's health. These are small and sometimes microscopic aquatic species that are commonly found in rivers and streams; they have generally not been Red List assessed. River health indicator species fall into five groups:

- Phytoplankton: photosynthetic organisms, including green and blue-green algae; often measured by the chlorophyll-a content, and indicative of eutrophication of the water.
- Benthic diatoms: brown algae growing as slime on the bottom or on rocks.
- Zooplankton: unicellular or multicellular animals, occupying the water column of lakes and rivers. They feed on phytoplankton and are themselves food for fish.
- Benthic and littoral macro-invertebrates: including molluscs, crustacea, and insects (both larvae and adults).
- Some fish species may also be used as indicators of river health.

The river health index can be built up from counting the numbers and diversity of species present in samples. The index is calculated from the balance between species that are sensitive to or tolerant of changes in flows and poor water quality.

2.2 What happens to biodiversity when hydropower is developed?

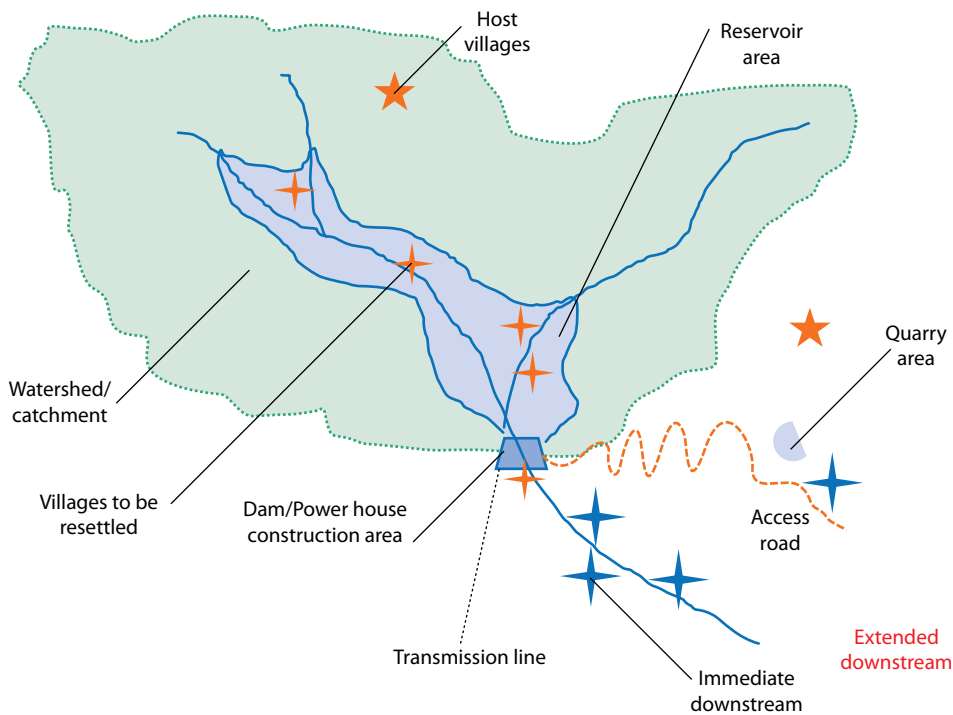
When a hydropower project is built, changes to land and water use will have impacts upon the ecosystems, habitats and species living in and using them (Table 2). The impacts during construction and inundation of the reservoir will be very different from operational impacts.

Table 2 Changes and key biodiversity impacts of hydropower projects

Change induced by HPP	Key Biodiversity issue	See chapter heading	Potential biodiversity impacts
Terrestrial			
Construction impacts: dam site, quarries, roads, transmission lines	Loss of habitat Disturbance and mortality	2.2.1 2.2.2 2.2.3	Permanent loss of habitats, including all the species associated with them. Increase in hunting pressure during construction; impacts on other Provisioning Ecosystem Services.
Air quality: dust and noise	Air pollution Construction noise Disturbance and mortality	2.2.3 2.2.4	Reduction in plant productivity when leaves coated in dust. Disturbance of species, especially if breeding or migrating.
Inundation of forest, grasslands, rivers and wetlands	Loss or change of habitat	2.2.1	Transformation of terrestrial habitats into a lake. Some habitats and their species may be completely lost, e.g. riparian forests; impacts on Provisioning Ecosystem Services.
Reservoir cuts across animal movement/ migration routes	Connectivity Habitat fragmentation	2.2.6	Reservoir reduces connectivity between habitats and may isolate breeding and feeding sites.
Aquatic – upstream, reservoir			
Transformation of free-flowing river into a reservoir	Loss or change of habitat	2.2.1	Loss and change of riverine habitats, changes in fish populations, multi-species composition and fish species' food-chain dynamics, reduced biodiversity, etc.; impacts on Provisioning Ecosystem Services.
Drawdown of water levels	Loss of habitat	2.2.1	Creates a 'bathtub' effect of a barren ring around the reservoir banks, with few plants and animals.
Water quality	Stratification of reservoir	2.2.4	Lower-level water may be lacking in oxygen and have a lower temperature. If the water intake for turbines is from lower levels, poor water quality can cause fish mortality, including downstream. Under some climatic conditions, upper and lower levels may mix, to cause poor water quality within the reservoir and downstream.
Changes in nutrient balance and light penetration	Water quality	2.2.4 2.2.8	Algal blooms and aquatic invasive plant species.

Aquatic – downstream			
Water temperature change Dissolved oxygen change	Water quality	2.2.4	Permanent change of habitat, mortality/ disappearance of fish and other aquatic species, disruption in fish community food-chain dynamics.
Changes in flows	Flow regime	2.2.7	Change in habitats downstream, reduced productivity of Provisioning Ecosystem Services, changes in fish migration triggers, abrupt change in fish community composition.
Trapping of sediments in reservoir	Sediment trapping	2.2.7	Instability of riverbed and banks downstream – loss of riparian habitat, loss of important trees for local aquatic fauna.
Dam fragments the river	Connectivity/ fragmentation	2.2.6	Upstream and downstream fish migration affected. Permanent disconnect of fish species to their spawning grounds.

Figure 2 Main area of influence of a hydropower project with zones of impact



Area of influence of a hydropower project

There are six main impact zones of a hydropower project within its area of influence, each with different types of biodiversity impact which need to be assessed and managed (Figure 2). Not all of these impacts will occur at every hydropower project (see Box 3), but the risks of these impacts should be considered in scoping and impact assessments.

- the dam, spillway and powerhouse sites;
- the reservoir area;
- the upstream catchment, with the rivers and streams flowing into the reservoir;

- the immediate downstream river, which may be affected by diversions and hydropeaking (5–10 km);
- the extended downstream river, which will be affected by changes in seasonal flow patterns, changes in sediment transport and connectivity issues; and
- areas affected by routes for access roads, transmission lines, quarries and resettlement villages.

The remainder of this section describes, in outline, the nature of potential biodiversity changes in these different areas, building on the key biodiversity issues listed in Table 2.

Box 3 Different types of hydropower have differing impacts on biodiversity

Storage projects have larger reservoirs, inundating significant areas of terrestrial habitat, with greater potential for making seasonal changes in flow (increased flows during the dry season and decreased peaks in the wet season), and increased potential for water quality and temperature changes downstream. Upstream, river habitats are converted into lake habitats. With dams higher than about 10 m, successful fish passage becomes more difficult.

Run-of-river projects have smaller impoundments, but may still cause loss of riparian and aquatic habitats in the reduced-flow stretch and impoundments. Although they make little change to seasonal flow patterns, they trap sediments and will change the free-flowing river into lake habitats. Run-of-river dams can fragment the river and result in loss of connectivity for migrating fish and other organisms.

River diversions may lead to a drying-out of the river between the dam site and the power station, which may be several or many kilometres downstream within the same river. If water is diverted into a different river (either another tributary within the same basin, or in a different basin), the original river will have permanently reduced flows, while the receiving river will have significantly increased flows and higher risk of flooding. Inter-basin diversions carry a risk of introducing species from one river basin to another, especially invasive species, which pose risks to native and endemic species.

Baseload vs hydropeaking: Plants operating on baseload maintain a steady flow of water through the turbines, which is better for downstream river habitats and biodiversity. Hydropeaking changes the daily flow patterns, damaging the aquatic habitats downstream, and reducing the river's health and productivity for fish and their food organisms.

Pumped storage projects: There are two types of pumped storage project – open-loop and closed-loop. Open-loop projects are continuously connected to a naturally flowing water feature, so they typically have more widespread and longer-lasting impacts on aquatic ecological resources, related to flow and water-level changes in the reservoirs and downstream river. Closed-loop projects are located 'off-stream' (i.e. not continuously connected to a naturally flowing water feature), so they can avoid many of the open-loop projects' impacts on aquatic ecological resources.

2.2.1 Loss or change of habitat

Loss of terrestrial habitat

Hydropower projects involve a change in land use and land cover. At the dam site and powerhouse, the land cover will be cleared to prepare for construction; and while some parts of the construction site may be rehabilitated and landscaped after completion, the terrestrial habitats, especially forest habitats, are difficult to restore completely. Typically, a construction site may cover an area of 10 to 100 hectares or more. If the site is in a remote location, the access road creates a corridor with an area of disturbance through a forest, many times the width of the road. Similarly, transmission lines cut across the landscape, often in much more direct routes than can be achieved with roads that have to follow the contours; nevertheless, these require corridors and access tracks that may have to be cleared and maintained. Generally, the downstream terrestrial habitats are less likely to be impacted.

The biggest loss of terrestrial habitat is associated with the inundation of the reservoir. Some reservoirs are located in narrow, steep-sided valleys, so that the footprint of inundation is relatively small in comparison to reservoirs in flatter terrain, where the footprint of a large dam may cover several hundred square kilometres. The significance of the loss of terrestrial habitats, whatever their size, depends upon the type and uniqueness of the species lost and their status – i.e. how intact or degraded they are, and the species recorded there.

One of the forest types that is almost always affected by inundation is the riverine and riparian forests that mark the transition from the river ecosystem to the terrestrial ecosystem. These are areas rich in biodiversity, often with specialised plants and animals which are dependent upon the availability of groundwater when there is a dry season.

Habitat changes from river to reservoir

When a river is dammed to create a reservoir, the conditions in the river in the impounded area are changed from riverine or flowing water (**lotic**), to **lacustrine** or still water conditions (**lentic**). The river

habitats of rapids, runs and pools are replaced by a deep, stationary body of water with less variation in habitat conditions, and major changes in the physical and chemical parameters of the water. Many species of fish and other aquatic organisms adapted to rivers cannot survive in reservoir environments, and will be replaced by other species. The banks of reservoirs are often steep-sided and exposed to operational drawdown, which creates rather barren conditions, in which neither terrestrial nor aquatic plants will grow well, and where both aquatic and terrestrial fauna are scarce.

Loss of access to breeding habitats

Inundation of the river habitats can destroy spawning sites for some fish species. Wetlands located within the floodplain of a river may be an important breeding site for fish that move into it to breed, as well for other aquatic species. If such wetlands are inundated, these breeding sites will be lost. Tributaries feeding into the reservoir are also important breeding sites for many migratory fish species, and access to these from the reservoir should be maintained if these fish are to survive in this section of the river and reservoir. The inundation of islands and sand banks can also permanently cover sites where other aquatic species feed, such as turtles and water birds.

Habitat changes downstream

Changes in downstream aquatic habitats may occur due to changes in flow, but they can also be affected by scouring and bank erosion (as described in the How-to Guide on Downstream Flow Regimes), which may damage some important downstream habitats. Increased water levels in the dry season, due to operation of storage hydropower projects, may reduce the area of exposed sandbanks and gravel beds, and the availability of breeding sites for some bird species and turtles. Lower flood peaks may decrease the flooding extent and duration of floodplain wetlands, resulting in the reduction of size and quality of these productive habitats. Sediment retention behind the dam, leading to reduction of sediment transport and replenishment downstream, can also affect these downstream habitats.

Changes in the water quality downstream may also make some habitats less favourable for aquatic life. A decrease in temperature and dissolved oxygen in the immediate downstream river reaches can reduce the fish diversity and populations, sometimes even leading to direct fish mortality. The chemical quality of the river water can also act as a barrier for migratory fish.

2.2.2 Impacts on Provisioning Ecosystem Services

Provisioning Ecosystem Services are likely to be impacted by any changes of land use associated with the construction site, the area to be inundated, access roads, quarries and transmission lines. Thus, the commercial and community use of trees from forests or woodlands (such as for timber, construction and fuelwood) will be lost with the clearance of the sites, although high-value trees may be removed and used. Less valuable trees may be used locally for fuel wood. All future use of these forests and woodlands would be lost.

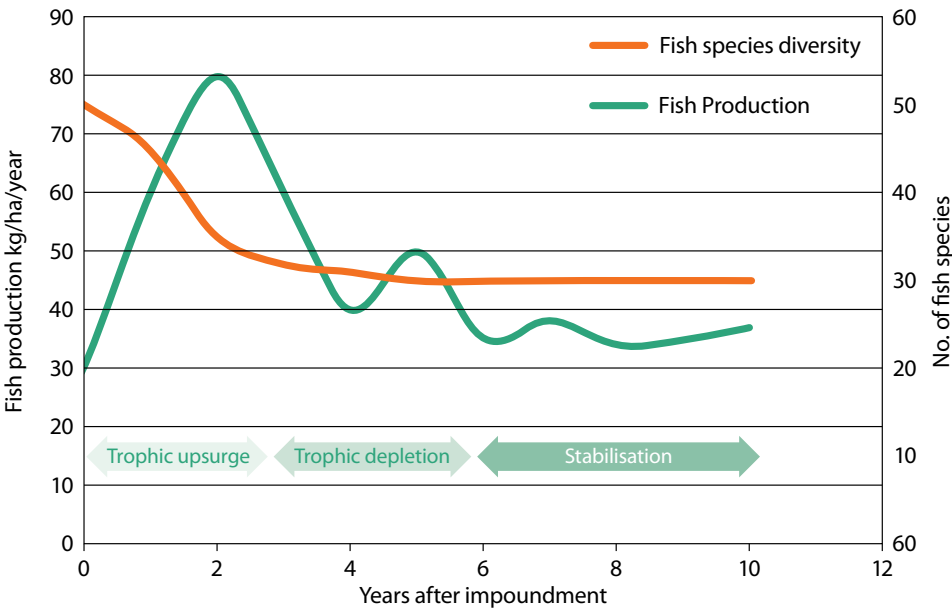
Similarly, future harvests of non-timber forest products (NTFPs), usually collected from the forests and woodlands that are cleared, would be lost. Non-timber forest products include plants, fungi,

fruits, tubers, insects and other wildlife used by local communities for food and natural medicines. Because these NTFPs are usually collected from common land, the loss of income and food that they represent is rarely compensated.

The grasslands in the floodplains are often used in the dry season by local communities for grazing sheep and cattle. When these floodplain areas are inundated, these opportunities for using these grassland Provisioning Ecosystem Services are lost.

The fish, waterfowl, frogs and snails, etc., which are caught for food in the rivers and wetlands that are changed, flooded, or otherwise damaged by the hydropower project, are also impacted. The change from riverine to reservoir conditions has an impact on the fish species that can live and thrive under the new conditions. Freshwater fish guilds and their sensitivities are outlined in Box 4. Some generalist fish species can live in both flowing and still waters, and these will survive; other fish species that depend upon flowing water will either die out or move upstream. Yet others which can survive in still water but need flowing water habitats to spawn, will only survive in the reservoir if they still have access to upstream spawning sites in tributaries. Up to 60 per cent of the fish species in the river may disappear once the reservoir is formed.

Figure 3 Typical changes in fish species diversity and fish production after impoundment (Adapted from Bhukaswan (1980), based on experience of fisheries in Lake Kariba)



Box 4 Freshwater fish guilds

Fish species can be grouped into ecological groups depending upon the river habitats they frequent, flow conditions, migration and movement, their reproductive behaviour, and resistance to low oxygen conditions. A typical guild framework might consist of the following:

1. Rhithron resident species: Living in upland, fast-flowing rivers in pools and riffles. Often includes endemic and restricted range species. Not migratory, but unlikely to survive in the reservoir.
2. Main channel resident (long-distance migrant) species: Longitudinal migratory fish moving upstream from main channels into tributaries to spawn at specific seasons. Intolerant of low dissolved oxygen. Unlikely to thrive in the reservoir, but may survive if adequate fish passage is provided and access to tributaries maintained.
3. Main channel spawner (short-distance migrant) species: Living in the main channel but migrating shorter distances to spawn in specific habitats in the main channel. Reservoir may inundate spawning habitats. Unlikely to thrive in the reservoir.
4. Floodplain spawner species: Latitudinal migrants that move from the main channels in the high flow seasons to spawn in the floodplains. They migrate back to the main channel as waters recede at times of low flow. Unlikely to thrive in the reservoir if the floodplains are inundated, and may be affected by reduced peak flows limiting access to floodplains downstream.
5. Eurytopic (generalist) species: No specific habitat requirements; found in many aquatic environments. Repeat breeders. Tolerant of low dissolved oxygen. Will thrive in the reservoir and under changed flow conditions.
6. Floodplain resident species: Living in the floodplain wetlands, channels, etc.; do not move into the main river. Repeat breeders. Tolerant of low dissolved oxygen. Sensitive to drawdown and amplitude of flooding, and to risks of drying out of the floodplain. May survive in reservoir.
7. Estuarine resident species: Living in estuaries with changing salinity and tidal influences. Unlikely to be affected by hydropower projects.
8. Anadromous species: Migratory species that move as adults from the sea into rivers, to spawn in freshwaters habitats, often in upland rivers and streams. Young fish migrate back to the sea to grow and complete their life cycle. Migration is potentially prevented by dams without appropriate fish passage.
9. Catadromous species: Migratory species that move down from upland areas as adults, to the sea where they spawn. Young fish migrate back up the rivers to grow and complete their life cycle. Migration is potentially prevented by dams without appropriate fish passage. Returning young fish may grow in the reservoirs, but the migrating adults may find the journey to the sea difficult without appropriate fish passage.
10. Marine visitor species: Fish coming into the estuaries and lowland areas from the sea. Unlikely to be affected by hydropower projects.

11. Non-native species: Exotics that have been introduced for aquaculture or stocking of water bodies, or aquarium escapees. Some may be invasive and represent a threat to native species. Often tolerant of changing environmental conditions, and may be dominant in reservoirs.

Most guilds will contain varied sizes and shapes of fish. Some families of fish will have representative species in several guilds. Not all guilds will be represented in every river system.

Source: Welcomme, R. L., Winemiller, K. O. and Cowx, I. G. (2006)

When a reservoir is first inundated, the flooded vegetation dies and rots, providing nutrients for algae and zooplankton in the reservoir. This is often followed by a rapid increase in fish populations, and fish catches can be high (Figure 3). After a few years, fisheries yields decrease to lower, more sustainable levels. The changes in conditions often favour exotic species that are more able to take advantage of the new reservoir conditions than native species, and fish population dynamics need to be well considered in the development of reservoir fisheries and stocking policies.

The creation of a reservoir fishery is often claimed as a potential benefit from hydropower; but after the initial boom in fish production, the long-term yields may not be as great as predicted. The fish species that make up the catch will reflect those species that can thrive in the reservoir environment, and are often exotics and sometimes invasive species, especially if these are stocked for enhancing the fishery.

2.2.3 Disturbance and mortality of biodiversity

Disturbance

Construction activities are very disturbing to wildlife, especially the noise and vibration from blasting, piling and construction traffic. Sensitive **congregatory species** such as bats or birds may be permanently displaced from roosting areas adjacent to the construction site or quarry. Disturbance by traffic along the access roads can reduce populations of mammals and birds within a corridor of 1 km on each side of the road, and up to 10 km if the access road opens the area for hunting and logging.

Direct mortality due to increased access

In addition to loss of habitat, harvesting of flora and fauna may increase during the construction and operation of hydropower schemes. The roads and transmission lines also facilitate access to forest areas that previously would have been very difficult to reach for the extraction of timber. Illegal logging may take place in the areas outside the footprint of the construction site and inundation area, with loggers taking advantage of site clearance activities to extract valuable timber trees. Hunting will also become easier, especially if driven by a demand for bush meat from the construction workers and local communities; and from the wider wildlife trade, which offers very high prices for some species of animals and plants for food, medicines and the pet trade. Direct mortality is an additional pressure that can push an already threatened species to local or even global extinction.

2.2.4 Air and water quality

Air quality during construction

Large volumes of dust and particulates are released into the air during construction and quarrying. If not adequately controlled, the dust settles on crops and natural vegetation in the surrounding areas. This results in lowering of photosynthetic activity in the plants, and reduced **primary production**. It can also render the leaves unpalatable to animals. These changes are often temporary, and plants generally recover post-construction.

Water quality

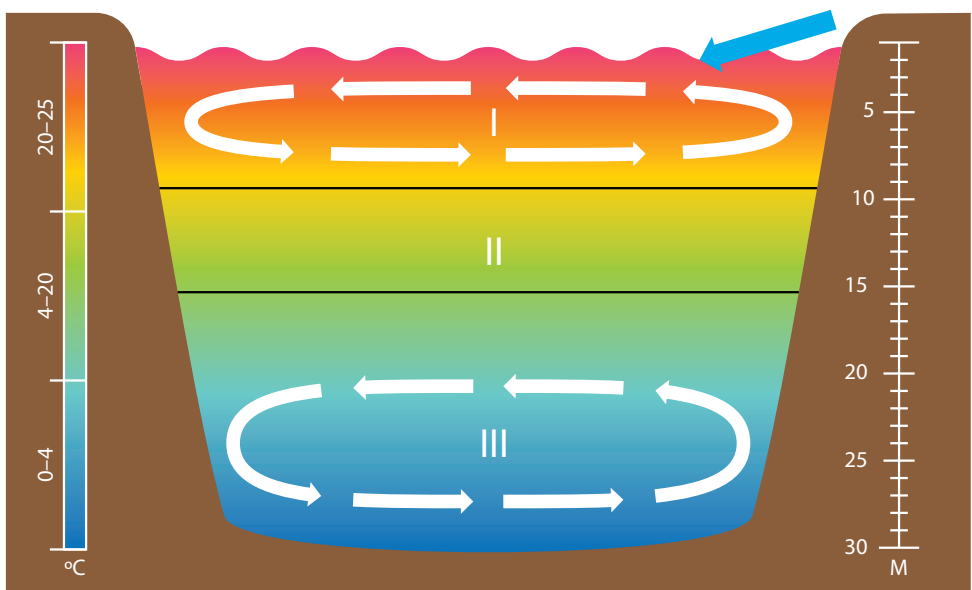
During construction, there are significant risks of water pollution from discharges of untreated sewage from construction workers' camps, leading to depletion of oxygen levels and foul conditions in the river. High sediment loads in the river result from runoff from excavation works and coffer dams erection, as well as from water pumped from the construction site, and soil dumped directly into the river from construction sites and access roads; in addition, high sediments cover the downstream river bed, making them unsuitable for many aquatic biota. Accidental spillages of oils and other chemicals leaching into the river can be toxic, polluting emergencies. All of these forms of pollution can affect the river health and populations of aquatic **macroinvertebrates**, and may even lead to fish mortality.

In deeper reservoirs, **stratification** may occur when the water separates into layers that do not easily mix because of temperature differences (Figure 4). The upper layer of water (or epilimnion, zone I, 5–10 m) will be warmed by the sun, aerated and full of aquatic life, but the bottom layer (hypolimnion, zone III) will become progressively cooler, anoxic and unmixed with the layers above (metalimnion, zone II). Water at the bottom which is devoid of

oxygen only supports anaerobic life forms. It may have acidic pH and high concentrations of metals (iron and manganese); it can form toxic methylmercury, which can bio-accumulate up the food chain to fish, which may then be eaten by local people. Water quality issues arise at certain times of the year when wind and turbulence mix the bottom layer with the top layer; this can give rise to mortality of fish both within the reservoir and downstream. In deep tropical reservoirs, this rarely occurs except when there is a strong storm event.

Trapping of sediments in the reservoir increases the transparency of the water. With high nutrient content (nitrate and phosphate) from upstream urban or agricultural pollution, the potential for photosynthesis and eutrophication may increase, and algal blooms occur in the still waters of the reservoir. Such algal blooms would not have occurred in the river because of lower transparency, and the flowing water would carry away the algae and not allow them to concentrate. Blue-green algal (cyanobacteria) blooms are a problem in recreational waters and drinking water, because high concentrations in the water are toxic for both humans and livestock.

Figure 4 Stratification of reservoirs leads to anoxic bottom layers and poor water quality discharged downstream



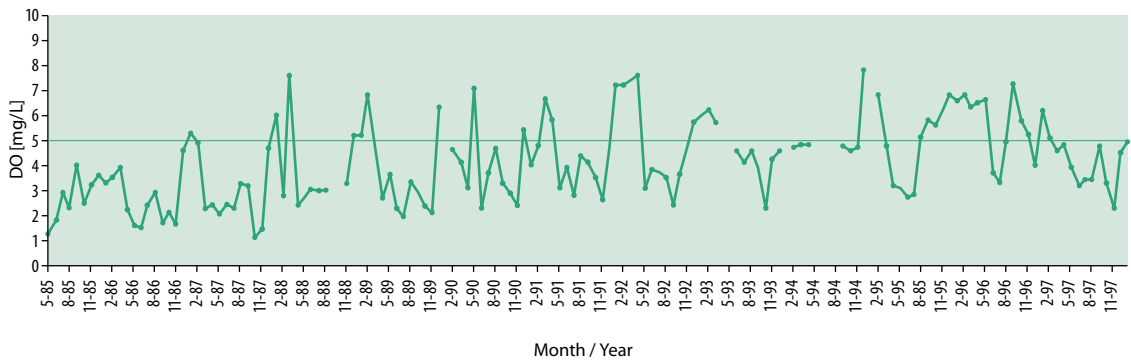


Figure 5 Monthly dissolved oxygen concentrations immediately below the Nam Ngum 1 dam, Lao PDR
 Source: Schouten, R. (1998). *Effects of Dams on Downstream Reservoir Fisheries, Case of Nam Ngum. Mekong Fish Catch and Culture. Mekong River Commission ISSN 0859-290X, Vol. 4, No. 2, December 1998.*

The discharge of poor water quality from lower layers through the turbines could kill much of the aquatic life below the dam, creating a zone downstream which is impassable for fish movement. Figure 5 shows the dissolved oxygen (DO) content immediately below the Nam Ngum 1 dam in Lao PDR, which rarely goes above the threshold of 5 mg/l that is recognised as necessary for good aquatic health.

Flushing of reservoirs to reduce sediment build-up can also result in large volumes of poor-quality water being released downstream. Often flushing releases water from the bottom layers with very high sediment concentrations over a short period, which can cause significant damage to the river habitats and biota for many kilometres downstream.

2.2.5 Catchment area degradation and sediment flows

The upstream catchment or watershed is an important resource for a hydropower plant, helping to regulate the run-off of rainfall and the quantity of sediment being washed into the reservoir. Degraded catchments can result in very rapid run-off and flash flooding.

Access roads and transmission lines from remote hydropower plants can sometimes cut through and damage the integrity and connectivity of parts of the upland catchments, including protected areas.

Watershed management plans are often a required component for hydropower environmental management. If sediment trapping in the reservoir is likely to reduce live storage, it is also in the interests of a hydropower company to maintain the forest cover and ecosystem integrity as part of the watershed management plan. This will also contribute to protection of the forest biodiversity, and there may be opportunities for establishing biodiversity protection measures in these upland catchment areas. National parks and protected areas are often located within these upland catchments, and hydropower developers have in many cases supported the management of these areas – for example, by ranger patrolling – as part of their biodiversity management plans.

2.2.6 Connectivity and fragmentation

Terrestrial habitat fragmentation

Some animals and plants are relatively sedentary, with a small habitat range within which they live, breed and feed. The populations of these species are determined by the density that the habitat can sustain, and so the impact of a hydropower plant is therefore directly related to the lost area of habitat. Other species are more mobile, and may move over a wider range to find suitable habitats for feeding and breeding. Some animal movements are related to seasonal availability of food plants and water, such as movement towards permanent water bodies in the dry

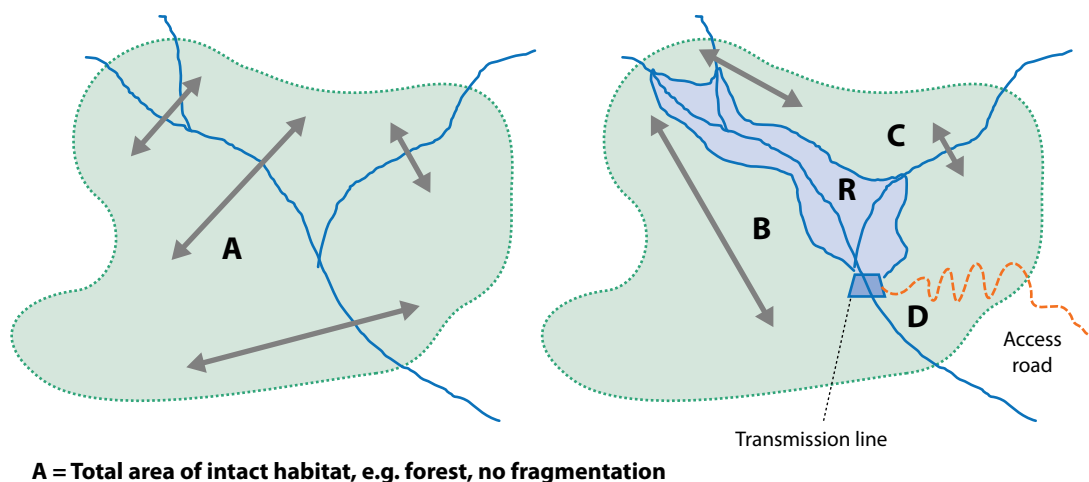


Figure 6 Monthly terrestrial habitat fragmentation and connectivity issues associated with a new dam and reservoir

Area A is fragmented into three terrestrial parts (B, C and D), and possible lines of animal movement are disrupted. Area D is further fragmented by transmission lines and access roads (arrows show feasible terrestrial wildlife pathways).

season; while others are clearly related to breeding cycles, with definite migration patterns which may cover tens or hundreds of kilometres.

Inundation can cause loss of suitable habitats, and the reservoir may prevent wildlife from moving between remaining habitats. Crossing the river during low flows will be impossible for some species, in the presence of a much wider and deeper body of water than had existed pre-project. Thus, fragmentation of the terrestrial habitat caused by the reservoir, and by access roads and transmission lines which also hinder movement, can be a serious issue for local biodiversity. The different habitat fragmentation and connectivity issues are illustrated in Figure 6.

A related connectivity issue is access to water and mineral deposits – salt licks – which some animals require for their healthy nutrition. It may be thought that the reservoir can provide drinking water for animals, especially in the dry season, but access to drinking locations can be difficult for many animals because of steep and muddy drawdowns. In some places the salt licks are inundated or cut off by the reservoir, and are thus inaccessible to a proportion of the animal population.

The reservoir will not only modify all terrestrial and riverine habitats, but it will also create a barrier for terrestrial species of biodiversity that used to move freely within the area, possibly crossing tributaries or even the main stem during the dry season. A reservoir several kilometres wide may constitute an insurmountable barrier for mammals, and even for some birds, insects and bats that will not cross open water. The dendritic form of many reservoirs risks creating ‘islands’ of land that are too small to be viable as habitat. Island theory demonstrates clearly that biodiversity richness drops significantly as the size of remaining ‘islands’ of habitat decline (see Box 5). Such islands may be cut off from neighbouring suitable habitats by the reservoir water on the one hand, and possible agricultural lands or roads on the other.

Aquatic connectivity

Hydropower dams fragment rivers, with high concrete barriers that break the connectivity between downstream and upstream. There are two significant impacts related to fragmentation: i) the trapping of sediment within the reservoirs, with changes to the downstream geomorphology and riverine habitats; and ii) the barrier to fish migration, both upstream and downstream.

Box 5 Island theory, biodiversity and the importance of connectivity

Biologists have known for a long time that there is a strong positive relationship between the size of the area that is sampled and the number of species (the 'richness') that is found there. The larger the area, the more species there are. Equally, the species richness of an 'island' of any given habitat (for example, a patch of forest in a savannah) is lower with the greater the isolation of the island. This is because it is harder for species to reach the 'island' from other areas of similar habitat.

This highlights the significance of fragmentation of a contiguous habitat into individual 'islands' of habitat, caused by the creation of a reservoir. The smaller the remaining fragments, and the less they are connected to other areas of similar habitat, the more impoverished the biodiversity richness will become. Species richness can be partially maintained by enlarging remaining fragments and seeking to connect them to other areas of similar habitat, through the creation or restoration of appropriate corridors.

One good example of this is the Reventazon project in Costa Rica, which explicitly supported the restoration and maintenance of corridors for large mammals in the Environmental Management Plan (see Annex 2).

There are several groups or guilds of migratory fish that will be affected by dams (see Box 4).

Anadromous fish species, such as salmon and shad, migrate from the sea to spawn in the upper reaches and tributaries. The young fish mature in the river and return to the sea some years later.

Catadromous fish, such as eels, migrate down the river as adults to spawn in the sea, and the young elvers migrate back upstream, even to the headwaters, where they grow and mature. Within the river, there will be long-distance migrants which swim upstream to spawn in the tributaries and headwaters, and short-distance migrants that move from one part of the main channel to spawning grounds upstream. There are also floodplain spawners that migrate laterally from the main channels into floodplains to spawn during periods of high flow; these are less likely to be affected by the dam barriers, though they can be affected by changing flow regimes.

Fish passages were originally designed to allow the migration of salmon, due to their economic and cultural importance; however, the application of similar designs has proved to be ineffective for most other migratory species, as these are of different sizes and have different swimming speeds in other parts of the world. Fish passes are generally possible on relatively low dams (up to 10 m), but are less effective the higher the dam; and even if

fish can negotiate a fish pass, they may lose their way when reaching the reservoir, since they are dependent upon the flow of water for their sense of direction. Often, fish that reach the reservoir are weakened by the ordeal, and may be easy prey to predators adapted to the reservoir habitat.

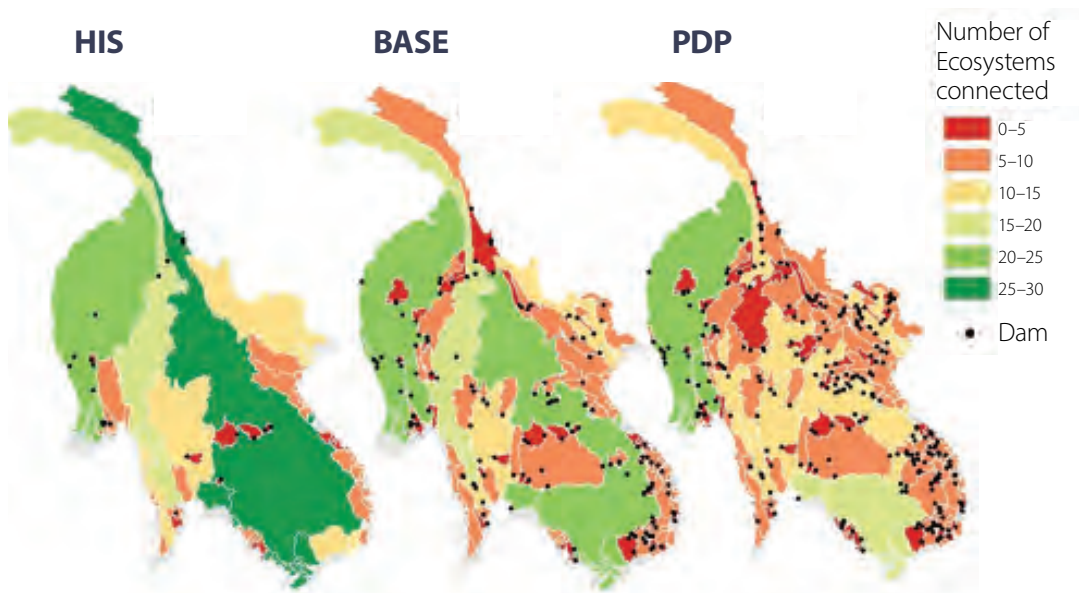
Downstream passage is equally problematic. Young fish, or fish such as eels and large fish returning from spawning, often do not survive the turbines and the rapid changes in barometric pressure across the dam during their passage downstream.

Some fish that are able to live in the reservoir conditions need to move into the upstream rivers and tributaries in order to spawn. It is essential that access to these upstream rivers and streams is maintained for healthy populations of fish in the reservoir. This is one of the challenges for cascades of dams which fragment the river into smaller river ecosystems, as illustrated in Box 6.

2.2.7 Changes in flow and sediment transport

An unmodified river has seasonal patterns of water flow and sediment transport that have created its characteristic river geomorphology and habitats. Hydropower will change the rates and timing of

Box 6 Cumulative effects on river ecosystem fragmentation from different hydropower development scenarios in the rivers of south-east Asia



A Strategic Environmental Assessment for the Asian Development Bank assessed the impacts of different hydropower development scenarios on the fragmentation of rivers in the Greater Mekong sub-region. The maps illustrate the progressive decrease in the numbers of river ecosystems that remain connected as more dams are built.

- **HIS:** historic river impoundments up to 1970.
- **BASE:** dams in 2010.
- **PDP:** planned dams to 2025.

Source: ADB (2014). *Strategic Environmental Assessment of regional power development in the Greater Mekong Sub-region*.

both seasonal and daily flows – especially storage projects and those that operate hydropeaking. The trapping of sediment in the reservoir will reduce sediment transport downstream. Both changes in the flow regime and sediment transport will have long-term impacts upon the downstream habitats.

In hydropeaking, the daily flow regime varies from very low flows being released when the turbines are not generating electricity, to much higher rates of flow at times of peak demand. The habitats in the river immediately downstream of a dam are likely to be degraded

by the changes in flow and ramping rates. The aquatic flora and fauna, macroinvertebrates and fish populations can become depleted, and may only recover many kilometres downstream; usually where tributaries join the dammed river and balance out the daily flow variation.

The changes in seasonal patterns of flow due to storage dams, with lower peak flows in the high-flow season and higher water levels in the low-flow season, will also affect downstream habitats. Lower peak flows mean that wetlands in the floodplains will receive less water on average each year, and

will tend to shrink in size and be less attractive for migratory and congregatory water birds. They may also be less accessible for fish that move seasonally into the floodplains to spawn. Fish production in the Inner Niger delta in Mali, for example, is linearly correlated with the maximum height of the annual flood of the Niger River. Higher water levels in the dry season result in smaller areas of exposed habitats such as sandbanks, which are important for nesting turtles and sand-bar nesting birds.

If there are fewer sediments in the water downstream of dams due to sediment trapping in the reservoir, the riverbed and banks downstream are likely to be eroded. This is the so-called 'hungry water' phenomenon, where the river erodes the channel in order to pick up more sediment. As a result, the eroded habitats will have impoverished aquatic flora and fauna. Changes in the sediment transport may also affect the fertility of the floodplains and delta, if the fine sediments which have attached nutrients are trapped in the reservoir.

2.2.8 Impacts of invasive alien species

An alien species is a species introduced to an area outside its natural past or present distribution; if this species becomes problematic, it is termed an invasive alien species. Not all exotic or introduced species become invasive, but only those that proliferate without the natural controls that existed in their region of origin. They may lead to changes in the structure and composition of ecosystems, thus detrimentally affecting ecosystem services, the human economy and well-being. They are recognised as one of the most common threats to already threatened species.

During implementation, hydropower construction activities can lead to the proliferation of invasive plant species that take advantage of the disturbed conditions in the construction site, which then provides a focus for spreading to other locations nearby. Some invasive alien species may be brought in from outside, in the construction materials – especially the sand and aggregate, which may contain the seeds and spores of the alien species. A tropical species transported in this way is the giant mimosa (*Mimosa pigra*), an aggressive

thorny shrub, which can be brought in with sand from a river that is infested, and introduced into a river system that does not have it yet.

Biofouling of hydraulic structures by zebra and quagga mussels (*Dreissena polymorpha* and *D. rostriformis bugensis*) is reported to occur in North American and European water structures, spreading from its native area around the Caspian and Black Seas. Growths of these species encrust trash racks and intakes of hydropower plants, and can reduce electricity generation. In the Alpaslan II HPP in southeast Turkey, the reduction in power generation due to zebra mussel growth has been estimated at 4.2 per cent, and the costs of Zebra mussel control in hydraulic structures in the American Great Lakes exceeds USD 500 million per year.

During operation, the aquatic invasive plants, such as water hyacinth (*Eichhornia crassipes*) (Box 7), kariba weed (*Salvinia molesta*) or water cabbage (*Pistia stratiotes*) can proliferate in the still waters of the reservoir and collect in large floating masses near the dam, blocking the trash racks and causing problems for boats and navigation on the reservoir. When they pass through the turbines, they may be cut up into smaller pieces that can then pass on to the downstream reaches, where they will continue to proliferate.

Invasive fish include tilapia (*Oreochromis mossambicus* and *O. niloticus*), an African species which is a major threat to native species through competition for food and breeding space in the Americas. The common carp (*Cyprinus carpio*) is considered as invasive, following its introduction as a source of protein for human consumption into tropical and subtropical lake systems. It is the third most frequently introduced species in the world. Its method of feeding churns up the sediments on the bottom of the water and uproots **macrophytes**, making it a keystone ecosystem engineer, altering habitats for native fish and other native aquatic species.

Box 7 Water hyacinth

Originally from South America, *Eichhornia crassipes* is one of the worst aquatic weeds in the world. Its beautiful large purple and violet flowers make it a popular ornamental plant for ponds. It is now found in more than 50 countries on five continents. Water hyacinth is a very fast-growing plant, with populations known to double in as little as 12 days. Infestations of this weed block waterways, limiting boat traffic, swimming and fishing. Water hyacinth also prevents sunlight and oxygen from reaching the water column and submerged plants. Its shading and crowding of native aquatic plants dramatically reduces biological diversity in aquatic ecosystems.



2.3 Risks to hydropower development if biodiversity is impacted

Hydropower development can pose a risk for species and habitats, some of which will already be pressurised by other kinds of human development within their range. The areas of influence of hydropower projects often extend into areas that are undeveloped, and which may have provided refuge from other kinds of disturbance. The developer of a sustainable hydropower project should be concerned about biodiversity mitigation and management, because of the risks to the implementation and operation

of the project (Table 3). In addition, there may be opportunities for further protecting and restoring biodiversity, creating new and diverse habitats.

2.4 Key biodiversity stakeholders

There are many stakeholders – both individuals and organisations – who are concerned about the increasing pressure upon threatened biodiversity, both globally and locally, and have the knowledge and expertise required for their protection. Some may be vocal critics of hydropower, but many are potential partners with whom the hydropower developer can work, to ensure greater sustainability of the scheme. Local communities are also key stakeholders when they are dependent on Provisioning Ecosystem Services.

Table 3 Risks to hydropower projects if biodiversity impacts are not properly addressed

Risks	Relevance of biodiversity
Licence to operate	Increasingly, biodiversity concerns are a significant component of the environmental management of hydropower and concession agreements. They will require compliance with biodiversity standards and regulations, especially if the project is located within an area of high biodiversity importance (e.g. Protected Area or Key Biodiversity Area) or its area of influence.
Financial risks	Many of the lenders (e.g. development banks and Equator Principles financial institutions) pay great attention to the biodiversity impacts and mitigation measures, especially if the project will affect critical habitats and endangered species.
Public criticism and Implementation delays	Impacts on biodiversity is one of the main topics of public criticism of hydropower, along with resettlement and dam safety. If the developers do not know what biodiversity is at risk in the project's area of influence and how this can be managed or mitigated, they may face considerable public criticism, which can lead to delays in construction.
Reputational risks	Reputational risk is associated with the developer's performance in managing and mitigating the biodiversity risks, and official and public perception of this performance. Reputational risk may affect ongoing operation of a project and the opportunities to develop new plants.
Operational risks	Operational risks include the length of life of the project, due to sedimentation associated with degraded watersheds (addressed through good catchment management upstream, which may also provide an opportunity and benefit for biodiversity); through accumulation of invasive aquatic plants in the reservoir, with potential damage to mechanical equipment; or through the loss of Provisioning Ecosystem Services for local communities affected by resettlement, e.g. declining fish production.

Stakeholders with rights, roles and responsibilities for biodiversity may be grouped into the following:

- Hydropower developers, including banks and financing institutions, who wish to reduce the risks to the project that the loss of or damage to biodiversity may entail. Other hydropower developers or operators in the same river basin should be included.
- Government ministries and agencies responsible for the environment, water and natural resources, including protected areas and international conventions related to biodiversity.
- Communities and river-user groups dependent upon the provisioning ecosystem services, which may also have local knowledge of the biodiversity in the project's area of influence.

- Environmental conservation and social development NGOs that may have specific interests regarding biodiversity and provisioning ecosystem services. These may also have detailed knowledge of the biodiversity and its management.
- Academic and research institutes that may have detailed knowledge and research relating to the biodiversity and its management.

The identification of partners with whom to work during the assessment of biodiversity impacts, implementation and monitoring of biodiversity management measures, is explored in greater detail in section 4.4.2.



3 Achieving good international industry practice



Achieving good international industry practice

This chapter maps out the aspects that are necessary to meet good international industry practice. It describes the mitigation hierarchy, and the key components of each of the main HSAP stages required for a project to meet good international practice in the management of biodiversity and invasive species. Cross-references to Chapter 4 describe the methodological tools for each of these good-practice approaches in more detail.



Whooshh FishL Recognition scanning system programmed to sort invasive species and pass desired ones at the Herting Hydropower Project in Falkenberg, Sweden
Photo credit: Whooshh Innovations

3.1 Biodiversity and invasive species in the project life cycle

The HSAP allows the assessment of hydropower projects according to four life cycle stage tools: Early Stage, Preparation, Implementation, and Operation. These different stages include the detailed studies familiar to those involved in dam design and construction. While timing varies between projects, an indicative timetable showing HSAP stages and the associated reports is shown in Figure 7.

It is evident that government or basin organisations need to have played their role upstream of individual project-related decisions – particularly in the early stages of site and options assessment – by fully assessing project alternatives, and where possible, avoiding negative impacts through good

site selection. In consequence, not all of the tools presented here can be delivered by a project developer, particularly one from the private sector, if it has not been actively involved in basin-level strategic impact and options assessment and planning.

Identifying and managing environmental impacts throughout the life cycle requires developers to understand in increasing detail how the project affects ecosystems and biodiversity, including invasive species, within the basin. The overall process is one of improving understanding, and a clearer focus on what is important and essential for the project to address. It is unrealistic to expect all aspects of a dam's impact to be mitigated or compensated. The ESIA process intends to understand impacts, assess their importance, and then manage or compensate for those that are considered significant. Each stage of the project

Figure 7 Approximate timings of studies and HSAP stages

Project stage:	Pre-feasibility	Feasibility and impact studies	Approval processes	Detailed design	Construction/implementation	Operation
Indicative duration:	~1–3 years	~1–3 years	~½–1 years	~½–1 years	~2–5 years	~50–100 years
HSAP tool:	Early stage	Preparation			Implementation	Operation

cycle builds on what precedes it, and it is important that no unexpected findings on ecosystems or biodiversity impacts appear late in the planning process, as these can potentially derail project development. Early and extensive scoping, full biodiversity surveys, and an assumption, until proven otherwise, that impacts will occur as far downstream as the delta, all help to prevent unexpected issues arising late in the project cycle.

3.1.1 The Mitigation Hierarchy

The HSAP assessment process puts particular emphasis on applying the Mitigation Hierarchy in dealing with environmental impacts. It is widely adopted by project developers, lenders, industry organisations, and consultants engaged in environmental assessment and impact management. It consists of the following steps (Figure 8):

1. **Avoid:** Measures are taken to avoid creating impacts from the outset, such as careful spatial or temporal placement of infrastructure or timing of disturbance. For example, selecting dam sites that are least rich in ecosystems or species, or those on tributaries, to avoid blocking fish migration in the main stem. Avoidance is often the easiest, cheapest and most effective

way of reducing potential negative impacts, but to be most effective it requires biodiversity to be considered in the early stages of a project, when several alternative designs or sites are still on the table.

- 2. **Minimise:** Measures are taken to reduce the duration, intensity and/or extent of impacts that cannot be completely avoided. Effective minimisation can eliminate some negative impacts: for example, reducing the reservoir level to lessen the reservoir footprint on sensitive forests, or releasing downstream flows for ecosystem maintenance.
- 3. **Mitigate** (also known as ‘rehabilitate/restore’): Measures are taken to restore biodiversity values or ecological functions affected by impacts that cannot be completely avoided or minimised. Restoration of disturbed sites tries to return an area to the original ecosystem that existed before impacts, whereas rehabilitation only aims to restore some basic ecological functions and/or ecosystem services (e.g. through planting trees to stabilise bare soil).
- 4. **Compensate:** Measures are taken to compensate for or offset any residual adverse impacts, after full implementation of the previous three steps of the mitigation hierarchy,

Figure 8 Mitigation Hierarchy
Redrawn from <https://www.forest-trends.org/bbop/bbop-key-concepts/mitigation-hierarchy/> and OECD Environment directorate (2013)

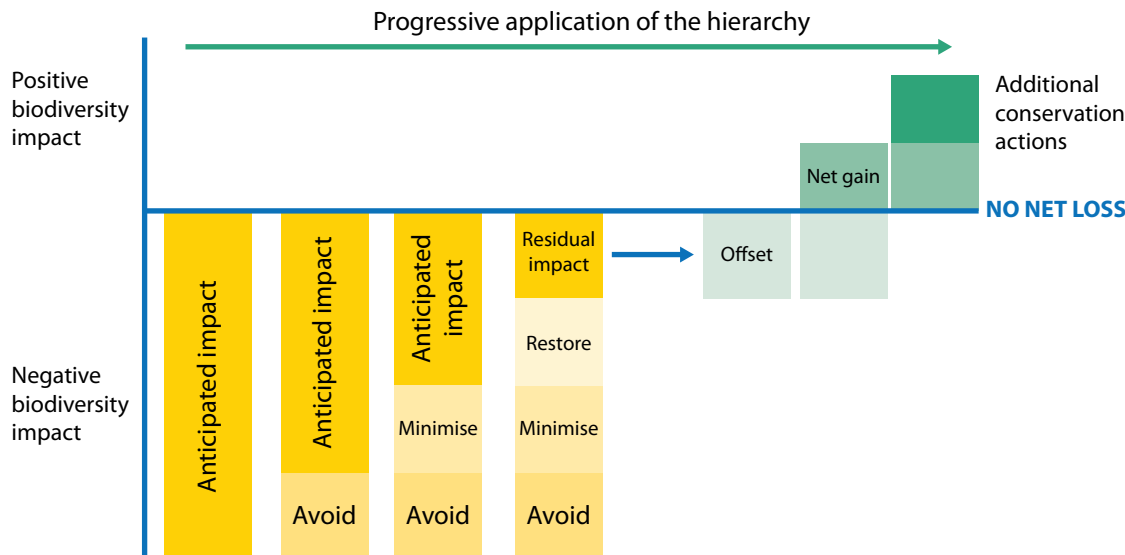
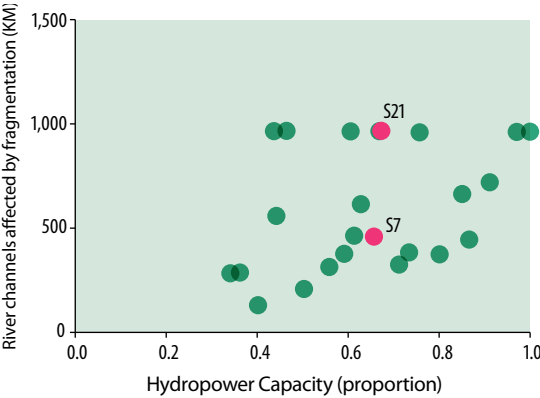


Figure 9 Results from the TNC study of Coatzacoalcos Basin in Mexico

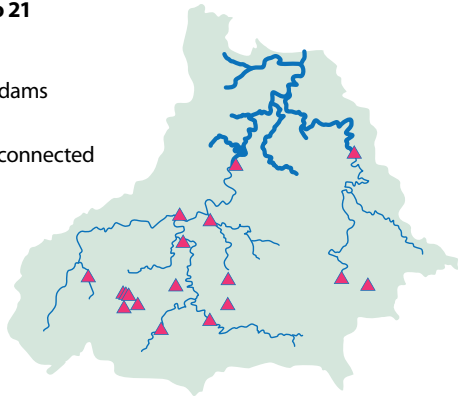


Above: Hydropower capacity and river kilometers affected by fragmentation for alternative development scenarios in the Coatzacoalcos. The two scenarios compared in the maps below are highlighted in red.

Scenario 21

▲ Planned dams

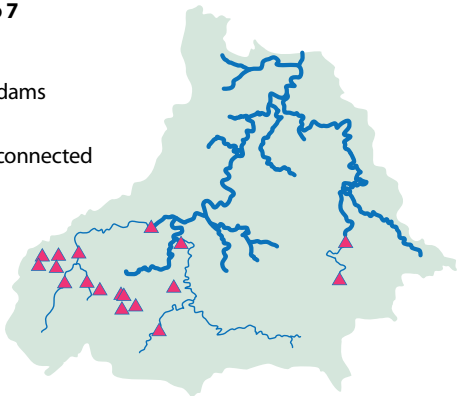
— Longest connected network



Scenario 7

▲ Planned dams

— Longest connected network



Above: Two scenarios with similar hydropower capacity, but considerably different levels of connectivity. Scenario 7 has 452 km affected by fragmentation compared to Scenario 21 with 970 km.

in order to achieve no net loss, or a net gains in biodiversity values.

3.1.2 Basin planning

Good site selection and assessment of alternatives is a key step in avoiding negative biodiversity impacts, both terrestrial ones (e.g. avoiding protected areas) and aquatic (e.g. avoiding the main stem of a particular river). Once a site is selected, a project developer's margin for manoeuvre to 'avoid' impacts is significantly reduced. Studies undertaken by, for example, TNC in Mexico (Figure 9) show that good site selection at basin scale can significantly avoid riverine and terrestrial impacts due to fragmentation, while delivering similar levels of power generation.

3.1.3 Early Stage

The key objective in the Early Stage is to identify and analyse the environmental issues and risks that may influence a decision to invest in further preparation of the hydropower project under consideration. Early evaluation of risks avoids the danger that developers will have invested significantly in project preparation before risks are identified, and it is difficult to then consider an alternative project. This stage includes all environmental risks, of which biodiversity is only one subset, along with health, pollution / water quality, greenhouse gas emissions, sedimentation, etc.

A dam project has several impact dimensions in its area of influence. It principally impacts the hydrological dynamics of the river; it floods terrestrial habitats in the reservoir area; and it potentially constitutes a blockage to connectivity, both aquatic and terrestrial. All these impacts have a geographical dimension to consider in the Early Stage. Developers need to look beyond the immediate impact of the individual project, and consider how it will affect its surroundings, upstream and downstream, by identifying and scoping the key issues that will need to be addressed in the Preparation stage. Some of this information may be available in basin development plans.

Table 4 Key tasks and activities for biodiversity and invasive species assessments during the Early Stage

Key tasks	Key activities	Chapter 4 reference
Identify the direct area of influence and project boundaries	Start with the whole basin and understand the most sensitive areas/ecosystems, and then focus on the selected site(s): • Reservoir area • Influences from upstream • Immediate downstream • Extended downstream Demonstrate the point downstream where ‘no impact’ due to modified flows or sediments is likely to be discernible. Identify, wherever possible, potential access roads, quarries, construction camps, transmission lines and resettlement sites	4.1 4.2
Identify key biodiversity features and invasive species impacts, to ensure no surprises later in the project cycle Follow the Mitigation Hierarchy	Consult the IUCN Red List of Threatened Species, World Database of Protected Areas, national protected species legislation and protected areas agencies, World Bases of Key Biodiversity Areas, Ramsar Sites and the Integrated Biodiversity Assessment Tool (IBAT), to identify what is significant. Connectivity and migration: Identify migratory species, both terrestrial and aquatic, in the affected river basin, and perform GIS spatial mapping of habitats. Assess terrestrial and aquatic dimensions of the transformation caused by the project (including diversions, inside/ outside basin).	4.3
Identify natural habitats providing Provisioning Ecosystem Services	Map areas providing Provisioning Ecosystem Services for communities in reservoir area (fisheries, grazing, wood collection, etc.) and downstream (e.g. flood dependent fisheries or grazing areas). Plan how to quantify the economic contribution of these services to livelihoods, and compensate for their possible loss. Hold a workshop to consult on the draft report and mobilise local knowledge.	4.3.1
Make plans to address any data deficiencies	Plans to contract NGO, university or institute(s) to conduct field surveys during full ESIA.	4.3.2
Identify potential invasive species issues	Document known invasives, their presence in the basin/ country, and their risks.	4.3.5
Initial consideration of potential compensation and offsets requirements	Identify whether the presence of critical habitats or threatened species may require broader (geographic) consideration of offsets in the ESIA.	4.3.6

Identify cumulative impact issues and any legacy issues	Refer to the basin plan	4.4.1
Link to Preparation stage studies, where proposed biodiversity measures may modify project design or viability	Ensure iterative interactions between the ESIA and design teams, to avoid impacts.	4.4.1
Propose provisional budgets, the required effort, and analyse potential for partnerships	Design partnership approaches that can build the capacity needed to deal with biodiversity and invasive species issues throughout the project cycle, starting at ESIA.	4.4.2

Projects will also benefit from early identification of a group of competent experts or institutions to accompany the design process. For example, experts in local universities, NGOs, and/or international researchers with knowledge of the principal ecosystems, can be located through an internet search.

Table 4 shows the key tasks and activities for this stage, which involve desktop analyses of environmental issues, strategic environmental assessments, expert opinion, and consultation with NGOs and local stakeholder groups. Readers can then refer to Chapter 4 for further detailed information on each task or activity. The approach should be as broad as possible, to ensure that a general understanding of potential impacts and data gaps is obtained at this Early Stage, in a way that can guide future studies during the ESIA process. The starting point is necessarily wide-ranging, in order to subsequently filter and focus effort on the most significant aspects in later project development stages.

Some of these tasks may more usually be carried out at later project development stages. In consequence, it becomes harder to 'avoid' impacts, as some degree of project selection and dimensioning has already occurred in the absence of biodiversity considerations. This guide therefore proposes that the consideration of biodiversity is considerably reinforced in the Early Stage.

One of the main outcomes of the Early Stage is a plan for additional field study (upstream, reservoir area and downstream), which will allow:

- improved knowledge of the distribution and ecology of critical habitats and threatened,

endemic and/or migratory species identified during the Early Stage, sufficient to allow the development of minimisation, mitigation and compensation plans in the ESIA;

- establishment of a baseline that will allow monitoring of the project impacts on threatened biodiversity and critical habitats throughout the project's lifetime; and
- identification of threatened biodiversity and/or Provisioning Ecosystem Services issues where avoidance and/or minimisation will require extensive interaction with the engineering design team.

3.1.4 Preparation stage (planning, design, assessment)

This guide proposes beginning with desk-study biodiversity assessment in the Early Stage, to allow the available information to help in avoiding impacts, and in properly dimensioning the work that will be required during ESIA.

If this has been started in the Early Stage, as proposed, then the Preparation stage involves focusing in increasing detail on each of the issues identified in the Early Stage, and filling gaps in knowledge (Table 5). There is therefore some inevitable overlap between this section and the previous one, where similar issues were addressed in more detail.

Once a project site is selected, there are still opportunities to avoid some impacts, but to a lesser extent than in the Early Stage. It is still feasible to adjust the final height of the dam, the area flooded

Table 5 Key tasks and activities during the Preparation stage

Key tasks	Key activities	Chapter 4 reference
Understand distribution and habitat needs of threatened biodiversity within the project-affected area	ToR that include the minimum required time and resources to: • Carry out field surveys by specialists in major flora and fauna groups, terrestrial and riverine, nocturnal/diurnal, annual cycle; and • Assess the connectivity needs of major species (terrestrial and aquatic).	4.3 4.4.4 4.5.5
Understand human uses of Provisioning Ecosystem Services	Study and evaluate human uses and their importance for livelihoods (see How-to Guide on Hydropower Resettlement). Identify extent and acceptability to communities of impacts on species habitat, ecosystems and livelihoods. Identify any fisheries and ecotourism development opportunities.	4.4.5 4.5.4
Identify the significant impacts on threatened biodiversity that need to be minimised, mitigated or compensated	Identify extent and acceptability of impacts on species, habitats and ecosystems. Prioritise the management actions to be undertaken.	4.4.3 4.4.4 4.4.5
Plan mitigation and compensation activities	Develop environmental and social management and monitoring plans for restoration/compensation in watershed/locally/nationally (e.g. creation of protected areas, new fisheries, etc.).	4.4 4.5
Identify who to work with	Scoping of potential partner institutions for delivery of ESMMP and any associated BAPs (e.g. protected area managers, fisheries organisations, universities, NGOs, communities).	4.4.2

in consequence, and the way in which storage and releases may avoid certain downstream impacts (e.g. through releasing E-Flows), through adjustments to design and operating rules. However, most of the study effort in this stage is usually devoted to the minimisation, mitigation, and compensation/offset components of the Mitigation Hierarchy. This requires both an understanding of intrinsic biodiversity values, key habitats, and an appreciation of human uses for Provisioning Ecosystem Services (which links in turn to HSAP Topics on Resettlement and on Indigenous Peoples).

Most of this stage concerns the collection and analysis of field survey data, to either reinforce understanding of distribution and population

size of key threatened species or habitat distribution in the project-affected area, or to identify where data may have been deficient in the Early Stage, by undertaking the fieldwork required to determine what species are present and the habitat composition. Field surveys should last at least one annual cycle, and address all major species groupings (birds, reptiles, amphibians, fish, mammals, invertebrates, etc.), using a harmonised mapping approach (i.e. the data for different species groups should be illustrated on a standardised GIS template).

The key challenge for impact assessment and management is to identify what is important. Biologists have spent many years developing

criteria for identifying important habitats, which have formed the basis for designating Protected Area networks in each country. These usually have a numerical (scarcity) dimension and a spatial (size, corridor connectivity) dimension. In too many cases, environmental assessments focus excessively on documenting the presence/absence of individual species. Yet what is essential in the assessment process is not solely what species are present. What really matters is whether their loss is 'significant'; this can only be determined by looking both at their intrinsic rarity and at the wider distribution of the species/habitat, as well as whether the loss at the project site significantly compromises populations of threatened species. For Provisioning Ecosystem Services, the significance of the loss is assessed in terms of impacts on livelihoods and/or economic assessments. The acceptability of the loss, and of the compensation measures proposed, is negotiated with the communities who use the services. ESIA processes therefore need to take a wide, spatial approach, and to consider the project-affected area within a broader geographic context.

During the Preparation stage, the developer can build the capacity of individuals and institutions on which it will rely to deliver the different components of the management plan. This might involve mobilising national universities or NGOs, financing local studies by researchers, or building mixed teams composed of biologists and ESIA specialists who are accustomed to planning management interventions. Developers also need to ensure that their own environmental department staff participate fully in the ESIA, so that they gain a full understanding of the issues involved. While it may be desirable to mobilise large external consultants to do ESIA work and to deliver a professional report, consideration should also be given to building the local capacity needed for effective long-term delivery and monitoring of any mitigation and compensation plans (for further information, please refer to the How-to Guide on Hydropower Environmental and Social Assessment and Management).

Box 8 Nested plans for biodiversity management

There is often a proliferation of plans for different aspects of environmental and social management; whether these are developed will depend upon the importance of the aspect, and whether it merits its own free-standing management plan. All plans should fall under the scope of the overall Environmental and Social Management and Monitoring Plan (ESMMP), often divided into a) construction and b) operation phases.

Sub-plans may include:

- **Biodiversity Management Plan (BMP):** Covers biodiversity management of minimisation and mitigation measures, usually under direct control of the developer or contractor. It may include rescue of wildlife, habitat rehabilitation, watershed management, reservoir and fisheries management, environmental flows, etc., and should also contain monitoring measures;
- **Biodiversity Action Plan (BAP):** Covers specific actions for the conservation of threatened species and critical habitats and offsetting, usually in collaboration with other conservation agencies. It may include detailed biodiversity offset design and monitoring;
- **Invasive Species Plan (ISP):** Covers identification, monitoring for outbreaks of invasive species, and control measures; and
- **Reservoir Management Plan:** Covers the impact of operations on the reservoir and activities such as fishery management.

Table 6 Key tasks and activities during the Implementation stage

Key tasks	Key activities	Chapter 4 reference
Consider impact of construction, BMP	Mitigate construction site impacts and indirect impacts of construction workers.	4.5.1
Reduce impacts on wildlife in reservoir area	Wildlife rescue operations on flooding, monitor impacts on connectivity.	4.5.3 4.5.5
Deliver BAP for threatened species and habitats	Develop and finance partnership with management institutions. Foster emergence of any institutions (e.g. community fisheries organisation) essential to delivering the plans.	4.5 4.4.2
Invasive species measures	Awareness of key invasive species. Monitoring of occurrence. Control measures.	4.4.5 4.4.6 4.4.7

3.1.5 Implementation stage

During the Implementation stage, the focus of biodiversity interventions is on (a) managing the direct and indirect consequences of the construction site; (b) clearing the reservoir area and rescuing any sensitive wildlife; and (c) continued planning for mitigation/compensation of negative impacts that will occur upon reservoir flooding. Table 6 identifies the key tasks during the Implementation stage.

The risks to biodiversity caused by oil spills, sediment release into the river, quarrying activities, transport, waste disposal, etc., should be dealt with in the Environmental and Social Management and Monitoring Plan (ESMMP) in order to reduce risks, especially to riverine biodiversity. Indirect impacts stemming from inward migration of construction workers and their families (such as poaching, increased wood consumption, clearing of woodland for crop cultivation, etc.) will also have been considered. The opening of new access roads into natural rural areas may disturb biodiversity and bring other risks that require attention.

Forest timber resources to be flooded by the reservoir may be valuable and merit removal, particularly in shallow reservoirs. Complete clearance of the reservoir area has been claimed to reduce greenhouse gas emissions, although

recent evidence suggests this benefit is marginal. Fishermen prefer the reservoir to be cleared, to allow good access for fishing boats and less risk to nets; however, it may be helpful to leave some areas uncleared, as these can act as important breeding and nursery grounds, as well as a fishery reserve. Clearance of trees further improves the landscape aesthetics of the area post-impoundment. Box 8 shows some of the different management plans that may be nested within the ESMMP.

3.1.6 Operation stage

During the Operation stage, the developer delivers the agreed biodiversity management components and monitors the outcomes, to ensure that the desired impact is achieved. Table 7 shows the key tasks to be undertaken during the Operation stage. The plans are financed directly by the developer, often as part of the licensing or loan agreement conditions; but they can be implemented by many different partner institutions who have the core expertise to manage the issue at hand. Thus, for example, fisheries institutes may manage fish-related issues; national parks or forest management committees may manage reforestation programmes as part of a watershed management plan, undertake anti-poaching activities or management of protected areas; and zoos or NGOs may manage any required captive

Table 7 Key tasks and activities during the Operation stage

Key tasks	Key activities	Chapter 4 reference
Monitoring the delivery of agreed BMP/BAPs	Partnership with management institutions. Establishment of an independent scientific committee. Regular, transparent cycles of review. Adapting to the changing context.	4.7
Formulation of clear management objectives		4.6
Watershed management		4.4.3
Invasive species plan (ISP)		4.5.2
		4.4.7

breeding programmes. All these activities should be monitored by independent experts, to report on the achievement of the desired outcomes.

The Operation stage covers many years, and the developer will have to decide how much of the required activity will be carried out in-house, and how much will be outsourced to independent experts. Regular independent review, perhaps through a scientific committee of university and/or NGO experts established for this purpose, is recommended in order to increase accountability and transparency of outcome monitoring; especially in cases where impacts are significant and may have been considered unacceptable by some local stakeholders, such as local communities or nature protection interests.

Good formulation of the expected management outcomes is critical for effective monitoring of impacts; this is addressed in sections 4.4.3 and 4.7. Data gathered during regular monitoring of species and habitat status are used to assess progress.

During the Operation stage, which often lasts many decades, the developer should put in place processes of regular review, at least every five years, to ensure that outcomes are being achieved and adjustments are made where mitigation or compensation programmes may initially have proved ineffective. Biodiversity interventions will also need to evolve with the changing context, and dam operators may need to consider modifying operations or design

many years after project construction, if local circumstances or changing national regulations demand it (see, for example, Box 20).

Invasive species are often a challenge during the Operation stage, and careful consideration needs to be given to species of fish introduced into the reservoir fishery, as well as monitoring for unexpected invasive species (e.g. aquatic plants) in the Invasive Species Plan.

3.2 International good practice requirements for biodiversity and invasive species

In the Preparation, Implementation and Operation tools of the HSAP, international good practice criteria are set out, articulating the core requirements that the developer should demonstrate are being met. The following sections present the criteria requirements; highlight the important points to note; and where relevant, indicate where Chapter 4 provides more detailed guidance on strategies and approaches to deliver a number of these core requirements of international good practice. All requirements need to be delivered as is proportionate to the risks and impacts associated with the project.

Table 8 HSAP and HESG assessment criteria on the topic of Biodiversity and Invasive species

Criterion	Biodiversity and Invasive Species Topic Requirements
Assessment	Early Stage: An assessment has been undertaken of environmental issues and risks most relevant to the project. Preparation stage: An assessment of terrestrial biodiversity; aquatic biodiversity, including passage of aquatic species and loss of connectivity to significant habitat; and risks of invasive species, has been undertaken with no significant gaps. Implementation stage: Biodiversity issues relevant to project implementation and operation have been identified through an assessment process utilising appropriate expertise; and monitoring is being undertaken during the project implementation stage, as appropriate to the identified issues. Operation stage: Ongoing or emerging biodiversity issues have been identified, and if management measures are required, then monitoring is being undertaken to assess if management measures are effective.

3.2.1 Assessment

Table 8 summarises the assessment criteria requirements for achieving good international industry practice in the HSAP topic for Biodiversity and Invasive Species.

Assessment should include establishment of a pre-project baseline. The developer needs to demonstrate a good understanding of the full range of biodiversity and invasive species impacts generated by the project, set within the geographic context of the basin; it must also have rigorously identified those that are sufficiently significant to require specific avoidance, mitigation or compensation plans.

Any legislative or lender requirements relating to biodiversity or invasive species should be identified in the assessment.

3.2.2 Management

The management of anticipated impacts flows directly from the assessment phase. Table 9 shows the management criteria for HSAP topic on biodiversity and invasive species. It involves demonstrating the required measures, along with the institutional capacity and budgets to deliver the necessary mitigation and compensation plans. These may include the following:

- measures to protect biodiversity;

Table 9 HSAP Management criteria on the topic of Biodiversity and Invasive Species

Criterion	Biodiversity and Invasive Species Topic Requirements
Management	Preparation stage: Plans and processes to address identified biodiversity issues have been developed for project implementation and operation, with no significant gaps. Implementation stage: Processes are in place to ensure management of identified biodiversity issues, and to meet commitments relevant to the project implementation stage; and plans are in place for the operation stage, for ongoing biodiversity issues management. Operation stage: Measures are in place to manage identified biodiversity issues.

Table 10 HSAP conformance and compliance criteria on the topic of Biodiversity and Invasive Species

Criterion	Biodiversity and Invasive Species Topic Requirements
Conformance and Compliance	Implementation stage: Processes and objectives in place to manage biodiversity issues have been and are on track to be met, with no major non-compliances or non-conformances; and biodiversity-related commitments have been or are on track to be met. Operation stage: Processes and objectives in place to manage biodiversity issues have been and are on track to be met, with no major non-compliances or non-conformances; and biodiversity-related commitments have been or are on track to be met.

- measures to address passage of aquatic species;
 - measures to address invasive species; and
 - demonstrated use of the mitigation hierarchy.
- compliance with any licensing requirements; and
 - conformance with any project-related plans or commitments that may have been agreed with other actors or made publicly.

3.2.3 Conformance and compliance

Conformance (respecting internal commitments) and Compliance (respecting regulations) are important for sustainability. Table 10 shows the conformance and compliance criteria for the HSAP topic on Biodiversity and Invasive Species. Hydropower projects have been criticised in the past for not respecting some commitments made during project authorisation or financing, and for giving inadequate attention to these issues once the project is completed and energy is being generated. Good practice in this area is demonstrated when the developer assumes full responsibility for the mitigation or compensation of biodiversity and invasive species impacts, as outlined in the relevant plans, and puts in place the necessary internal processes (staffing, budget, reporting) to ensure their delivery. The assessment approach involves demonstrating that the developer has indeed done (or is doing) what it promised, and that the delivery mechanisms are proving robust and transparent.

This framework may include commitments to maintain certain populations of species, and to manage or restore particular habitats or particular commitments to budgets, deadlines or transparency obligations. The fulfilment of these commitments and the timely achievement of outcomes will be central to achieving full sustainability. In many cases, commitments on biodiversity or invasive species issues will require the project to have established its own internal monitoring systems, which report regularly both internally and externally, and assess whether outcomes have been achieved (or are likely to be achieved).

The conformance and compliance framework for a project includes:

- compliance with national legislation;
- compliance with any lender conditionalities;



4 Methodologies and technologies



Methodologies and technologies

This chapter describes the methodologies and approaches that will allow project developers to achieve good practice in managing biodiversity and invasive species impacts during the design, construction and operation of hydropower projects.





Fish passage on the Blanda River
in Iceland
Photo Credit: Joerg Hartmann

4.1 Basin-level planning

Prior to selection of individual project sites, it is good practice to undertake a basin-level study (which may involve a Strategic Environmental Assessment) that should:

- identify and avoid the most sensitive sites for threatened biodiversity sites and Provisioning Ecosystem Services (terrestrial and aquatic);
- identify particular biodiversity-rich or representative tributaries (or the main stem) that should, depending on basin or national policy, be left in a natural state (see, for example, Box 9 and Box 10);
- assess the need for basin-scale environmental flows to maintain any flow-dependent biodiversity values (both threatened species and Provisioning Ecosystem Services);
- analyse the cumulative impacts on flows that may come from the operation of hydropower cascades; and
- identify the best order of construction in order to minimise fragmentation and other biodiversity impacts, while optimising benefits.

Avoiding negative biodiversity impacts should be a key technical criterion in project selection (siting and dimension), both at basin scale and at project level. This stage is generally carried out by governments or basin organisations, and is usually beyond the remit of individual developers. This stage requires good assessment of project alternatives, and ensures that the site(s) selected avoid the most biodiversity-rich areas. Clearly, site selection also has links to the avoidance of resettlement risks at identified sites (for further information, please refer to How-to Guide on Hydropower Resettlement), as terrestrial biodiversity richness is often inversely correlated with the density of human habitation. The increased human pressure on biodiversity in the locations or host communities where people are to be resettled should also be considered.

If a developer has an option to choose between several sites for hydropower development within a basin where a full biodiversity assessment has not been done, a screening study could help to identify the sites that would involve the least impact upon biodiversity – such as by avoiding protected areas, or by building on rivers that are already dammed, and leaving some free-flowing tributaries in their natural state.

Box 9 Developing goals for river protection – Wild and Scenic Rivers Act USA, 1968

The US Congress declared “that the established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes.”

Each river in the National System is administered with the goal of protecting and enhancing the values for which it was designated. Designation neither obligatorily prohibits development, nor gives the federal government control over private property. Agreed recreation, agricultural practices, residential development, and other uses may continue. The Act purposefully strives to balance dam and other construction on appropriate sections of rivers, with permanent protection for some of the country's most outstanding free-flowing rivers.

As of March 2019, the National System protects 13,413 miles of 226 rivers in 41 states and the Commonwealth of Puerto Rico; this is less than half of one per cent of the nation's rivers by length. By comparison, more than 75,000 large dams across the country have modified at least 600,000 miles, or about 17 per cent (possibly more than 20 per cent – figures are best estimates) of American rivers.

Box 10 Protecting riverine ecosystems in Norway

The Protection Plan for Water Courses, which has legal status through the Water Resources Act of 2001, seeks to balance massive river development for hydropower with protecting all or part of some rivers from such development, due to their threatened biodiversity, or value for Provisioning Ecosystem Services.

The Watercourse Protection Plan was produced in close cooperation between the energy and water authorities and the environmental authorities. It is based on an evaluation of nature conservation values and other interests related to the watercourses, such as cultural heritage, fish, wildlife, outdoor recreation, pollution control, agriculture, forestry and animal husbandry.

By 2018, 388 localities, covering about 30% of Norway's land area, were protected against hydropower development and other types of encroachment that could destroy the protection values. A locality may be a whole river basin system, a part of a river basin system, or an area including many small river basins.

4.2 Identifying the area of influence and project boundaries

Project developers should identify key species and habitats, positioning the project site within the wider catchment area (or national context), and clearly identify the project boundaries. The area of influence is taken to mean the area where the negative and positive impacts of the project are expected to occur. The project boundaries will be larger if there are compensation offsets outside the project area of influence, or if any upstream activities are expected to influence, negatively or positively, the environmental quality components of a downstream hydropower project. This step usually takes place during the ESIA. A checklist is given in Box 11.

The area of influence includes the identification of:

- the dam and powerhouse site(s);
- the reservoir footprint and immediate surroundings;
- the downstream area, which is here divided into the ‘immediate downstream’, where the dam significantly affects water quality and flows (including potentially dewatering of some stretches); and the ‘extended downstream’, which continues to the point where impacts on the flood curve are no longer discernible;
- the area upstream of the future reservoir, including all tributaries that flow directly into the reservoir area. Developers need to consider the project area as a ‘receiver’ of environmental changes emanating from upstream, and which may impact the ecology of the reservoir area (e.g. hydrological effects of upstream dams, or potential pollution from agriculture or cities, sedimentation flows due to erosion, etc.); and
- the construction site (including offsite camps), quarries, waste rock dumps, access roads and transmission lines, and any potential resettlement areas.

Any compensation or offsetting for impacts on threatened species may take a variety of forms; but this essentially means that the species or habitat that is damaged within the project area of influence is conserved or increased elsewhere outside the project area. As compensation often involves areas beyond that which is directly affected by the project, developers should be prepared to take a broad geographic scope in the ESIA studies; they should ensure that ESIA consultants include the impacts and possible compensation interventions within a proper geographic perspective.

The **reservoir footprint** is the most immediate and discernible local impact. A significant area of land may be converted to a lake; and the river, instead of freely flowing with seasonal floods, will become still and calm, possibly over tens or even hundreds of kilometres.

The key characteristics of the reservoir area that need to be clearly surveyed and documented include:

- The topography of the area, usually using digital elevation models and/or high-resolution LIDAR technology, and identification of any alternative footprints for dams at different heights.
- A mapping of habitats and land use within the proposed reservoir area, using satellite or aerial photography or drone images (feasible for areas of up to 500 ha). This may include villages, roads, natural and degraded forests, grasslands and other natural habitats, agricultural areas, known protected areas, etc. This mapping exercise also informs other processes such as resettlement impacts (for further information, please refer to the How-to Guide on Hydropower Resettlement), as well as providing base maps for any detailed mapping of the distribution of threatened species or critical habitats.
- Any Provisioning Ecosystem Services of value to local communities.
- A mapping of river morphology that identifies the pools, meanders, sandbanks, rapids, floodplains, etc., that will be flooded by the reservoir, and which will require additional fieldwork during ESIA to identify biodiversity

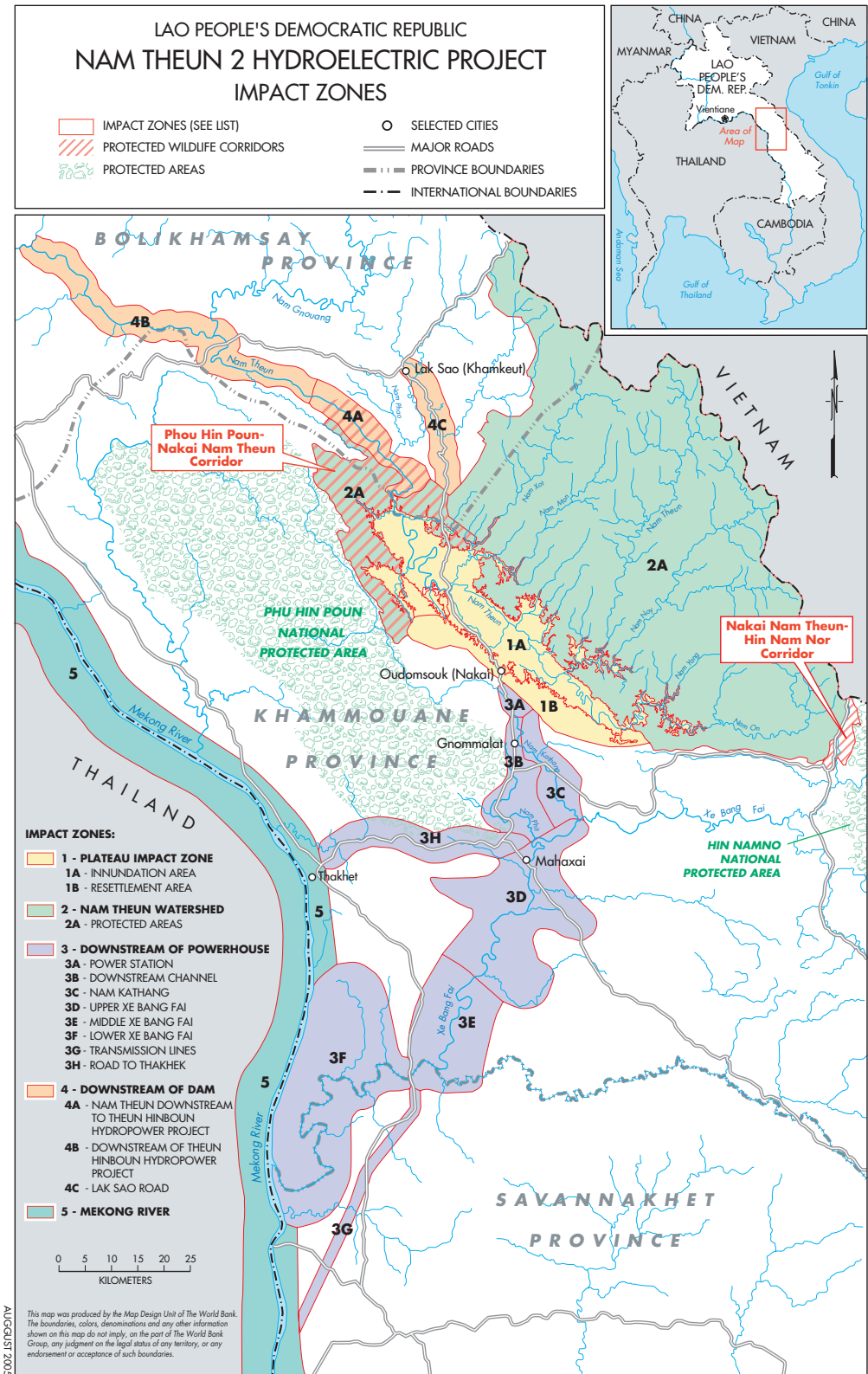


Figure 10 Impact zones of Nam Theun 2 HPP – In complex hydropower projects such as this, the area of influence has been subdivided within the broader project boundaries
Source World Bank

values, and conditions required for any offset areas.

- An initial assessment of the potential drawdown zone, to allow an assessment of its extent, seasonality, and the technical feasibility of biodiversity mitigation and compensation actions in this area.

Once the footprint(s) of the reservoir area alternative(s) can be superimposed on the land-use maps, the team needs to actively consider the consequences of the footprint(s) in terms of terrestrial connectivity.

The **downstream area** involves identification of two main zones with different issues: firstly, the **immediate downstream area**, which may run for many kilometres. The impacts in this area are potentially significant due to changes in two main factors: water quality (oxygen, temperature, sediments), and quantity (daily and seasonal changes to flows). The dam operating regime has a direct and immediate influence on this area; this diminishes downstream only as water quality improves, and/or with the diluting effects of flows from other (undammed or dammed) tributaries. In the case of diversion dams, a section of the river may effectively be de-watered.

The developer necessarily takes full responsibility for the impacts on this section of the river, and needs to consider design and operating rules that minimise impacts (e.g. measures to ensure reoxygenation, re-regulation weirs to smooth peaking flows, etc.). Particular caution needs to be taken if the river holds migratory species, as ineffective mitigation on this stretch of the river will effectively create a 'dead zone' that prevents any movement of fish within the 'immediate downstream' section, thus multiplying the barrier effect of the dam itself.

Secondly, the **extended downstream area** defines the downstream boundary of discernible project influence, and the observed impacts will normally be related to changes in hydrology (although sediment flows may also be important). Developers should identify all downstream areas of potential importance for aquatic biodiversity or Provisioning Ecosystem Services, particularly wetlands, that are potentially sensitive to changes in flows of water,

nutrients and sediments. Lower-reach floodplains and/or delta systems may have significant fisheries, grazing areas or other Provisioning Ecosystem Services, which may be impacted by upstream impoundments. Where these services are significantly impacted, an E-Flow should be planned (see section 4.5.6). Readers are invited to refer to the How-to Guide on Hydropower Downstream Flow Regimes for further information on the topic.

If water is discharged (diverted) into another river, the downstream areas would include the river downstream of the dam, which will have reduced flows for much of the year, and the receiving river downstream of the powerhouse, which will have increased flows during power generation (see Figure 10).

The mapping of potential extended downstream effects, and the need for any E-Flow, will assist in identifying the scope of work for the full ESIA in the Preparation stage of the project. This should include both direct biodiversity impacts and the assessment of economic and cultural importance of downstream Provisioning Ecosystem Services from the river and its associated wetlands.

Developers should assess the **upstream catchment** and identify any geomorphological, land-use or pollution trends that may affect the project in the long term. These may include issues such as pollution from urban and agricultural sources, which may lead to eutrophication and algal blooms affecting the water quality of the reservoir (and therefore, for example, its fishery productivity); heavy metal pollution that might accumulate in fish and make them inedible; excessive sediment flows due to erosion, which impact reservoir lifetimes or affect water quality; known existence of potentially invasive species upstream in the catchment, etc.

Where the developer may envisage implementing measures in the upstream catchment (for example, to reduce soil erosion), there may exist significant synergies with methods of managing threatened biodiversity impacts. These include using appropriate reforestation programmes for native species, to create protected areas (including community managed areas) or new upstream woodlands, in ways that meet both sedimentation reduction and biodiversity

Box 11 Considerations in establishing the direct area of influence and the project boundary that could be included in ESIA ToR

- ☐ Identify the point downstream at which the project's impact on flood curves is no longer clearly discernible;
- ☐ Describe how land use or other changes in the upstream catchment (e.g. deforestation, pollution, other dams) may affect the environmental quality of the project area, particularly the reservoir ecosystem;
- ☐ Determine the reservoir footprint using an accurate topographic profile that allows the flooded area to be determined with precision for all project alternatives;
- ☐ Assess the project's impact on (terrestrial and aquatic) Provisioning Ecosystem Services that support livelihoods or cultural values;
- ☐ Where significant threatened biodiversity impacts require compensation offsets, identify potential sites/actions outside the project's area of influence and reframe the project boundaries;
- ☐ Identify known risks from invasive species (e.g. from existing dams upstream) and the critical pathways for their potential introduction at the project site;
- ☐ Determine whether the reservoir depth profile is likely to lead to stratification and de-oxygenation of lower layers; and if so, ensure the design minimises the risks of riverine anoxia;
- ☐ For diversion projects, fully consider the impacts of flow changes in the river receiving the diverted water.

improvement objectives. GIS mapping of terrestrial biodiversity hotspots within the catchment will assist in identifying possible terrestrial biodiversity compensation opportunities, and how to improve connectivity between natural habitats.

Construction site, quarries, access roads and transmission lines and any potential resettlement areas constitute direct impacts on terrestrial habitats. In some cases, they may also create indirect impacts by facilitating other activities beyond the project's immediate control (e.g. logging, poaching).

The spatial organisation of these activities needs to be properly assessed by overlaying them on the land-use maps used for assessing reservoir impacts, and applying the same connectivity considerations. Where possible, they should avoid impacts on threatened biodiversity hotspots, and avoid causing fragmentation of high-quality terrestrial habitats.

Perhaps uniquely in terms of project impacts, the construction site and quarries can all be subject to rehabilitation measures once construction is complete. Landscaping, replanting and habitat restoration may be required under ESIA approval conditions; this represents an opportunity for biodiversity enhancement, though the ability to achieve no net threatened biodiversity loss may be limited. The management plans undertaken during the ESIA should include provision for rehabilitation measures within biodiversity objectives post-construction (for further information, please refer to the How-to Guide on Hydropower Environmental and Social Assessment and Management).

4.3 Understanding the distribution and value of biodiversity

4.3.1 Identifying the distribution of biodiversity from existing knowledge

The developer needs to identify the significant biodiversity impacts, and to put in place effective management processes to address them. During the pre-feasibility stage, a desk study should compile data on known distribution and populations of aquatic and terrestrial biodiversity within the project boundaries. This covers the four main types of biodiversity described in Box 1 (Threatened biodiversity, Provisioning Ecosystem Services, species affecting human health, and invasive species). The assessment has two steps: firstly, an assessment of what is present; and secondly, how significant it is.

The nature conservation sector has already developed a number of tools that help governments to decide what threatened biodiversity is significant, and to put in place measures to ensure its survival on the ground. The normal result of this at national level is a gazetted set of Protected Areas; these may range from fully protected status, to partial fauna reserves for particular species. Government may also nominate exceptional sites of global significance as a UNESCO World Heritage site, or in the case of wetlands, as a Ramsar site of international importance. Such nominations need to meet strict eligibility criteria. The threatened biodiversity values of each area are normally identified in the documentation that justifies their gazetting, especially for recently gazetted sites; and various degrees of monitoring scheme, run by Protected Area managers, can give contemporary information on species distribution and abundance. Governments may also establish protected species legislation, and/or lists of species for which hunting is prohibited. These sources

Box 12 Sources of information on Protected Areas, species status and river fragmentation

- National databases on Protected Area networks, legislation on nationally protected species, (national ministries of environment and/or forests)
- Global IUCN Red list of Threatened Species: <https://www.iucnredlist.org/>
- National Red Lists for the country concerned (Ministry for Environment)
- World Data Base of Protected Areas: <https://www.unep-wcmc.org/resources-and-data/wdpa>
- The World Data Base on Key Biodiversity Areas: <http://www.keybiodiversityareas.org/home>
- Degree of fragmentation of the world's rivers: <https://www.mcgill.ca/newsroom/channels/news/worlds-most-detailed-database-maps-characteristics-earths-rivers-and-catchments-303255>
- Biodiversity A–Z from UNEP-WCMC – provides clear, concise and relevant information about biodiversity, designed to be a useful reference to all sectors including business, government and environmental agencies: <https://www.biodiversitya-z.org/>
- Global Biodiversity Information Facility: <https://www.gbif.org/>
- Fish names and distribution: <https://www.worldfishcenter.org/publications-resources>
- The Integrated Biodiversity Assessment Tool is available by subscription, and allows identification of threatened species, protected areas, and key biodiversity areas near project sites: <https://www.ibat-alliance.org/>

give contextual information on what species government policy considers to be significant in the national context. The Forest Stewardship Council has produced guidance on enhancing conservation values, specifically in forests.

All of this information should be compiled by the developer, informing decision-makers regarding the areas already gazetted at national level as significant for biodiversity conservation. In terms of level of detail, the mapping process will either show that a proposed dam has no impact on existing protected areas, or that impacts are potentially minimal, or that impacts are potentially substantial. If data are insufficient, then the process will indicate that few clear conclusions can be drawn, and more survey fieldwork is required.

In addition to the national network of Protected Areas, there are two other levels of data that can be used to scope potential threatened biodiversity impacts. Firstly, the IUCN Red List data provides maps and descriptions of the status and trends of threatened species; these

are established by expert scientific committees and updated on a regular basis. The data include a map element that shows the distribution of the known threatened species, and a population section that describes population trends and known threats to the survival of each species. In many cases, this information is also available as a map (Figure 11). Secondly, particularly threatened biodiversity-rich sites may already have been inventoried as Key Biodiversity Areas (KBA) and/or as wetlands of international importance (Ramsar sites). While protected areas may cover some KBAs, they are not necessarily fully overlapping.

Developers can compile their own maps and status information from the data sources listed in Box 12, or seek regularly updated, geographically specific information on biodiversity compiled from all these databases, through the Integrated Biodiversity Assessment Tool (IBAT). IBAT includes all the spatial and category nature conservation information in a single site, which requires a subscription to access the data.



Figure 11 Number of threatened freshwater fish species within each sub-catchment across Mexico, according to the IUCN Red List (taken from IUCN Global Species Programme, Freshwater Biodiversity Unit, 2018). See <https://www.iucn.org/theme/species/our-work/freshwater-biodiversity/freshwater-publications> for freshwater biodiversity assessments in other parts of the world, e.g. eastern Himalayas; Indo-Burma; northern, eastern, western and southern Africa)

Table 11 IFC performance standards concerning biodiversity

Habitat category	IFC Performance Standard 6
Modified habitats	Areas that may contain a large proportion of plant and/or animal species of non-native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones, and reclaimed wetlands. Note that even Modified habitats may be important from a biodiversity point of view, especially if they lie in a recognised biodiversity corridor, within a migration route or species range. Furthermore, they may also qualify as Critical habitats.
Natural habitats	Areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition.
Critical habitats	Areas with high biodiversity value, including: i. Habitat of significant importance to critically endangered and/or endangered species; ii. Habitat of significant importance to endemic and/or restricted-range species; and iii. Habitat supporting globally significant concentrations of migratory species and/or congregatory species; iv. Highly threatened and/or unique ecosystems; and/or v. Areas associated with key evolutionary processes.

River fragmentation is an indicator of river ecosystem health, and both the World Resources Institute and the University of McGill (Montreal) have published maps and data bases that assist in defining critical indicators for this issue. The DCI (Dendritic Connectivity Index) is a recognised indicator for assessing the overall connectivity in a catchment. The DCI calculates the proportion of length of disconnected fragments in relation to the entire network. The DCI can be extended by different weighting factors (e.g. density of migratory species, flow volume, Strahler order) to reflect the importance for aquatic organisms.

Degree of river fragmentation has been used as an indicator of the natural or modified nature of the catchment where the project will be developed. The existing degree of fragmentation due to dams will also help developers to consider the site selection within a river basin, and identify if cumulative impacts on biodiversity and river habitats will need to be addressed (see Section 4.1.1).

Wherever a species or habitat is identified that is evidently 'significant' (e.g. presence of an IUCN threatened Red List species, or a Protected Area), then the early stage process can already begin to frame possible avoidance, minimisation, mitigation and compensation approaches that can be further elaborated in the ESIA. This may require additional fieldwork, especially if compensation outside the project area is being considered, or additional consultation with other institutions (fisheries, forest management, NGOs, lenders, etc.) is required. This early assessment allows the ToR for the ESIA to be appropriately framed.

The assessment should also include a classification of the habitats within the areas of influence into Modified, Natural and Critical Habitats, using the definitions and assessment techniques indicated in Table 11, noting that Natural and even Modified habitats can be assessed as Critical if they are subsequently discovered to contain threatened species, endemic or restricted-range species,

Box 13 Identifying Ecosystem Provisioning Services during the Early Stage

- ☐ Identify the people using the direct area of project influence (terrestrial and aquatic) and the natural resources that are being exploited.
- ☐ Plan for socioeconomic surveys during the ESIA that will establish the economic value and/or social significance of these activities for local livelihood security.
- ☐ Identify any Ecosystem Provisioning Services in the extended downstream of the project area.
- ☐ Consider how and where these resources can be replaced or compensated post-project, including the need for an E-Flow assessment.
- ☐ Consider the opportunities for the creation of new Provisioning Ecosystem Services in or around the reservoir area (especially fisheries and/or afforestation, eco-tourism, etc.).

Box 14 Scoping approach for disease vectors and human health

Where diseases are spread by aquatic vectors, hydropower can have a direct impact on transmission risks, especially in tropical areas.

- ☐ Identify the major diseases occurring locally, or nationally, which have aquatic vectors.
- ☐ Understand how the project may increase or decrease the habitats for those vectors during and following construction, and the likely impact on human health.
- ☐ Identify any consequences of vector control programmes that are likely to be put in place by, for instance, the Ministry of Public Health, which may affect plans to conserve threatened biodiversity or Provisioning Ecosystem Services (e.g. widespread spraying of pesticides).
- ☐ Consider the opportunities for the creation of new Provisioning Ecosystem Services in or around the reservoir area (especially fisheries and/or afforestation, eco-tourism, etc.).

migratory or congregatory species; or if they represent highly threatened or unique ecosystems, or support key evolutionary processes.

If finance from multilateral banks or Equator Principles financial institutions is being sought, a habitat assessed as Critical will require the preparation of a BAP and possibly an offset, or in some cases, may not be considered eligible for financing when the project is considered likely to result in measurable adverse impacts or reductions in populations of critically endangered or endangered species. It is also useful to assess the condition of the habitats in the areas of influence,

e.g. in comparison to similar intact habitats in the country, since this could be the basis for estimating the biodiversity offset requirements later.

Similar desk-based approaches can be used to identify the potential impacts on Provisioning Ecosystem Services (Box 13), invasive species (see 4.4.7), and on biodiversity changes likely to be harmful to human health, particularly in tropical areas (Box 14).

4.3.2 Addressing biodiversity data deficiencies during the ESIA fieldwork

It is likely that the data available from existing sources are not sufficiently detailed to allow impacts on threatened biodiversity, Provisioning Ecosystem Services, invasive species, or species affecting human health, to be properly identified, or mitigation and management decisions to be made and costed. During the early or scoping stage, the issues to be addressed through detailed field surveys during the ESIA will be defined, particularly those that have not been avoided or minimised through pre-feasibility design.

Developers can expect to find threatened or migratory species whose ecology and distribution are quite well known. Expertise exists for their management, and there is an extensive literature and experience available to draw upon. In other cases, species may not be well known, and proper field-research data need to be obtained to support the development of effective mitigation plans. In the former case, large environmental consulting companies may be well placed to offer good advice in compiling and using existing knowledge. However, in the latter, it will be important to also mobilise appropriate specialist expertise from universities or NGOs, to provide the necessary field biological understanding before bespoke or innovative solutions can be found.

It is expected that any management plans for threatened biodiversity should at least address the impacts on known threatened species and critical habitats. There is often less time within an ESIA to address mitigation needs for threatened species that have only been discovered during ESIA field surveys, as additional work may delay project implementation. It is also not uncommon for surveys to discover species new to science in remote river basins. If there is an opportunity to separate the ESIA into a phase 1 of the field survey and a phase 2 of mitigation planning, then this is one possible solution, wherever the project calendar allows. In cases where new species are encountered, there may be little time to describe and name such species; but this should not mean that they are inadequately protected by mitigations or offsets.

ToR for threatened biodiversity studies should envisage fieldwork throughout at least one annual cycle, to identify species and habitat distribution within the direct project area of influence (i.e. reservoir area; construction areas, access roads, quarries, transmission lines; immediate and extended downstream and resettlement sites). This is important, given that for individual species, particular parts of the project-affected area will differ in significance through the seasons of the year (e.g. when certain trees are fruiting, or fish are migrating upstream to breed, or waterfowl are gathering outside the breeding season). Such studies may include:

- surveys for breeding, wintering and/or migratory birds (transect surveys, mist nets surveys, night surveys);
- surveys for mammals, reptiles and amphibians (transect surveys in wet and dry seasons, trapping methods and night surveys);
- sampling by nets, hook and line, and electroshocking or alternatively other non-destructive sampling methodologies (e.g. gill net, cast net, eDNA, etc.). for the presence, abundance and composition of fish. Note that in some countries, electro-fishing is illegal, and surveys using this technique may require specific permissions. Fish sampling may require a number of methods, depending on the nature of the habitats and the species present. Interviews with local fisherfolk are also important during the early-phase work;
- aquatic macroinvertebrate surveys;
- sampling of plankton, include fish eggs and larvae at appropriate seasons for the target species; and
- surveys of aquatic and terrestrial flora.

Project developers are encouraged to discuss the early stage findings with the environmental specialists of potential lenders, in order to determine any additional requirements for the ESIA studies, as well as to identify any potential red flags that may preclude financing. Where a project is seeking finance from multilateral banks or Equator Principles financial institutions,

developers should discuss any potential offsetting plans with lenders as early as possible. It is often challenging to align the timeframes for loan approval processes with developing an offset plan.

4.3.3 Managing risks associated with lack of knowledge

Some threatened species and critical habitats have been comprehensively studied, and their ecology is well known. In these cases, there will be a substantial body of knowledge to draw on; existing experts can be mobilised, and will bring their experience to design the best possible mitigation plans, which can be expected to deliver improved species-level outcomes. The developer can have some confidence that species conservation plans are likely to prove effective.

In many other cases, especially in tropical regions, very little may be known about a species. Its distribution, or even its presence in the project area, might be disputed. And even if it is known to be present, the threats to the population, the contribution of the dam project, and possible mitigation actions, might be difficult to quantify with confidence. In these cases, developers need to rely on expert judgement, often made using experience from similar species in other places, and to simultaneously put in place field research programmes to gather improved information on the species, its ecology and distribution. Mitigation plans in this case are therefore built during the operation of the project, with iterative research, feedback and planning cycles to develop and implement sustainable, effective species conservation programmes (Box 24). The key aspect of 'good practice' is therefore to demonstrate commitment in terms of good objectives, scope of work, adequate staffing and budget.

4.3.4 Assessing significance of biodiversity impacts

As noted in Chapter 2, ESAs are often quite effective in listing the presence of different species and habitats, but they often struggle to prioritise the impacts, or help decision-makers identify what is significant and requires action by the developer. Consultants need to go beyond

identifying exhaustive lists of low, moderate and high-risk impacts, and provide practical help that enables developers to focus on what is essential.

This section proposes processes for assessing significance in general terms, and in the absence of the comprehensive internal review processes of Equator Principles and multilateral lending institutions.

Any assessment of the impacts' degree of significance requires a holistic view of the factors contributing to a threatened species or critical habitat decline, and the incremental contribution that the project may make. Mitigation measures can address not only the components for which the dam is responsible, but may also fund other components of any overall species recovery plan. The outcome sought is No Net Loss, and where possible, an overall population increase of a threatened species that might lead to a change of IUCN Red List status (e.g. a population growth that would justify changing the species status from 'Critically Endangered' to 'Endangered', for example – see section 2.1).

Other factors that may be taken into consideration in assessing significance are listed in Table 12. These include the degree of endemism, the population status, whether the species is a keystone species, or is economically or culturally valuable. Developers should also bear in mind that if a species of threatened biodiversity is already considered endangered, then there are existing downward pressures on its population. A dam may exacerbate these, but is unlikely to be the 'sole cause' of any decline. The ESA process should clearly describe the other threats acting on the population, identify the 'contribution' that the project will make, and design compensation measures that include both the contribution of the project (see Table 12), and the management of other existential threats to the species.

Ultimately, the acceptability of identified impacts is a complex mix of respecting legal requirements, defining the limits of environmental change acceptable to any given society (thresholds may not be the same in Costa Rica as in Mozambique or in Turkey, for example), and meeting lender requirements. Engaging with NGO and/or community concerns (see section 4.4.2) on

Table 12 Considerations in assessing the ‘significance’ of impacts on any given species or habitat

Criterion	Less significant impact	More significant impact
Species vulnerability		
Geographical range of the species affected (degree of endemism)	Widely distributed	Occurs in only a few places
Population size (cf. IUCN Red List)	Large population	Small population
Population status	Stable or increasing	Declining throughout its range
Cultural or economical value	Low	High
Is a keystone species affected	No	Yes
Scale of the potential impact		
Contribution of the project to overall threat levels to a species	Diffuse	Clear-cut and measurable
Cumulative impacts from other developments projects	Low	High
Impact on any Key Biodiversity Area	Low	High

threatened biodiversity may also be important where broad social acceptance is seen as a key part of the social licence to operate; such engagement will help to avoid local conflicts that can persist throughout the lifetime of the project if they are not addressed in a timely manner.

4.3.5 Identifying potential invasive alien species

As anthropogenic impacts within a catchment increase, and the natural ecosystems are modified, there will be changes in biodiversity composition, often including increases in alien invasive species. Invasive species can appear at any time during the construction or operation of a hydropower power plant, either brought in with construction materials or spread from upstream, downstream, or through inter-basin transfers. Typically, terrestrial invasive plants will develop during the construction period, while aquatic invasive flora and fauna may proliferate during operation. During project design, developers should analyse the risks and specify regular monitoring for invasive

species, and suggest management measures should invasive species be observed. The key characteristic of an invasive species is that it is able to take advantage of a changed situation, such as the disturbed ground of a construction site or quarry, or the new lake-like conditions in a reservoir; it then spreads without natural controls.

In the Early Stage, scoping should identify known invasive species in the watershed and assess the risk that species known to be present will colonise the project area; it should identify topics for further study during the ESIA, which may lead to the development of specific plans for their active management. National and global databases on invasive alien species should be consulted, to identify the likely presence and risks of spreading invasive species in the project area of influence. Box 16 provides the links to the main global IAS databases.

Box 16 Invasive alien species databases and management knowledge

Both IUCN and CABI offer resources on the identification, distribution and management of invasive alien species.

The Invasive species specialist group of IUCN maintains the Global Invasive Species Database, available at <http://www.iucngisd.org/gisd/>. It is a free, online searchable source of information about species that negatively impact biodiversity. The GSD aims to increase public awareness about invasive species, and to facilitate effective prevention and management activities, by disseminating specialists' knowledge and experience to a broad global audience. It focuses on invasive alien species that threaten native biodiversity, and covers all taxonomic groups, from micro-organisms to animals and plants.

CABI also maintains a global database at <https://www.gbif.org/dataset/b351a324-77c4-41c9-a909-f30f77268bc4>. It provides a range of dedicated knowledge tools on invasive species. These include information on how to prevent the spread of invasive species, how to detect outbreaks, and best practice solutions for controlling known invasive species.

National governments usually also hold lists of invasive species for each country, either in the Ministry for Environment or associated agencies.

4.3.6 Considering compensation measures for threatened biodiversity

Where the project will have significant impacts on a known threatened species or critical habitat, then compensation offset measures should be considered if mitigation proves insufficient to manage impacts. Where compensation is required beyond the project's immediate area of influence (see Table 13), it is unlikely that the developer alone can deliver this effectively, and it will have to build relationships with other institutions. Considering the time required to undertake fieldwork in different sites, to engage partners and design compensation measures, it is important that these actions are clearly included within the scope of the ToR for the ESIA, and are included within the 'project boundary' for study (Box 17). Where compensation is directly within the project-affected area, the dam developer has more control and oversight of these measures than if they take place elsewhere in the country or catchment.

A dam project is often only one contributing factor in the decline of a threatened species, and maintaining a viable population will require conservation efforts across many sectors and geographies if the population levels are to

recover. In other cases, the species may be very clearly impacted by the project, and the developer is therefore directly responsible for mitigation and/or compensation.

4.4 Designing mitigation and compensation measures

4.4.1 Interactions between environmental team and design team

The first step of the Mitigation Hierarchy is to avoid impacts wherever possible. This can only be done through frequent iterations between the environmental assessment team and the design team, as early as possible in the project life cycle. As the project progresses towards detailed feasibility and design, the margin for manoeuvre becomes reduced, as some decisions will already have been taken; therefore, it is important that discussions on avoidance are held as soon as practically feasible.

From the developer's perspective, the earlier the range of possible impacts is known, the easier it will be to properly implement good practice by adopting the Mitigation Hierarchy, and the easier it will be to define the scope of the detailed ESIA

Table 13 Examples of compensation measures – area of influence and project boundaries

Compensation measures outside the area of direct influence of the project	Compensation measures inside the area of direct influence of the project
• Creation of a protected area (collaboration with local authority) higher up the watershed, and financing of its management • Captive breeding and release of threatened species affected by the project elsewhere in their range • Active breeding and releasing of local species that are economically important to impacted communities • Expansion of an existing protected area where the species/critical habitat also occurs	• Establishment of a protected area around the reservoir, with reforestation • Creation of wetland sites within the reservoir drawdown area • Active breeding and releasing of local species that are economically important to impacted communities

Box 17 Key issues for threatened, endemic or migratory species: assessment through ESIA

1. Assess the local and global impact of the project on the population of the threatened species
2. Identify other factors influencing these species during their life cycle, and the relative contribution of the project to the overall viability of its population
3. Ascertain the impact of the project on the habitats that are critical for these species
4. Identify which project impacts are potentially reversible and which are permanent and/or cumulative
5. Determine whether impacts are specifically linked to particular stages of the construction and will affect schedules
6. Design a sampling methodology to assess the habitat requirements of the threatened species throughout an annual cycle
7. Collect local people's knowledge of the threatened species, and their ecology and distribution
8. Avoid and minimise impacts on all critical habitat for any threatened species. Where residual post-impacts are significant, envisage a compensation offset
9. Identify qualified specialists to prepare a dedicated Biodiversity Action Plan for any threatened species impacted by the project
10. Plan and budget for a research programme to monitor and improve mitigation and compensation measures, and to ensure conservation outcomes are achieved in practice

studies needed to refine any residual mitigation and compensation measures. As the ESIA studies progress, the opportunities for design changes are reduced, and more of the environment team effort is devoted to the definition of the environmental management plans and their component parts (e.g. the Biodiversity Action Plan).

E-Flow requirements (see 4.5.6) will also need to be established early, so that the required flow regimes can be built into the design and operation models.

Examples of biodiversity related issues requiring consultation include:

- variable-level offtakes to maintain water quality immediately downstream of the dam;
- design and integration of fish passes and their operating regimes (upstream and downstream migrations);
- downstream re-regulating and re-aeration weirs to stabilise fluctuating flows (in case of peaking operations) and water quality;
- design of E-Flow release structures to allow required maximum and minimum flows;
- impact of different operating regimes on the natural resources (e.g. fisheries) of the reservoir area / drawdown zone;
- avoiding downstream and local biodiversity impacts by assessing alternative dam heights / storage volumes; and
- potential requirements for fish passage.

Once significant biodiversity issues have been identified, and avoided wherever possible through siting and design modifications, the developer should be in a position to identify the significant biodiversity features that require active management and/or compensation. This involves a transition from the identification and assessment of biodiversity towards management planning of field actions and investments, which may require different skills and competencies.

4.4.2 Identifying who to work with

Biodiversity management is not generally a core area of expertise for hydropower developers; thus, it will be essential for the project to retain qualified consultants, and also to develop good working relationships with specialist organisations and local groups, in order to manage and monitor the biodiversity mitigation measures put in place (Table 14). The case studies in Annex 2 indicate the types of organisations that dam developers have been working with. They include international and national NGOs, academic and research groups, and local forestry, fishery or wildlife management authorities that have particular knowledge and expertise regarding the habitats or species of concern. River basin authorities may also be involved in setting or monitoring E-Flows. They may include some of the organisations that have been involved in the baseline surveys and impact-assessment stages. They may also include community groups, such as local angling groups or community rangers, if required for the protection of some offset areas, or for payment of forest ecosystem services in the watershed. The design and monitoring of biodiversity offsets is a complex and technical subject that will require the participation of qualified experts, and consultations with a range of stakeholders that include lenders, NGOs, governments and communities.

4.4.3 Formulating clear management objectives

After identifying the needs for actions to mitigate potential impacts on key biodiversity values, developers need to formulate biodiversity conservation objectives in a way that makes clear what is intended to be achieved, in a measurable way. Wherever possible, the objectives should be SMART (Specific, Measurable, Attainable, Realistic, Timed). They should clearly describe the desired outcome or goal, and may or may not be fully deliverable by the developer alone. If, for example, there is a broad objective to maintain migratory fish populations in a river, then perhaps the developer's specific contribution is to ensure effective fish passage through the dam and across the reservoir. The management objective could be framed as "ensure that 90 per cent of fish arriving at the bottom of the dam regain the river at the

Table 14 Conservation-sector stakeholders

Organisation Type	Role in biodiversity conservation/ management	Potential role in hydropower development
Government departments		
Ministries of Environment	• Overall responsibility for environmental and natural resources • Setting of policies and regulations for environmental and biodiversity management, including Environmental and Social Impact Assessment (ESIA) procedures, air and water quality standards • Focal point for international biodiversity conventions	• ESIA approval, setting of environmental and biodiversity conditions in concession agreements • Requiring regular reporting of compliance and monitoring
Water resources department	• Regulation and licensing of water abstraction and use, and discharge of effluents • May include river basin management and river basin organisations	• Management of water resource use and water quality conditions • May be responsible for setting environmental flow conditions
Protected Areas and Wildlife department	• Responsibility for the designation and management of Protected Areas, including Ramsar sites • Identification of nationally protected species and application of regulations	• Hydropower projects that lie within or affect Protected Areas will require specific permission from the Protected Area authority
Forestry department	• Responsibility for national forestry resources, setting of forestry regulations, enforcement and management • Data on status and extent of forest resources	• Permissions for cutting and clearance of forest areas, especially within Forest Reserves • Forest restoration, watershed protection and management
Fisheries department	• Responsibility for management of fishery resources • Setting of fishery regulations and licensing • Collection of fishery statistics and regulation of markets • Support for community fisheries and fishery reserves	• Impacts of hydropower on wild fish populations and productivity • Regulations on reservoir fisheries, aquaculture and stocking • Management of fish hatcheries and nurseries

Lenders		
Development banks (ADB, AfDB, World Bank, IFC, etc.)	• Specific conditions related to biodiversity impacts and management, e.g. IFC Performance Standard 6, ADB Environment Safeguards	• Appropriate biodiversity impact assessment and management will be an important lending condition • BAPs and offsets may be required
Equator Principles Banks	• Use Equator Principles (EPs) as a risk-management framework to manage environmental and social risks in projects, including biodiversity	• ESIAs include protection and conservation of biodiversity (endangered species and sensitive ecosystems in Modified, Natural and Critical Habitats) • Identification of legally protected areas affected
International organisations		
IUCN, WWF, WCS, FFI, CI, TNC, WCMC, BirdLife International	• International conservation organisations have regional and national representation in many countries, and may have field conservation and research projects • They may have detailed knowledge databases and expertise in biodiversity monitoring and management	• Can be strong critics of hydropower projects • Need to be convinced of rigour of biodiversity assessments, and effectiveness of biodiversity management and Biodiversity Action Plans (BAPs) • Can become partner organisations for biodiversity management
National and local groups		
Local communities	• Primary users of local provisioning ecosystem services and biodiversity • Often project-affected people requiring resettlement	• Source of local knowledge about biodiversity in the areas of influence • Reservoir inundation likely to impact upon local use of biodiversity and livelihoods
Private sector, e.g. timber companies	• Sustainable forest management (SFM)	• Reservoir inundation may affect or impact timber concession areas • Could be involved with catchment and biodiversity management
NGOs and CSOs	• Local conservation and environmental groups. Links with local communities, and some with detailed biodiversity knowledge and conservation projects	• Can be strong critics of hydropower projects • Need to be convinced of rigour of biodiversity assessments and effectiveness of biodiversity management and BAPs • Can become partner organisation for biodiversity management

Universities and research institutes	• Scientific knowledge and research into local ecosystems and biodiversity	• Can be contracted to carry out field surveys and biodiversity monitoring
Media	• General communication about biodiversity and impacts of hydropower	• Can be strong critics of hydropower projects, and need to be included in communications about biodiversity management activities

top of the reservoir, every year". An independent monitoring programme would be put in place to monitor achievement of the objective.

Alternatively, the developer could join a national effort to conserve migratory fish species, by contributing to reducing broader threats – such as maintaining spawning grounds, or dealing with illegal fishing – while also delivering fish passage through the dam. In this way, the outcome is framed as "increasing populations

of migratory fish by 20 per cent by 2030", and the developer will be just one of several actors who contribute to achieving that goal.

In defining the objectives, it is important to distinguish outputs from outcomes. An output is delivered specifically following activities that are directly under the control of the project, and is easily measured. An outcome is more complex and cannot be directly controlled, but this is what the project seeks to achieve. If, for example, creation of a forest corridor is required to increase

Box 18 Fish passes and migratory species conservation on the Atlantic seaboard, USA

Most efforts to maintain migratory fish populations using fishways and ladders in the eastern USA began in the 1960s, when these were mandated during the licensing of hydropower projects. Research now shows that of the migratory American shad that managed to pass the first dam of a cascade, only 4 per cent, 16 per cent and 32 per cent passed the second dam on the Connecticut, Merrimack and Susquehanna Rivers respectively. Loss of adults at hydropower dams, combined with restricted downstream migration through dams (often through turbines), decreases the size and age of adults, and results in fewer repeat spawning runs.

Hundreds of millions of dollars have been spent on salmon hatcheries, release and transport systems; yet populations continue to decline, not least because wider life-cycle challenges (water quality, over-fishing) also impact on these species. Both shad and Atlantic salmon have now been listed in the Endangered Species Act, and petitions have also been made for the inclusion of two additional migratory species: the American eel and river herring.

Hydropower dams affect fish movements, but other factors such as pollution and over-fishing also have negative impacts on population health. For overall conservation and restoration, it is essential to fix a population target, and for all federal and state agencies to work together to improve all the factors affecting the life cycle – not just the connectivity dimensions linked to hydropower. In contributing to achieving this objective, hydropower developers should ensure that the fish passes do achieve their intended outcome.

Source: Brown, J., Limburg, K., Waldman, J., Stephenson, K., Glenn, E., Juanes, R. F. and Jordaan, A. (2013). Fish and hydropower on the US Atlantic Coast: failed fisheries policies from half-way technologies. Conservation Letters 6:4 pp. 280–286.

connectivity for chimpanzee populations, this may require restoration of 200 ha of forest. An output-based approach (under the control of the project) would fix the management objective as “restore 200 ha of forest”. However, the intended outcome may be “to ensure that chimpanzees can move freely between forest habitats by 2025”. Even if the 200 ha of new forest are properly restored, this outcome may not be achieved due to other factors not having been considered. It is therefore important to define the desired outcome, even when adopting an output-based planning approach. Monitoring programmes can then be properly set up to chart progress towards the real, underlying objective. The risks of simply adopting an output-based approach are also clear for the implementation of fish passes, where the output is achieved, but not the intended outcome (Box 18)

As it is usual for any threatened species to be suffering from multiple pressures, developers should consider the extent to which they feel comfortable about acting beyond the immediate area they locally control (dam and reservoir), in pursuit of broader biodiversity conservation objectives. In many cases, developers contribute financially to compensation schemes or offsets beyond their immediate project area, and in partnership with research institutions, NGOs and relevant government departments, throughout operations. These provisions may also be necessary to comply with national legislation, to meet lender requirements, and/or to respect licensing conditions.

Box 19 Outline of a Biodiversity Action Plan (adapted from IFC PS 6)

1. Introduction
 - 1.1 Structure of the BAP: Describes overall outline and flow of the BAP
 - 1.2 Project description and ecological setting
 - 1.3 Summary of project-related impacts on biodiversity
 - 1.4 Habitat classification and biodiversity values
 - 1.5 Goals: No Net Loss, and/or Net Gain
2. Stakeholders
 - 2.1 Consultation overview
3. Project policies and commitments
 - 3.1 Institutional framework
 - 3.2 Lender requirements
 - 3.3 Corporate framework and policies
4. Mitigation strategy
 - 4.1 Avoidance
 - 4.2 Minimisation
 - 4.3 Restoration
 - 4.4 Offset
5. Technical rationale for No Net Loss/Net Gain
6. Biodiversity Monitoring and Evaluation Plan
7. BAP timeline
8. Annexes

4.4.4 Developing Biodiversity Action Plans for species and habitats

Biodiversity Action Plans (BAPs) are developed to address the impacts on species of concern and critical habitats. They form part of the more general Environmental and Social Management and Monitoring Plan (ESMMP), which is an operational document developed to address a wide range of environmental and social issues. The BAP may include actions for off-site areas (e.g. offsets and additional actions) and involve external partners.

The IFC Performance Standard 6 Guidance Note, for example, specifies that a BAP is required for projects located in critical habitat, and is recommended for high-risk projects in non-critical natural habitats (Box 19). The BAP describes (i) the composite of actions and a rationale for how the project's mitigation strategy will achieve net gain or no net loss, (ii) the approach for how the mitigation hierarchy will be followed, and (iii) the roles and responsibilities for internal staff and external partners. BAPs are living documents that should include agreed-on timelines for regular review and updating. Adaptive plans are therefore developed as a result of monitoring against intended BAP outcomes, and changes to the conservation context over time (see Box 20).

4.4.5 Managing impacts on provisioning ecosystem services

The loss of provisioning ecosystem services is a local livelihood issue requiring the compensation of local communities and river users, or the provision of alternative livelihood resources. Thus, the loss of forests from which timber and fuelwood are collected by local communities, may be addressed by establishing community fuelwood lots. Where non-timber forest products have been collected for income generation, the opportunities for cultivation (e.g. of mushrooms or fodder crops for cattle) may be considered. These alternatives should be developed under the Resettlement Action Plan or Livelihood Development plans, rather than in the BAP.

However, in developing these alternative livelihood practices, the loss of the natural and modified habitats that harbour the local flora and fauna (which support these provisioning ecosystem services) may need to be recognised. Remaining habitats around the reservoir may need additional management measures to ensure that their provisioning ecosystem services are harvested sustainably, and retain their levels of biodiversity and ecosystem integrity. If forests and woodlands

Box 20 Retro-fitting to improve connectivity for migrating short-finned eels in Tasmania

The Trevallyn Dam in Tasmania was built in 1955 without any provision for migratory fish passage. In the 1990s, an upstream fish way (an elver ladder) was installed to allow young eels to migrate up and over the dam. This has been effective in assisting upstream migration. However, monitoring has shown that adults migrating downstream to breed in the ocean have trouble passing the dam, which does not frequently spill; and there is therefore mortality of adults passing through the turbines.

A sample of adult eels was caught and monitored in the reservoir, using minute tracking devices surgically inserted in the body cavity, and through depth tracking by sonar. This demonstrated that during downstream migration, adult eels were disorientated as they searched for a suitable outlet. Hydro Tasmania took the decision to drill a hole through the dam wall near an area where adult eels were known to congregate, and by releasing water through this outlet during the migration period, has facilitated the passage of adult eels through the dam.

As the national conservation context has changed, Hydro Tasmania has therefore invested in monitoring, research and adaptive management to update its biodiversity management approaches.

Source: Hydro Tasmania <https://www.hydropower.org/news/conserving-tasmanias-short-finned-eel-with-a-dam-bypass>

are to be planted or restored, it is better to use native tree species rather than exotics, and to plant a diversity of species, rather than mono-cultures.

The changes in fishery resources with the construction of a dam and impoundment of a reservoir are often significant. If the river is used for commercial, artisanal or recreational fishing, the creation of the reservoir offers an opportunity for the development of a different type of fishing. Reservoirs will have different potential for fisheries depending upon their location, elevation, shape and depth – large, narrow, steep-sided and deep reservoirs in upland areas tend to be less productive than smaller, shallow reservoirs lower down in the catchment. Attention should be paid to the design and management of the reservoir for fishery production, ensuring a diversity of aquatic habitats, access to tributaries for spawning, and the operation of the dam. Reservoirs with large drawdowns tend to be less productive. If stocking reservoirs with fish fry and fingerlings is necessary, native species should be chosen, rather than exotics that may become dominant. Fishery regulations and designation of fish conservation zones within the reservoir may be required. In addition, the fisherfolk may need to be equipped and trained in new fishing techniques.

Downstream fisheries are also likely to be changed by the operation, especially if the plant applies hydropeaking, which tends to depress catches. This needs to be recognised through the provision of alternative livelihoods, and in compensation for loss of recreational fishing.

4.4.6 Managing species that affect human health

If any of the species that affect human health are observed to be increasing with the changed habitats in the construction site, reservoir or downstream, or if there is increased incidence of disease, then management of the species may be required. Insect vectors of disease in the construction site may be controlled by ensuring that pools of standing water are minimised; if insecticide sprays have to be used, they should not be persistent, and should be applied safely as recommended.

Vectors of schistosomiasis and liver flukes, such as snails, may need to be controlled. However, the use of molluscicides should be avoided. Identification of the main infestation areas can pinpoint where physical control measures, such as habitat modification or weed clearance, can be put in place. The prohibition of swimming or drinking in these areas may also reduce the spread of the disease.

Blue-green algae blooms within the reservoir indicate eutrophication of the waters, and if the water is drunk at high concentrations by humans, domestic animals, or even wildlife, it can be toxic and cause death. If algal blooms occur regularly, it may be necessary to try to reduce the incoming organic pollution and nutrients from upstream areas; though this may be outside of the control of the hydropower company.

4.4.7 Managing invasive alien species

The invasive species databases (Box 16) contain sections on the management of invasive species, classified into four management options: Prevention, Eradication, Control and Monitoring. For example, for water hyacinth, control strategies must address both watershed management to reduce nutrient supply, and direct weed control – through mechanical clearance, or by introduction of biological control agents. Box 21 shows the elements of an Invasive Species Plan.

4.5 Biodiversity management throughout the project area of influence

4.5.1 Managing impacts during construction

Apart from loss of habitat, the main impacts upon biodiversity during construction result from the noise and air quality disturbance at the construction site and in the quarries and access roads; and from water quality changes in the river, due to increased sediment and sewage from workers' camps. All of these can be managed as part of the overall environmental management plans. Noise, especially from blasting, can cause disturbance of wildlife such as bats and nesting

Box 21 Elements of an Invasive Species Plan

If the risk of invasive species proliferating is judged to be high, then a management plan needs to be developed during the ESIA. The design of an invasive species plan should consist of the following sections:

- Risk assessment
 - Identify the main invasive species that have already been recognised to cause problems within the country or within the river basin (upstream and downstream);
 - Describe the main mechanisms for transmission and spread of these invasives; and
 - Relate these known transmission mechanisms with specific construction activities and/or operation conditions likely to occur during the project.
- Preparation and awareness
 - Prepare information sheets and identification keys for workers and staff;
 - Carry out regular surveillance for growth or appearance of invasive species on or near to the construction site or quarry, or access roads (Implementation stage);
 - Regularly monitor the reservoir and downstream for appearance of invasives, e.g. on the trash racks at the inlets or spillways (Operation stage); and
 - Monitor the fish catches and regular fish programme to observe for unwanted fish species (Operation stage).
- Management measures
 - For each of the priority invasive species, describe the management measures to be applied if they are observed. The key is to catch them early before they proliferate and spread; and
 - Assess the effectiveness of management measures through monitoring for recurrence.

or roosting birds, and the timing and charges of blasting may have to be moderated at certain times of year for sensitive species. Dust generated from earth moving, stone crushing, etc., may cover sensitive vegetation within adjacent areas, and should always be mitigated by dust management measures in any environmental management plan.

The water quality in the river will affect the fish and other aquatic organisms; increased sediment will tend to smother the riverbed immediately below the construction site, and measures should be taken to limit the soil erosion and sediment discharges into the river. All organic wastes from workers' camps should be treated before being discharged, to maintain the quality of the river water. Accidental spillage of hazardous and controlled materials and wastes that might cause fish kills should be prevented, through good design of the construction site and waste management practices; and emergency plans should be put in place for limiting the spillage, and cleaning up.

The influx of large numbers of construction workers into the area can increase the demand for wildlife and bush meat, and lead to an increase in hunting, poaching and destructive fishing (use of dynamite, poisons and illegal nets). The access roads and transmission lines will allow hunters access to the surrounding areas, which may be critical if they are located near or within a protected area. This will have to be managed with strict employment rules, worker awareness, and gate controls on access roads. Illegal logging will have to be managed by the control and monitoring of contractors used to clear the vegetation in the reservoir area. The local wildlife authority may be engaged to conduct spot checks on workers' camps, and improve awareness. Biodiversity awareness campaigns should cover the threatened species, threats and rules for construction workers and staff, and how to recognise invasive species and deal with them.

4.5.2 Watershed management for biodiversity conservation

Watershed or catchment management is an important concern for hydropower developers, especially when considering the negative impacts that soil erosion and sediment trapping in the reservoir have on the life of the project. The catchment is often a suitable location for developing biodiversity offsets, particularly if the habitat conditions are degraded but could be improved through rehabilitation, reforestation, and other habitat enhancement methodologies (e.g. artificial structures). Watershed or catchment management plans may include protection and/or restoration of the forested areas, as well as check dams and erosion management techniques. Revegetation and reforestation with a biodiversity objective should use native species rather than exotic or tree plantations. The system of Payments for Forest Ecosystem Services (PFES), for the protection of watershed forest biodiversity and reduction of soil erosion, is an example that has been developed in Vietnam and Costa Rica; this puts a value on the ecosystem service provided by maintaining forest cover. Under such systems, hydropower developers or power companies make regular payments to local communities in the catchments, to incentivise them to protect the forests and not to fell the trees.

4.5.3 Reducing impacts on biodiversity in the reservoir area

The inundation of the reservoir leads to the elimination of terrestrial and some aquatic habitats. While it is often an unavoidable impact, and there is some opportunity for minimisation, it is likely to cause a significant residual impact (i.e. which remains after the Mitigation Hierarchy has been implemented). These are the habitats and areas that are likely to need compensation and offsetting, especially if they are critical or natural habitats and contain threatened species.

Before clearance of the vegetation and inundation, it may be necessary to capture and translocate flora and fauna from the reservoir into another area nearby, so that the populations are not completely lost; this is also a means of minimising reputational risks associated with the mortality of charismatic

fauna due to the reservoir. It is important that the movement or capture of animals is done using the least traumatic methods, and that the receiving habitats are both suitable and large enough in area for the new populations. The most high-profile rescue operation was that of the elephants from the area inundated by Lake Kariba, but many other hydropower projects also undertake such rescues. For Nam Theun 2 in Laos, in addition to the exclusion of 140 elephants from the area to be inundated and creation of mineral licks in the watershed, the project's wildlife rescue team rescued over 250 animals, including endemic endangered species, which it released to the watershed. Nearly 500 turtles were captured from the river pools before inundation, and relocated to artificial wetlands created in the forest area above the reservoir. However, some experts question the efficacy of such translocation methods from a biodiversity conservation perspective; more guidance from IUCN is available in the *Guidelines for Reintroductions and Other Conservation Translocations*.

During vegetation clearance, the seeds, seedlings and saplings of native species may be collected, cultivated in special nurseries, and used for revegetation and reforestation in the catchment or along the banks of the reservoir. Assisted natural regeneration (ANR) is a simple, low-cost forest restoration method that can effectively return deforested lands back to forests that provide valuable ecosystem services. The method aims to accelerate, rather than replace, natural successional processes, by removing or reducing barriers to natural forest regeneration such as soil degradation, competition with weedy species, and recurring disturbances (e.g. fires, grazing and wood harvesting). Compared to conventional reforestation methods involving the planting of tree seedlings, ANR offers significant cost advantages because it reduces or eliminates the costs associated with propagating, raising and planting seedlings. It is most effectively utilised at the landscape level in restoring the protective functions of forests, such as watershed protection and soil conservation.



Figure 12 Decisions on how many of the trees in the reservoir should be cleared are part of reservoir design and management

Photo Credit: Peter-John Meynell

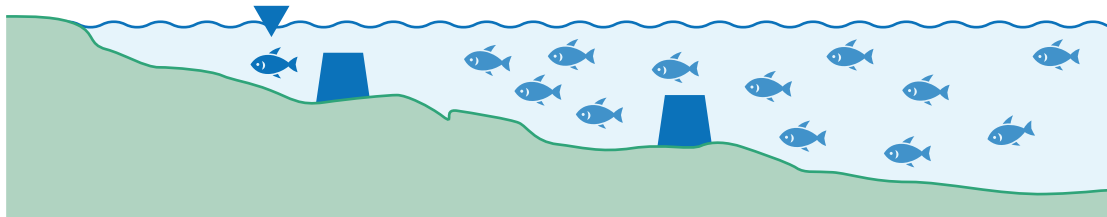
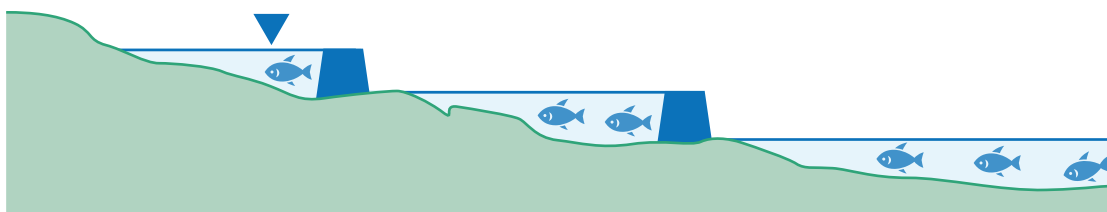
4.5.4 Reservoir management for biodiversity conservation and fisheries

If the reservoir is to be managed for biodiversity conservation, especially for fish diversity, it is important to consider its design, and the creation of diverse aquatic habitats within the impounded area. One of the first design decisions will concern the extent of vegetation clearance from the inundated area (Figure 12). This will depend upon the extent of the forested area, the value of the timber, and the visual impact of dead and dying trees within the reservoir, as well as legal and lenders' requirements. The decaying vegetation will increase the nutrients in the reservoir, giving rise to an initial boom in aquatic productivity and fish production. Retention of some trees within the reservoir will reduce access for fishermen and create protected habitats for breeding fish.

During the preparation of the reservoir banks and clearance of vegetation, there is an opportunity to landscape the shoreline and areas to be submerged,

in order to create a greater diversity of islands (breeding birds, refuges for aquatic reptiles, etc.) and diverse aquatic habitats. Artificial wetlands maintained by small earth banks can create fish refuges and spawning areas, and opportunities for recreational sports can also be optimised (Figure 13). Access for fish migrating from the reservoir up the tributaries and side streams should be maintained, and certain areas within the reservoir and the immediate vicinity of the reservoir should be designated as fish conservation zones.

If the reservoir fisheries are to be a feature for both riparian community livelihoods or for recreation, fishery management will be required – bearing in mind that there is likely to be a boom in fisheries for the first few years after inundation, stabilising within 5–10 years at lower production levels. This is likely to involve fishing regulations and the permitting and recording of catches. If stocking of the reservoir is considered, wherever possible avoid stocking exotic species that may become invasive and reduce populations of native fish species. In some cases, these exotic fish species may already be present

Wet season: reservoir full**Dry season: reservoir drawn-down**

a)



b)

Figure 13 (a) Constructed wetlands or (b) submerged islands with artificial habitat for fish refuge within a reservoir can create refuges and spawning grounds for fish

in the area, e.g. in fish ponds, from which they will escape to populate the reservoir when the ponds are inundated. Even in this case, restocking with exotics should not be considered, because this will strengthen their dominance in the reservoir.

Reservoir management should also consider the risks of algal blooms and invasive aquatic flora, both of which are likely to occur if nutrient levels in the water start to rise, e.g. because of upstream use of agricultural chemicals and organic pollution. Decaying vegetation in anoxic conditions also releases dissolved nutrients into the reservoir and generates greenhouse gases – in particular, methane is about 28 times more powerful than carbon dioxide at warming the Earth, on a 100-year timescale.

4.5.5 Re-establishing connectivity for migratory fish

Fish migration is complex, and measures to re-establish connectivity should consider both upstream and downstream migration, the swimming/passage capabilities of the different fish species, and the timing and triggers for migration. There may be opportunities to use natural channels to provide a fish pass around a dam (Box 22), and/or technical fish passage types that include pool passes, vertical slot passes, Denil passes (counter-flow passes), eel ladders, fish locks, and fish lifts. While fish passages for single species such as salmon have been effective, there is considered to be a height limit of about 10 m for many tropical migratory fish species using more conventional fish passage types. This means that for most

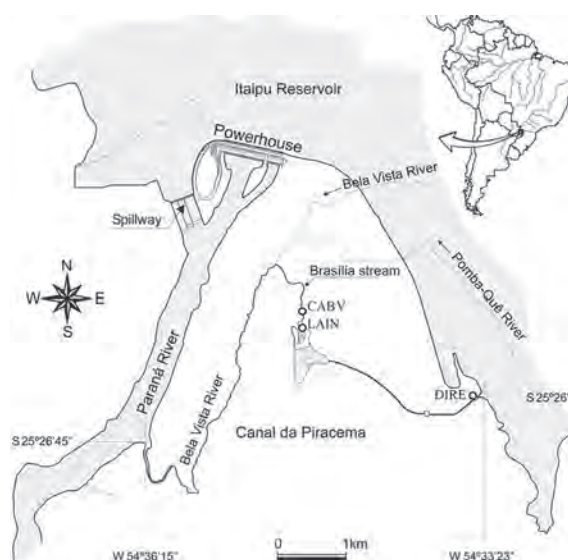
large dams, the fish passage both upstream and downstream may require several carefully selected designs to suit the types and sizes of fish.

Effective fish passage is usually defined as “providing safe passage for 95% of the target species under all flow conditions”, according to the Mekong River Commission. Such high effectiveness rates are

especially important when a cascade of dams is being implemented. As indicated in the Kabeli-A HSAP case study in Nepal, a fish pass for cold-water species was built into the design, but because effectiveness has not been proven, a fish hatchery was also planned to allow the release of fingerlings of migratory fish above the dam (Annex 2).

Box 22 Canal de Piracema fish passage at the Itaipu dam

The Canal da Piracema fish passage was completed in 2002 in order to mitigate the habitat fragmentation caused by the Itaipu dam, built 20 years earlier. It links the Paraná River with the dam reservoir. This fish passage system consists of a natural channel followed by four fish ladders, and four artificial lakes aimed at allowing fish to rest. Altogether, this fish passage system is 10 km long and 120 m high, which makes it the longest and the highest in the world.



Segment 1 consists of a 6.8 km long nature-like river, created using the original bed of the Bela Vista River and that of the Brasília Creek; its entrance is located 4 km below the dam. Segment 2 features a 200 m long fish ladder, with concrete deflectors every 4 m to reduce the water velocity, the opening between two deflectors being 1 m wide; it links segment 1 to an artificial Lower Lake (1.2 ha area, 4 m maximum depth). Segment 3 connects the Lower Lake to the artificial Principal Lake (14 ha; 5 m maximum depth) via a 521 m long fish ladder. Segment 4 includes a 1.6 km long fish ladder opening into the artificial Grevilhas Lake (0.5 ha, 3.0 m depth). Segment 5 includes another fish ladder extending over 730 m.

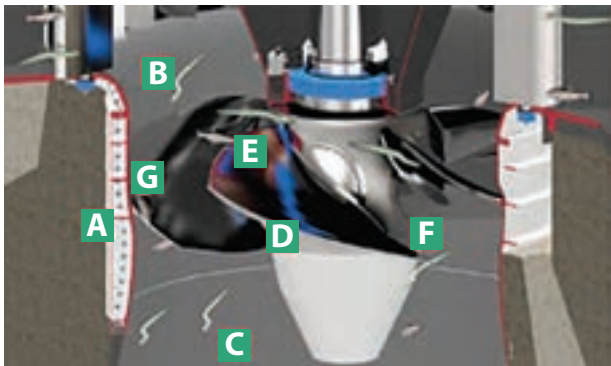
Above this uppermost ladder is the upstream entrance of the Canal de Piracema in the Itaipu reservoir. This entrance is 3.3 m deep and is located 5.8 km from the closest turbine. A concrete structure captures water from the reservoir to hold it in a stabilisation lagoon (area: 0.4 ha) before discharging it into the ladder.

Prior to the construction of the Canal da Piracema, a study was carried out between 1995 and 1997 at an experimental fish ladder near the Itaipu dam. Twenty-two species were recorded as using the facility, out of which five species comprised 87 per cent of the total catch. Analysis of fish abundance at different places along the ladder clearly indicated a lower abundance in the upper part of the facility. The migratory species that were found to ascend the Canal da Piracema with least difficulty were the strongest swimmers, which suggests that the fish passage may have a selective effect on other migratory species. Once the Canal da Piracema was constructed, Makrakis et al. found that 116 species used that facility, including 17 long-distance migratory species. These migratory species represented 3.8 per cent of the total abundance. The highest number of migratory species were caught at the lower end of the canal, and decreased in the upper parts of the fish passage system.

Source: Gätke, Pelle et al. (2013).

Box 23 ‘Fish-friendly’ turbine designs

Since the 1990s, ANDRITZ HYDRO has followed a combined design strategy to ensure high rates of fish survival. Different design features are possible in connection to the various injury mechanisms caused by the different stressors. These fish-friendly designs address the aforementioned direct injury mechanisms.



Direct turbine-related fish injury mechanisms

- A Rapidly pressure changes
- B Shear stress
- C Turbulence
- D Cavitation
- E Impacts on walls and components
- F Grinding
- G Abrasion

Injury Mechanism	Fish-friendly design features
Grinding/ shear	Reducing the gap between rotating and stationary components reduces the chance of fish getting trapped in gaps
Strike	Blunt leading edges on runner blades reduce impact severity Guide vane alignment reduces the probability that a fish will hit the wicket gate Reduced rotational speed reduces impact velocity between the fish and runner Fewer runner blades lower the strike probability and expand inter-blade passages
Turbulence	Variable speed for very high efficiencies across a wide operating range. Modern high-performance runners generally have a very low turbulence level, to improve fish survival rate
Cavitation	Bubble-free runner or at least a minimum-cavitation runner will reduce damage to fish tissues
Rapid pressure change	Blade design (e.g. longer blades), with CFD monitoring to monitor the pressure gradient
Water quality	Oil-free hub, to eliminate risk of oil leakage into the river water

Installations include:

- Swansea Bay tidal lagoon – 16 x 22 MW variable-speed bulb turbines
- Hydrodynamic screw turbines safe for smaller fish passage
- Rehabilitation of five Kaplan turbines (22.5 MW) at Rock Island power plant (Columbia River, WA, 2006)
- Priest Rapids Refurbishment (vertical Kaplan turbine, Columbia River, WA, USA)
- Seven Kaplan turbines (Ø 8.6 m, 186.6 MW) at Xayaburi power plant (Mekong River, Laos)

Source: <https://www.andritz.com/hydro-en/hydronews/hn31/fish-friendly-designs>

Once the fish reach the reservoir, they may be disorientated by the lack of flow, so that onward migration beyond long reservoirs to spawning grounds upstream may be problematic. Similarly, floating fish-eggs and fry may sink to the bottom of a reservoir and die. Mortality may also occur during downstream migration through the turbines, or due to pressure differences as they pass from upstream to downstream.

‘Fish-friendly’ turbines

Passage downstream through the turbines results in injury to fish. The potential fish injury mechanisms as they pass through turbines include direct injuries leading to death, and indirect effects of turbine passage (sub-lethal injuries, disorientation, stress), which lead to downstream predation, increased chances of illness, and adversely affected behaviour. The development of fish-friendly turbines is complex, but Box 23 illustrates the design features considered by one manufacturer that can improve the survival of fish passing through turbines.

4.5.6 Managing downstream flows for biodiversity

Aquatic ecosystems are dependent on the timing, duration and cycle of annual flows. Changes to flood maxima, flood minima, and duration of different flood heights can all impact wetland values. For example, if a wetland only fills when water flows over a sill, then flood height is critical, and this needs to be maintained for long enough to allow the wetland to fill. Equally, if a lake connected to a river is replenished through a narrow channel, then sufficient flows may need to be sustained post-project to allow it to be refilled annually. At the lower end of the hydrological scale, seasonal low flows reveal mud and sandbanks that can be essential for breeding reptiles and birds, or low river levels may allow fishers access to fish concentrated in particular pools.

Lastly, some parts of the flood cycle are known to be critical for triggering or allowing certain behaviours in fish and invertebrates. For example, seasonal fish migration may be triggered by increasing flows after the dry season (e.g.

Irrawaddy and Mekong), or by snow-melt floods (e.g. Columbia River). Smoothing of hydrological flows may mean that flood triggers are lost, and mimicking the natural regime can be assisted by planned releases and modified operating rules.

For many years, planners and operators of dams referred to the need to maintain a ‘minimum flow’ in the river below the dam, often arbitrarily established as 10 per cent of mean annual flow (m^3/sec). A growing understanding of downstream ecosystems’ complex responses to variations in flow has led to the emergence of a whole range of approaches that focus in more detail on release requirements and seasonal cycles, in order to benefit particular ecosystem components.

Many aspects of flow can be analysed, but eight key parameters are recognised by river scientists as important ecological and social descriptors of flow. Using these, hydrological data can be summarised to characterise a river’s flow regime and the ecological responses to changing flows (Table 15).

From this kind of information, ecologists can build an understanding of the impact of different flows on the quality and productivity of downstream ecosystems: for example, identifying the flow requirement for fish habitat. E-Flows should take into account the biological requirements of aquatic species to be conserved, and the social dimensions when any economically productive uses may be affected, such as fisheries, or floodplain grazing land. The latter issues may require communication and negotiation with affected communities. This is especially important in developing countries, where large numbers of people depend on river resources, and approaches should include the ecological, social and economic dimensions of river flow.

The approaches currently in use seek to describe the health of complete ecosystems rather than single species, and take a holistic approach to flow design. Some are ‘prescriptive’, focusing on a narrow and specific objective, and describe the single flow or flow regime to achieve this. They could be used, for instance, to define a dam release that would achieve a specific level of inundation of a downstream floodplain. The prescriptive approaches are poorly suited to negotiation with affected communities, because most effort is directed towards justifying

Table 5 Ecological significance of changes in hydrological parameters

Hydrological parameters	Example of ecological/biodiversity significance
Mean annual runoff (millions of m ³ per year);	Overall water availability for river ecosystems
Dry season onset (calendar week)	Trigger for return fish migration, downstream or from floodplain into main channel refuges
Dry season duration (days)	Length of exposure of banks and sand/gravel bars for nesting birds and turtles; die-back of seasonal floodplain grasslands; death in floodplains of some parasite vectors (e.g. snails, mosquitoes)
Dry season minimum five-day flow (m ³ /sec)	Maintenance of aquatic ecosystem components: fish/reptile/amphibian refuges; primary productivity of riparian vegetation; limitation of saline water incursion (if near a maritime delta)
Flood season onset (calendar week)	Trigger for upstream migrations for fish spawning in tributaries, and for lateral migration into floodplains
Flood season five-day peak (m ³ /sec);	Maximum extent of inundation of floodplain River channel geomorphology and habitat definition
Flood season volume (millions of m ³)	Depth and extent of inundation Primary productivity in aquatic zones; fish biomass production and catch Riparian vegetation diversity and extent
Flood season duration and type (days)	Duration of inundation is long enough for aquatic biodiversity lifecycles (e.g. spawning and growing for fish, flowering and setting seed for plants)

the single value. Other methods are ‘interactive’, scenario-based approaches that allow the exploration of options and facilitate discussion and negotiation. They may be applied at the basin level or the individual hydropower project level, including projections of impacts from seasonal flow changes and hydropowering. The project level approaches, which have been developed since the 1990s, include the Building Block Methodology (BBM), Downstream Response to Imposed Flow Transformation (DRIFT), Instream Flow Incremental Methodology (IFIM), Ecosystem Functions Model (HEC-EFM), Habitat-Flow Stressor-Response (HFSR) and Murray Flow Assessment Tool (MFAT). Readers are invited to refer to the IHA How-to Guide on Hydropower Downstream Flow Regimes, and the World Bank Group/IFC Handbook entitled Environmental Flows for Hydropower Projects: Guidance for the Private Sector in Emerging Markets, for further information on the topic.

The E-Flow assessment chosen should be able to provide, for all scenarios under consideration and for any point along the downstream river, the past, present and potential future flow regime for at least the eight key parameters in Table 15. As a general rule, the greater the potential conflict over water, the conservation status of the biological components of the river system, or the potential for social or political tension, the more holistic and detailed the E-Flow assessment should be. Box 24 describes how E-Flows were used to assess No Net Loss measures on the Jhelum River in Pakistan.

The E-Flow assessment will help to define the ecological flow requirements for the river downstream, and these may require design adaptations to be implemented (see also 4.2.1). There are several ways to ensure that the required flows are released, including the use of a smaller turbine that operates continuously to maintain a minimum flow release, even when

Box 24 Using E-Flows to assess No Net Loss mitigation measures for threatened fish species on the Karot dam on the Jhelum River in Pakistan

The Biodiversity Management Plan for the 720 MW Karot hydropower project on the Jhelum River in Pakistan was designed using a detailed DRIFT model E-Flow assessment, which included consideration of baseline scenarios without Karot dam in place, and operational flow scenarios with varying levels of environmental release from the dam. In addition, it studied the impact of protecting the river to reduce the harm done by illegal fishing, unregulated sand and gravel mining, and harvesting of vegetation along the river banks. Seven species of fish were used as indicator species, including the endangered mahasheer (*Tor putitora*) and vulnerable Alwan snow trout (*Schizothorax plagiostomus*)

The E-Flow assessment recommended that to achieve No Net Loss, the dam should be operated at baseload or as a true run-of-the-river project, and protection measures should be maintained in the main river and its tributaries. Operating the project at baseload would support movement of fish from the river to the tributaries in the wet season for breeding, and from the tributaries to the main river for refuge in the pools in the dry season. The protection measures, financed by the project, focused on reducing the non-flow threats to fish biodiversity by banning commercial fishing, and enforcing regulations on the use of illegal and damaging fishing methods (use of poisons, dynamite, electrocution, and non-selective gill nets); as well as controlling sand and gravel mining in the river, and riparian vegetation, to protect key breeding habitats.

Because of the height of the dam (96 m), it was decided not to build a fish pass in the first instance, but to focus on research into the attraction of fish migrating upstream to spawn, and collecting and transporting them to provide genetic diversity for the upstream fish populations. An Institute for Research in River Ecology, financed by the developer, was proposed, to undertake monitoring and research on the genetics of isolated fish populations to avoid inbreeding, along with other topics.

the main turbines are not in operation. Another method is the construction of a re-regulating pond downstream of the dam, which can release the required flow continuously, while balancing out the high and low flows caused by hydropеaking. A re-regulating pond can also address the issues of stress on the downstream ecosystem, caused by very rapid ramping rates when the turbines are brought on stream.

4.6 Biodiversity compensation measures – offsets

Offsets are a last resort designed to compensate for significant adverse residual impacts that remain after all feasible avoidance, minimisation and restoration has been carried out. To meet international best practice standards, most hydropower projects will need to offset residual impacts on priority biodiversity. Box 25 provides key information requirements for the design of biodiversity offsets.

Offsets are measurable conservation outcomes, resulting from actions designed to compensate for significant adverse residual biodiversity impacts from project development. Residual impacts are those that persist after avoidance, minimisation and restoration measures have been undertaken (see section 3.1.1). Generally, offset measures are not within the project site but within a comparable landscape, river basin or habitat type. Biodiversity offsets are designed to: achieve measurable, additional and long-term conservation outcomes through compensatory actions; achieve 'no net loss' of biodiversity at a minimum; and ideally, demonstrate 'like-for-like or better' outcomes, compared with the unimpacted project site.

Measurable conservation outcomes for biodiversity are demonstrated in situ (on-the-ground) and on an appropriate geographic scale (e.g. local, basin-level, national, regional). The principle of 'like-for-like or better' indicates that biodiversity offsets must be designed to conserve the same

biodiversity values that are being impacted by the project (an 'in-kind' offset). In certain situations, however, areas of biodiversity to be impacted by the project may be small or marginal, and not really viable in the long term. There may be other areas of biodiversity with similar values that are a better choice for conservation and sustainable use, and are under imminent threat or require protection or effective management. In these situations, it may be appropriate to consider an 'out-of-kind' offset.

Two general types of offsets can be used to compensate for significant residual impacts:

- **Restoration offsets**, which remediate past damage to biodiversity (due to factors unrelated to the project), via rehabilitation or enhancement of biodiversity components (or even re-creation of ecosystems and their associated biodiversity values) at suitable offset sites.
- **Protection or averted loss offsets**, which protect biodiversity in an area demonstrated to be under threat of imminent or projected loss (due to factors unrelated to the project). Projections of the losses of biodiversity that will be averted by an offset require credible analysis of those trends. In some cases, this type of offset may not be appropriate where there is great uncertainty, or there is a lack of stakeholder support for the analysis supporting those projections.

Riverine offsets differ from terrestrial offsets, and will need specific methods to assess losses and gains of biodiversity. They can be complex to design because the impacts often extend over long distances upstream and downstream. The watershed interacts with other ecosystems far from the river, and may have a unique species composition, making it difficult to find an equivalent offset site elsewhere. Watersheds often have significant ecosystem services, which makes it challenging to integrate social and biodiversity concerns.

Examples of offsets applicable to hydropower projects include:

- Restoration of degraded habitat similar to that which will be lost, e.g. within the same or nearby

catchment; (Box 26 illustrates the potential for restoring a tributary for fish diversity, in China).

- Improved management and protection for a stretch of free-flowing river in another part of the catchment (see Box 9 and Box 10).
- Provision of protection to a habitat or species in a newly designated protected area, or additional support to an existing protected area (see for example Figure 10).
- Establishment or support for a captive breeding and reintroduction programme for local fauna or flora species (see case study examples in Annex 2).

Additional conservation actions are actions that the developer may take or support, which do not fit directly into the offset classification, but are supportive of biodiversity conservation. These may include research studies into the species populations or biology, which can inform future management.

One of the usual measures for verification of offsets is to determine the size and habitat condition or status of the area to be inundated by the reservoir. This generates a value of 'habitat hectares', which includes a habitat condition factor of existing vegetation against a benchmark for the same vegetation type in an undisturbed area. The offset is then calculated to achieve the same (or better) improvements in the habitat hectares in the offset area. In the case of a river offset, the equivalent metric would be 'quality x length'.

Design of offsets and verification measures will vary with the country or lender's requirements, but guidance on the establishment of offsets is shown in Box 25. The design and implementation of a biodiversity offset are included in a BAP (see section 4.4.4).

4.7 Monitoring, reporting and feedback cycles

The biodiversity baseline and impact monitoring is an essential part of good biodiversity management. Monitoring programmes should be built into any Biodiversity Action Plans (BAPs) and Environmental

Box 25 Information requirements for biodiversity offset design*(adapted from Business and Biodiversity Offsets Programme guidance notes)*

For areas affected:

- Inventory of species and habitats
- Status and area occupied by each species / habitat
- If possible, an assessment of trends in biodiversity

For the wider region:

- Current status and area occupied by each species and habitat
- Potential (historic) area occupied by each species and habitat
- Existing potential threats to biodiversity
- Potential mitigation measures relevant to local requirement and needs

For proposed offset sites:

- Target area to be occupied by each species and habitat
- Target status (within the target area) for each species and habitat
- Offset measures for protection of biodiversity in offset areas
- Metrics for assessing No Net Loss or Net Gain
- Indicators of effectiveness of mitigation, and proposed monitoring and assessment procedures

Box 26 Removal of a low-head dam and restoration of a tributary on Lancang River, China

When the Miaowei dam was being planned on the mainstem of the Lancang River, the removal of the Jidu dam was proposed in order to restore the Jidu river for fish populations, and to provide a spawning habitat for fish from the Miaowei reservoir. The low-head Jidu dam had a very small reservoir and a 4.5 km dewatered stretch of river between the dam and power station on the Jidu River, near the confluence with the Lancang River.

Fish surveys were carried out before and after removal of the dam, to assess how effective this approach can be for aquatic biodiversity restoration. Asian mountainous rivers are dominated by Cypriniformes fishes, and the effects of dam removal on these fish communities are not well known. Fish surveys were designed using the before-after-control-impact (BACI) model, with the fish populations in the restored river being compared with those in the control, Fengdian River, where a similar dam was retained. Surveys were carried out one year before and for three years after the Jidu dam removal.

Rapid changes in fish biodiversity metrics and assemblage structure occurred in the Jidu River within the first year after dam removal in 2012. Overall, fish species richness, density and Shannon-Wiener diversity all increased immediately in above- and below-dam sites, and maintained a stable level in subsequent years, compared to the unchanged situation in the control river. Before dam removal the fish populations were dominated by omnivorous fish species, but after dam removal, insectivorous species increased, indicating that the riverine habitat had been restored and macro-invertebrate populations increased.

Source: Ding Chengzhi et al. (2019)

and Social Management and Monitoring Plans (ESMMPs), and inform adaptive management over the lifetime of the project. However, by the very nature of biodiversity, extensive ongoing monitoring could become a costly item in the operating budget, and monitoring therefore needs to be targeted towards the key impacts, management measures and their effectiveness. The design of any hydropower monitoring programme should have clear objectives on what is being monitored, the indicator species, locations, and frequency of monitoring. Box 27 illustrates good practice in the design of monitoring during implementation and operation.

The basic principle is that monitoring serves to inform decision-makers on the historic and current status and trend of any particular indicator (physical or biological). If the indicator begins to deviate from that which is fixed in the management plan(s) (or the trend is away from the intended outcome), then additional research is triggered to find out why this is happening, and what can be done about it. See, for example, Box 20.

Indicators that change frequently need frequent monitoring: these include river flows, where daily or even hourly data can be important for riverine biodiversity (e.g. for flood pulses that

trigger fish migrations). There is little advantage in daily monitoring of indicators that change much more slowly, such as populations of elephants or macro-invertebrates in the river. These can be monitored every year, or even every three years, using specific survey methods.

While biodiversity monitoring and reporting may be required by concession and lender conditions, the results of monitoring are important for adaptive management of the biodiversity impacts, and for water quality and reservoir fishery management. There should be a clear feedback loop, to allow the developer's Environmental and Social Management Team to review the monitoring reports and adjust the management measures appropriately. This may include adjustment of operating procedures of the hydropower plant – if, for example algal blooms occur in the reservoir, or poor water quality affects downstream fish populations. A wider transparency of monitoring results and adaptive management measures is recommended, in order to strengthen the reputation of the hydropower company and the industry generally. Monitoring by an independent agency/organisation will also strengthen the credibility of the biodiversity management and the mitigation measures.

Box 27 Good practice in monitoring during the Implementation and Operation stages

- Express biodiversity management objectives clearly (SMART)
- Include indicators, sampling designs, and frequencies for each of the management objectives
- Prepare the necessary budget and staffing
- Ensure results on the ground are being independently monitored
- Involve local stakeholders (local wildlife authorities, local universities, etc.) in monitoring activities
- Report results transparently to local communities, national ministries, local government, river basin organisations, media, online, etc.
- Adjust plans based on monitoring feedback loops
- Establish an independent expert review panel
- Share field data with the Global Biodiversity Information Facility

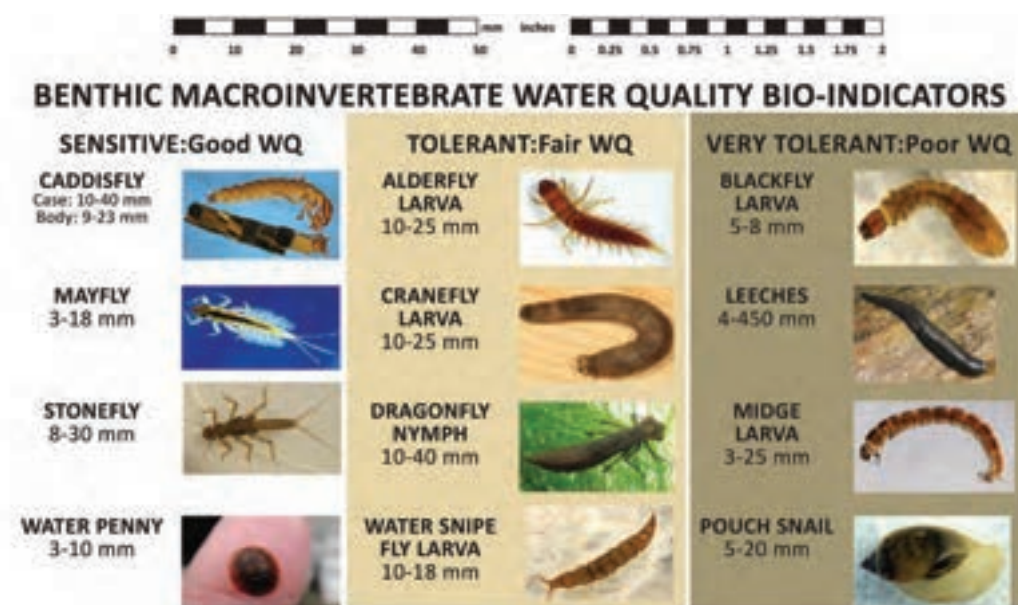


Figure 14 Example of benthic macroinvertebrate water quality indicators used in the USA. Presence of 'sensitive species' indicates excellent water quality
Source: Beaver Water District, Arkansas, USA

In addition, as of 2020, the Equator Principles banks are required to encourage borrowers to publicly share biodiversity field data collected through baseline studies and monitoring schemes, via the Global Biodiversity Information Facility (see <https://www.gbif.org/>).

4.7.1 Designing a monitoring system

Choosing indicators and indicator species

Setting clear management objectives, as described in section 4.4.3, will assist in the design of monitoring programmes. SMART objectives (Specific, Measurable, Attainable, Realistic, Timed) are much easier to monitor than vague commitments to 'conserve biodiversity'. In some cases, log frame approaches may be appropriate.

The 'specific' component of a SMART objective will assist in the choice of indicators. If the focus for management is on a particular species, then the populations and distributions of that species at the appropriate times of year should be the basis for monitoring. It may be that the species is so rare, and the populations so dispersed, that quantifiable

monitoring may be difficult. In such cases it may be necessary to choose another related species as a proxy indicator, or the integrity and condition of the habitat on which it is dependent. In this scenario, monitoring becomes more of an ongoing research programme, where intensive surveys undertaken every few years validate the link between the species population and the proxy indicators.

For management measures that relate to replanting and rehabilitation of habitats, indicators of success are likely to be based upon the survival of planted species and the improving condition of the habitat. For those related to E-Flows, monitoring schemes should include both the flow parameters listed in 4.5.6, and the intended downstream threatened biodiversity or Provisioning Ecosystems Services outcomes.

Biodiversity monitoring should be a component of the environmental monitoring programme that all hydropower plants are normally required to undertake. Routine biodiversity monitoring elements include ecological health of the river, by measuring biotic parameters such as phytoplankton (often measured by chlorophyll-a content and the presence of blue-green algae, to reflect eutrophication), zooplankton, benthic diatoms, and

littoral and benthic macro-invertebrates. These species indicators have been used to develop river health indices in many parts of the world, and a hydropower project should use or adapt the most relevant river health index for its situation. Zooplankton and diatoms require laboratory and microscopic identification, but macro-invertebrate monitoring (see Figure 14) provides the simplest of these river health parameters; it has even been applied by local communities and school children.

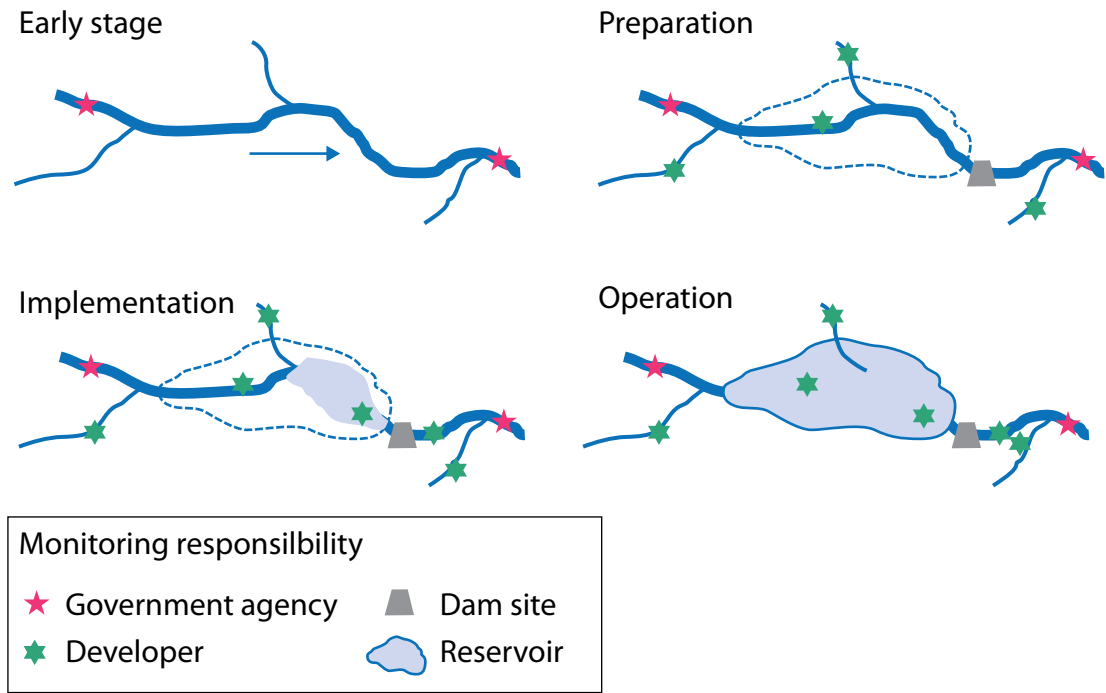
In addition, fisheries and fish passage monitoring is required. Fish diversity monitoring records the different species occurring in different habitats in the reservoir, tributaries and river downstream; this is done by non-selective fishing methods, such as gill nets and/or electrofishing. The fisheries monitoring records the fish catches (species, numbers, weight) by month, and catch per unit effort of the fishers. If fish migration is significant and fish passage is provided through the dam, fish surveys are done at the time of fish migrations, by recording species and numbers of fish below the dam waiting to move upstream, as well as the presence of the migratory species within the reservoir, and their spawning

status. Fish passage effectiveness monitoring may include fish tagging studies, to see how many fish marked at the bottom actually reach the top. These can be complex, requiring expert application and interpretation. Aiming to balance monitoring needs with available resources, the Mekong River Commission has been developing an environmental monitoring programme for mainstream hydropower projects, which combines these linked elements of biotic and abiotic parameters.

Selection of monitoring sites

The choice of sampling stations for environmental and biodiversity monitoring is important to assess the impacts of the dam and reservoir on the river ecosystems: these include the biodiversity in the upstream rivers and basin; within the reservoir itself; and downstream aquatic, riparian and floodplain ecosystems. Figure 15 shows the locations for sampling sites at different stages of hydropower development.

Figure 15 Monitoring locations at different stages of hydropower development
Source: Adapted from Mekong River Commission (2020)



If the reservoir fishery is to be developed, regular recording of the fish catches and catch per unit effort (CPUE) will be an important measure, together with annual surveys to assess the species diversity.

Frequency of monitoring

The typical parameters that may be used for monitoring general ecosystem health are shown in Table 16, together with suggested frequency of measurement to establish the baseline, and during implementation and operation. These surveys are of a general nature; they do not replace specific plans to monitor outcomes of

measures to protect threatened biodiversity, to re-establish Provisioning Ecosystem Services, or to address disease vectors and invasive species.

4.7.2 Verifying biodiversity offsets

If biodiversity offsets are included in the mitigation measures, verification of the outcomes of the offset are required. The BAP monitoring plan includes assessments of the baseline status and condition of the species and habitats within the offset area; it monitors these at least annually, in order to assess the effectiveness of the offset in achieving net gain or no net loss. Offsets usually

Table 16 Parameters for general monitoring of ecosystem health: frequency at different stages

Parameter	Preparation (baseline)	Implementation	Operation
Routine hydrology, water quality and river health monitoring			
Hydrology (flows and water level)	Daily (for feasibility studies)	Daily	Daily
Water temperature	Monthly (for ESIA)	Daily	Daily
Dissolved oxygen	Monthly (for ESIA)	Daily	Daily
Suspended solids, turbidity	Monthly (for ESIA)	Daily	Daily
Aquatic indicator species (selected zooplankton, benthic diatoms, benthic and littoral macro-invertebrates)	Annually in low flows at appropriate season	Annually in low flows at appropriate season	Annually in low flows at appropriate season
Phytoplankton (algae), chlorophyll-a & blue green algae	Monthly in river	Monthly, to see changes during construction, or strengthen baseline	Monthly, especially in the reservoir, and downstream to monitor eutrophication

Other monitoring that may be required to complement specific management plans			
Vector species of human disease*	Baseline surveys to record presence of potential disease vectors (snails, insects, etc.) Records of disease in local communities	Monthly inspections of construction sites for vectors identified. Records of disease incidence among workers and local communities	Two annual inspections of reservoir areas and downstream river for vectors identified Records of disease incidence amongst local communities
Invasive species *	At least twice per year (dry and wet seasons) to confirm presence of known invasives (esp. plants, molluscs, fish)	Monthly inspections of construction sites	Monthly inspections of reservoir, trash racks and downstream sites
Fish diversity and fisheries production	As part of ESIA Survey of fishers to record historic catches (species and quantities) At least twice per year (dry and wet seasons) Fish diversity sampling to establish species present in different river habitats (non-selective gill nets or electrofishing)	At least twice per year (dry and wet seasons) Fish diversity sampling to establish species present in different river habitats (non-selective gill nets or electro-fishing)	If reservoir fishery is established Monthly catch returns in reservoir Daily/weekly catch of selected fishers (catch per unit effort, CPUE) Fish diversity sampling to establish species present in different reservoir and downstream habitats (non-selective gill nets or electrofishing)
Fish passage	To assess need and requirements for fish pass Seasonally, at times of fish migration (from above fish diversity sampling, observing presence of migratory species)	If fish pass has been installed Seasonally, at times of fish migration	If fish pass has been installed Seasonally, at times of fish migration. Presence of migratory fish collecting at entrance of fish passage and in reservoir Possible fish tagging to assess effectiveness of passage through the dam
Terrestrial ecology	As part of ESIA Seasonally, at least two to four times per year Baseline surveys of vegetation, insects, reptiles and amphibians birds, mammals, to establish presence and structure of flora and fauna, and habitat condition More specific flora/fauna surveys to record status of species of concern	Before construction/site preparation begins, as part of moving terrestrial species away from construction sites or vegetation clearance Monitoring disturbance of specific fauna of concern, e.g. roosting, nesting and congregatory species (birds and bats) and along access roads. Reports of hunting and wildlife trade infringement	To assess effectiveness of management measures and offsets Seasonally, at least twice per year. This may be reduced after some years, depending on the stabilisation of the impact area. Monitoring of bird strikes/kills on transmission lines

* monitoring in the absence of a pre-identified threat; otherwise, specific monitoring plans are included in the appropriate action plans.

require a long-term mitigation commitment, and monitoring is necessary to facilitate adaptive management. Offset monitoring and verification is usually a requirement of the government and lenders. Verification of aquatic biodiversity offset measures requires monitoring of the hydrological and water quality parameters, and/or of appropriate riverine or wetland indicator species.

species monitoring (to satisfy the functional connectivity metric), compared to the section of the Reventazón River isolated by the project.

Verification of aquatic biodiversity offset measures may be undertaken through the E-Flow design and monitoring process of the hydrological and water quality parameters, or through tracking of appropriate riverine or wetland indicator species. In the case of Reventazon HPP (see Box 28), the offset monitoring component might carry out monthly water quality sampling on the Parismina River (to satisfy the structural connectivity metric), and annual ecological health and fish

Box 28 Riverine offsetting for no net loss of natural habitat – Reventazón HPP, Costa Rica

Reventazón HPP, with an installed capacity of 305 MW, consists of a 130 m dam, flooding an area of 6.9 km², creating an 8 km long artificial lake. It is located on the Reventazón River downstream of the Angostura HPP.

The Reventazón River qualifies as Natural Habitat according to IFC PS6, and impacts include the loss of 8 km of flowing river; this creates a barrier effect for migratory fish species entering 38 km of Reventazón River mainstream, and tributaries downstream of Angostura HPP. It has changed the hydrology, sedimentation and water quality in downstream Reventazón river, including in the Tortuguero National Park.

Offsetting was required to compensate for project impacts on the sub-corridor, to ensure no net loss of river natural habitat, and to compensate for impacts on migratory fish species. The Parismina River, which runs parallel and adjacent to the Reventazón River, was identified as equivalent to latter – a like-for-like offset. This is an averted-loss offset; it was agreed that hydropower will not be developed on the Parismina River in the future. Two methods for measuring no net loss were used.

Method 1 used the 'quality x length' metric for structural connectivity. No net loss is achieved by offset actions when water quality in the section of the Parismina River that would have been disconnected if a Parismina dam were constructed, is better than water quality in the river reach disconnected by the Reventazón project.

Method 2 uses a metric for functional connectivity of the river system, based on the abundance of indicator species. No net loss is achieved when with offset actions, species abundance in the relevant sections of the Parismina River is greater than species abundance in the section of river that will be disconnected by the Reventazón project.

Source: The Biodiversity Consultancy (2016)



5 Conclusions



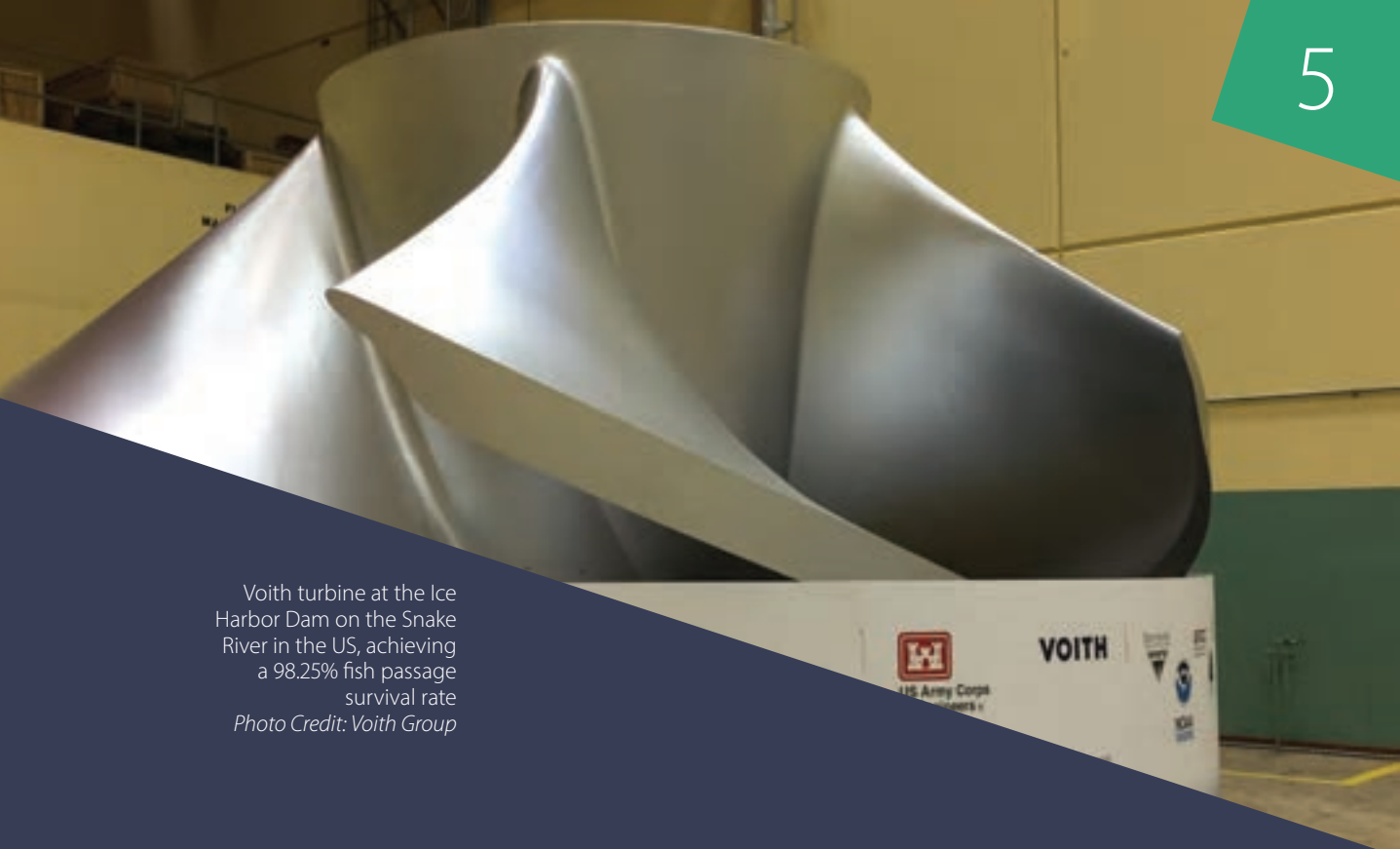
Conclusions

This How-to Guide has laid out the key considerations involved in identifying, understanding and managing impacts on biodiversity – whether as threatened species, species that provide Provisioning Ecosystem Services, or those that impact negatively on human activities, such as invasive species and disease vectors.

Negative biodiversity impacts are managed more effectively if they are identified early, well studied, and appropriate measures are incorporated in project plans, staffing and budgets. This guide has offered insights into the nature of biodiversity impacts, and how to identify those that are most significant; it has also proposed approaches and technologies that can be used to manage biodiversity risks. It is also important for developers to rapidly identify potential invasive species and put management responses in place.

The key recommendations of this guide are to:

- start early and adopt a broad geographical approach to biodiversity assessment;



Voith turbine at the Ice Harbor Dam on the Snake River in the US, achieving a 98.25% fish passage survival rate
Photo Credit: Voith Group

- identify good local and national partners to work with, and build capacity early in the project;
- ensure collaboration between environment and design teams, to avoid as many biodiversity impacts as possible;
- gradually refine and focus on the management of the most significant biodiversity impacts;
- ensure that biodiversity management objectives and monitoring plans are clear; and
- actively support research programmes that can improve adaptive management over the lifetime of the project.

Annex 1

Bibliography

ADB (2012). *Environment Safeguards – A Good Practice Sourcebook*.

ADB (2014). *Strategic Environmental Assessment of regional power development in the Greater Mekong Sub-region*.

Aksu, S., Yildiz, D. and Güngör, A. P. (2017). How Zebra Mussels Threaten to Water Supply Security and Effects of Preventive Measures in Turkey. *World Scientific News*, 64: 99–126.

Arthington, A. H., Bunn, S. E., Pusey, B. J., Bluhdorn, D. R., King J. M., Day J. A., Tharme R. E., O’Keeffe J. H. (1992). Development of an holistic approach for assessing environmental flow requirements of riverine ecosystems. In *Proceedings of an international seminar and workshop on water allocation for the environment*, November 1991, The Centre for Water Policy Research, University of New England. Pigram, J. J., Hooper, B. P. (eds). Armidale, Australia.

Bernacsek, G. (1984). *Guidelines for dam design and operation to optimize fish production in impounded river basins*. CIFA Technical Paper No. 11. Rome: FAO.

Bhukaswan, T. (1980). *Management of Asian Reservoir Fisheries*. FAO Fisheries Technical Paper No. 207. <http://www.fao.org/3/AC865E/AC865E01.htm>

Biodiversity Consultancy (2016). *Hydropower: applying the mitigation hierarchy to manage biodiversity risks – Briefing Note*.

Brown et al. (2013) Brown, C. A. and Watson, P. (2007). Decision Support Systems for Environmental Flows: Lessons from Southern Africa. *Journal of River Basin Management*, 5(3): 169–178.

Brown J., Limburg, K., Waldman, J., Stephenson, K, Glenn, E., Juanes, F., and Jordaan, A. (2013). Fish and hydropower on the US Atlantic Coast: failed fisheries policies from half-way technologies. *Conservation Letters*, 6(4): 280–286.

Business and Biodiversity Offsets Programme (BBOP) (2009). *The Relationship between Biodiversity Offsets and Impact Assessment: A BBOP Resource Paper*. BBOP, Washington, D.C.

Business and Biodiversity Offsets Programme (BBOP) (2012). *Guidance Notes to the Standard on Biodiversity Offsets*. BBOP, Washington, D.C. Available from: http://bbop.forest-trends.org/guidelines/Standard_Guidance_Notes.pdf

Cote, D., Kehler, D. G., Bourne, C. and Wiersma, Y. F. (2009). A new measure of longitudinal connectivity for stream networks. *Landscape Ecol.*, 24: 101–113.

Ding Chengzhi et al. (2019). Fish Assemblage Responses to a Low-head Dam Removal in the Lancang River. *Chinese Geographical Science*, 29(1): 26–36. <https://doi.org/10.1007/s11769-018-0995-x>

European Commission (2003). *Common Implementation Strategy for the Water Framework Directive (2000/60/EC) Guidance document no. 13. Overall approach to the classification of ecological status and ecological potential*.

FAO (Food and Agriculture Organization of the United Nations), DVWK (Deutscher Verband für Wasserwirtschaft und Kulturbau e.V.) (2002). *Fish passes – Design, dimensions and monitoring*. FAO and DVWK, Rome, Italy. 119 pp.

Gätke, P. et al. (2013). *Fish Passage Opportunities for the Lower Sesan 2 Dam in Cambodia – lessons from South America*. Project report: Challenge Program on Water & Food Mekong project MK3 “Optimizing

the management of a cascade of reservoirs at the catchment level". ICEM – International Centre for Environmental Management, Hanoi Vietnam.

Grill G., Ouellet Dallaire, C., Fluet Chouinard, E., Sindorf, N. and Lehner, B. (2014). Development of new indicators to evaluate river fragmentation and flow regulation at large scales: A case study for the Mekong River Basin, *Ecol. Indicators*, 45: 148–59.

Gullison, T., Hardner, J., Antsee, S. and Meyer, M. (2015). *Good Practices for the Collection of Biodiversity Baseline Data*. Prepared for the Multilateral Financing Institutions Biodiversity Working Group & Cross-Sector Biodiversity Initiative. Available from: <https://publications.iadb.org/publications/english/document/Good-Practices-for-the-Collection-of-Biodiversity-Baseline-Data.pdf>

Halls, A. S., Kirkwood, G. P. and Payne, A. I. (2001). A dynamic pool model for floodplain river fisheries. *Ecohydrology and hydrobiology*, 1(3): 323–339.

Hardner, J., Gullison, T., Antsee, S. and Meyer, M. (2015). *Good Practices for Biodiversity Inclusive Impact Assessment and Management Planning*. Prepared for the Multilateral Financing Institutions Biodiversity Working Group. Available from: <https://publications.iadb.org/publications/english/document/Good-Practices-for-Biodiversity-Inclusive-Impact-Assessment-and-Management-Planning.pdf>

Hughes and Louw (2011). Integrating hydrology, hydraulics and ecological response into a flexible approach to the determination of environmental water requirements for rivers. *Environmental modelling and software*, 25(8): 910–918.

Hughes, D. A. and Hannart, P. (2003). A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. *Journal of Hydrology*, 270: 167–181.

HydroWires (2020). *A Comparison of the Environmental Effects of Open-Loop and Closed-Loop Pumped Storage Hydropower*. US Dept. of Energy. PNNL-29157.

IFC (2012, updated 2019). *Guidance Note 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources*.

IFC (2013). *Good Practice Handbook on Cumulative Impact Assessment and Management: Guidance for the Private Sector in Emerging Markets* (IFC Handbook).

IFC (2018). *Good Practice Handbook on Environmental Flows for Hydropower Projects*. World Bank Group.

IFC *Cumulative Impact Assessment Guidelines for HPP in Lao PDR* https://www.ifc.org/wps/wcm/connect/028897b1-7a06-4653-a20c-aba5864d7d72/Lao+PDR+HPP+CIA+Guidelines_English+version.pdf?MOD=AJPERES&CVID=ItRkF7I

International Finance Corporation's Guidance Note 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources. 1 January 2012 (updated 27 June 2019): GN 91.

IPBES (2019). *Global Assessment Report on Biodiversity and Ecosystem Services*. <https://ipbes.net/global-assessment>

IUCN (2012). *IUCN Red List Categories and Criteria: Version 3.1. Second edition*. Gland, Switzerland and Cambridge, UK: IUCN. iv + 32 pp.

IUCN (2006). *Status and distribution of freshwater fish endemic to the Mediterranean region*. Smith, K. and Darwall, W.

IUCN (2013). *Guidelines for Reintroductions and Other Conservation Translocations*. <https://portals.iucn.org/library/efiles/documents/2013-009.pdf>

- IUCN (2014). *Biodiversity management in the cement and aggregates sector: Biodiversity Indicator and Reporting System (BIRS)*. Gland, Switzerland: IUCN. 72 pp.
- IUCN (2016). A Global Standard for the Identification of Key Biodiversity Areas, Version 1.0. First edition. Gland, Switzerland: IUCN.
- Ketelsen T, V. A. (2014). Impacts of landuse change on sediment transport. In *ICEM, On optimizing the management of cascades or system of reservoirs at catchment level* [www.optimisingcascades.org] (Chapter 4.3). Hanoi, Vietnam: International Centre for Environment Management.
- King, J. M. and Louw, D. (1998). Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. *Aquatic Ecosystems Health and Restoration*, 1: 109–124.
- Larinier, M., Travade, F. and Porcher, J. P. (2002). Fishways: biological basis, design criteria and monitoring. *Bull. Fr. Pêche Piscic.* 364 suppl., 208 pp.
- McCartney, M., Funge-Smith, S. and Kura, Y. (2018). *Enhancing fisheries productivity through improved management of reservoirs, dams and other water control structures*. Penang, Malaysia: CGIAR Research Program on Fish Agri-Food Systems. Program Brief: FISH-2018-11.
- Mekong River Commission (2020). *Piloting a Joint Environmental Monitoring Programme on two Mekong mainstream dams 'Don Sahong Hydropower Project and Xayaburi Hydropower Project': An inception report*. Vientiane: MRC Secretariat. <http://www.mrcmekong.org/assets/Publications/JEM-InceptionRep.pdf>
- Mekong River Commission (2018). *Hydropower Risks and Impact Mitigation Manual – Key Hydropower Risks, Impacts and Vulnerabilities and General Mitigation Options for Lower Mekong*, Vientiane, Lao PDR
- Meynell. P. (2014). Improving reservoir ecology with constructed wetlands. *Hydropower & Dams*, 2014(3), 78–80.
- Mekong River Commission (2009). *Preliminary Design Guidance for Proposed Mainstream Dams in the Lower Mekong Basin*.
- Mekong River Commission (2010). *Biomonitoring Methods for Lower Mekong Basin*. Mekong River Commission, Vientiane. 65 pp.
- Mekong River Commission (2019). *Review of the design change made for Xayaburi hydropower project: A technical reference paper*.
- Mekong River Commission (2020). *Piloting a Joint Environmental Monitoring Programme on two Mekong mainstream dams 'Don Sahong Hydropower Project and Xayaburi Hydropower Project': An inception report*. Vientiane: MRC Secretariat. <http://www.mrcmekong.org/assets/Publications/JEM-InceptionRep.pdf>
- OECD (2013). *Environment directorate*.
- Opperman, J., Grill, G. and Hartmann, J. (2015). *The Power of Rivers: Finding balance between energy and conservation in hydropower development*. The Nature Conservancy: Washington, D.C.
- Poff, N. R. et al. (2010). The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental standards. *Freshwater Biology*, 55: 147–70.
- Richter, B. D., Baumgartner, J. V., Wigington, R. and Braun, D. P. (1997). How much water does a river need? *Freshwater Biology*, 37(1): 231–249.
- Schouten, R. (1998). *Effects of Dams on Downstream Reservoir Fisheries, Case of Nam Ngum*. Mekong Fish Catch and Culture. Mekong River Commission ISSN 0859-290X, Vol. 4, No. 2 – December 1998.
- Shono, K. et al. (2007). Application of Assisted Natural Regeneration to Restore Degraded Tropical Forestlands. *Restoration Ecology*, 15(4): 620–626. DOI: 10.1111/j.1526-100X.2007.00274.x
- SNIFFER (2006). *Development of environmental standards (water resources). Stage 3: environmental standards for the Water Framework Directive*. Report to the Scotland and Northern Ireland Forum for Environment Research. Centre for Ecology and Hydrology, Wallingford and University of Dundee, Dundee. <http://www.sniffer.org>.

SNIFFER (2007). *Guidance of environmental flow releases from impoundments to implement the Water Framework Directive*. Scotland and Northern Ireland Forum for Environment Research, Edinburgh. <http://www.sniffer.org>.

SNIFFER (2008). *Rapid validation of WFD83 Standards for Freshwater Flows to Estuaries*. Project WFD83 Ext. Tennant (1976).

Southern Waters (2012). *Development of a basin-wide IWRM-based development plan for the Kagera Basin. Burundi, Rwanda, Uganda and Tanzania. Environmental Flow Task*. Part I: Tool development. Final. Contract no.: Kagera/2011/s/bdp-01. Sida ref: 73001016. 33 pp.

Stalnaker, C., Lamb, B. L., Bovee, K. and Bartolow, J. (1995). *The Instream Flow Incremental Methodology: a primer for IFIM*. Biological Report 29, National Biological Service, U.S. Department of the Interior. <http://www.fort.usgs.gov> USGS (2011).

The Biodiversity Consultancy (2016). *Offsetting for a hydropower project in Costa Rica – Applying the mitigation hierarchy to manage biodiversity risk*. Poster for Hydro 2016 international conference and exhibition.

Thoms et al. (2000). *River Murray Scientific Panel report on Environmental flows*. <https://www.researchgate.net/publication/274007430>

Turpie, J. K., Taljaard, S., Adams, J., Van Niekerk, L., Forbes, N., Weston, B. Huizinga, P. and Whitfield, A. (2013). *Methods for the determination of the Ecological Reserve for estuaries. Version 3*. Water Research Commission and Department of Water Affairs, Pretoria. Water Research Commission Research Report.

Welcomme, R. L., Winemiller, K. O. and Cowx, I. G. (2006). Fish environmental guilds as a tool for assessment of ecological condition of rivers, *River Research and Applications*, 22: 377–96.

World Bank (2011). *Doing a dam better: the Lao People's Democratic Republic and the story of Nam Theun 2*. Porter, I. C. and Shivakumar, J. (eds.).

World Bank (2018). *Good Practice Handbook Environmental Flows for Hydropower Projects. Guidance for the Private Sector in Emerging Markets*.

Young, W. J., Scott, A. C., Cuddy, S. M. and Rennie, B. A. (2003). *Murray Flow Assessment Tool – a technical description. Client Report, 2003*. CSIRO Land and Water, Canberra.

Annex 2

Project examples

From assessments using the Hydropower Sustainability Assessment Protocol

Project	Assessment	Management	Outcomes and Compliance
Blanda 150 MW Operation stage Iceland	Environment report draws on extensive field research carried out previously, with a focus on the loss of land to the reservoir and changes in the river's hydrology. Vegetation mapping for the area listed plants, mosses, lichens and fungus, but did not identify any rare species of plant. Long-standing research on fisheries and fish counters are in place nearby. Impacts on valuable salmon fishery are projected. No rare or endangered species present. Identification of emerging biodiversity issues does not fully account for risks and opportunities; this is considered a significant gap at the proven best practice level. Repeat fisheries surveys and aquatic and terrestrial flora and fauna have not been carried out to assess the changes.	Good partnerships with biodiversity organisations (Soil Conservation Service and Institute of Natural History) for revegetation and stabilisation of soil around reservoir. Agreements with angling club to maintain the downstream river flow to support the salmon in the river. Institute of Freshwater Fisheries (IFF) monitors the salmon run and juvenile population, with management measures in place if necessary. Mink recognised as an invasive species, but no changes in population due to presence of project.	No non-compliances registered.

Project	Assessment	Management	Outcomes and Compliance
Chaglla 456 MW Implementation stage Peru	One of the most biodiverse ecoregions in the world, in the headwaters of the Amazon basin. Presence of PAs and KBAs in area of influence, indicating importance. Initial EIA was more general and indicated moderate significance of impacts. More extensive EIA of transmission line, including impacts such as opening up access routes for deforestation, and bird collision with transmission towers. Biodiversity Compensation Plan and Ecological Flow Management Plan. Hydrobiological monitoring and monitoring of terrestrial fauna, but biodiversity monitoring is not linked to the potential causes of biodiversity loss or a management response.	Rescue of fauna and flora from sites prior to construction works; reintroduction of flora, particularly orchids, to intact areas; rescue of stranded fish following the diversion of the river; the use of native species for revegetation of construction sites; a leaflet to raise awareness to prevent hunting by workers, and environmental education in local schools; and eradication of the kudzu vine (<i>Pueraria</i> sp.) – an invasive species, originally used for slope stabilisation. During operation, to permanently maintain an environmental flow to minimise downstream effects; to monitor characteristics of the fish upstream and downstream of the reservoir; and introduce fish fry in watercourses if necessary, to ensure the presence of fish species in the river. Compensation plans combined the restoration of areas of modified habitat with support to Tingo Maria National Park and the University of San Marcos. Offset plans linked to management of environmental flows, to maintain habitat connectivity of the Huallaga with its tributaries upstream of the powerhouse.	All commitments are met. Legal requirements include avoiding biodiversity impacts, minimising effects on the aquatic ecosystem, and conserving habitat. There are no significant non-compliances or non-conformances.
Devoll 72 & 184 MW Implementation stage Albania	DHP has monitored aquatic ecology (phytoplankton, zooplankton, benthic fauna and fish fauna) during the implementation stage. DHP plans a study to update and verify the status of aquatic biodiversity using these data, and a similar study on terrestrial biodiversity. These studies will verify ESIA findings and establish monitoring practices, which are intended to identify any unforeseen biodiversity impacts. However, the surveys do not focus on specific risks for biodiversity but refer simply to tracing the development of biodiversity.	A reforestation programme, to re-establish an area of forest in the Devoll catchment equal to the forest removed from the reservoir areas, designed for catchment management and benefits for local communities. No biodiversity-related actions were proposed as priority mitigation actions in the ESMP, except reforestation. There are no processes to identify and respond to emerging opportunities to make a positive contribution to biodiversity, beyond any impact caused by the project.	DHP has set 'no high impact on biodiversity in the river and the reservoir surroundings' as a key indicator of success. There is no evidence that DHP has not met this objective to date.

Project	Assessment	Management	Outcomes and Compliance
Kabeli-A 38 MW Preparation stage Nepal	Some CITES-listed terrestrial plants found, but the area of reservoir is small, so with little impact. 31 species of fish identified, but only 12 encountered in surveys: five long-distance migrants, four medium-distance migrants. One endangered fish species, one vulnerable. Migration route would be cut. Detailed special-purpose downstream-flow study undertaken to address issues of in-stream releases of water to the reduced-flow section below the intake. A Rapid Cumulative Impact Assessment (RCIA) informed the mitigation identification for aquatic biodiversity. There are two plant species identified as high-risk invasives: <i>Ageratina adenophora</i> (crofton weed) and <i>Lantana camara</i> (lantana).	Mitigation measures for key biodiversity-related issues such as the fish passage and a fish hatchery, the maintenance of a minimum release past the intake, and forest compensation and planting. EIA recognised that the knowledge of aquatic biodiversity in general, and fish diversity, is quite weak for the Kabeli River. A comprehensive monitoring programme is designed to address this. The fish passage is built into the dam/intake design, but its effectiveness is largely unproven in the context of Nepalese rivers and fish species. To deal with potentially poor effectiveness of the fish passage, the cold-water fish hatchery has been included as additional mitigation, in order to breed fingerlings of the target species for release upstream of the KAHEP. The reservoir has dedicated management interventions planned, especially for algal removal in order to avoid algal blooms.	No significant enhancements to pre-project biodiversity conditions, or contributions to addressing biodiversity issues, beyond identifying the project's own impacts.

Project	Assessment	Management	Outcomes and Compliance
Reventazón 306 MW Implementation stage Costa Rica	Faunal surveys identified the presence of mammals (25 species), birds (251), reptiles (31), amphibians (32) and fish (52); and significance was assessed with reference to the National Protected Species list of Costa Rica. A key impact identified was disruption to the biological corridors for threatened mammals.	The project contributes to the establishment and management of the Biological Sub-corridor Barbilla-Destierro, especially for ensuring connectivity between habitats suitable for panthers and other large mammals, through partnerships with the NGO 'Panthera' and the biological corridor committee, to join efforts and share experiences. The ESMP includes a plan to strengthen the biological corridors through payments for environmental services, with Costa Rica's national Forest Financing Fund; and minimum environmental flows, specifically to meet the depth and velocity preferences of the fish species bobo and tepemechin. On filling, flow downstream of the dam was below 10 per cent of normal for 45 to 60 days. A fish rescue plan maximized survival of fish in the river downstream by translocating over 10,000 fish to tributaries.	Environmental Management Plan measures have been implemented, with the exception of the creation of a fishery to restock fish in the reservoir, transport migratory fish, creation of vegetation screens, and creation of a community programme for frog breeding. Some of these measures were not feasible, and other and more effective measures, such as the Parismina and Dos Novillos offset programme, were developed and implemented to address impacts on aquatic ecology. Plans envisaged reforestation of 728.8 hectares of forest, protection of 78 hectares to promote the regeneration of natural vegetation, and planting of 34,150 trees in the area of the biological corridor Barbilla-Destierro, and around the tail of the reservoir. The programme had achieved 95, 48 and 95 per cent of those targets respectively at the time of assessment and was on track.
Trevallyn 96 MW Operation stage Australia	The Water Management review identified 244 endangered, vulnerable or rare species; however, the river is not of high conservation importance compared to other sites in Tasmania. An endemic snail and threatened migratory fish and eels occur.	Management measures put in place include an improved elver migration ladder, collection of eels and lampreys in the tailrace, and an environmental flow of 1.5 m³/sec – ostensibly to benefit the endemic snail, but with little scientific basis.	Studies had shown that flow modification carries no risk to the endemic snail, but this was not monitored, and constitutes a significant gap. Impacts on eels and lampreys are mitigated by the ladders and translocation operations. However, there is little monitoring of biodiversity and little scientific understanding of the ecology, meaning that no conclusions can be drawn concerning broader avoidance or mitigation of biodiversity impacts.



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