PAANI PROGRAM | पानी परियोजना

HIGH CONSERVATION VALUE RIVER ASSESSMENT - METHODOLOGY AND RESULTS

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Abbreviations

CBD	Convention on Biological Diversity
CSI	Connectivity Status Index
DEM	Digital elevation model
DFD	Discharge Range Factor – downstream
DFU	Discharge Range Factor – upstream
DoED	Department of Electricity Development
DOF	Degree of Fragmentation
DOM	Dominant Pressure Factor
DOR	Degree of Regulation
DOS	Department of Social Services
DRF	Discharge Range Factor
DSCWM	Department of Soil Conservation and Watershed Management
FEPA	Freshwater Ecosystem Priority Area
FFR	Free-flowing river
GDP	Gross domestic product
GIS	Geographic information system
GoN	Government of Nepal
GUF	Global Urban Footprint
HCVR	High Conservation Value Rivers
HON	Himalayan Otter Network
IBA	Important Bird Area
MODIS	Moderate Resolution Imaging Spectroradiometer
MOFE	Ministry of Forest and Environment
MOFSC	Ministry of Forests and Soil Conservation (now MoFE)
NBS	Nepal Biodiversity Strategy
NBSAP	National Biodiversity Strategy and Action Plan
NP	National Park
OSM	OpenStreetMap
RDD	Road density indicator
RoR	Run of river
RS	Remote sensing
SDG	Sustainable Development Goal
SESA	Strategic Environmental and Social Assessment
SP	Stream power
SRTM	Shuttle Radar Topography Mission
URB	Urban areas indicator
USE	Consumptive water use indicator
WECS	Water and Energy Commission Secretariat
WQ	Water Quality
WQPI	Water Quality Pressure Index
WWF	World Wildlife Fund

1 Executive summary

A *High Conservation Value River* (HCVR) as defined within the Nepali context is a **clean, highly connected** or **free flowing** river or stretch that acts as **a lifeline**, maintaining **ecosystem services** for present and future generations, providing **refuge** and **habitat** for high levels of **aquatic biodiversity**, and supporting important **socio-cultural values.** This definition was developed and refined by Nepali experts.

This is the first time that HCVRs have been identified and categorized in Nepal. The datasets and maps provide new insights into the location of high conservation value areas, both for individual indicators and for summarized levels of value. The high conservation value rivers assessment combines evaluations of the freshwater status (river and floodplain health) and freshwater values (ecosystem services) of the rivers of Nepal followed by an assessment of the representation of the diversity of all river types and regions in Nepal in the HCVR results. The evaluation of freshwater status includes two components related to river health: an assessment of river and floodplain connectivity and of water quality pressures on rivers and floodplains. Freshwater values include socio-cultural and environmental services of rivers of Nepal.

The process of determining a first map of High Conservation Value Rivers of Nepal took 18 months and was highly participatory. One of the first steps was to convene two workshops in Kathmandu and Surkhet in July 2019 with representation from the Government of Nepal, non-governmental organizations, and academic institutions. During discussions in these workshops, the participants agreed on the definition for a High Conservation Value River, freshwater values were identified, and a draft framework for the methods was developed.

A volunteer Advisory Group composed of Nepali experts across multiple disciplines played a crucial role in supporting the process with provision of data, expert knowledge and review, and guidance on methodology development. Beyond the in-person workshops, an additional set of six Advisory Group meetings and two additional workshops were held virtually during the 18-month long project to provide project updates and receive feedback and guidance to improve results. A team of local and international hydrology and geographic information system (GIS) experts conducted in-depth data collection and GIS mapping which resulted in more than 20 layers of novel data. These data layers represent freshwater values for aquatic and floodplain-related biodiversity, recreation, livelihoods, and the social-cultural uses of rivers in Nepal.

An index-based multi-criteria model was developed, and a stakeholder-driven approach was used to agree on a weighting scheme for integrating these layers into an HCV value score used to rank individual rivers and river stretches. Then, freshwater status was combined with the freshwater values assessment, and rivers were categorized into four HCVR types. Each HCV type aligns with specific recommendations for protection, management, or restoration.

The HCVR typology includes the following categories:

- HCVR Type 1: High Value + High connectivity + High Water Quality (WQ): these rivers or river reaches have one or more freshwater values, remain free-flowing and have been classified as high water quality. They are rivers of the highest conservation value and their status should be maintained.
- HCVR Type 2: High Value + High WQ: These rivers or river reaches have one or more important freshwater values and have been classified as high WQ, but river connectivity is reduced (i.e., the river is no longer classified as free-flowing). The recommended management action for these rivers is to increase connectivity, for example by removing dysfunctional or unused barriers, by implementing environmental flows (increasing

minimum flows by creating a release schedule that mimics the natural flow regime), by improving passability through bypass reaches, or by increasing the effectiveness of fish ladders.

- HCVR Type 3: High Value + High connectivity: These rivers or river reaches host one or more important freshwater values, are classified as free-flowing, but have a high level of water quality pressures. Recommended management interventions include those focused on the sources of water quality degradation including water treatment or buffers.
- HCVR 4: High Value: These rivers or river reaches show one or more important freshwater values, but they are neither classified as free-flowing, or as high-water quality rivers. While these rivers contain important freshwater values, they are at risk due to pressures from degraded water quality and loss of connectivity and would need interventions to address both.

Across Nepal, 50,500 km of rivers were evaluated in the HCV Rivers assessment. Out of these, most river reaches — 31,300 km or close to 62% — are classified as HCVR Type 1, meaning that they have at least one conservation value and are both free-flowing and of high water quality. The Karnali River Basin stands out as the basin with the highest number of HCVR type 1 rivers, followed by the Gandaki, Koshi, Mahakali, and the West Rapti basins, which all show more HCVR type 1 rivers than other types. The second largest category are HCVR type 3 rivers that make up 27.8% (14,000 km) of the total river length in Nepal. These river stretches are under high water quality pressure from both domestic and agricultural pollutants. HCVR type 2 rivers, make up 7% (3,500) of rivers of Nepal and are rivers with compromised connectivity (i.e., they cannot be classified as free-flowing), primarily due to river fragmentation impacts from dams and barriers. The fourth category, HCVR type 4 are rivers where both losses of connectivity and reduced water quality are observed, with about 3.4% (1,700km) of rivers belonging to this category. It should be noted that any HCVR river type can harbor important and extensive freshwater values, which is indicated by the increasing saturation of the colors in the map.

At the river scale, the results of this assessment highlight the following rivers (among others) in Nepal with high freshwater values: the Karnali, East Rapti, Sunkoshi, Seti and Narayani. These rivers provide high biodiversity values, recreation opportunities, livelihood values, and socio-cultural services along most of their watercourses through Nepal.

Identification of HCVRs provides critical information for planning at different levels through quantitative evaluation and spatial mapping of the values that rivers provide to society. Understanding where areas of high conservation value - i.e., those that support high levels of biodiversity, recreation, fisheries, or other socio-cultural values - occur within the country allows for more scientifically grounded decisions on river management. Natural resources managers and others involved with conservation efforts benefit from the identification of freshwater conservation priorities, which can guide decisions on where to focus their limited resources. Identification of HCVR can also guide hydropower development decisions. For instance, under concepts of sustainable hydropower, the high social and environmental values of a free-flowing Karnali River should be balanced against the benefits of hydropower development. Developing projects in other locations may have lower impacts. The results from the HCVR assessment will contribute to a set of ongoing hydropower planning processes under the leadership of the Water and Energy Commission Secretariat (WECS), the apex agency of the Government of Nepal for water and energy policies and plans. These processes include a Hydropower Master Plan, River Basin Plans and Strategic Environmental and Social Assessments (SESA) for all river basins of Nepal.

Identification and ranking of Nepal's HCVRs can also help the country in meetings its national and international commitments. Nepal's National Biodiversity Strategy and Action Plan (2014-2020) and National Strategic Framework for Sustainable Development (2015-2030) prioritized maintaining north-south biological connectivity in at least three rivers. The HCVR results can be instrumental in supporting the identification of these rivers, preparation of the National Integrated River Basin Strategy and Action Plan, developed by the Ministry of Forestry and Environment (MOFE), and associated legislation.

Finally, HCVR maps can provide insights into opportunities for mitigation of development impacts. Avoidance, minimization, restoration and offsetting are options to mitigate the potential negative impacts of hydropower on river biodiversity and other values. Our results can provide quantitative assessment of rivers to avoid and rivers to protect or restore, to compensate for impacts.

2 Background & Purpose

Nepal is blessed with remarkable rivers supporting aquatic and terrestrial biodiversity, providing ecosystem functions like groundwater recharge and flood abatement, and offering socio-economic opportunity through livelihoods, recreation, tourism, natural beauty and cultural identity. However, despite the country's historic leadership in creating protected areas from the mountains to the Terai, there are no specific policies and legislation that offer protection for the nation's rivers.

The purpose of this project was to complete a first national level map of High Conservation Rivers in order to:

- Highlight the increasing degradation of rivers in Nepal, and where restoration interventions could be directed to slow the loss of ecological, livelihood, cultural and other values
- Respond to the increasing calls to maintain portions of Nepal's river systems in a natural state and provide information on where rivers of high conservation value remain
- Provide information on the location of baseline rivers that could be monitored over time for comparison against rivers which are being developed
- Identify rivers or river stretches that are still relatively intact and that are providing critical ecosystem services to nature and people and, are thus candidates for protection
- Provide decision makers information needed on current state of rivers of Nepal in order to conserve or restore the integrity of these rivers and river stretches for current and future generations

3 Accomplishments, outputs & deliverables

During the duration of the project (Mar 2019-Dec 2020), the following were achieved:

- Six Advisory Group meetings
- Two meetings each with Department of Forest and Soil Conservation and Environment and Biodiversity Division
- One webinar organized to share findings with and solicit feed from the Ministry of Forest and Environment

- Series of meetings conducted with Strategic Environmental and Social Assessment (SESA) consultant team of Water and Energy Commission Secretariat (WECS) for data sharing and integration of findings
- Webinar to share and review draft results on 13th March 2020 with the participation of 39 participants representing government of Nepal (GoN), Nepalese academic institutions, civil society organizations, private sector and financial institutions, and development organizations
- Final technical sharing webinar organized on 10th Nov 2020 with the participation of 108 participants representing GoN, Nepalese academic institutions, civil society organizations, private sector and financial institutions, and development organizations
- An assessment compiling and synthesizing data on fish species and fisheries of Nepal
- An assessment of water quality pressures in the rivers of Nepal
- An assessment on river classification for Nepal
- A compilation of data on river values into GIS database
- An assessment and identification of the HCVRs of Nepal

4 Introduction

4.1 Overview: Freshwater Resources & Ecosystems

Freshwater ecosystems and the biodiversity that they support are highly threatened in many parts of the world. Primary threats to freshwater ecosystems include over-exploitation, flow modification, water pollution, habitat degradation, climate change, and invasive species. Additionally, freshwater is subject to severe competition among multiple human stakeholders throughout the world. Populations of freshwater species tracked by the Living Planet Index have declined by 84% on average since 1970, nearly double the rate of decline for populations of species in terrestrial and marine environments. If trends in human demands for water remain unaltered and species losses continue at current rates, we will see continued steep declines in freshwater biodiversity and species extinctions.

Rivers are essential sources of environmental health, economic wealth, and human well-being. For millennia, rivers have provided food, contributed water for domestic use and agriculture, sustained transportation corridors and, more recently, enabled power generation and industrial production. Some of these goods and services require building infrastructure, and society has addressed these demands by constructing dams, regulating flows, and creating canals for navigation and transport and building irrigation and water-diversion schemes. As a result, rivers are exposed to sustained pressure that has resulted in fragmentation and the loss of connectivity, affecting many fundamental processes and functions characteristic of healthy rivers and leading to the rapid decline of biodiversity and some ecosystem services (Grill et al., 2019).

Opperman et al. (2018) reported that nearly a quarter of gross domestic product (GDP) in Asia and a fifth of the GDP in Africa lies within watersheds with high to very high-water risk (using a measurement of water risk that incorporates a range of values supported by rivers). Environmental managers, practitioners, and stakeholders are frequently challenged to deal with a multitude of pressures, risks, and threats that put the integrity of ecosystems in jeopardy. They are faced with the need to find increasingly innovative and complex solutions that support sustainable development and foster the coexistence of ecosystems and human society.

4.2 Nepalese Freshwater Resources & Ecosystems

Nepal is a water rich country, according to the FAO (2003), ranking 64th overall in water supply capacity (m^3/inhabitant/year) with approximately 185 billion cubic meters of water generated within the country annually (WECS, 2011). Nepal is ranked 43rd globally in average total Nepal has been described as having 6,000 km of streams with 76% of their watersheds lying within national boundaries; a channel spacing of 0.3km/km^2; and an average discharge of 7,125 m^3/s (Bennett et al., 2016).

Given the abundant freshwater resources in Nepal, the commercial hydroelectric potential has been estimated at up to 45,000 MW. The potential for crop irrigation is also very high, probably approaching 90% of cultivable land. The major perennial river systems that drain the country are the Mahakali, Karnali, Narayani, and Koshi Rivers, all of which originate in the Himalayas (

Figure 1). These big river basins hold water resources with significant potential for large-scale hydropower and irrigation development. Medium-sized rivers include the Babai, West Rapti, Bagmati, Kamala, Kankai, and Mechi rivers; these generally originate in the Mid-hills or in the Mahabharat range. The Terai region has a large number of small and usually seasonal rivers, most of which originate in the Siwalik Hills (HMGN/ADB/FINNIDA, 1988).

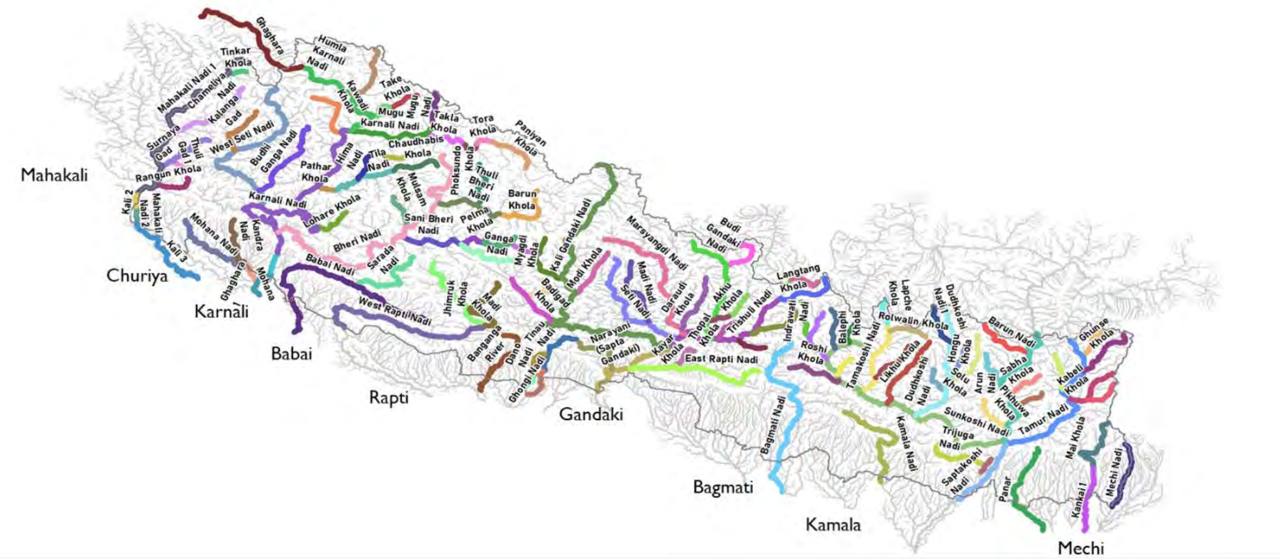

Figure 1: Overview of major rivers in Nepal.

Nepal is in the Eastern Himalayan region and is part of the Indo-Burma and Himalaya Biodiversity Hotspots, which are particularly diverse. The extreme elevational gradient of Nepal's rivers (50 m to 3000+ m) is the foundation for an especially rich diversity of fish, odonates (dragonflies and damselflies), and mollusks. Nepal has unique natural geologic structures and faulting characteristics which govern sediment production types and rates, surface water flow regimes, and groundwater storage capacities that drive many of the aquatic resource characteristics which govern freshwater biodiversity.

The working concept of a wetland in Nepal is very broad and covers all aquatic habitats. The Nepalese term for wetland is "simsar" which means land with a perennial source of water. Nepal National Wetland Policy (2003) defined a wetland as "perennial water bodies that originate from underground sources of water or rainwater. It includes swampy areas that are stagnant or flowing fresh or salt waters, which are natural or man-made or which are permanent or temporary. Wetlands also include marshy lands, riverine floodplains, lakes, ponds, water storage areas and agricultural lands". However, this description in policy does not rise to the level of a legal definition of a wetland in Nepal, and there is no legal basis for implementing the National Wetland Policy.

4.3 Threats to Freshwater Ecosystems in Nepal

Nepal is a country rich in freshwater resources with more than 11,000 rivers and streams and thousands of lakes, including nine internationally recognized important wetlands. These freshwater resources, however, are facing a number of threats, including over-fishing and illegal fishing, watershed and habitat alteration, sand and gravel mining, channeling and damming of rivers, water pollution, invasion of alien species, illegal hunting and trapping of birds and other wildlife, erosion and sedimentation, encroachment, overlap of sectoral policies of government, and climate change.

Figure 2: Dam on Babai River, Nepal. (Photo credit: WWF)

In recent years, threats to rivers have been increasing, particularly due to a substantial increase in development of hydropower dams in Nepal. While energy security is critical for the economic development of Nepal, rapid expansion of hydropower poses considerable threats to both aquatic biodiversity and livelihoods of wetland-dependent local communities and fishermen. Major impacts of dams on fishes include habitat destruction, changes in the flow regime, obstacles in fish migration, and fish injury and predation (ADB, 2018). Dam can also negatively impact floodplains, which are critical features of river systems that support diverse and productive ecosystems. Flow regulation by dams can reduce the frequency of connectivity between rivers and floodplains and the capture of sediment behind dams reduces the delivery of sediments needed to maintain and build floodplains. This can reduce habitat for fish and lead to channel incision and increased erosion of riverbanks. In addition to blocking sediments, dams block the transport of organic material, such as large wood and vegetation detritus. These materials provide nutrients, food, and shelter for aquatic life. Flow regulation and fragmentation by dams also impacts on recreational activities including rafting and kayaking. With the proposed large increase in hydropower development, the scale of these threats is expected to increase in the future.

Introduction and rapid expansion of exotic fish has also emerged as a threat to native species. Eleven alien fish and one freshwater prawn species have been introduced in Nepalese wetlands for aquaculture development (GON, 2014). Some of those exotic species are invasive, including tilapia. Sand and gravel mining also pose a serious threat to many rivers of Nepal including East Rapti, where these dredging activities are causing the river to change course, impacting environmental and recreational values. Climate change is rapidly altering freshwater ecosystems around the globe. The impacts from climate change act synergistically with other threats, accelerating the degradation of biodiversity and ecosystems. Aquatic-obligate cold-water species like Asla (one of the coldwater flagship fish species of Nepal) may be particularly vulnerable to the effects of climate change because they require cold, connected and high quality habitats, which are easily fragmented by climate-induced changes in thermal and hydrologic regimes.

Many other threats exist beyond dam development. Some of these threats include improper use of pesticides and chemical fertilizers; over-fishing and fish-poisoning (which negatively impacts piscivorous birds); and water pollution from agricultural runoff and from households and industrial discharges (particularly urban rivers such as Bagmati).

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4.4 Values of Rivers

Water is critical to all life and economic activity for humans; however, it has been consistently undervalued in comparison to the wide range of uses and benefits it provides. Traditionally in most parts of the world, rivers have been valued primarily as water sources to drive the economic engines of irrigation and hydropower. However, rivers provide a broader set of services that deliver immense benefits to people, economies, and nature: 1) two billion people rely directly on rivers for their drinking water; 2) 500 million people live on deltas that can only be sustained by sediments from rivers; 3) 25 percent of the world's food products depends on irrigation from rivers; and 4) at least 12 million tons of freshwater fishes are caught each year, providing food for subsistence and livelihoods (Opperman et al., 2018).

But far too often, these benefits are not understood, recognized, and valued and so are not a priority for river management – until clear problems emerge from their neglect.

Flood-risk reduction, freshwater fisheries, and sediment delivery to floodplains are critical services that rivers provide to people. Functioning floodplains and healthy wetlands can provide a buffer to reduce the risk of flooding for cities. The loss of floodplains and wetlands to urban development has exacerbated recent floods in cities from Bangkok to Houston (Opperman et al., 2018).

Rivers provide a critical capacity of delivering sediment and nutrients to sustain deltas and floodplain areas. These are among the world's most productive agricultural regions and home to hundreds of millions of people. In some rivers, nearly all sediment is captured within reservoirs or extracted by sand mining and many of the world's largest deltas are now sinking and shrinking due to insufficient sediment delivery – just as the seas are starting to rise (Opperman et al., 2018).

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Rivers are important from social, cultural and livelihood perspectives. Some communities including Hindus in Terai, Nepal pray to rivers as Goddesses during the Chhat festival and many communities use rivers as holy places for bathing, praying and cremation ceremonies. There are also many ethnic groups that are dependent on wetland resources for their livelihoods in Nepal and around the world.

Emerging methods and frameworks, such as the HCVR assessment described in this report, can be used by governments, the private sector, and financial institutions to improve how they recognize and manage a broader set of values that come from water and rivers. Emerging methods and frameworks, such as the HCVR assessment described in this report, can be used by governments, the private sector, and financial institutions to improve how they recognize and manage a broader set of values that come from water and rivers.

Figure 3. A woman fishing in a river near Simjung, Nepal. (Photo credit: Karine Aigner/WWF-US)

4.5 Definitions and Applications: FFR and Wild Rivers

High conservation value rivers support ecosystems and their services that benefit communities, including fisheries, tourism and recreation, spiritual or cultural value, and clean water supply. There are many terms similar to HCVR, including Community Valued Rivers, Free-flowing rivers (FFRs), and Wild Rivers. The term HCVR draws on and integrates components from these other terms.

Here we define a free-flowing river (FFR) as a river where natural aquatic ecosystem functions and services are largely unaffected by anthropogenic changes to fluvial connectivity allowing an unobstructed exchange of material, species, and energy within the river system and beyond. (Grill et al. 2019).

Wild rivers are rivers with no or minimal human disturbance and may include additional characteristic that distinguished them from FFR, such as remoteness, or water quality (Modified from Karr, 1999 cited by Thieme, 2019; Figure 4). For example, a project in India defined a "wild river" as "one that, despite human influences, continues to retain its character and capacity to maintain **natural river processes**, in all their seasonal variations; **sustains aquatic and riparian species diversity**; and **provides ecosystem functions and services for present and future generations of all life forms**." In 1993, the Australian Heritage Commission, Wild Rivers were defined as those rivers for which "the biological, hydrological and geomorphological processes associated with river flow have not been significantly altered by modern or colonial society."

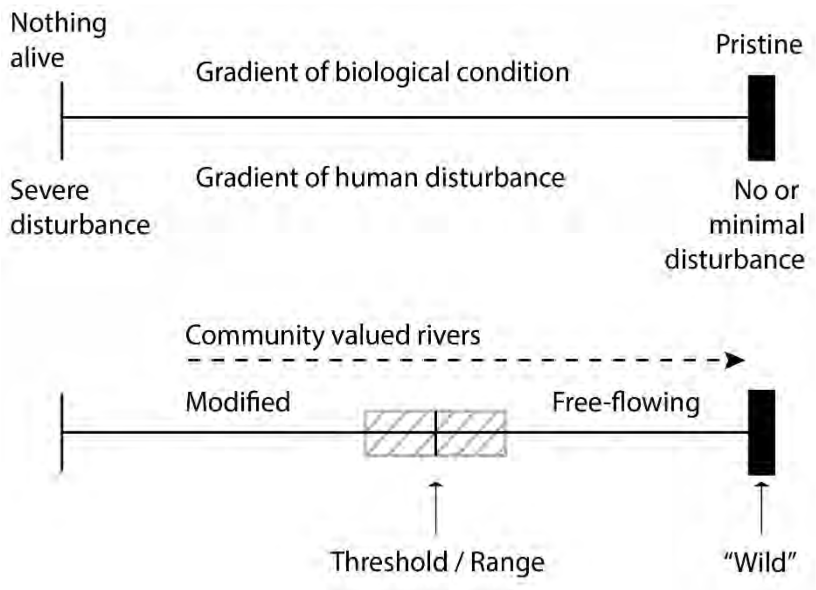


Figure 4: Conceptual graph showing a continuum of anthropogenic disturbance between "nothing alive" to "Pristine" (top panel). The lower panel proposes a conceptual framework to locate modified, free-flowing, and wild rivers on a continuum of human disturbance. A threshold or range is used to determine FFR from modified rivers. Wild rivers are rivers with no or minimal human disturbance and may include additional characteristic that distinguishes them from FFR, such as remoteness, or water quality (lower panel). Modified from Karr (1999).

Another example is from the USA where rivers can be designated as wild, scenic, or recreational according to the US Wild and Scenic Rivers Act, 1968. The Act offers these definitions:

> ***Wild River Areas*** are those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America. ***Scenic River Areas*** are those rivers or sections of rivers that are free of impoundments, with shorelines or watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads. ***Recreational River Areas*** are those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past.

Wild Rivers are the most remote, while recreational rivers have many access points, roads, railroads, and bridges.

Community valued river are rivers that offer value even in a modified freshwater state. For example, rivers that have lost full river connectivity due to dams or are partially polluted may still offer important biodiversity, recreational, or other types of values. For additional examples and further information see Moir et al. (2016).

4.6 Concept of Free-Flowing Rivers (River Connectivity)

River connectivity is a common element in the definitions described in the previous section and is crucial to the framework of HCV described in this report. In this section we provide additional review of the concepts of river connectivity and free-flowing rivers. Healthy and free-flowing rivers (FFRs) support diverse, complex, and dynamic ecosystems globally, providing important societal and economic services. The capacity of rivers to flow freely is governed by the connectivity of pathways that enable the movement and exchange of water and of the organisms, sediments, organic matter, nutrients, and energy that it conveys throughout the riverine environment.

While the generic term “free-flowing river” has generally emphasized longitudinal connectivity, Grill et al. (2019) expanded on this view and proposed a more comprehensive definition based on the four dimensions of connectivity, explicitly recognizing that connectivity is necessary within all of those dimensions for a river to flow freely.

These four dimensions include:

(1) longitudinally (up- and downstream in the river channel)
(2) laterally (between the main channel, the floodplain, and riparian areas)
(3) vertically (between the groundwater, the river, and the atmosphere)
(4) temporally (seasonality of flows). River connectivity is also spatially and temporally dynamic, largely driven by the natural flow regime.

Based on these four dimensions of connectivity, free-flowing rivers (FFRs) are defined as those where ecosystem functions and services are largely unaffected by changes to the fluvial connectivity, allowing unobstructed movement and exchange of water, energy, material, and species within the river system and with surrounding landscapes. Fluvial connectivity can be compromised by (i) physical infrastructure in the river channel, along riparian zones or in adjacent floodplains; (ii) hydrological alterations of river flow due to water abstractions or regulation; and (iii) changes to water quality that lead to ecological barrier effects caused by pollution or alterations in water temperature.

Large-scale environmental changes, including climate and land-use change, will further increase the pressure on rivers through disruption of flow patterns, increased frequency and intensity of floods and droughts, and changes to water quality and biological communities. FFRs may increase the resilience of aquatic and riparian ecosystems under these added stresses because they allow for species to move to suitable habitats in other parts of the basin in response to changing conditions. To maintain this resilience, infrastructure planning and decision making should maintain connected networks of rivers and include scenarios of future environmental change in development plans.

5 Background and overview

The definition of High Conservation Value Rivers of Nepal was developed through highly participatory process. The core HCV team convened two workshops in Kathmandu and Surkhet with representation from the Government of Nepal, non-governmental organizations, and academic institutions. During discussions in these workshops, the participants agreed on the following definition for a HCVR:

> "a clean, highly connected or free-flowing river or stretch that acts as a lifeline, maintaining ecosystem services for present and future generations, providing refuge and habitat for high levels of aquatic biodiversity, and supporting important socio-economic and cultural values."

A preliminary list of values to be evaluated and mapped at the national scale was also identified during the workshop discussions. To allow sustained dialogue, an Advisory Group was formed during these initial in-person workshops. Members of the Advisory Group (see list and affiliations at beginning of this report) volunteered their time during the 18-month process to help guide and provide their expert input to the mapping and identification of the HCVRs of Nepal. One of the first tasks completed with the Advisory Group was further review and refinement of the values to be assessed and mapped. Over the following months, the core team started collecting available data and hired consultants to fill data gaps and provide up-to-date data compilations. The methodology to integrate the freshwater values with the freshwater status was co-developed with the Advisory Group over the course of 18 months. A total of six Advisory Group meetings were conducted remotely and multiple informal expert meetings were conducted on specific topics for which a sub-set of experts were need, e.g., to discuss the water quality pressures assessment, the river types classification, and the fish data compilation. Due to Covid-19, the second and third workshops were held virtually in March 2020 and November 2020 to present draft and final results, respectively. Details of the meetings and photos are presented in Annex 10.1.

5.1 Project components

The High Conservation Value Rivers assessment combines evaluations of the *freshwater status* and *freshwater values* of the rivers of Nepal followed by an assessment of ecosystem representation to ensure that all river types are represented in the HCVR results (see Figure 5 for an illustration of these components). The evaluation of *freshwater status* assessed two components related to river health: (1) river and floodplain connectivity; (2) water quality pressures on rivers and floodplains. The *freshwater values* included biodiversity and socio-cultural and ecosystem services of rivers. The assessment also sought to achieve representation of important riverine and aquatic ecosystems across the diverse river types and regions of Nepal.

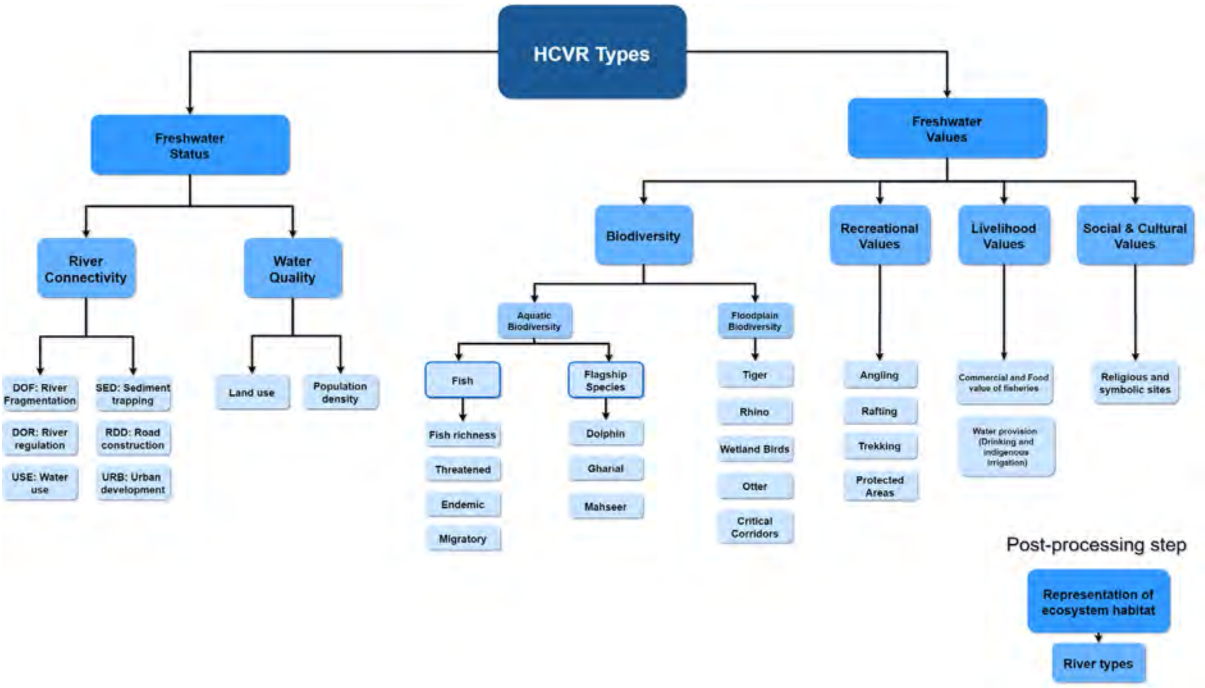


Figure 5: Tree-diagram identifying the freshwater status and value components. Representation of ecosystem habitat, using river types was an important post-processing step to ensure representation of diverse river types across Nepal.

5.1.1 Freshwater status

Freshwater status represents river health in our assessment. To maintain the health of aquatic habitats, it is necessary to maintain both the connectivity and water quality of the rivers of Nepal (Figure 6). Lower water quality is unable to sustain important social-cultural and environmental services including wildlife habitat, livelihood, and recreation services. On the other hand, with decreasing connectivity, rivers are susceptible to losses of ecosystem services like recreational and tourism associated with connected, healthy rivers and losses of biodiversity, introduction of exotic/weed species, and loss of habitat for freshwater and terrestrial wildlife. See section 4.4 for general description of the values provided by healthy, connected rivers.

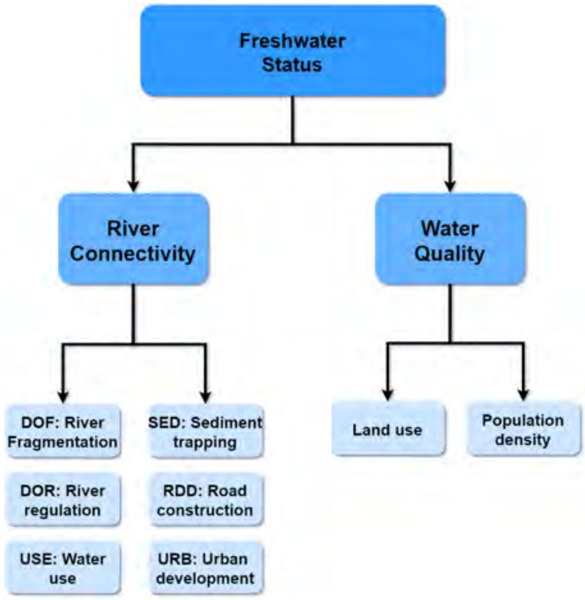


Figure 6: Tree-diagram identifying freshwater status.

5.1.2 Freshwater value mapping

Freshwater values include important socio-cultural and environment services of rivers identified by stakeholder consultations. Freshwater values were identified by Nepalese stakeholders which reflect freshwater ecosystem services in Nepal that are reliant on healthy, connected rivers and floodplains for their delivery (Figure 8).

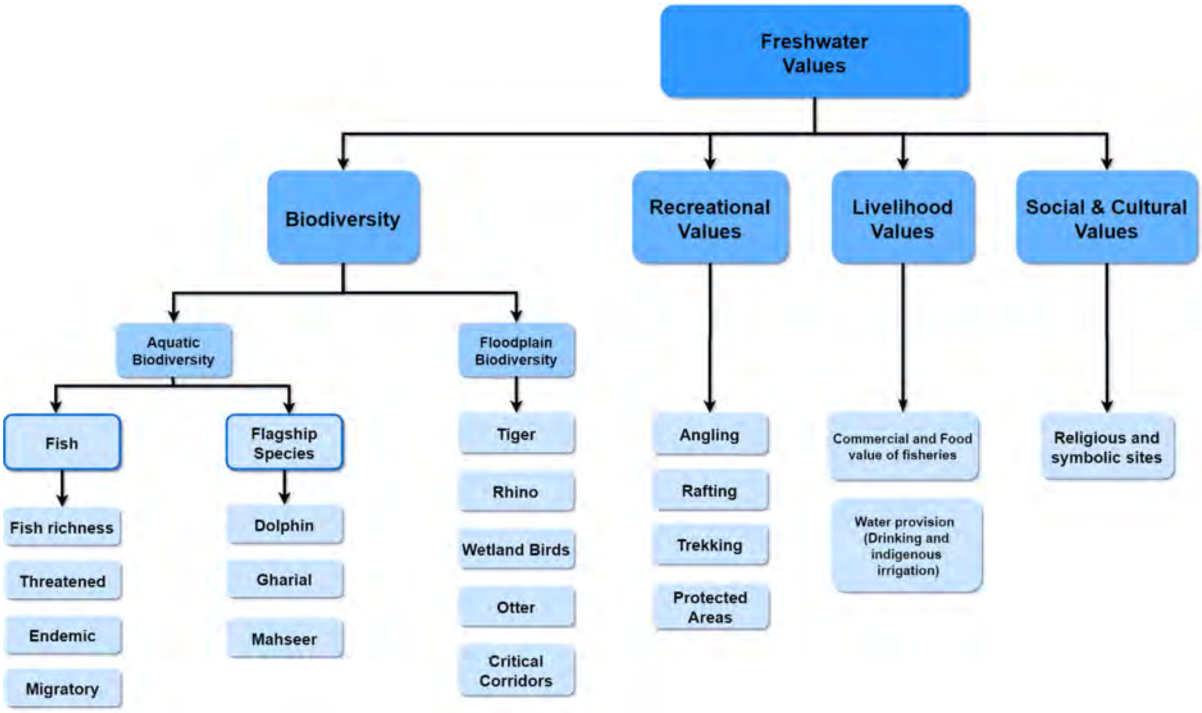


Figure 7: Tree-diagram identifying freshwater values.

5.1.3 High-Conservation Value rivers

Identification of HCVRs is of utmost importance in integrated basin planning at multiple scales. HCVRs provide a quantitative evaluation and spatial mapping of some of the important "hidden values" that rivers provide to society, allowing these to be better included in decisions related to a basin's sustainable utilization and development. Understanding where areas of high conservation value - i.e., those that support biodiversity, recreational, fisheries, or other socio-cultural values - occur within the basin allows for more scientifically grounded negotiations regarding trade-offs with development. Natural resources and protected area managers and others involved with conservation and restoration efforts also benefit from the identification of freshwater conservation priorities, which help guide decisions on where to focus their work and limited resources.

5.1.4 Ecosystem representation analysis

In order to ensure that the results of the HCVR assessment were not biased to a subset of ecosystem types or completely left out certain types, it was necessary to first complete a national-level assessment of Nepalese river ecosystem types, building on prior studies. A post-processing assessment of the HCVR results was then completed to assess whether all river types were captured in the results.

6 Methodology

6.1 Data sources and materials

We used the HydroSHEDS database (Lehner et al., 2008; Lehner and Grill, 2013) to provide a consistent global river network at 15 arc-second spatial resolution (approximately 500 m pixel resolution at the equator) for mapping of freshwater status and values alike.

HydroSHEDS is a hydrographic mapping product created by World Wildlife Fund that provides river and watershed information for regional and global-scale applications in a consistent format. It offers a suite of geo-referenced datasets at various resolutions ranging from 3 arc-second (approximately 90mat the equator) to 30 arc-second, including river networks, watershed boundaries, and drainage directions. HydroSHEDS is based on high-resolution elevation data obtained during NASA's Shuttle Radar Topography Mission (SRTM) in February 2000. The extent of HydroSHEDS is near-global, currently only excluding regions above 60northern latitude due to the lack of SRTM source data; the global extent is scheduled to be completed by inserting alternative elevation data within 2013. The data is available to the scientific community at http://www.hydrosheds.org.

Besides its core layers, HydroSHEDS includes a suite of attribute layers and to establish linkages to auxiliary datasets. Consistency between the layers is ensured in terms of spatial alignment, and quality indicators are provided where possible.

HydroSHEDS includes an estimate of long-term average "naturalized" discharge, derived by downscaling coarse resolution (0.5°) discharge estimates of the global hydrological WaterGAP model (v2.2 as of 2014; Döll et al., 2003). This data layers plays a fundamental role in the free-flowing river assessment, and provides the foundation for the calculation of fragmentation, sediment capture and flow regulation indicators.

The river network used to map HCV values was derived from HydroSHEDS. We defined the study extent to extent the administrative boundaries of Nepal because hydrological applications should be conducted on hydrological, rather than administrative units to be able to account for river connectivity effects.

The river network extracted for this study consists of 24,284 river reaches, with a total length of 70,786 km, which includes areas outside of Nepal We define a river reach as a stretch of river between consecutive tributaries—with a minimum average discharge of 100 l/second (0.1 m^3/second). Smaller rivers have been excluded from the analysis, primarily due to increasing uncertainties in the underpinning global hydrographic and streamflow data.

The river reaches of the river network are relatively small, evenly sized partitions of the full rivers. They have an average length of 2.7km and start and end at the point where new confluences merge with the river reach. In order to calculate statistics at the river level (e.g., for the Karnali river etc.), we grouped the river reaches together. In Nepal, we identified 9,519 rivers with a total length of 50,531 km length. Most of these rivers, 89% in fact, are shorter than 10 km. About 10% of rivers are between 10 and 50km long. The remaining 87 rivers are between 50 and 504 km long, with Karnali river as the longest river identified in Nepal.

6.2 Assessing the Freshwater status of Nepalese Rivers

6.2.1 Free-flowing river assessment

Healthy and free-flowing rivers (FFRs) support diverse, complex, and dynamic ecosystems globally, providing important societal and economic services. The capacity of rivers to flow freely is governed by the connectivity of pathways that enable the movement and exchange of water and of the organisms, sediments, organic matter, nutrients, and energy that it conveys throughout the riverine environment (Grill et al. 2019).

According to the authors, river connectivity or fluvial connectivity extends in four dimensions: longitudinally (up- and downstream in the river channel), laterally (between the main channel, the floodplain, and riparian areas), vertically (between the groundwater, the river, and the atmosphere) and temporally (seasonality of flows). River connectivity is also spatially and temporally dynamic, largely driven by the natural flow regime, enabling and regulating hydrological, geomorphic, and ecological processes in river networks and providing the aquatic medium for matter and species to move along the river and into adjacent habitats.

Humans have altered natural river connectivity in multiple ways, either directly, by placing structure into the longitudinal or lateral flow paths, such as dams and levees, or indirectly, by altering the hydrological, thermal, and sediment regimes of the river.

Expanding on the traditional view, which focused mostly on longitudinal connectivity, Grill et al. (2019) proposed a more comprehensive definition based on the four dimensions of connectivity, explicitly recognizing that connectivity is necessary within all of those dimensions for a river to flow freely. We also adopted this definition for the FFR assessment in Nepal:

"FFRs are rivers where ecosystem functions and services are largely unaffected by changes to the fluvial connectivity, allowing unobstructed movement and exchange of water, energy, material, and species within the river system and with surrounding landscapes. Fluvial connectivity encompasses longitudinal, lateral, vertical and temporal components and can be compromised by (i) physical infrastructure in the river channel, along riparian zones or in adjacent floodplains; (ii) hydrological alterations of river flow due to water abstractions or regulation; and (iii) changes to water quality that lead to ecological barrier effects caused by pollution or alterations in water temperature."

To map free-flowing rivers using this definition, we followed the methodology in Grill et al. (2019) with local adaptations of the methodology for the Nepalese context, which are described below. We first calculated the Connectivity Status Index (CSI) of each river reach in Nepal (6.2.1.1). The CSI index is next used to further classify river stretches as free-flowing or impacted, which was one of the fundamental freshwater status components in the HCVR assessment (6.2.1.2).

6.2.1.1 Connectivity Status Index (CSI)

The first step was to determine the connectivity status of rivers using the Connectivity Status Index (CSI). The Connectivity Status Index is a novel metric that was developed by Grill et al. (2019) in their study to map the global extent of 'free-flowing rivers'. The CSI quantifies the degree to which an individual river reach (i.e., the short river segment between two tributaries) remains connected to its neighboring reaches within the larger river network. River connectivity is defined to extend in four dimensions: longitudinal (connectivity between up- and downstream river reaches), latitudinal (connectivity to floodplains and riparian areas), vertical (connectivity to groundwater and atmosphere), and temporal (connectivity based on seasonality of flows). The CSI considers five 'pressure factors' that represent the main human interferences within the four dimensions of river connectivity:

a) river fragmentation (longitudinal)
b) flow regulation (lateral and temporal)
c) sediment trapping (longitudinal, lateral, and vertical)
d) water consumption (lateral, vertical, and temporal)
e) infrastructure development in riparian areas and floodplains (lateral and longitudinal).

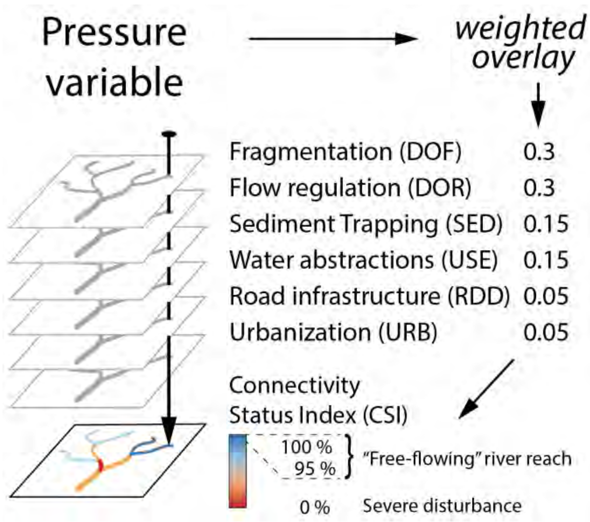


Figure 8: Concept diagram of Connectivity Status Index (CSI).

These five pressure factors are represented by six proxies (as infrastructure development is represented by two proxies), i.e., 'pressure indicators', which are informed by available global data and numerical model outputs (see Table 1 for an overview of pressure factors). Using this conceptual approach, CSI values are calculated for every river reach by producing a weighted average of the six individual pressure indicators (Figure 9).

CSI values range from 0% to 100%. A CSI value of 100% indicates that a reach is fully connected, i.e., its natural connectivity status is not affected by any anthropogenic modifications, while values deviating from 100% indicate that the reach is increasingly impacted. In the study by Grill et al. (2019), values between 100% and 95% were defined to indicate a 'good' connectivity status, while values below 95% indicate river reaches that are affected by severe disturbances and are thus not 'free-flowing'. As a unique feature, the CSI takes waterfalls into account, i.e., the baseline for all calculations is the naturally connected river network after considering natural fragmentation at the location of waterfalls.

Table 1: Overview of pressure factors used to calculate CSI index within the free-flowing river assessment.

Pressure factor	Pressure indicator	Description	Connectivity aspect affected	Source data
River fragmentation	DOF	Degree of Fragmentation	Longitudinal	HydroSHEDS; Lehner et al. (2008); GRanD v1.1; Lehner et al. (2011); GOOD2 v1, Mulligan et al. (2020); DoED list of existing dams; OpenStreetMap (OpenStreetMap contributors, 2020)
Flow regulation	DOR	Degree of Regulation	Lateral, temporal	HydroSHEDS; Lehner et al. (2008); GRanD v1.1; Lehner et al. (2011); GOOD2 v1; Mulligan et al. (2020); HydroLAKES, v1.0; Messager et al. (2016)
Sediment trapping	SED	Sediment trapping index	Longitudinal, lateral, vertical	Erosion map; Borrelli et al. (2017); HydroSHEDS; Lehner et al. (2008); GRanD v1.1; Lehner et al. (2011); GOOD2 v1; Mulligan et al. (2020); HydroLAKES, v1.0; Messager et al. (2016)

Water consumption	USE	Consumptive water use (abstracted from rivers)	Longitudinal, Lateral, vertical, temporal	WaterGAP Döll et al. (2003) (v2.2 as of 2014); HydroSHEDS; Lehner et al. (2008)
Infrastructure development in riparian and floodplain areas	RDD	Road density	Lateral, longitudinal	OpenStreetMap road network (OpenStreetMap contributors, 2020); reclassified
	URB	Nightlight intensity in urban areas	Lateral	GUF; Esch et al. (2012)

6.2.1.2 Free-flowing river status

CSI values have been used by Grill et al. (2019) to map 'free-flowing rivers' (FFRs), i.e. contiguous river courses that remain above a CSI value of 95% along their entire path from source to sink. A free-flowing river is classified as having a CSI of 95% or greater over its entire length (see Figure 10) for the difference between river and river reach). For a discussion on using the 95% threshold please see the original research article by Grill et al. (2019). If a river was above the CSI threshold of 95% over its entire length from source to sink (mainstream, or 'backbone' river) the team classified it as 'free-flowing.' However, if only part of a river was above the CSI threshold, the entire river was no longer considered free-flowing, and the river section above the threshold was classified as having a 'good connectivity status', whereas the river sections below the threshold were classified as 'impacted.'

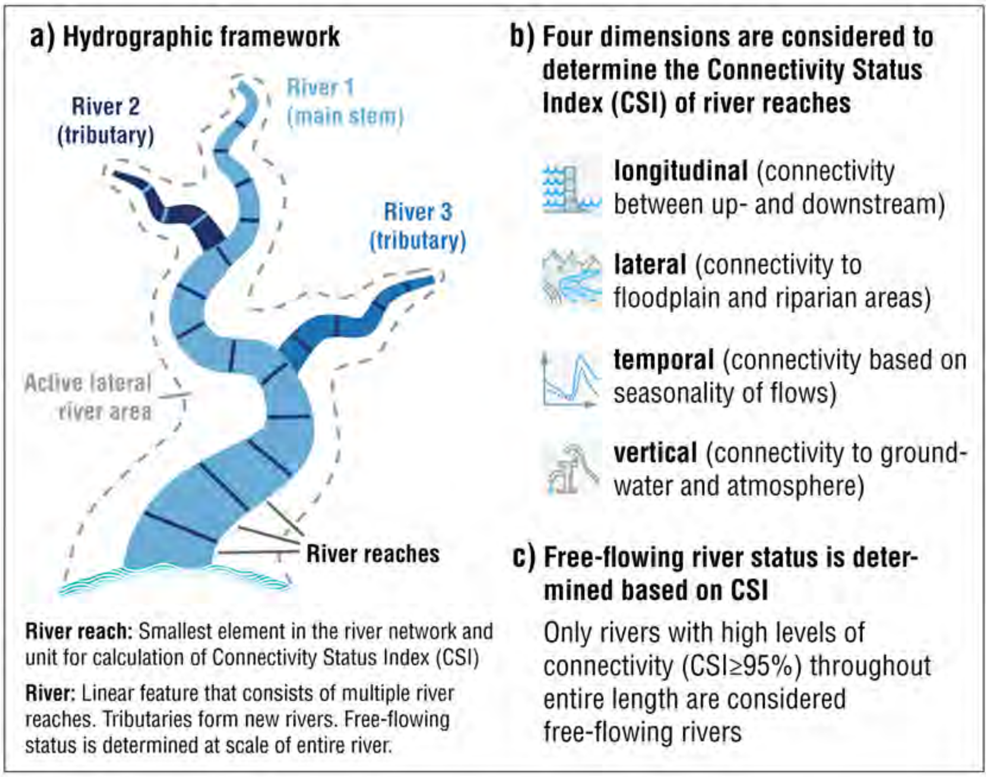


Figure 9: Relationship between river reaches and rivers in the context of the FFR assessment.

6.2.1.3 Modification of FFR methodology to local situation in Nepal

Although the methodology in Grill et al. (2019) was generally followed, we improved the global results for application in Nepal by a) replacing global datasets with local datasets (if available); adjusting the backbone river grouping to the local situation, including the naming of rivers, and c) adjusted some of the parameters used to calculate pressure indices, in particular the parameters used to derive the 'Degree of Fragmentation index (DOF)', among other adjustments described below.

6.2.1.3.1 Dams and barriers

A local dam dataset was used including operating dams collected from various sources. Data were compiled from multiple sources including DoED (for hydropower projects), Open Street Maps (OpenStreetMap contributors, 2020), and the GRanD global database of dams (Lehner et al., 2011) for other types of projects (irrigation, etc.).

The data from DoED did not include precise coordinates for projects, but rather places provides an area in which the dam is located. In order to guarantee that the point location given corresponds to the correct river reach and river location, we confirmed their location by satellite imagery if clear satellite imagery was available for dam location.

Some barrages outside Nepal were also included in the assessment because they may affect rivers inside Nepal through upstream fragmentation effects. Irrigation projects were included if they include a structure across the entire river. If no such structure exists, fragmentation is not affecting the river, for example in the case of the Rani Jamara Kulariya Irrigation project. The project was then not considered in the assessment.

6.2.1.3.2 Degree of Fragmentation adjustments

The Degree of Fragmentation (DOF) estimates the loss of longitudinal connectivity within the river network. The DOF is typically highest at the location of a barrier (dam, diversion) and then diminishes in the upstream and downstream direction until the fragmentation effect drops to zero and longitudinal connectivity is restored. The rate at which the DOF effect diminishes was set by global freshwater experts and is targeted for a global situation.

However, Nepal's rivers are primarily located in steep mountainous terrain, stretch from very low to very high altitudes, and are relatively small (compared to rivers such as the Amazon River). Furthermore, barriers such as barrages in the lowlands, cause less fragmentation than others, because they block the river only during certain times of the year.

Based on discussion with Indian and Nepali experts, we adjusted the parameters that govern the strength of the DOF effect for individual dams and barriers based on their attributes. The parameters "discharge range factor" (DRF) governs to strength and distance at which the DOF effect occur upstream or downstream of a barrier. The DRF can be individually adjusted in the upstream (DFU) and downstream direction (DFD).

The group of experts generally agreed that the fragmentation effects in the upstream direction should be set lower than in the downstream direction.

Based on the *migratory behavior* of fish in the study area, we distinguished between a *masheer* zone and a *trout* zone. Barriers in the trout zone are considered to incur less fragmentation than barriers in the *masheer* zone. The following matrix to assign DRF values to each dam individually was developed. In the *trout* zone (Elevation > 1000 meter masl), the DOF effect was reduced to 1.5 times in the upstream direction, and to 3 times in the downstream direction. In the *masheer* zone (Elevation <1000 meter masl), the DOF effect was reduced to 3 times in the upstream direction, and to 7 times in the downstream direction.

Table 2: Local adjustments of the discharge range factor (DRF) in the upstream and downstream direction for different barrier types. More information on the DRF is provided in the methodological section in Grill et al. (2019).

Barrier Type	Upstream *drf*	Downstream *drf*
Barrage	1.07	1.5
Dams > 1000 msl	1.5	3
Dams < 100 msl	3	7

Based on the *permeability of barriers*, the group suggested that barrages are distinct from other barrier types. Based on discussions with experts on the effect of the Kailashpuri Dam / Girija barrage in India on dolphin and masheer populations in Nepal, we were able to establish that barrages cause a far lower effect on flagship species than other barriers due to their full permeability during the rainy season allowing for species exchange and the maintenance of viable populations. As such, the DOF effect was reduced to 1.07 times in the upstream direction and to 1.5 times in the downstream direction. A summary of the adjustments is shown in Table 2.

6.2.1.3.3 Degree of Regulation

Dams may cause flow alteration in the downstream direction, if water is stored and then released at times of increased power demand. The storage and release cycle are short for so-called peaking run-of river dams, which follow a daily schedule and typically store about one day of water. This type of release cycle does not change the monthly flows, however, may drastically change the daily flow. This hydropeaking, and the associated frequent flow changes, can significantly disrupt downstream river ecology (Boavida, 2015).

Another type of hydropower dam, storage dams, capture larger amounts of water during the rainy season and release the water during the drier months, when irrigation demand is high. The consequences for downstream ecology can be severe, as the storage-release cycle affects the monthly and annual flow regime. The severity of the impacts depends on the operation scheme of the project and can be particularly high if no minimum flow rules or ecological flows are implemented.

The so-called 'run-of-river' projects (RoR) are often deemed less impactful as they are thought to have no active storage. However often, RoR projects cause flow regulation by dewatering an extensive downstream section, often leaving too little flow remaining in the main channel.

To estimate the downstream flow changes from dams appropriately, a hydrological model linked to a reservoir operation model would be most adequate. In light of the lack of information of operation rules of existing dams we use an indicator called the 'Degree of Regulation' (DOR) that estimated downstream flow impact using a relationship between the storage volume of the project, and the river discharge (Lehner et al., 2011). However, information on storage volume is only available for the largest projects. In order to fill these data gaps, we used a power regression between installed capacity and storage volume that was based on information provided by Tractebel (Figure 11). The purpose of estimating the storage volume was primarily to fill data gaps for planned projects, however some missing data points could be estimated with this method for existing dams as well. The relationship used for the regression —installed capacity and storage volume — is based on the assumptions that larger dams tend to have larger storage reservoirs. However, there are exceptions to these observations, particularly for RoR dams, which often cause flow changes due to "dewatering" of river reaches. Nevertheless, the estimated storage volumes are within an acceptable range of the observed storage volumes and therefore serve to provide a first-order estimate of the storage volume in the context of this project.

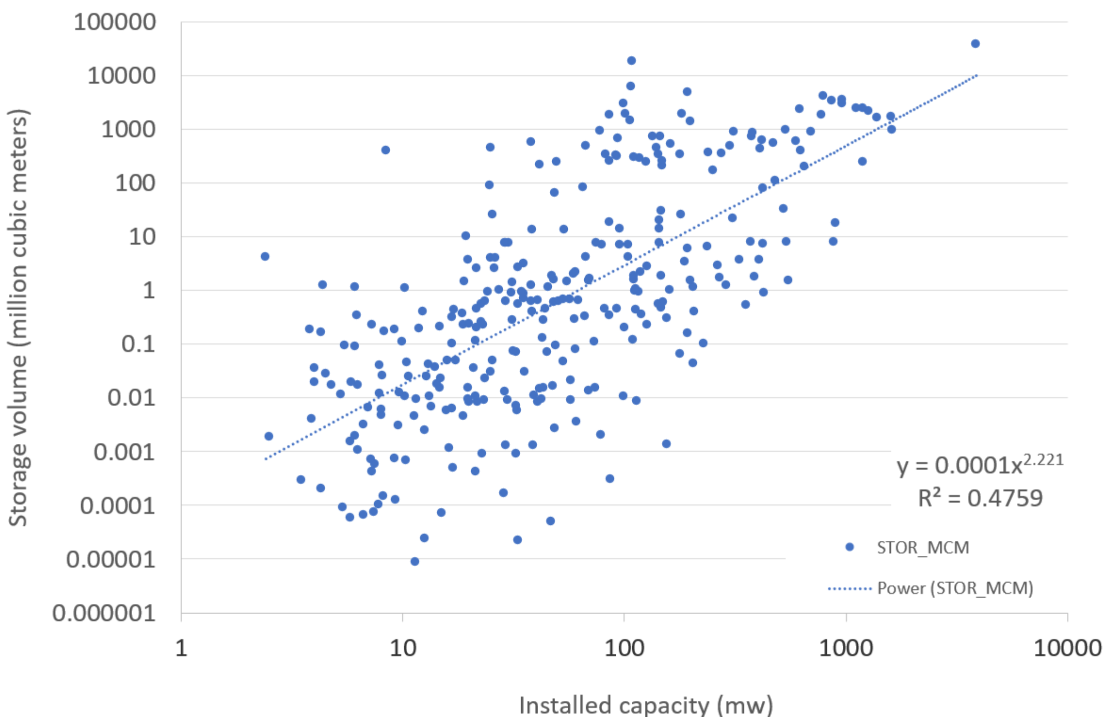


Figure 10: Estimation of storage volume using a power relationship based on data from Tractebel (2020).

6.2.1.3.4 Road density

Table 3: Estimated road width for road types in Nepal.

Highway	40 m
Primary roads	30 m
Secondary roads	20 m
Tertiary roads	10 m
Local roads	5 m

Roads may cause fragmentation of smaller river channels, lead to the introduction of culverts and the associated fragmentation effects, and may cause erosion. Such effects are captured by the 'Road density' indicator (RDD). The road network used in the global database was deemed to be insufficient in Nepal. First, the road network did not seem to be updated to include the latest roads and excluded smaller rural, and local roads. The road network provided by OpenStreetMap (OSM, 2020) was deemed better suited for our analysis. We first reduced the number of road categories from 26 to 5 broader types: 'Highways', 'Primary', 'Secondary', 'Tertiary' and 'Local' (Figure 12).

In addition, the global analysis used a constant road width of 50m to calculate the road density, which is inadequate for mountainous regions. Instead of a constant, we assigned variable widths based on the road type identified. We then estimated the width of roads for each category by spot checking with satellite imagery (Table 3). The estimated road width was used to calculate the total coverage of roads within a river reach catchment, which resulted in the RDD.

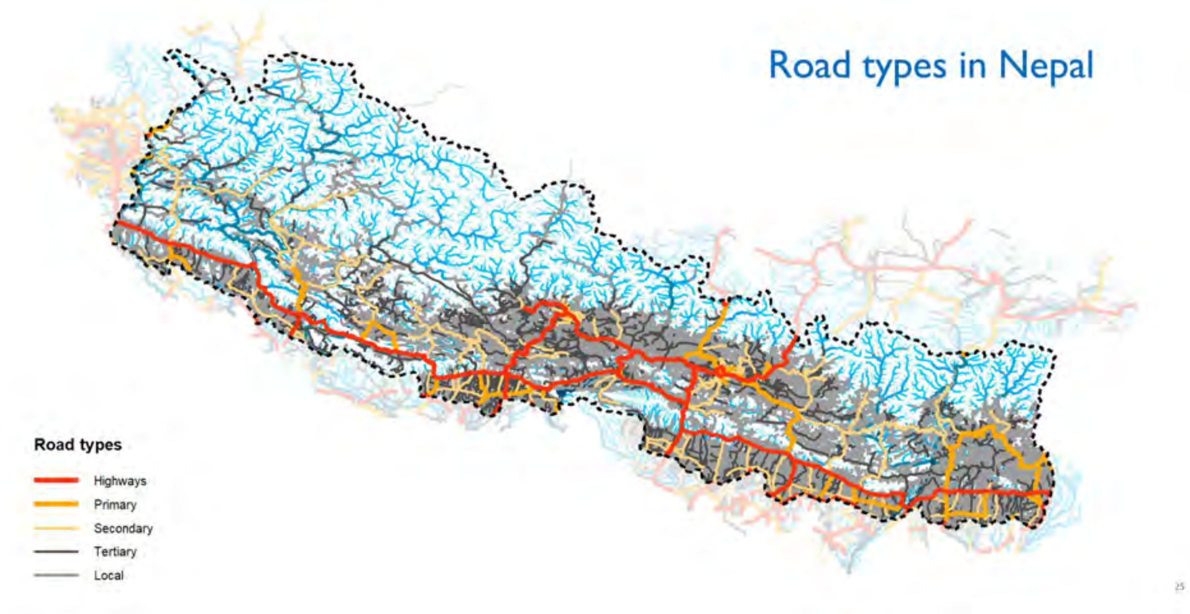


Figure 11: Road types in Nepal, based on OpenStreetMap (OSM, 2020). Reclassified into five principal types.

6.2.1.3.5 Urban Areas

Urban areas are used as a proxy to estimate the occurrence and impact of infrastructure on rivers and floodplains. The global dataset used was based on a satellite assessment with 500m resolution (MODIS; Schneider et al., 2009), which is relatively coarse. To improve on this data, we used the land cover classification of Nepal (ICIMOD, 2010a), which improved upon the global layer, however upon examination, we also noticed misclassifications. We therefore merged the land use map with the Global Urban Footprint dataset (Esch et al., 2012), which mapped urban areas specifically at 10m resolution worldwide.

Unlike in the global assessment, the nightlight map was not used in this assessment because of the focus on a smaller geographic scale where the comparison between "bright" and "dark" societies is not relevant.

6.2.1.3.6 Benchmark rivers

Benchmark rivers are rivers used in the free-flowing river assessment to help validate the results of the FFR model. Benchmark rivers were nominated by local experts with detailed knowledge of Nepal's rivers. Given the definition of FFRs, and considering the pressure factors used to calculate FFRs, experts nominated rivers or river stretches as free-flowing. The FFR assessment model automatically determines if its classification results agree with the expert's classification. If the FFR status calculated by the model is not in agreement with the expert's judgment, this may point to errors in the database (e.g., a dam was snapped to the wrong river reach) or may point to an over-weighting of pressure factor.

Based on results from workshop in Kathmandu and Surkhet in July of 2019, the group of experts nominated the Humla Karnali, Budhi Gandaki, Seti, and Tamor as benchmark rivers (Figure 13). The nomination of benchmark rivers was a useful element in validating the settings of the FFR assessment model, and the model results agreed with the status of the benchmark rivers.

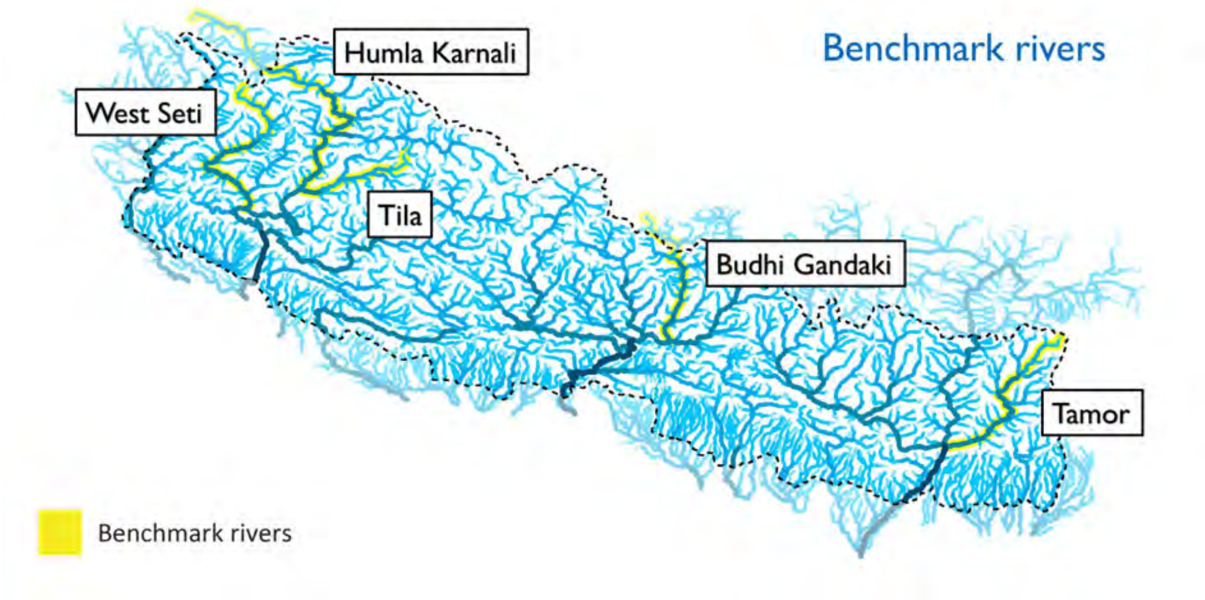


Figure 12: Benchmark rivers selected by advisory group for FFR assessment validation.

6.2.1.3.7 Adjustment of river names

In addition to river reaches, we also analyze entire rivers. The results of the HCV analysis are first calculated at the river reach scale and then aggregated to the river scale, which enables us to rank rivers using the sum of the HCV values.

The original river identification system provided by HydroSHEDS was calculated by an algorithm for all global rivers, which classified rivers and their tributaries strictly by length. The project team made manual adjustments for local conditions in Nepal. For example, the global river identification system does not distinguish between the Karnali and the Humla Karnali as it classifies the river as the mainstem Karnali. In order to account for these occasions, river sections were renamed based on local knowledge and using the naming on the topographic base data of Nepal (Hydrography) by DOS (1996).

Figure 13 shows the result of the adapting and renaming. Distinct colors are used to separate rivers from each other visually. The resulting river "units" shown in this map were used to calculate HCV statistics as shown in Table 14.

Figure 13: Overview of main rivers of Nepal.

6.2.2 Water quality pressures assessment

Water quality in rivers impacts both aquatic ecosystems and people. Poor water quality can have negative health impacts and reduces ecosystem services, such as fisheries. Deterioration of water quality is often driven by human impacts, e.g., by land use change, fertilizer application or insufficient treatment of domestic wastewater.

Except for a few rivers such as the iconic, but substantially polluted Baghmati river (e.g., Shrestha et al., 2008), little is known about the water quality of rivers in Nepal. The number of available measurements are spatially and temporally sparse, and few water quality attributes have been collected, leaving the water quality of many rivers of Nepal unknown, and making it challenging to collect a comprehensive set of water quality measures for modelling or data validation.

Figure 14: Bagmati River in running through Kathmandu. (Photo credit: Global Warming Images/ WWF)

Due to the limitations of available water quality measurements, it is currently unfeasible to derive a complete picture of water quality in Nepal's rivers. To extrapolate water quality pressures in rivers for which water quality measurements do not exist, we modelled water quality pressures in Nepal's rivers using available water quality measurements and global datasets as proxies for water quality. The goal of this assessment was not to create a stand-alone water quality index, provide accurate predictions of individual water quality indicators, nor to create a water quality index that will be used to guide policy interventions directly. The basic principle was to use existing data to generate water quality proxy indicators, and then combine the indicators into a final water quality pressures index (WQPI), i.e., the water quality pressures in Nepal's rivers.

6.2.2.1 Stakeholder Meetings

Stakeholder meetings were essential for estimating the best possible results of water quality pressures in Nepal. Feedback was received first during High Conservation Value Rivers Advisory Group meetings and then, a specialized stakeholder meeting with water quality experts was held in September 2020. During the September 2020 meeting, two different methods and results were presented: (1) modeling water quality using machine learning methods with nitrate, phosphate, biological oxygen demand and dissolved oxygen measurements; and (2) modeling water quality using spatial accumulation methods with global data for urban areas, phosphorous application and population density and results from a study on sediment pollution from road construction. Based on feedback received during this meeting and additional consultation and feedback processes, the results of water quality pressures were based on a combination of these two methods.

6.2.2.2 Methodology

We mapped water quality pressures in Nepal using five pressure indicators (Table 4). The results enabled us to model key drivers of water quality pressures and derive a WQPI for all rivers of Nepal. The WQPI was then the main input included in the water quality component of the HCVR assessment.

Table 4: Data sources used to predict a water quality pressures index for Nepali rivers.

Proxy Indicator	Rationale	Source	Resolution	Method
Urban areas	Urban areas are a source of industrial and manufacturing pollutants	Global Urban Footprint; Esch et al. (2014)	0.4 arcsec (~12 m)	Spatial accumulation
Phosphorous application	Phosphorus fertilizer is an important source of phosphorous pollution	West et al. (2014)	5 arcmin	Spatial accumulation
Sediment pollution from road construction	Sediment from road construction increases the sediment load, and constitutes are constant source of sediment delivery through ongoing erosion	World Bank study (Vogl, Schmitt, et al. 2019); own calculations using OpenStreetMap (OpenStreetMap contributors, 2020)	Calculated on river-reach scale	Spatial accumulation
Population density	Human settlements introduce nitrate and phosphate via waste and waste-water streams	WorldPop 2020; Gaughan et al. (2013)	30 arcsec	Spatial accumulation
Nitrate	Nitrate is important source of water pollution with impacts on humans and aquatic organisms	Training data (Nitrate observations): PAANI Covariates: global river and nutrient data sets	Variable	Machine learning model

Data for the five indicators were not received in the same format, therefore they were processed and modeled in two different ways. Below, we outline the steps we took to calculate the pressure indicators and WQPI on a river reach scale:

A) Predicting nitrate concentrations using machine learning

Data for nitrate have been measured only in 119 sites in Nepal. Thus, we created a numerical model to predict the nitrate concentrations for all rivers in Nepal, based on the 119 observations. The aim of this model was to predict nitrate based on environmental data that are available everywhere in the country.

These environmental data are herein referred to as covariates. Covariates can be, for example, application of nitrogen fertilizer and population in the upstream area of a river reach. Modeling nitrate concentration was then based on the following steps:

(1) Collected covariate data for all 119 river reaches where there are observations for nitrate
(2) Trained a model that, based on covariates, predicted nitrate well
(3) Collected covariate data for all river reaches in Nepal

(4) Used the trained model from step 2 and covariate data throughout Nepal to predict nitrate in all of Nepal's rivers.

B) Estimating impacts from urban areas, phosphorous application, sediment pollution and population density using spatial accumulation

Due to limited water quality measurement, we also included global data for three pressure indicators (i.e., urban areas, phosphorous application, population density) and sediment pollution from road construction that are known to impact water quality (see Table 4).

The concentration of these four indicators were found using the following steps:

(1) The three global datasets were downloaded in raster format and transferred onto the river network using spatial accumulation. The river reach catchment was used to aggregate the raster values to each individual river reach. (Note: This step does not apply to sediment erosion as data for this pressure indicator was received on river reach scale).
(2) A river routing tool was used to accumulate downstream values for the four pressure indicators.
(3) A decay function was applied to the three global datasets, a tool commonly used during water quality modelling to account for the downstream movement and dilution of pollution. The decay function was applied to account for the pollutant traveling downstream of the point of pollution. The mass decay is dependent on the length and velocity travelled along the river. Typically, after about 50km, the contaminant load is reduced to 10% of its original mass. (Note**:** Decay function was not applied to sediment erosion pressure indicator).

C) Calculating Water Quality Pressure Indicator

To calculate the WQPI, the following steps were then taken:

(1) A normalized index (weighed 0-5) for all five indicators were generated using the concentration and river discharge at each river reach to account for dilution of pollution.
(2) For each indicator, values were distributed into quantiles to scale values from 0 to 5 effect (Figure 38).
(3) A WQPI, an integrated index, was created by aggregating the normalized quantiles of each indicator, then weighted each indicator equally to scale values from 0 to 5 (Figure 39).

6.3 Assessing the Freshwater values of Nepalese Rivers

The principal steps to assess freshwater values, ranging from the identification and selection of values, to creating the final HCV typology, are described in this section and are outlined in Figure 16.

6.3.1 Identification and selection for freshwater values

Based on the definition of a 'High Conservation Value' river identified by participants in the July 2019 workshop, there are four key thematic areas that were identified: **biodiversity, recreational values, livelihood values and social and cultural values**.

Several data layers were included in each of these four key thematic areas, based on expert advice during Advisory Meetings and depending on data availability (Figure 17). A more detailed description and the justification for including the freshwater value can be found in more detail in section 7.2 and in Annex 10.2.1.

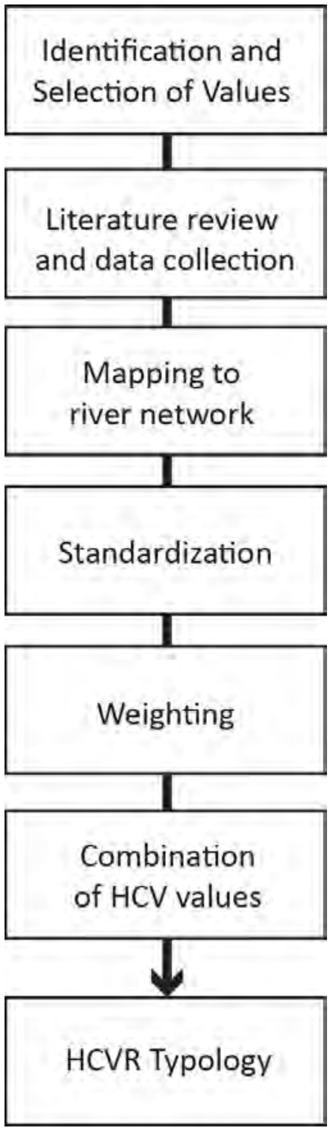


Figure 15: Steps for assessing the freshwater values of Nepalese rivers.

6.3.2 Data collection and review

After identifying freshwater values, an extensive search for existing data began, and a GIS database with available raw data was populated. While most of the data could be used as is, some of the data needed revision and updates during the project. In particular, the databases of fishes (Shrestha, 2008) were deemed outdated and incomplete, therefore a group of fish specialists were formally consulted to update and extend the current database with their latest expert knowledge and information from the literature. The data sources for the respective freshwater values are described in more detail in section 7.2 and in Annex 10.2.1.

6.3.3 Mapping of freshwater values to the river network

The next step of the assessment was to transform the raw data collected from maps, reports, and scientific articles, to the individual river reaches of the river network. This step could not be automated, so it was conducted primarily manually, and occasionally, in the case of fishes, using spatial network selection tools, that helped guide the mapping. This extensive manual processing ensured best-possible fit between raw data and our target river network.

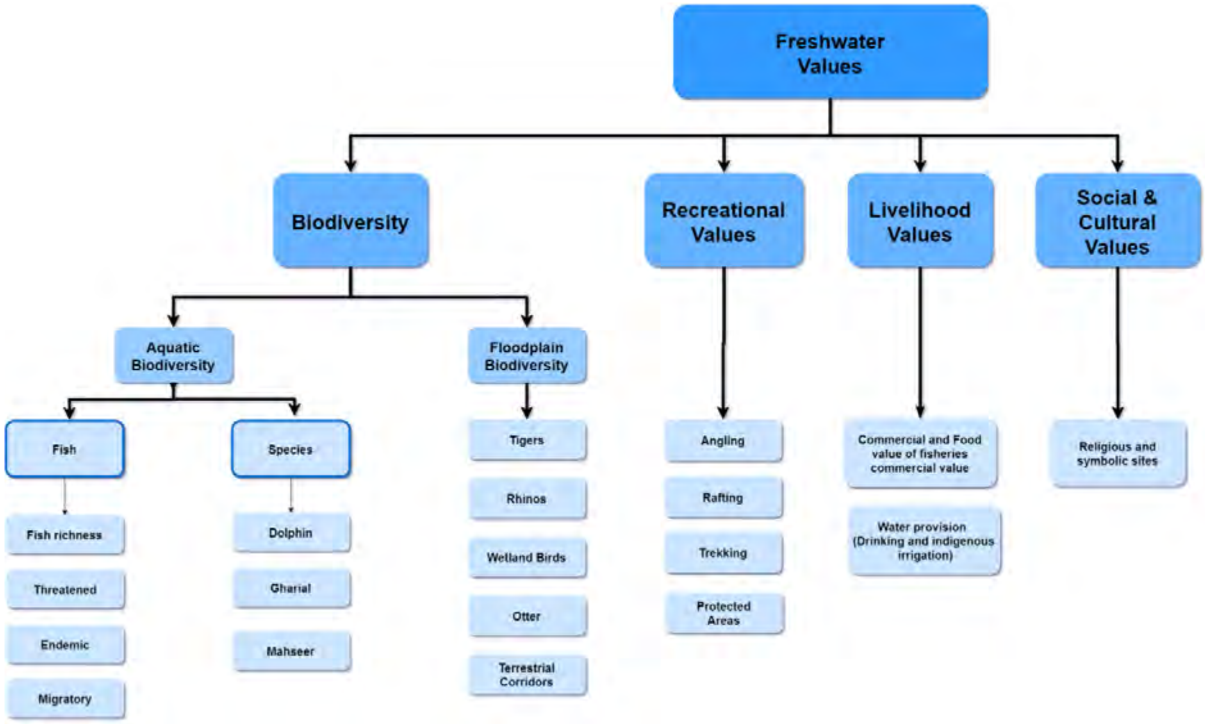


Figure 16: Freshwater values identified for Nepal.

6.3.4 Standardization of freshwater values

After the mapping of the raw data and its translation to the river network, we could identify three principal types of data:

1) **Categorical data**: This data describes freshwater values qualitatively, for example within the 'Rafting' group, river reaches were classified as valuable for "rafting and kayaking", whereas others were only valuable for rafting alone, for which a lower HCV score was assigned.
2) **Binary data**: This type of data identified important freshwater values as either present or not in a particular river reach. For example, in the case of Rhino population, there were no species of Rhino counted that could be used for detailed value mapping. Therefore, if Rhino were present the river reach was classified as HCV with a value of 5, other reaches received a value of 0.
3) **Quantitative data**: This data type includes freshwater values where the data could be ranked from low to high using absolute values. For example, the fish data was treated under this type, and each fish subcategory (migratory, endemic, etc.) was grouped into 5 quintiles representing HCV values from 0-5. The primary goal of this was to assign higher HCV scores to river reaches where higher species numbers were found. This also ensured that more or less an equal amount of river reaches was present within each quintile. An overview of the mapped values, their data type the harmonization technique used and details on the expert mappings is shown in Table 5. For more details on each HCV, please also consult section 10.2.1 in the Annex.

Table 5: Overview of mapped high conservation values (HCV), their data type, and the data standardization technique used in this assessment. See section 10.2.1 in the Annex for more details on each freshwater value.

SN	Value category	HCV Value type	Data Standardization technique	HCV value mapping
1	Biodiversity	Quantitative	n.a.	
1.1	Aquatic Biodiversity	Quantitative	n.a.	
1.1.1	Fish	Quantitative	n.a.	
1.1.1.1	Fish richness	Quantitative	Quintile mapping	0 - 5
1.1.1.2	Threatened	Quantitative	Quintile mapping	0 - 5
1.1.1.3	Endemic	Quantitative	Quintile mapping	0 - 5
1.1.1.4	Migratory	Quantitative	n.a.	0 - 5
1.1.1.4.1	Long Migratory	Quantitative	Quintile mapping	0 - 5
1.1.1.4.2	Medium and Short Migratory	Quantitative	Quintile mapping	0 - 5
1.1.2	Mahseer	Categorical	Expert mapping	
			1 species identified	2
			2 species identified	3
			3 species identified	4
			4 species identified	5
1.1.3	Dolphin	Categorical	Expert mapping	
			Historical, non-viable or seasonal population	3
			Viable population but no species found	4
			Viable population larger than 0	5
1.1.4	Gharial	Categorical	Expert mapping	
			Historical presence	2
			Recently recorded	3
			Recorded in latest census	4
			Gharial population > 0 latest census	5
1.2	Floodplain/Wetland-Dependent Biodiversity	Quantitative	n.a.	
1.2.1	Tigers	Binary	Presence/absence mapping	0 / 5
1.2.2	Rhinos	Binary	Presence/absence mapping	0 / 5
1.2.3	Wetland Birds	Binary	Presence/absence mapping	0 / 5
1.2.4	Otter	Categorical	Expert mapping	
			Probable habitat	3
			Not confirmed	4
			Confirmed habitat	5
1.2.5	Critical Corridors	Binary	Presence/absence mapping	0 / 5
2	Recreation	Quantitative	n.a.	
2.1	Angling	Categorical	Expert mapping	
			Asla species	1
			Warmwater species	1.5
			Mahseer	2
			Mahseer + Asla	3
			Mahseer + Warmwater species	4
			Mahseer + Aslar + warmwater species	5
2.2	Rafting	Categorical	Expert mapping:	
			Kayaking only	3
			Rafting only	4
			Rafting and Kayaking	5
2.3	Trekking	Binary	Presence/absence mapping	0 - 5
2.4	Protected Areas (large rivers)	Binary	Presence/absence mapping	0 - 5
3	Livelihood	Quantitative	n.a.	
3.1	Commercial and Food value of Fisheries	Quantitative	Quintile mapping	0 - 5
3.2	Water provision	Categorical	Expert mapping based on capacity (m3 person / day)	
			> 1000	1
			10 – 1000	2
			1-10	3
			0.1-1	4
			< 0.1	5
4	Socio-cultural	Quantitative	n.a.	
4.1	Religious and Cultural Sites	Quantitative	Quintile mapping	0 - 5

6.3.5 Weighting Values

After the HVC values were standardized to a common HCV scale from 0 to 5, we weighted each individual value. We consulted our expert group on appropriate weights and calculated results for multiple different weighting schemes. Four weighting schemes are shown in Figure 17. The figure shows the freshwater values and their hierarchical position within the freshwater value tree. Each value received a weight relative to its hierarchical level, adding to 100%. For example, Aquatic Biodiversity and Floodplain Biodiversity are subcomponents of the Biodiversity level and each received weights of 60% and 40%, respectively. Next to the relative weights, we display the global weights, which represents weights relative to all other values. In this case Aquatic Biodiversity and Floodplain Biodiversity receive values of 33%, and 22%, respectively.

SN	Level	ID	Parent	Value_cat	Value_category	Weights_v1 _Relative	Weight_v 1 Global	Weights_v2 _Relative	Weight_v2 Global	Weights_v3 _Relative	Weight_v3 Global	Weights_v4 _Relative	Weight_v4 Global
1	1	1		BIODIVERS	Biodiversity	25.0	25.0	50.0	50.0	55.0	55.0	60.0	60.0
1.1	2	2	1	AQUA_BIODIV	Aquatic Biodiversity	50.0	12.5	50.0	25.0	60.0	33.0	70.0	42.0
1.1.1	3	3	2	FISH	Fish	25.0	3.0	25.0	6.0	55.0	18.0	55.0	23.0
1.1.1.1	4	4	3	FISH_SPECIES	Fish richness	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.2	4	5	3	FISH_THRTND	Threatened	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.3	4	6	3	FISH_END	Endemic	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.4	4	7	3	FISH_MIGR	Migratory	25.0	0.8	25.0	1.6	25.0	4.5	25.0	5.8
1.1.1.4.1	5	8	7	FISH_LG_MIGR	Long Migratory	60.0	0.5	60.0	0.9	60.0	2.7	60.0	3.5
1.1.1.4.2	5	9	7	FISH_ST_MIGR	Medium and Short Migratory	40.0	0.3	40.0	0.6	40.0	1.8	40.0	2.3
1.1.2	3	10	2	MAHSEER	Mahseer	25.0	3.1	25.0	6.2	15.0	5.0	15.0	6.3
1.1.3	3	11	2	DOLPHIN	Dolphin	25.0	3.1	25.0	6.2	15.0	5.0	15.0	6.3
1.1.4	3	12	2	GHARIAL	Gharial	25.0	3.1	25.0	6.2	15.0	5.0	15.0	6.3
1.2	2	13	1	FLOOD_BIODIV	Floodplain/Wetland-Dependent Biodiv.	50.0	12.5	50.0	25.0	40.0	22.0	30.0	18.0
1.2.1	3	14	13	TIGER	Tigers	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.2	3	15	13	RHINO	Rhinos	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.3	3	16	13	BIRD	Wetland Birds	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.4	3	17	13	OTTER	Otter	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
1.2.5	3	18	13	CRITICAL_CORR	Critical Corridors	20.0	2.5	20.0	5.0	20.0	4.4	20.0	3.6
2	1	19		RECREATION	Recreation	25.0	25.0	16.7	16.7	15.0	15.0	15.0	15.0
2.1	2	20	19	ANGLING	Angling	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
2.2	2	21	19	RAFTING	Rafting	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
2.3	2	22	19	TREKKING	Trekking	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
2.4	2	23	19	PROTECTED	Protected Areas (large rivers)	25.0	6.3	25.0	4.2	25.0	3.8	25.0	3.8
3	1	24		LIVELIHOOD	Livelihood	25.0	25.0	16.7	16.7	15.0	15.0	10.0	10.0
3.1	2	25	24	FISH_COMM_FOOD	Commercial and Food value of Fisheries	50.0	12.5	50.0	8.3	50.0	7.5	50.0	5.0
3.2	2	26	24	PROVISION	Water provision	50.0	12.5	50.0	8.3	50.0	7.5	50.0	5.0
4	1	27		SOCIO_CULT	Socio-cultural	25.0	25.0	16.7	16.7	15.0	15.0	15.0	15.0
4.1	2	28	27	RELIGIOUS	Religious and Cultural Sites	100.0	25.0	100.0	16.7	100.0	15.0	100.0	15.0
						Equal Group		High Biodiversity (current)		High Biodiversity (alternative 1)		High Biodiversity (alternative 2)	

Figure 17: Quantitative value score for freshwater values. Four plausible scenarios were produced and evaluated by the advisory group. The "High Biodiversity scenario (alternative 1)" was selected as the most appropriate. All maps are produced using this weighting scenario.

6.3.6 Combining HCV values

The integration of HCV components occurs on two distinct scales. The first scale is the *river reach* scale, which is the fundamental unit of analysis in the HCVR assessment and assigns HCV values to each individual river reach. The second scale is the *river* scale, which provides a single HCV values for an entire river. For a discussion on the distinction between river and river reach, please see section 6.1 and Figure 10.

6.3.6.1 HCV at reach scale

After assigning weights to each of the values, a weighted average for every river reach was produced to combine the weighted freshwater values:

$$HCV_j = \frac{\sum_{i=1}^{n} x_{i,j} * w_i}{\sum_{i=1}^{n} w_i}$$

where HCV_j is the weighted HCV value at river reach *j; $x_{i,j}$* is the HCV value of the freshwater value *i* at reach *j*; w_i is the weight applied to the HCV value of the freshwater value *i*; and *n* is the number of freshwater values. We prescribe the sum of w_i to be 100%, hence the resulting CSI values can range from 0 (low HCV value) to 5 (maximum HCV value).

The HCV integration occurs from the bottom up. For example, the two values "Long-distance migratory" (ID 8) and "Short-distance migratory" (ID 9), weighted using the above methodology into the overarching HCV value "Migratory fishes" (ID 7). This value is in turn grouped with other values from this level (ID 4, 5, and 6) into the higher-level HCV value group "Fishes" (ID 3). This continues until finally the broad HCV value group "Biodiversity", "Recreation", "Livelihood", and "Socioeconomic" are calculated. Finally, these four groups are weighted into a final HCV value score. The GIS data layer includes a field for each of these group categories and a value per river reach.

6.3.6.2 HCV at river scale

In addition to the river reach scale, a useful perspective it to aggregate the HCV values further to the river scale. This allows to talk about the values of entire rivers, not just small river sections. As shown in Figure 19, a river is composed of several river reaches, each of which has a distinct aggregated HCV value. The length-weighted HCV for a river is calculated as:

$$HCV_R = \frac{\sum_{i=1} HCV_i * l_i}{\sum_{i=1} l_i}$$

where HCV_R is the HCV in the river *R; HCV_i* is the HCV value of the river reach *i* and *l* is the length of river reach *i.* The resulting aggregated HCV values can range from 0 (no value mapped) to 5 (maximum value of all components). The results of this integration are shown in section 7.2.5.

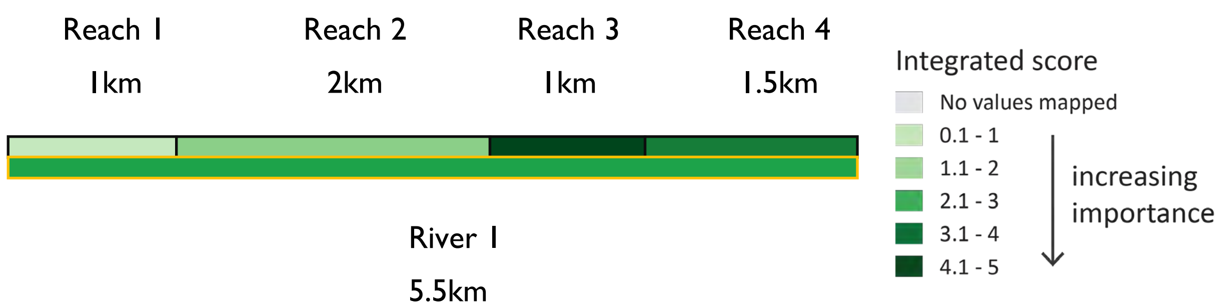


Figure 18: Illustration of integrating HCV values from the river reach scale to the river scale using length-weighted averages.

6.3.7 HCVR typology

The HCVR typology integrates the freshwater status and the freshwater values into the final HCVR classification. We define 4 HCVR types that classify river reaches based on the freshwater status and then distinguishes HCV groups within each type (Figure 20).

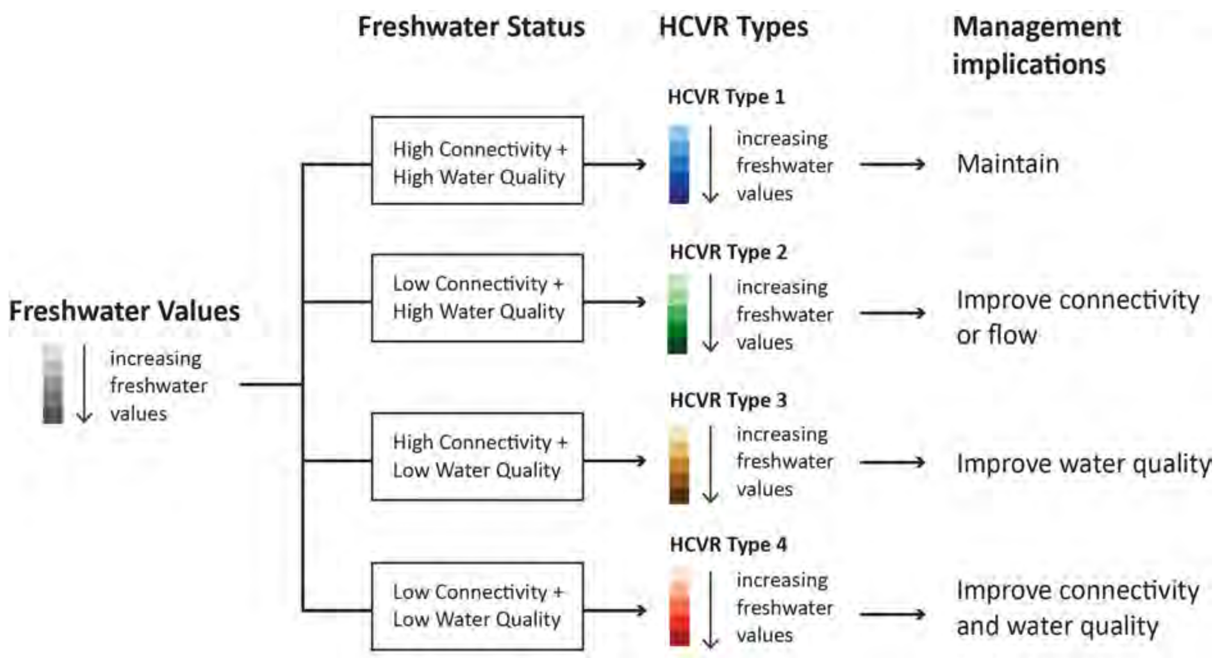


Figure 19: Classification scheme for final HCVR river typology. The corresponding map is shown in .

6.3.7.1 HCVR 1: High Value + High connectivity + High WQ

This HCVR category includes rivers and river reaches that a) show one or more important freshwater values (HCV value > 0), b) were classified as 'free-flowing', and c) show low water quality pressures (WQPI < 3). This category shows the highest conservation value, and its status should be maintained.

6.3.7.2 HCVR 2: High Value + Low connectivity + High WQ

HCVR type 2 can be described as rivers that a) show one or more important freshwater values (HCV value > 0), but where b) river connectivity is reduced, i.e., the river is no longer classified as free-flowing. This could be due to local, upstream or downstream effects from dams or barrages, sometimes from far away. These rivers are classified as high water quality rivers, due to their low WQPI values (WQPI < 3). The conservation value of rivers of this type is reduced, so the recommended management action is to increase connectivity, for example by removing dysfunctional or unused barriers, by implementing environmental flows (increasing minimum flows of creating a release schedule that mimics the natural flow regime better), or by improving passability through bypass reaches or by increasing the effectiveness of fish ladders.

6.3.7.3 HCVR 3: High Value + High connectivity + Low WQ

HCVR type 3 are rivers (or river reaches) that show a) one or more important freshwater values, b) are classified as free-flowing, but show c) high water quality pressures (WQPI >= 3). These rivers may still show high amounts of freshwater values, but show lower conservation value, due to pressures from pollutants from agriculture or domestic use (household products), or due to increased sediment pollution. The preliminary management implication for this HCVR type is to improve water quality by reducing aforementioned water quality pressures.

6.3.7.4 HCVR 4: High Value + Low connectivity + Low WQ

HCVR type 4 rivers (or river reaches) show a) one or more important freshwater values, but they are neither classified as free-flowing, or as high water quality rivers, reducing the conservation value of these rivers. While these rivers contain important freshwater values, they are at risk due to pressures from loss of water quality, loss of connectivity, or from other threats. In order to maintain or improve the freshwater values found in these rivers, it is recommended to both increase connectivity and reduce water quality pressures.

6.4 Mapping of freshwater values

6.4.1 Biodiversity values

The biodiversity values component integrated both aquatic biodiversity and floodplain-related biodiversity into the first of the four main freshwater values categories. Within the Aquatic biodiversity group, we further distinguish between the group ‘Fishes’ which have been mapped for the major rivers in Nepal and a group of flagship species, which include dolphin, gharial and mahseer. For the floodplain-related biodiversity group, we chose to map species dependent on functioning river and riverine ecosystems, such as tigers, rhino, wetland birds, and otter. An additional element in this group, ‘Terrestrial Corridors’, are areas that link important habitat for terrestrial species.

6.4.1.1 Aquatic Biodiversity

Under the aquatic biodiversity category, species groups to include in the assessment were identified based on inputs provided during the July 2019 workshop and subsequent advisory group meetings.

6.4.1.1.1 Fishes

Bennett et al. (2016) mapped the distribution of 245 fishes in river systems of Nepal based on the “Ichthyology of Nepal” book by Shrestha (2008). The Advisory Group suggested using these data as the base and further updating it with information from recent studies and research articles. GEEC Pvt Ltd. was contracted to update the fisheries data for the country. Newly available fish distribution data was collected from the recent literature and EIA reports. Fish distribution data was then updated into a spatial database and assigned to the river network through the steps shown in Figure 21. The data has been provided through GIS with GOID, River ID and River Name attributes. Based on these data, species distribution maps, and threatened, endemic and migratory maps were then created. The resulting data was further validated during Advisory Group meetings, two separate fisheries experts’ meetings, and a number of consultations with fisheries experts.

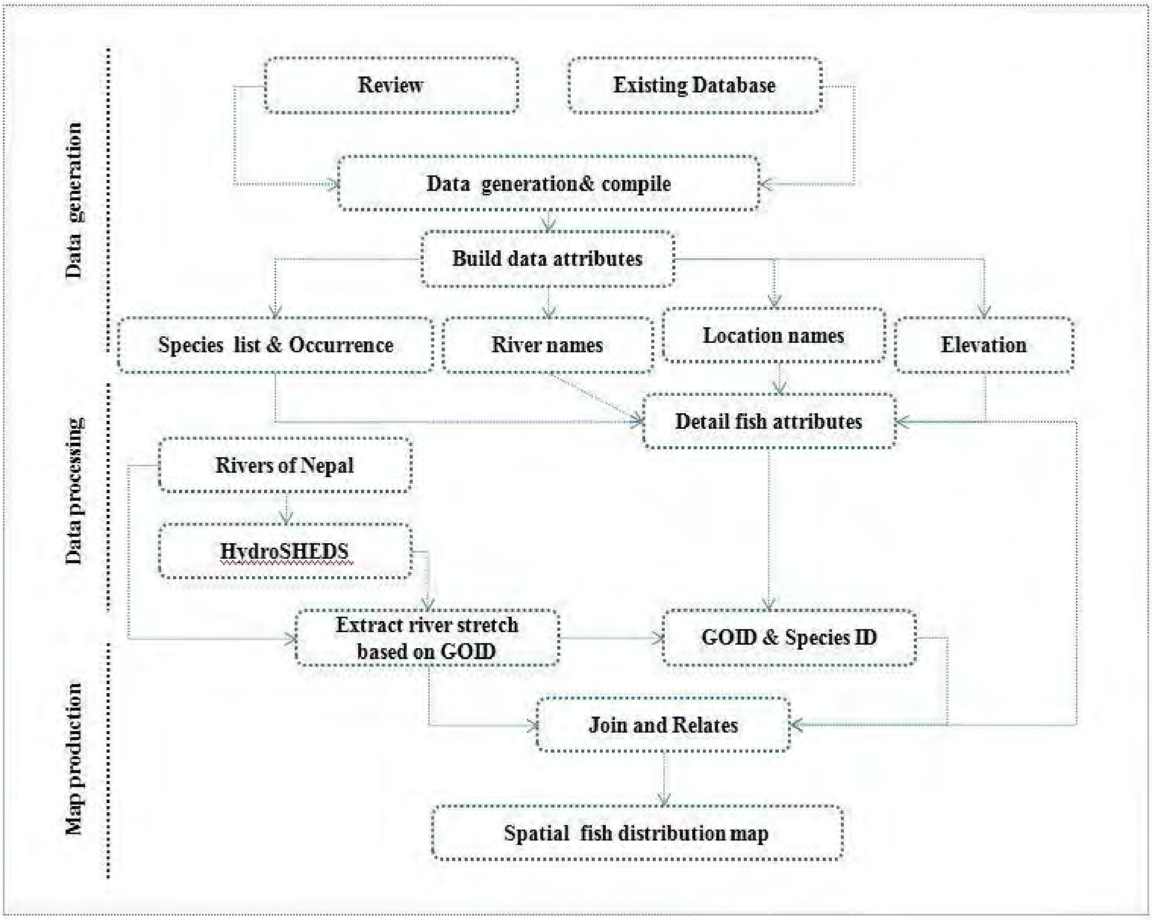


Figure 20: Flowchart on distribution mapping of fishes.

A total of 256 fishes were mapped under this study, and distribution information was revised in existing mapped rivers and new data has been included for additional 30 rivers of Nepal including Thuligad, Tila, Sarada, Modi, Badigad, and Trijuga Rivers (Figure 23), and available data on rivers have been validated and revised based on best available information. These data have been used for the mapping of all fish-related values including fish richness, endemic, migratory and threatened fishes, mahseer distribution, angling value under recreation component, and commercial and food value under livelihood component.

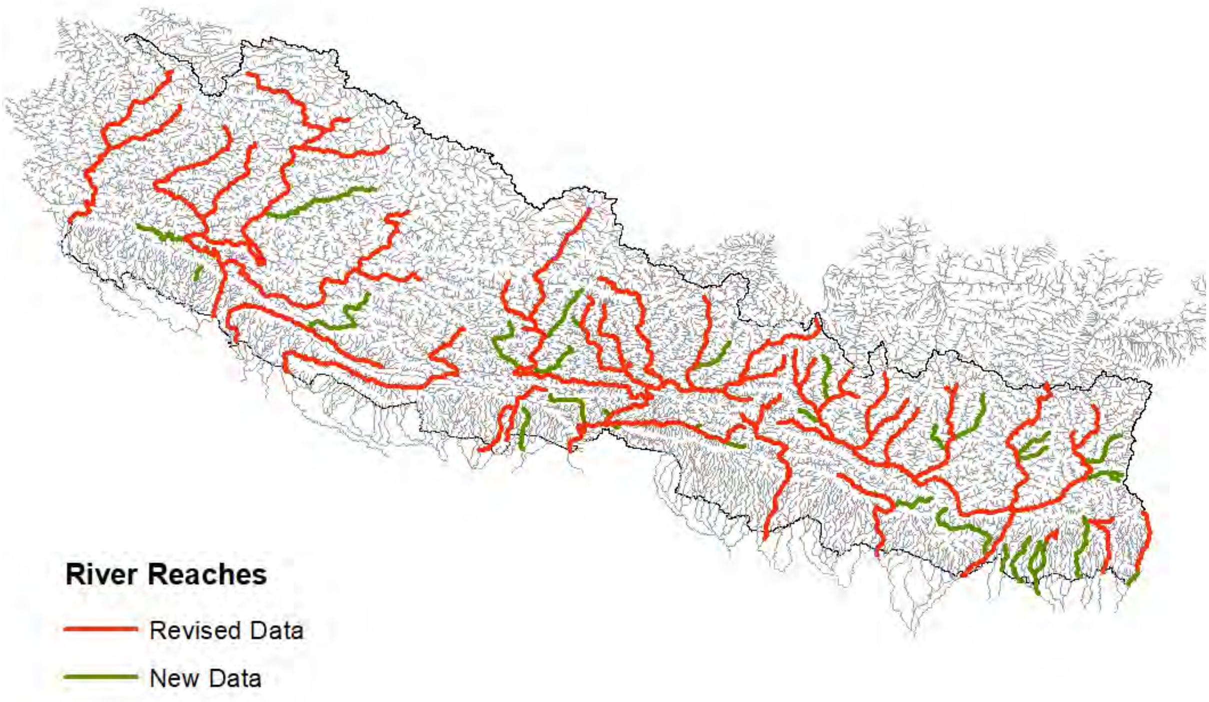


Figure 21: Revised fisheries data after Bennett et al. (2016).

Fish richness, endemism, migratory and threatened fish values have been mapped as the number of fishes in each river reach. The numbers of fish species in each category was also discussed and validated in Advisory Group meetings and fisheries group meetings.

Threatened species includes species that are under the critically endangered, endangered, or vulnerable categories in the IUCN Red Data list.

Under the migratory fishes two categories have been made including long, and short and medium migratory species based on available information on each fish species. Among these two value categories more weight has been provided to long migratory fishes (60%) than short and medium migratory fishes (40%).

All values under the fish category are quantitative, therefore, more weight has been given to river reaches that have higher numbers of fishes (quintile mapping technique).

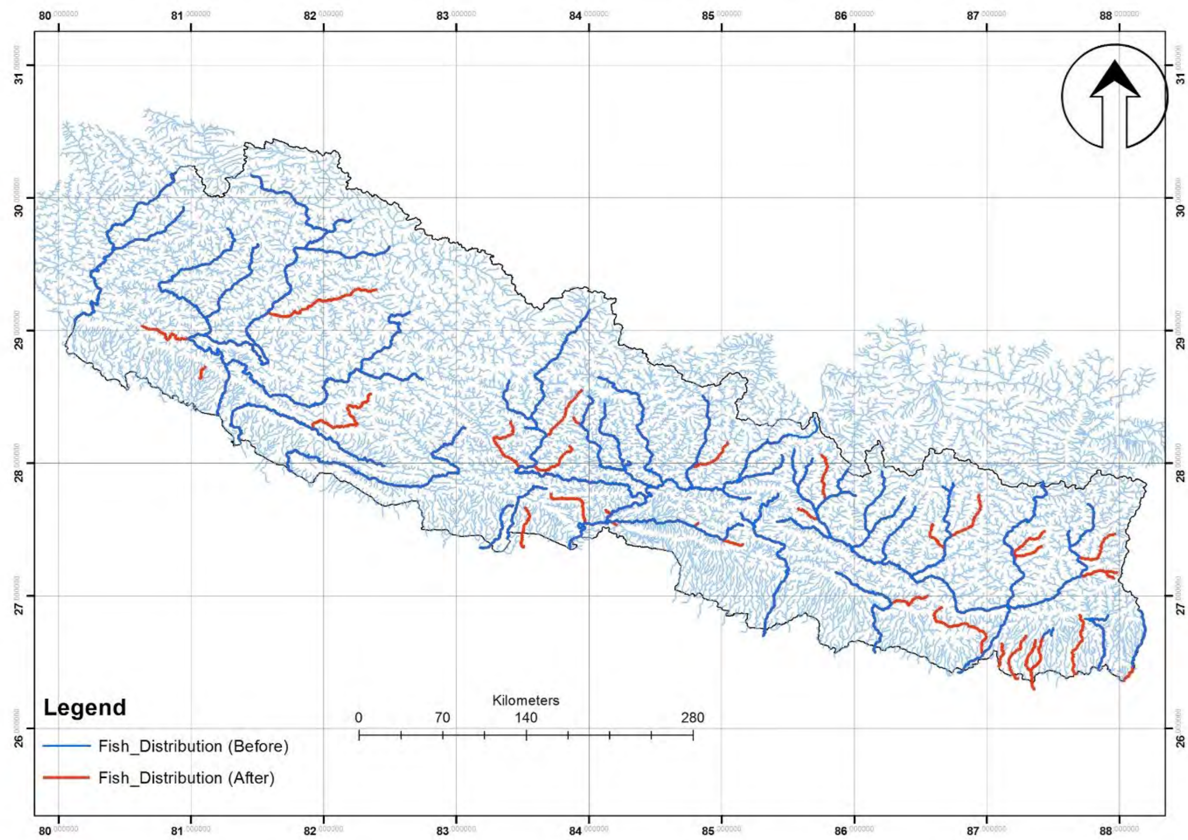


Figure 22: Fish distribution data was originally mapped by Bennett et al. (2016) based on Shresta et al. (2008; blue locations), and then updated by the project team (red locations).

6.4.1.1.2 Flagship species

While there is debate over the ecological role that flagship species play, most societies have some flagship species that capture attention and raise awareness of the importance of protecting and preserving them. Though species conservation strategies take time to implement and often face significant legal and legislative constraints, flagship species have become a prime mechanism to promote conservation. They can play a role in controlling the ecosystem within their habitat, affect the types and number of other species in their environment and without them the balance in that environment is disturbed. Flagship species in aquatic ecosystem often play a critical role in maintaining the structure of an ecological community.

Under the Paani program, several flagship fish species have been identified for Nepalese rivers. Flagship species have identified for Mahakali and Karnali river basin based on their high economic and ecological value. These include *Tor putitora, Schizothorax richardsonii, Labeo angra, Labeo dero* for Mahakali and *Tor putitora, Schizothorax richardsonii, Labeo angra, Labeo dero and Acrossocheilus hexagonolepis* in Karnali (Figure 24).

Under this assessment flagship species were identified by workshop participants and through consultations in advisory group meetings. Initially in the July workshop dolphin and gharial were included under the flagship category but later based on the suggestion from the Advisory Group meeting, mahseer was also included in this category as this species is also important for gharial and dolphin to survive in Nepalese rivers.

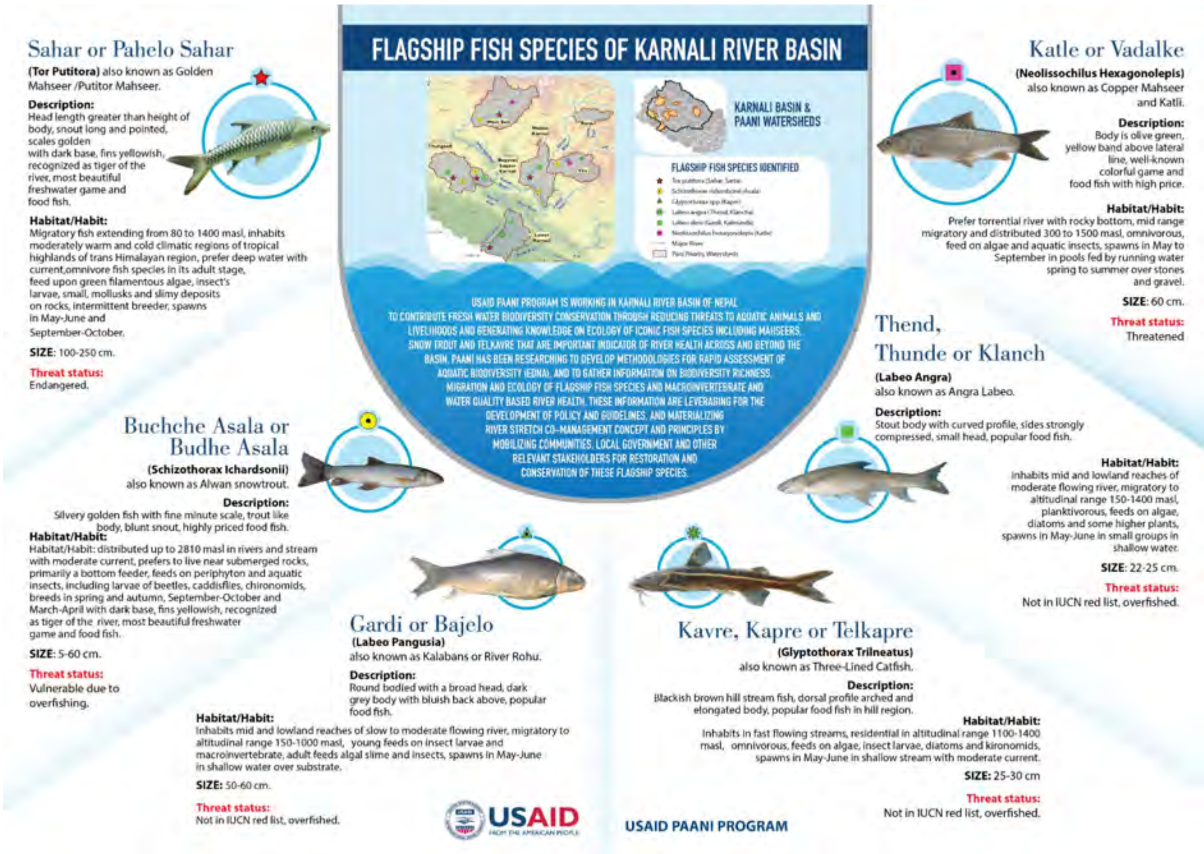


Figure 23: Flagship fish species of Karnali river basin. Source: USAID PAANI Program, 2020

6.4.1.1.2.1 Dolphins

Gangetic River Dolphin is the only recorded cetacean species and legally protected mammal in Nepal. The River Dolphin plays an important role in the riverine food chain. Though it is regarded as an endangered flagship species, its habitat has been highly degraded by human interference thereby shrinking its distribution range and lowering its population numbers. Maintaining adequate habitat for river dolphins requires connected river corridors without barriers.

Data on dolphin distribution has most recently been collected during the dolphin census that took place in 2016 (IUCN Nepal, 2017). We manually mapped available dolphin distribution data to river reaches and recorded the number of dolphins counted in each reach. River reaches with a viable population and more than one individual documented in the recent census received the HCV value of 5, representing the highest HCV value within this category. River reaches with known viable populations, but where no species were recorded in the latest census received an HCV value of 4.

Historical dolphin habitat has also been mapped based on knowledge of Advisory Group members and research articles. These are locations that may be re-colonized by dolphins in the future. This category was assigned an HCV value of 3.

6.4.1.1.2.2 Gharial

Gharials (*Gavaialis gangeticus*) are critically endangered species and considered as habitat specialist and indicator species of healthy freshwater ecosystems. It is one of the protected reptiles of Nepal under the Schedule I of National Parks and Wildlife Conservation Act, 1973.

Figure 24. A gharial in Rapti River, Nepal. (Photo Credit: Karine Aigner/ WWF-US)

Number of gharials in rivers was compiled from the Crocodile survey of 2016 and the type of gharial habitat (current/potential/historical) was compiled from DNPWC (2018) and Acharya et al. (2017).

We distinguished four gharial habitats, that were based on the following categorization:

- Locations (river reaches) where gharials were counted in the current census of 2016 (Gharial number > 0), confirming their actual current presence. Regardless of the number of species recorded, these locations received an HCV value of 5.
- Locations (river reaches) where gharials were not recorded during the latest census (Gharial number=0), but we know these habitats are current habitat based on available information. These locations were given an HCV value of 4.
- Locations (river reaches) considered as potential habitat where a gharial has recorded in 2019 by WWF Nepal, which received an HCV value of 3. Proper survey needs to be conducted in these locations therefore, these locations are considered as potential; and
- Known historical gharial habitat confirmed by studies and the Advisory Group, which received an HCV value of 2.

6.4.1.1.2.3 Mahseer

Mahseer are commercially important game fish as well as highly esteemed food fish. Golden Mahseer (*Tor putitora*) and Dark Mahseer (*Tor chelynoides*) are under the endangered category of IUCN Red List. Golden Mahseer is one of the most highly popular sport fish attracting anglers from around the world. It is also an important food fish harvested for both commerce and subsistence throughout its range often using unsustainable fishing methods. Golden Mahseer has shiny golden yellow scales and is widely distributed in south and southeast Asia, with a restricted area of occupancy. However, the species is under severe threat from overfishing, loss of habitat, decline in quality of

Figure 25: Golden Mahseer (Tor putitora). It is categorized as 'Endangered' in the International Union of Conservation of Nature Red List. (Photo credit: Juha Rouhikoski).

habitat resulting in loss of breeding grounds, and from other anthropogenic threats that have resulted in declines in harvest in several locations (Raymajhi et al., 2018a).

Neolissochilus hexagonolepis	Copper Mahseer
Tor chelynoides	Dark Mahseer
Tor putitora	Golden Mahseer
Tor tor	Deep Bodied Mahseer

Deep Bodied Mahseer (*Tor tor*) is considered to be the most widely distributed among the mahseers, which does not grow to a large size (Raymajhi et al., 2018b). This is a highly valued food and game fish. Major threats include habitat loss due to deforestation and erosion, urbanization, and over-exploitation. This migratory species is also threatened in parts of its range by current and planned hydropower developments e.g. the proposed Pancheshwar Dam in the Ganges basin on the border between India and Nepal (Everard and Kataria 2010 cited by Arunachalam, 2010). The fourth species is Copper Mahseer (Neolissochilus hexagonolepis).

All four species of mahseer have been mapped during the fisheries data compilation by fish ecologists and experts. Since there were only 4 species, we could not use a quintile classification like for other numerical data. We therefore treated Mahseer as a categorical value. Our experts assigned HCV values relative the number of Mahseer species found. If all four species were found in a river reach, an HCV value of 5 was assigned. A species count of 3, 2, and 1 species received and HCV value of 4, 3, and 2, respectively.

6.4.1.2 Floodplain and riverine biodiversity

'Floodplain' and 'riverine' have been used interchangeably in this document. However, floodplain biodiversity values included in this section are species that depend on riverine ecosystem in Terai region of Nepal (i.e., rhinos and tigers) and critical corridors. Riverine biodiversity values include otter habitats, and important wetland bird river reaches.

6.4.1.2.1 Rhinoceros

Habitat specialists like the one-horned rhinoceros (*Rhinoceros unicornis*) are completely dependent on floodplain grasslands that are governed and maintained by flood dynamics. Maintaining adequate habitat for rhinos requires healthy functioning floodplain systems that have natural variability with the seasons.

Figure 26: Chitwan National Park is home to the second largest population of greater one-horned rhinoceros. (Photo Credit: Sameer Singh / WWF Nepal).

Data on rhino distribution has been collected from the Nepal National Rhino Count in 2015. Available data on rhino distribution were mapped to river reaches as rhino habitats and the maps were validated during advisory group meetings.

We treated the rhino data as binary, meaning that a river location with known rhino occurrence received an HCV value of 5, while no rhino occurrence received an HCV value of 0.

6.4.1.2.2 Tigers

Maintaining adequate habitat for tiger's prey species requires healthy functioning floodplain systems that have natural seasonal variability. Impact on flow regime of the floodplains affect the species that depend on the natural ecosystem function for their survival. Tigers (*Panthera tigris*), though generalist species, reach their highest densities on floodplain grasslands.

Figure 27: A tiger in Bardia National Park, Nepal. (Photo Credit: Emmanuel Rondeau / WWF-US)

Data on tiger distribution has been compiled from National Tiger Survey in 2018, Dhakal et al. (2014), and Poudyal et al. (2018). Available data on tiger distribution in river reaches have been mapped in the river network as tiger habitats and the maps have been validated during Advisory Group meetings. As such, river reaches where tigers have been mapped received an HCV value of 5.

6.4.1.2.3 Otters

Representing the top of the food chain of the freshwater ecosystem, river otters are often regarded as indicator species for intact healthy wildlife habitat. Sustenance of this species in an aquatic ecosystem requires a connected river network and a virgin ecosystem. River otters in Nepal historically included *Lutrogale perspillata*, *Lutra lutra* and *Aonyx cinerea*. However, there is no strong evidence of existence o*f Aonyx cinerea* in any region in the country, therefore based on the expert consultations, its habitat is not included in our assessment. Initially otter distribution was mapped based on the available literatures and data sources including IUCN (2015a), IUCN (2015), Kafle (2009) and Acharya and Rajbhandari (2009) and further review and validation have done through consultations with experts from Himalayan Otter Network (HON). River reaches where Otter were found received an HCV value of 5.

6.4.1.2.4 Wetland Birds

A total of 863 species of birds has been reliably recorded in Nepal (DNPWC and BCN 2008). Of these nearly 200 species of birds are considered to be heavily dependent on wetland habitats (Grimmett et al., 2016). Wetland birds comprise a significant portion of the avian fauna of Nepal. Wetlands in Nepal are rich in biological diversity and are known to regularly support more than 20,000 waterfowl during the peak period between December-February. Rivers are home to many bird species: some go there to eat, nest, or rest, while others follow the course of a river, using it as a migratory route. In Nepal, there are many important river reaches that are home to wetland birds including Koshi River, Narayani River along Chitwan National Park (NP), Rapti River in Dang Deukhuri Important Bird Area (IBA), Karnali River, and Babai River.

Important wetland river reaches have been mapped based on the data provided by Bird Conservation Nepal. This freshwater value was treated as a binary category, which means that locations with known wetland bird occurrence received an HCV value of 5.

6.4.1.2.5 Critical Corridors

Critical corridors were considered a floodplain and riverine biodiversity value. Critical corridors connect protected areas and facilitate movement and dispersal of wildlife, especially megafauna.

6.4.2 Recreational values

Recreational-based tourism is an important part of the economy for Nepal. Among the many recreational activities conducted, rafting and kayaking, trekking, and angling are among the most important tourism activities that are associated with freshwater ecosystems. Nepal is also considered as one of the best places in the world for multi-day trips.

6.4.2.1 Angling

Angling or sport fishing is a fishing activity done with a rod and reel for sport or recreation purpose. Over the years, increasing concern about declining fish stocks has led to the emergence of catch and release as the new norm of sports fishing, whereby anglers catch, measure, photograph, and then release their catch in the hopes of the fish becoming bigger for another fight another day. Angling is an important eco-tourism activity but has not been fully developed in Nepal. A typical 3-night expedition on the Babai River can sell for around 1,600 USD/person.

There are several species that can be considered gamefish species important for angling in Nepalese waters, among them Golden Mahseer (*Tor putitora*), Goonch (*Bagarius bagarius*), many warm water species, and Asla species (Table 6). The golden mahseer is the most sought-after gamefish of the Himalayan waters. It migrates upriver to their spawning grounds (smaller tributaries of the major rivers) in the spring, the prime fishing season. As they migrate upriver, they stop for a day or two in deep pools, and feed in the nearby shallow rapids during the early morning and late afternoon. Spawning populations will hold in deep pools near the tributary and enter the tributary at night to spawn.

Table 6: Primary fish species important for angling (Rana, 2020)

S.N.	Scientific Name	English Name	Nepali Name	Current IGFA All Tackle World Record
1	*Tor putitora* (Hamilton, 1822)	Golden Mahseer	Sahar; Pahele Sahar; Satta (western Nepal)	29.94 kg (66 lb 0 oz) caught by Greg Iszatt on 14-Jun-2017, Mahakali River, India
2	*Tor tor* (Hamilton, 1822)	Deep-bodied Mahseer; Red-finned Mahseer	Rattar (Narayani River); Sahar	43.09 kg (95 lb 0 oz) caught by Robert Howitt on 26-Mar-1984, Cauvery River, India
3	*Bagarius bagarius* (Hamilton, 1822)	Goonch	Gonch; Thed (western Nepal)	75.00 kg (165 lb 5 oz) caught by Jakub Vagner on 06-Mar-2009, Ramganga River, India
4	*Neolissochilus hexagonolepis* (McClelland, 1839)	Copper Mahseer	Katle	Unlisted
5	*Channa marulius* (Hamilton, 1822)	Great Snakehead	Sauri	6.86 kg (15 lb 2 oz) caught by Gavin Niles Butera on 24-Jun-2018, Fort Lauderdale, Florida, USA
6	*Wallago attu (*Bloch & Schneider, 1801)	Wallago Catfish	Buhari	18.6 kg (14 lb 0 oz) caught by Kasem Lamaikul on 4-Dec-2004, Khaolam Dam, Sangklaburi, Thailand
7	*Raiamas bola* (Hamilton, 1822)	Trout Barb	Galara	Unlisted
8	*Schizothorax progastus* (McClelland, 1839)	Dinnawah Snowtrout	Chuche Asla	Unlisted
9	*Sperata seenghala* (Sykes, 1839)	Long-whiskered Catfish	Kanti	Unlisted
10	*Sperata aor* (Hamilton, 1822)	Long-whiskered Catfish	Kanti	Unlisted
11	*Catla catla* (Hamilton, 1822)	Catla	Bhyakur	18.90 kg (41 lb 10 oz) caught by Gerhard Posch on 23-Dec-2011, Palm Tree Lagoon, Ratchaburi, Thailand
12	*Cirrhinus mrigala* (Hamilton, 1822)	Mrigal	Naini	8.0 kg (17 lb 10 oz) caught by Eddie Grey on 03-Jan-2012, Gillhams Fishing Resorts, Krabi, Thailand
13	*Chitala chitala* (Hamilton, 1822)	Clown Knifefish; Featherback	Chital	6.58 kg (14 lb 8 oz) caught by Michael Donvito on 27-Jul-2018, Lake Ida, Florida, USA
14	*Labeo calbasu* (Hamilton, 1822)	Orangefin Labeo	Kalonch; Kalabans	2.70 kg (5 lb 15 oz) caught by Jean-Francois Helias on 17-Dec-2012, Cauvery River, India
15	*Labeo rohita* (Hamilton, 1822)	Rohu	Rohu	12.50 kg (27 lb 8 oz) caught by Pakron Suwannat on 08-Jul-2003, Dan Tchang Dam, Thailand

Golden Mahseer (*Tor putitora*) and Goonch (*Bagarius bagarius*), provide equally valuable angling experience, followed by Asla, and other warmwater species.

Each category has been assigned an HCV value based on perceived recreational value: If only Asla species were available for angling at the location we assigned an HCV value of 1. If other warmwater species were available as well, we increased the HCV value to 1.5. Locations with Mahseer/Gonch were given HCV value 2, locations with Mahseer/Gonch and Asla received HCV 3, Mahseer/Gonch and other warmwater species HCV 4, and locations with Mahseer/Gonch, Asla, and other warmwater species received the highest HCV value of 5.

6.4.2.2 Rafting

Nepal is a river runner's paradise – no other country has such a choice of multi-day trips, away from roads, in such magnificent mountain surroundings, with warm rivers, a semi-tropical climate, impressive topography, exotic cultures, wildlife, and friendly welcoming people

*Table 7: Rafting and Kayaking summary of Nepalese rivers. Total days means total days for a typical trip, to and from Kathmandu or Pokhara. Scenic/Wild subjective rating for scenery and wildlife. Kayak Stars is the rating of the river as kayaking or rafting trip- total experience, where *** means Highly recommended, ** means Recommended and * means Specialist interest. † Bagmati River from Chovar to Minbhawan has been added as rafting route from the suggestion of Advisory group, and there is no further information available on its rafting experiences.*

SN	River Name	Kayaking			Rafting		
		Kayak Class	Scenic Wild	Kayak Star	Raft Class	Scenic Wild	River Star
1	Arun Gorges	5	**	***			
2	Babai Nadi	2	**	*	2	***	*
3	Badi Gad	4-	**	*			
4	Bagmati †						
5	Balephi Khola	4-	*	***			
6	Bheri Nadi	3+	***	**	3+	***	**
7	Bhotekoshi Nadi	4+	**	**	4+	**	**
8	DudhKoshi Nadi	5	**	*			
9	Humla Karnali	5-	***	***			
10	Indrawati	2	*	*			
11	Lower Karnali	4	***	**	4	***	***
12	Lower Arun	4-	**	**	4-	**	**
13	Lower Buri Gandaki	3-	*	*	4	*	*
14	Lower Kali Gandaki	2	**	**	2	**	**
15	Lower Modi Khola	4-	**	**			
16	Lower Myagdi Khola	3	**	**			
17	Madi Khola	4	***	***			
18	Mahakali Nadi	3	***	*	3	***	*
19	Marsyangdi Nadi	4+	***	***	4+	**	***
20	Seti Nadi	3	**	**	3-	**	**
21	Seti/Karnali	3	***	**	3	***	**
22	SunKoshi Nadi	4-	**	**	4-	**	***
23	Tamba Koshi	5-	*	**			
24	Tamor Nadi	4	**	***	4	**	***
25	Thuli Bheri	4+	***	***			
26	Trishuli River	3+	*	**	2/3+	*	**
27	Upper Kali Gandaki	4-	**	***	4-	**	***
28	Upper Modi Khola	4+	***	***			
29	Upper Myagdi Khola	4+	**	**			
30	Upper Seti (Pokhara)	3	**	**			
31	Upper Sun Koshi 1	3	*	**	1	*	**
32	Upper Sun Koshi 2	1	*	*			
33	Upper Buri Gandaki	4+	**	**			

(Knowles and Clarkson-King, 2011). For instance, the Karnali River is famous for its rafting opportunities. It is one of the top ten world class locations for white water rafting. Within the Karnali Basin, the Seti, Upper Seti, and Bheri rivers are also popular tributaries for kayaking and rafting. Connected river networks are crucial for the success of these recreation opportunities. The rafting and kayaking summary of Nepalese rivers has been provided in Table 7.Table 7.

The rafting and kayaking routes data have been collected from White Water Nepal: Third Edition Book by Knowles and Clarkson-King (2011), and revised and validated by members of the Advisory Group.

Using the book and based on the suggestion from the Advisory Group, we created three principal categories. The first category are locations where both Rafting and Kayaking was possible, and we assigned an HCV value of 5 to these locations. Second were locations where rafting was possible, and we assigned a value of 4. Lastly, for locations where only kayaking was possible, we assigned an HCV value of 3.

6.4.2.3 Trekking

The diversity of trekking trails found in Nepal cannot be found in any other part of the world. Trekking has been the leading activity of tourists in Nepal and thousands come to the Himalayas, some for a few days of hiking, while others take on a month-long trek through valleys and high mountain passes. There are many trekking regions including Everest, Annapurna, Langtang, and Kanchenjunga regions. There are also important trekking sites along rivers where people go bird watching, take walks, and other recreational activities in those sites.

Trekking routes that follow rivers have been mapped as important river reaches for trekking. The trekking routes have been digitized from Great Himalayan Trial Map of Nepal (Maharjan et al., 2017), however great Himalayan trail has not been included in this analysis as this is accessible for only very few trekkers. As such important river reaches have received an HCV value of 5.

6.4.2.4 Protected Area

There are 20 protected areas in Nepal including 12 National Parks (NPs) and 1 Wildlife Reserve with their Buffer zones, 6 Conservation Areas, and 1 Hunting reserve conserving flagship wildlife, diverse assemblage of wild fauna, flora, and important natural resources of the country. About 45 percent of tourists come to Nepal to visit protected areas for recreational purpose, and big rivers in those areas are important the recreational experience.

Maintaining the natural flow regime, large rivers and associated tributaries within protected areas is critical to ensure that the natural ecosystem functions and services are delivered.

Larger rivers within protected areas are targets of recreational activities, such as hiking and trekking, and are therefore particularly important as a freshwater value. Here we defined rivers as ‘large’ if they showed a long-term average discharge above 10 cubic meters per seconds. These rivers were clipped using the boundaries of the protected areas (source) which resulted in 725 river reaches. We treated these river reaches in a binary sense, meaning that we assigned an HCV value of 5 to these river reaches, and we assigned no value for all other rivers for this particular freshwater value.

6.4.3 Livelihood values

6.4.3.1 Food and commercial values of fisheries and SIS

Freshwater biodiversity plays a significant role in supporting the livelihoods of human communities particularly people in rural and poor communities. Indigenous fishes are a key source of nutrition and income for much of the rural and fisher communities. As the riverine fisheries have various opportunities for development of fisheries and aquaculture, they are generally unrecognized and undervalued. Majority of fish species are used as food value with multiple use. Overfishing, damming, habitat degradation and destructive fishing practices are reported to have contributed to reduction in stocks. Marginal people and fishers with low income are unable to afford costly farm fishes, the capture fisheries benefit directly by increasing income and also improving nutritional status. Some riverine fishes have considered more delicious than cultured species so have high demand with good market price. The species that have high livelihoods value must be protected from threats.

Under this category, the fish consultancy group updated the list and the range maps of 165 species that had food and commercial value in Nepal based on previous work by Shrestha et al. (2008). In this list, a number of "Small Indigenous Species" (SIS) were identified and added to this list. The Small Indigenous Fish Species (SIS) are generally considered to be those fish which grow to a length of approximately 5-25 cm in adult stage in their life cycle (Felts et al., 1996). Although small in size they constitute a major part of fish caught in the inland fisheries due to their large numbers and high abundance. SIS are valuable and easily available sources of food rich in protein, vitamin and minerals which are not commonly available in other foods. Many SIS are consumed entire fish parts contributing calcium, phosphorus and vitamins as the human diet. All small fish contain large amounts of calcium and phosphorus. SIS plays an important role in livelihood to uplift the nutritional as well as socioeconomic status of fisher groups, particularly in fisher communities in developing countries like Nepal. There is considerable demand for small indigenous fishes viz. mola (*Amblypharyngodon mola*), suiya (*Gudusia sps*), tengra (*Mystus sps*), pabda (*Ompok pabda*), kotre (*Colisa fasciata*), punti (*Puntius sps*) and chela (*Chela cachius*) both in rural and urban markets. Marginal farmers and people with low income are unable to afford costly species like carps so benefited directly by increasing income and also improving nutritional status.

This value has quantitative data; therefore, higher value is provided to river reaches having higher number of species having food and commercial value (quintile mapping).

6.4.3.2 Water provision value

An important ecosystem service from rivers is to provide water for local populations for drinking water and indigenous irrigation. Many of Nepalese rivers experience periods of low flows, especially in mountainous regions, making the resource precious in areas of high demand, and vulnerable to interannual rainfall fluctuations and long-term climate change.

To evaluate the freshwater value of river flow for local consumption, we assumed that the HCV value increases with the local scarcity of the resource. For example, we assume that small rivers that provide water to a relatively large population has a higher HCV value than a small river that provides water to few, because disturbances to the local water provision can affect that population disproportionally. As such, the value for water provision was essentially a function of capacity to provide versus local demand:

$$Value = \frac{River\ Flow\ (\frac{m3}{day})}{Population\ count}$$

We first mapped population centers provided by the Department of Survey (DoS) as point locations to each river reach catchment. Since no information about the population size of the point locations were available as part of the data, we used the VDC level polygon areas as a source of population count that is based on the population census of 2011. Based on the number of population centers within each VDC area and the number of people inhabited in the VDC area, we calculated the average population count for each population center point. We then summarized the population count of all the population centers within the river reach catchment to derive a population value that was linked to each river reach.

The resulting capacity values are within a range between < 0.01 m^3 per person / day to millions of m^3. As the final step we reclassified these values using the categories outlined in Table 8, indicating that greater local water demand increases the HCV values.

Table 8: Expert mapping based on capacity of the river in relation to demand (m^3 person / day)

m^3 person / day	HCV value assigned
> 1000	1
10 – 1000	2
1-10	3
0.1-1	4
< 0.1	5

Due to the lack of data and model, we were unable to incorporate small-scale water diversions for agriculture, nor model the actual amount of water consumed for domestic use. However, our index-based assessment shows which river stretches are particularly valuable for the local population compared to other stretches.

6.4.4 Socio-cultural values

There are many river reaches in Nepal that are equally important for religious and cultural activities including cremation, sacred bathing, and other cultural and regions events. Maintenance of river flow and water quality are important to continue these socio-cultural services.

We used a database of religious landmarks based on the Topographic Data of Nepal (Buildings) by DOS (1996b). We calculated the distance from each religious site to the river and used the distance for weighting its importance. Religious site further away from the river therefore received smaller HCV values than religious sites near the river shoreline.

In addition, we used the river's size (expressed in average discharge) to weight religious sites on larger rivers higher than those on smaller rivers. This was based on the understanding that religious sites at larger rivers are typically larger, and potentially older religious sites, and are therefore more iconic, prestigious or valuable as a historic landmark than sites on smaller rivers. The calculations were conducted as follows:

$$religous\_value_i = \sum_{j=1}^{n} \left(\frac{flow_{i,j}}{flow_{i,max}} \Big/ \frac{distance_{i,j}}{distance_{j,max}} \right)$$

where $religous\_value_i$ is the religious value of river reach *i*, as the weighted sum of all religious sites *j* near the river reach *i*. As the final step, the religious values are considered as a quantitative value score and classified into HCV values from 0 to 5 using quantile classification.

6.5 Ecosystem representation analysis

6.5.1 Objective

The ecosystem representation analysis is a post-processing step conducted to validate the HCVR mapping results. In this way, we can ensure that all types of rivers are represented in our final High Conservation Rivers typology.

For this, we conducted a national-level classification of the unique types of rivers in Nepal based on a set of hydrologic, geomorphic, and physio-climatic characteristics that shape the physical template of rivers across Nepal.

The following steps were taken for this assessment:

- Review of various published literature related to river system classification
- Review of GLoRiC database (Dallaire et al., 2019), a global river classification for its suitability in Nepal
- Geomorphic classification (stream power, gradient, and order)
- Hydrologic Classification (mean annual flow, discharge variability), and
- Physio-climatic Classification (sources and physiographic region of river reach, and climate).
- Final classification of Nepalese rivers based on selected characteristics

The scope of the study includes the use of available digital resources such as available 30m digital elevation model (DEM), climatic and physiographic, and topographic map of Nepal and freely available remote sensing (RS) data (e. g. Landsat and google earth). The uses of such datasets were to make sure the river system classification was applicable and practical at the national scale.

After the river classification was conducted, we calculated how many river types were included in the HCV mapping, and to what extent they were included.

6.5.2 Introduction to river classifications

River classifications can provide opportunities to better understand river ecosystems and their function, highlight similarities or differences between climatic or physiographic regions, allow for international comparisons of freshwater resources, enable assessments of the representation of system types, and frame other analyses. Some general river classifications have been made in Nepal based on the river/stream origin, stream order, and general physiography.

Building of the concept of (WECS, 2011), Bennett et al., (2016) introduced a slightly different classification of streams that incorporates both physiographic zones and climatic features in order to characterize stream hydrologic response, effect on water supply consistency throughout the year and sediment transport. The result is seven different stream classifications of which six could only mapped. They are 1. Antecedent Stream, 2. Glacial-fed streams, 3. Intermittent Streams, 4. Snow-fed Streams, 5. Rain-fed streams, 6. Siwalik Streams and 7. Terai Streams. Building on the concept of WECS (2011), Bennett et al., (2016) introduced a slightly different classification of streams that incorporates both physiographic zones and climatic features in order to characterize stream hydrologic response, effect on water supply consistency throughout the year and sediment transport. The result is seven different stream classifications of which six could only mapped. They are 1. Antecedent Stream, 2. Glacial-fed streams, 3. Intermittent Streams, 4. Snow-fed Streams, 5. Rain-fed streams, 6. Siwalik Streams and 7. Terai Streams.

Classification of river systems is imperative to distinguish spatial and temporal disparities and is a basic way to recognize a river's complexities (Zhao and Ding, 2016). The classification of river systems or the river networks are also important from the conservation point of view. River classification is the first step in understanding the complexity of rivers and it also serves as an essential component of river management. Classification of river systems always have importance for water conservation as well as ecosystem restoration.

River classification is important (Zhao and Ding, 2016) because it:

- Provides a basic unit for river management by dividing the river network into reaches with similar structures and functions
- Carries out resource cataloging according to river types, and to target different management goals for each river type
- Facilitates biological/ecological monitoring research design
- Chooses typical reaches to monitor to understand their structures, behaviors, and function characteristics, which are extrapolated and applied to other similar reaches in the end
- Promotes the communication between scholars and administrators with different backgrounds
- Establishes the 'reference state' for each river type, i.e., the basis of river design
- Extracts the rules from same river types and predicts behaviors of rivers. Above all these points, important scientific value for river management is embodied by river classification.

Classification of river networks or river systems contribute to river conservation and management in various ways. For this reason, researchers around the globe have proposed different methods for river system classification. For example, Schumm (1977) recognized three geomorphic zones within a watershed based on the sediment transport process: erosion, transport, and deposition zone. He also provided a conceptual framework to couple channel type and channel response potential. Brussock et al. (1985) developed a hierarchical system for large rivers that linked the river channel shape and the community structure. Many other approaches have been adopted by Frissell et al. (1986), Rosgen (1994), Montgomery and Buffington (1997), and Thorp et al. (2010).

6.5.3 Methodology

Initially, this work has been awarded to Forum for Energy and Environment Development (FEED Pvt. Ltd.), and further revision has been made based on comments from Advisory Group meetings. GIS tools and RS data were used to determine the major river types of Nepal along with the available data from the HydroSHEDS river network. Moreover, empirical models were used to classify the river system for the hydrologic, geomorphic, and physio-climatic classification of the rivers.

Pertinent scientific articles, government documents/reports and other publications related to geomorphology, hydrology, classification of river, and river ecology were collated and reviewed. In order to classify the given river network in the context of Nepal, following documents and dataset have been reviewed:

- GloRiC documents (World's river system classification related publications, legends)
- Digital maps/images provided (river network, DEM)
- GloRiC data (DEM, river network, flow accumulation, flow direction)
- Published scientific and government documents/reports
- Remote sensing images (MODIS, Landsat and Google Earth).

The available database and relevant documents were reviewed and accessed for their usefulness to contribute to a river type classification in the context of data scare situation. Data from the GloRiC database such as annual (mean) river discharge, river order, stream-power, were reviewed or enhanced to produce a river type classification appropriate for Nepal.

This study established a comprehensive model with the application of GIS, RS, and empirical methods (Figure 29) to classify river network in terms of hydrologic, physio-climatic and geomorphic classes.

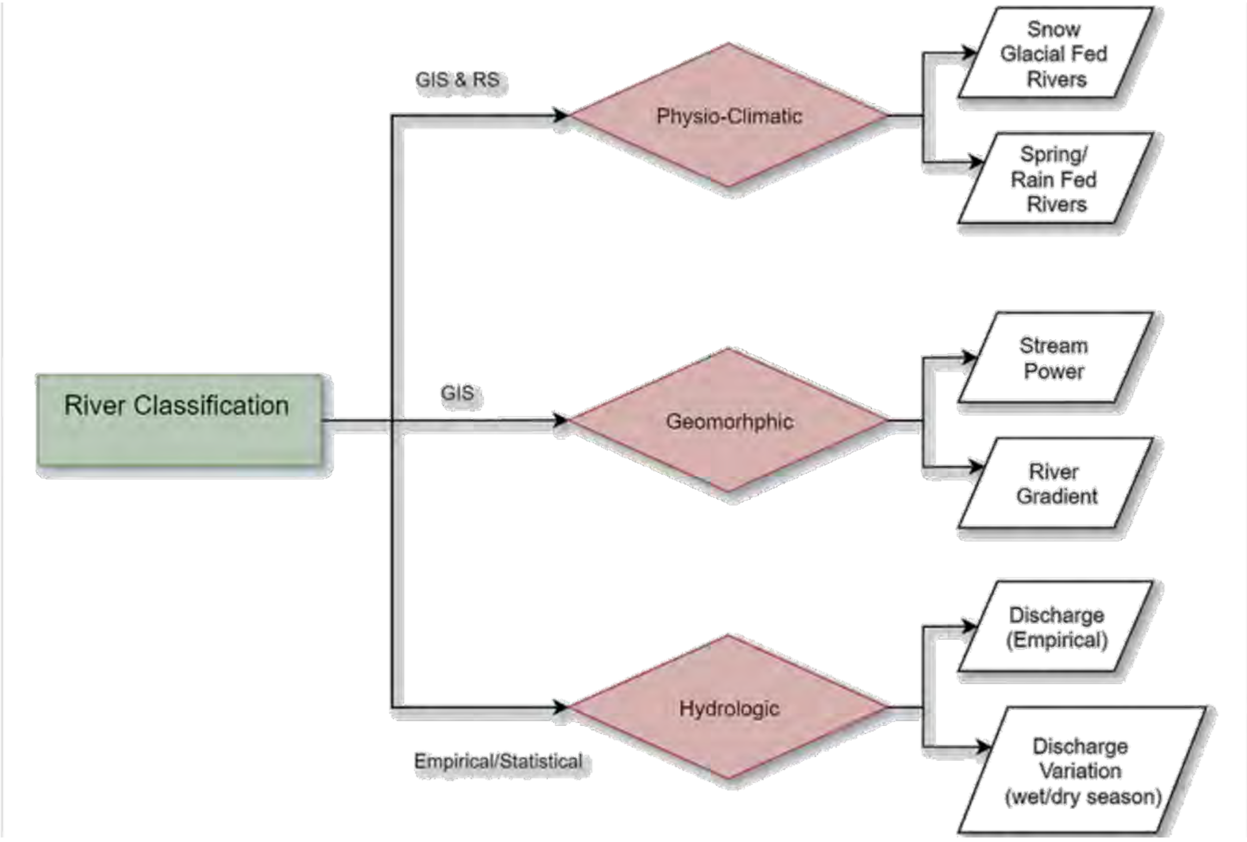


Figure 28: Methodological framework for river classification.

6.5.3.1 Physiographic Classification

The physiographic division of Nepal is unique which is mainly controlled by altitude (Rai and Gurung, 2005) and are runs through east to west as of the hills and mountains. The unique environment of Nepal's physiography demonstrates exclusive climate and geomorphology within a narrow north-south width of the country.

This physiographic classification of Dahal and Hasegawa (2008) has been selected based on the suggestion from Advisory group meeting. It has also been used by Bennett et al. (2016) in the natural resource baseline assessment for Nepal. According to our purpose of river classification, we further grouped Inner and Trans Himalaya, Fore Himalaya, and Higher Himalaya into Himalaya physiographic region as these three regions possess similar physiography.

Himalayan region of Nepal is the origin of major rivers and runs through different physiographic zones until it reaches River Ganga in northern India. Considering the location of rivers on which they flow, rivers in Nepal have classified according to the physiography as: Himalayan River, Midland River, Mahabharat River, Churia River, Dun Valley River, and Terai River (Figure 30).

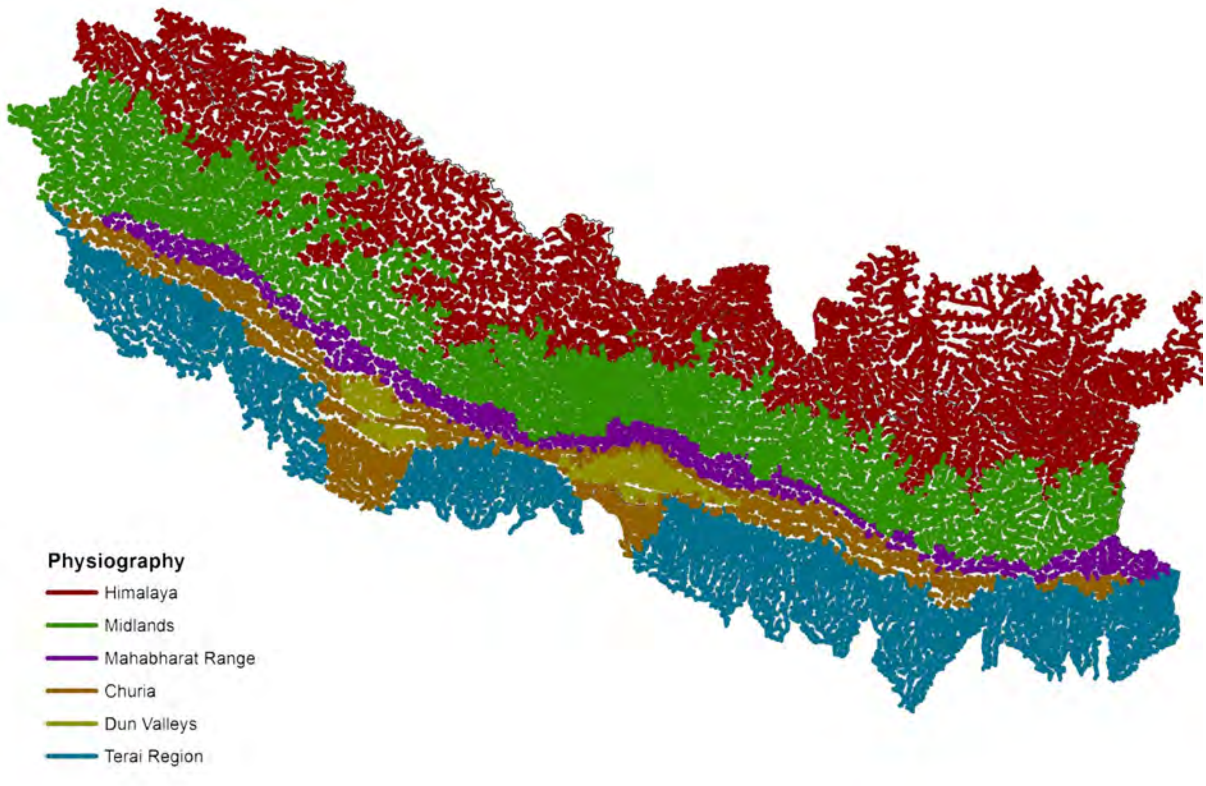


Figure 29: Physiographic Classification for River Classification for Nepal.

6.5.3.2 River Source / Influence

Rivers in Nepal can be classified into three broad groups based on their origin (WECS, 2005). The first group of rivers is snow fed among the main rivers— Koshi, Gandaki, Karnali, and Mahakali. They originate from snow and glaciated regions in the Himalayas. As a result, flow in these rivers is perennial with sustain flow during the dry season. These rivers are reliable source of water and also provide potential opportunities for hydropower generation, and irrigation.

The eastern part of the country, the snow-fed rivers are drained by Koshi River, which has seven major tributaries—Tamor, Likhu, Dudhkosi, Sunkosi, Indrawati, Tamakosi, and Arun. The principal tributary is Arun, which rises about 150km inside the Tibetan Plateau. The Gandaki River (also known as Narayani) drains the central part of Nepal and has seven major tributaries— Daraudi, Seti, Madi, Kaligandaki, Marsyandi, Budhigandaki, and Trisuli. The Kaligandaki, which flows between Dhaulagiri Himal and Annapurna Himal, is the main river of this drainage system. Its three immediate tributaries are the Bheri, Seti, and Karnali rivers, the latter being the major one. The river draining the western part of Nepal is Karnali. The Mahakali, which is also known as Kali River and flows along the Nepal-India border in far west.

The second group of rivers originates in the middle mountains and hilly regions. Their flow regimes are affected by both monsoon precipitation and groundwater (i.e., springs). Contribution from groundwater yield maintains the minimum flow level and prevents from drying during non-monsoon periods. The Bagmati, Kamala, Rapti, Mechi, Kankai, and Babai rivers fall into this group.

The third group of rivers originates in Siwalik zone. Tinau, Banganga, Tila, Sirsia, Manusmara, Hardinath, Sunsari, and other smaller rivers fall in this group. The flow in these rivers is mostly dependent on monsoon precipitation and their flow level could deplete significantly during the non-monsoon period. Summer monsoon (Jul-Sep) is an important period when about 60-85% of annual runoff of all river systems in Nepal occurs.

The rivers originating in the Siwalik Hills and further south in the Terai region are seasonal and mostly depending on the monsoonal rain (Jun-Sep) and remains dry rest of the months.

Under this assessment, we classified rivers as glacial, snow, or rain influenced based on the contribution of glacial or snow in the discharge of rivers.

For the snow contribution, data has been taken from Muhammad and Thapa (2020) based on Terra-Aqua MODIS snow cover data of 2018.

Glacial data has been taken from ICIMOD (2010) and the glacial and snow cover is seen in Figure 31. This dataset was created by ICIMOD using Landsat TM, ETM+ imageries of 2010. The glacier outlines were derived semi-automatically using an object-based image classification method separately for clean ice and debris cover. Further editing and validation was done carefully by draping over the high-resolution images from Google Earth.

Due to the lack of reliable hydrological models for the study area, a simplified method was developed to categorize rivers based on river source and hydrological influence. At any point in the river network, if the accumulated upstream glacier area is at least 5% of the total upstream area, then the river source is classified as 'glacier'. If upstream snow area is at least 15% of total upstream area, then river source is classified as 'snow'. In other cases, the rivers source was classified as 'rain'. Based on expert advice, we classified larger rivers (order greater than 5) as 'glacial and snow' origin as this is difficult to separate the two components conclusively into either a snow or a glacial category.

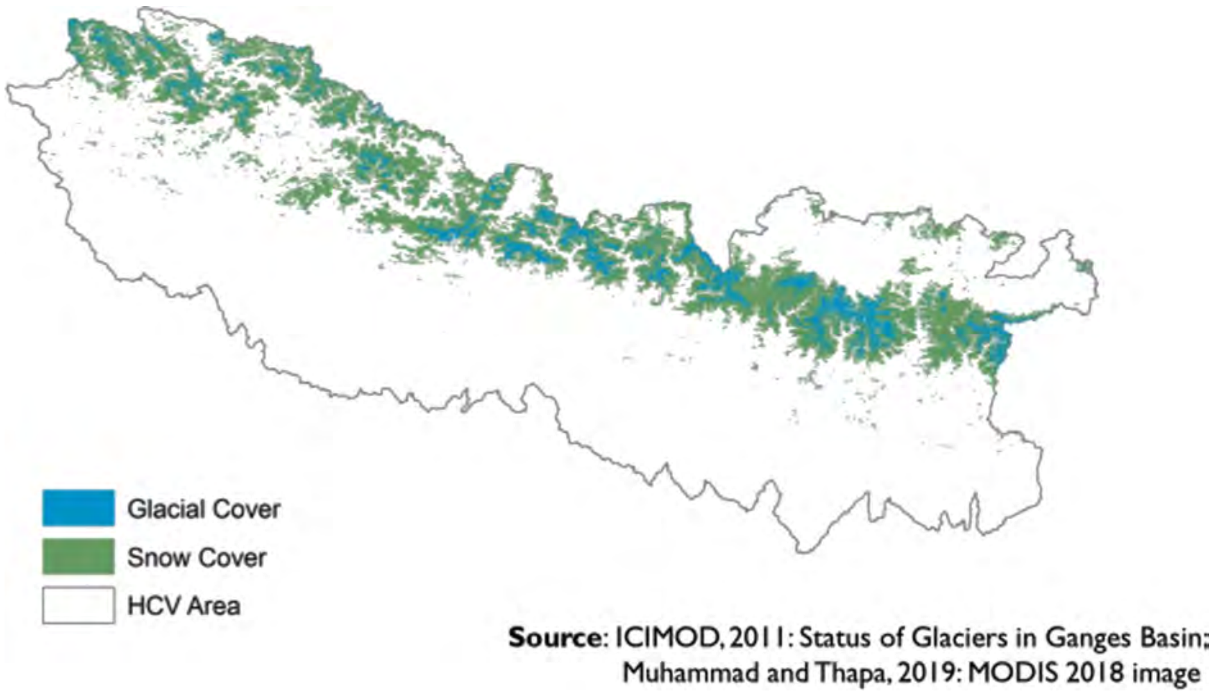


Figure 30: Glacial and snow cover in Nepal.

The results of this classification can be seen in the Figure 31. The rivers draining from the Himalayas and High-hills are mostly snow fed, which contains reliable flow. Snow contribution is insignificant in the river below 3000 masl (WECS, 2011). Those rivers draining from Mid-hills, Siwalik, and Terai are mostly rain fed.

The available annual mean discharge from GloRiC database was used for hydrologic classification and source identification. A heuristic approach has been adopted and the assumption was made that the first and second order streams in the higher altitude (~above 4,000 masl) are major snow fed channels. These low order channels as drains downstream get merged with other channels, subsequently increasing the order and discharge. The snow-fed rivers are perennial that contains reliable flow, while the rivers originating in Mid-hills, Siwalik, and Terai are rain fed and highly variable in discharge (WECS, 2005 WECS, 2011). Depending on the altitude and MODIS snow cover map, the high altitude (Himalayan and High-Hill) river channel sources are expressed as snow fed. As the river drains further south in Mid-hills, Siwalik, and Terai regions, the river discharge is increasingly contribution by rain. This study suggested snow-fed and rain-fed rivers in terms of sources respectively draining in the snow cover regions (e. g. Himal and High-hill) and the rivers draining from Mid-Hill and southern physiographic regions.

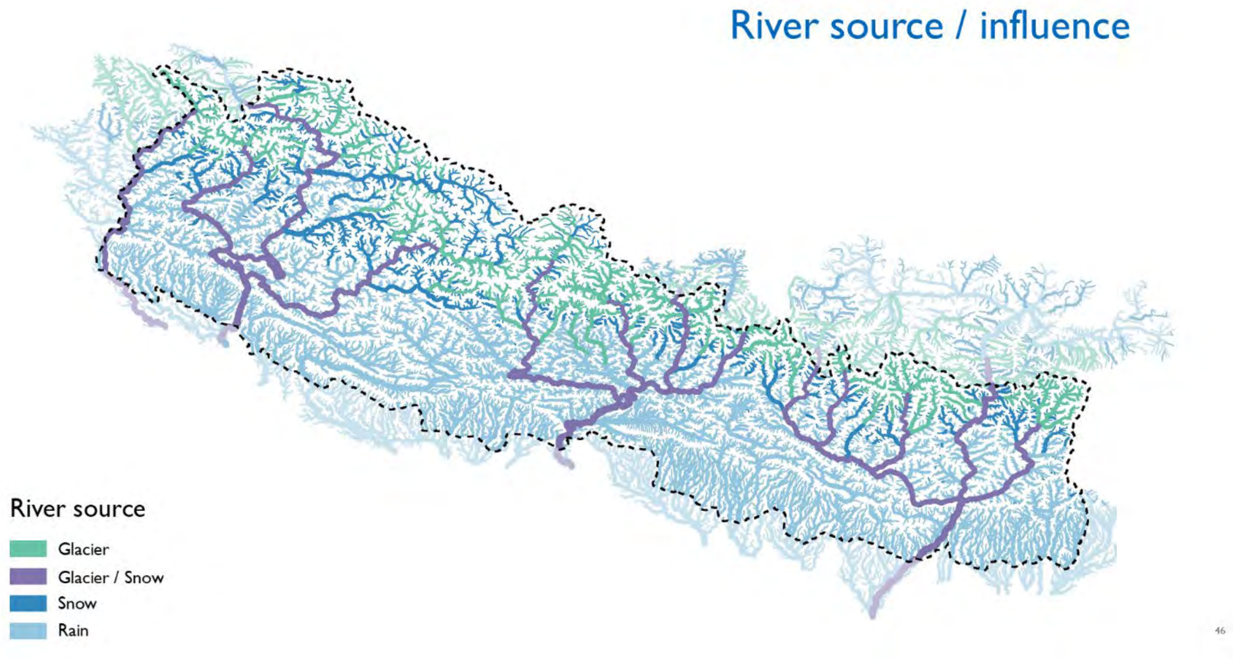


Figure 31. River classification based on source.

6.5.3.3 Geomorphic Classification

In this study river order (i.e., Strahler river order) have been determined. According to the "top down" system devised by Strahler, rivers of the first order are the outermost tributaries. If two streams of the same order merge, the resulting stream is given a number that is one higher. River order was manually entered in to the attribute table in GIS to maintain the consistency of given river network and to justify the Strahler (1964) approach. Further, considering the river order, the river reaches were classified into three broad groups:

- Large: ≥ 6th order stream
- Medium: 4th and 5th order stream
- Small: ≤ 3rd order stream

The rivers in the initial stage in Himalayas are the first order stream or the head rivers, as flows downstream tributaries comes across that increases the river order and the discharge (Figure 33).

6.5.3.4 River Classification

For the final grouping into river classes, we combined the selected hydrologic, physio-climatic, and geomorphic attributes of Nepalese rivers — river size, physiography, and river source/influence — into a set of river types. Each of the identified components of the groups could form their own river type. For example, one of the 29 identified rivers classes are "Large, rainfall dominated rivers of the Midhills". The results of the classification and the application of the river classification for ecosystem representation analysis is described in section 7.4.

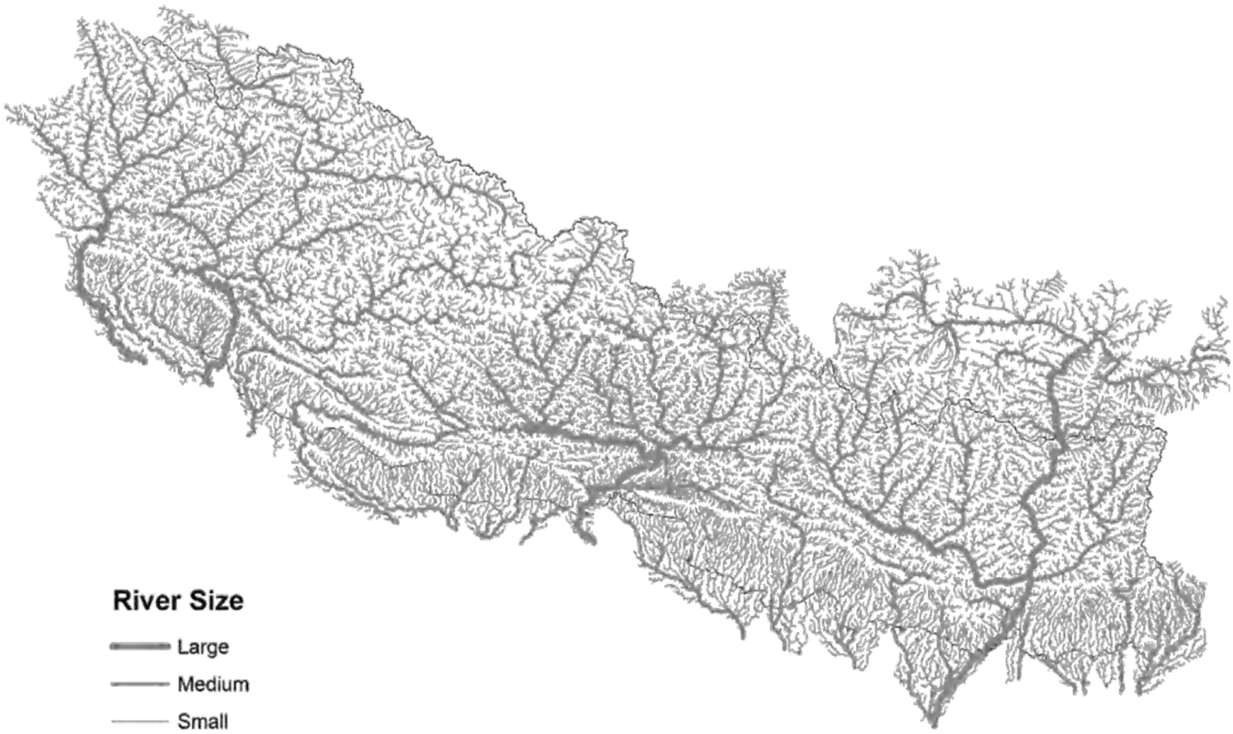


Figure 32. Geomorphic component of river classification based on size (Strahler stream order system)

7 Results

7.1 Freshwater status

7.1.1 Free-Flowing Rivers Assessment

The Free-flowing river assessment shows three types of results for the rivers of Nepal. The first type of result is a map of the Connectivity Status Index (CSI) showing a quantitative measure of connectivity for each river reach of Nepal's rivers and beyond (7.1.1.1). The second type is related to the CSI and shows which of the 6 subcomponents of the CSI was the driving force (had the most weight) for the calculation of CSI index. This is called the "Dominant Pressure Factor" (DOM; 7.1.1.2). The third type of result is a derivative of the CSI and classifies the rivers of Nepal into either free-flowing or non-free-flowing rivers using a CSI threshold (7.1.1.3). This classification result in one of the components of the Freshwater status (Connectivity) and is used for the final HCVR typology.

7.1.1.1 Connectivity Status Index

The results of the Connectivity Status Index (CSI) assessment are shown in Figure 34. Rivers in blue shades are those that have not been affected by the loss of connectivity given the pressure factors used in our assessment. These rivers are mostly remote rivers of the Himalayan range, which are generally untouched by human development or larger infrastructure.

Other river reaches, colored from green to yellow to red show increasing levels of pressure from one or a combination of six pressure factors used in this assessment: a) River fragmentation, b) flow regulation, c) sediment capture, d) water consumption, e) urban development, and f) road construction (see methodology section in section 6.2.1 form more details).

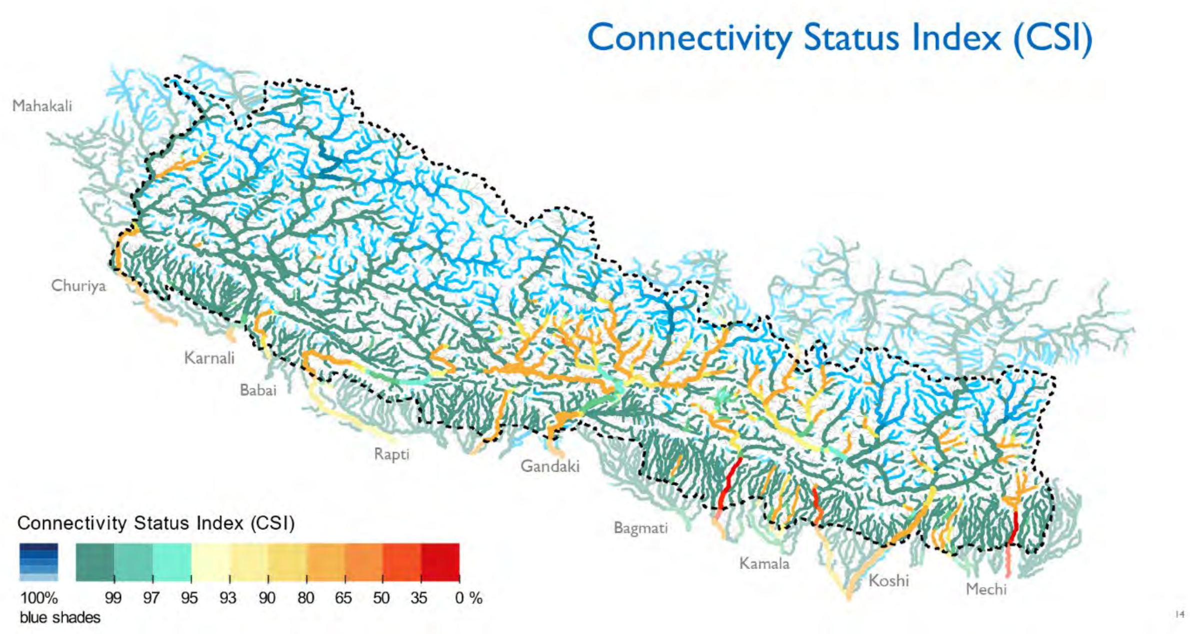


Figure 33: Connectivity Status Index (CSI)

The three shades of green are used for river reaches that show some degree of impact, for example from road development, urban areas, or water use. However, these rivers are still considered relatively intact, as they fall above critical threshold that was used in Grill et al., (2019) to distinguish major impacts from minor impacts. Most rivers fall in this category, including most of the rivers in the midlands and the Terai and adjacent regions.

A smaller number of river stretches show more severe losses of connectivity, indicated by the yellow and orange colors. These typically river stretches that were affected by dam effects such as river fragmentation, flow regulation, sediments capture, or a combination of the three. The other three factor may contribute further to reduce the CSI in these river stretches. We see from the maps that these river stretches correspond to river stretches on and upstream or downstream of river stretches with existing hydropower or other dam projects. Rivers most impacted by the losses of CSI are major sections of Gandaki river, the Bagmati river, parts of the Koshi river basin and tributaries and stretches of the Babai, Rapti, and Mechi rivers.

7.1.1.2 Dominant Pressure Factor

The Dominant Pressure Factor, or DOM, essential describes the main pressure factors responsible for the loss of connectivity in each river reaches (Figure 35). The DOM does not indicate the magnitude of impacts, only the type of impacts, and should therefore be interpreted together with the CSI results, which show the magnitude of losses. Like in the CSI map, the blue shades refer to rivers that are unaffected by the loss of connectivity.

On the other hand, all river stretches that have CSI values below 100% also show which (if there were several) pressure factor was most dominant at the location. River reaches that show low levels of CSI losses (CSI > 95% to < 100%) are mainly having pressures from road construction (RDD; green), for example throughout the mid-hills or lowlands, or from water use (USE; grey), for example in major arteries of the Karnali river. These impacts are generally considered minor, and do not signify major impact or influence the status of the river as free-flowing. Similarly, urban areas (URB; black) can play a role locally, for example around the Kathmandu area or for induvial reaches nearby other urban centers.

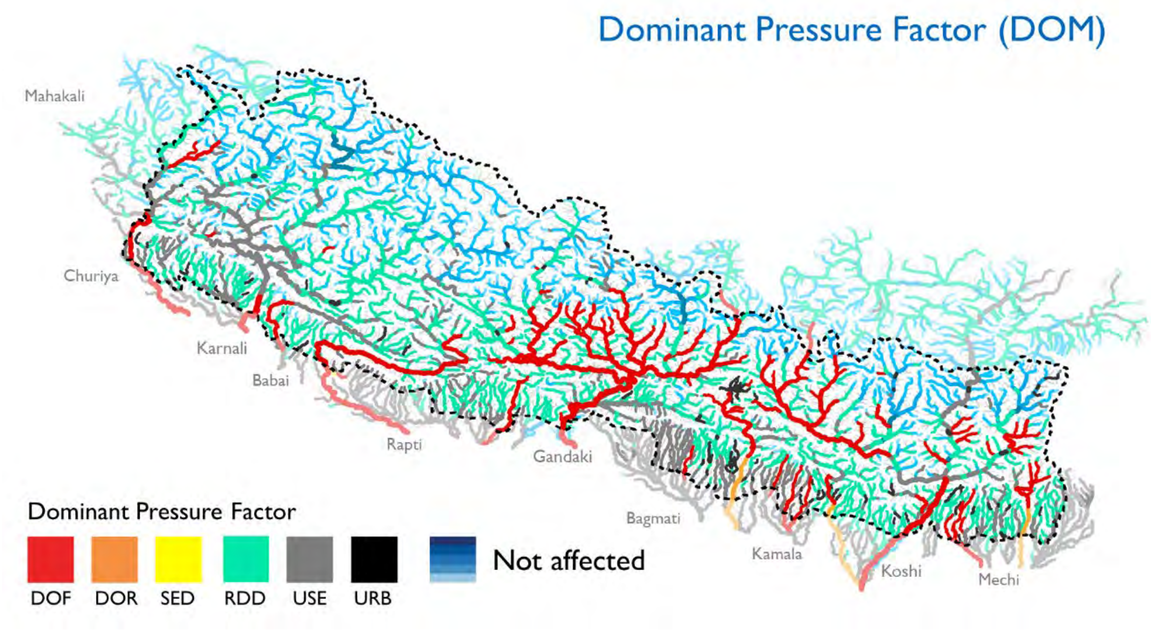


Figure 34: Dominant Pressure Factor (DOM)

If major losses of connectivity occur, the reason is typically dam effects, such as river fragmentation, flow regulation, or sediment capture. We see that the rivers of Nepal are primarily affected by river fragmentation (DOF; red color), as river structures block the longitudinal flow migration pathways. Flow regulation from dam operations (DOR; orange) does not play a major role, because many existing dams do not have major storage that could regulate river flow in a major way. Similarly, due to the small reservoir, sediment capture does not play the major role in many river systems but can significantly to contribute to lowering of river connectivity.

7.1.1.3 Free-flowing River Status

The map in Figure 36 shows the result of the categorization of rivers into free-flowing, or non-free-flowing. Free-flowing rivers are shown as blue colors in the map. These are rivers that showed no, or low levels of CSI losses throughout the entire river, i.e., the CSI index was found to be above 95% from source to the next major confluence. As road effects or water use do not play a major role in lowering the CSI score below the 95% threshold, we can see that despite low levels of impact, most rivers in Nepal, particularly in the Karnali river, can be considered free-flowing.

If major impacts occur anywhere within a river (CSI <95%), the river is non-free-flowing but will show sections that are "impacted" (red) or "good connectivity" (CSI <95%). The red sections are typically those with dams and major impacts can occur both upstream and downstream of a barrier, in both directions, in cases up to several hundred kilometers. As such we can see many rivers that are colored red, which means they have been impacted by river fragmentation in combination with other factors, such as flow regulation or sediment trapping.

The Karnali river basin may be considered as one of the very few major rivers that is almost completely free-flowing, including the main stem and major and minor tributaries, a unique characteristic for Himalayan rivers and worldwide.

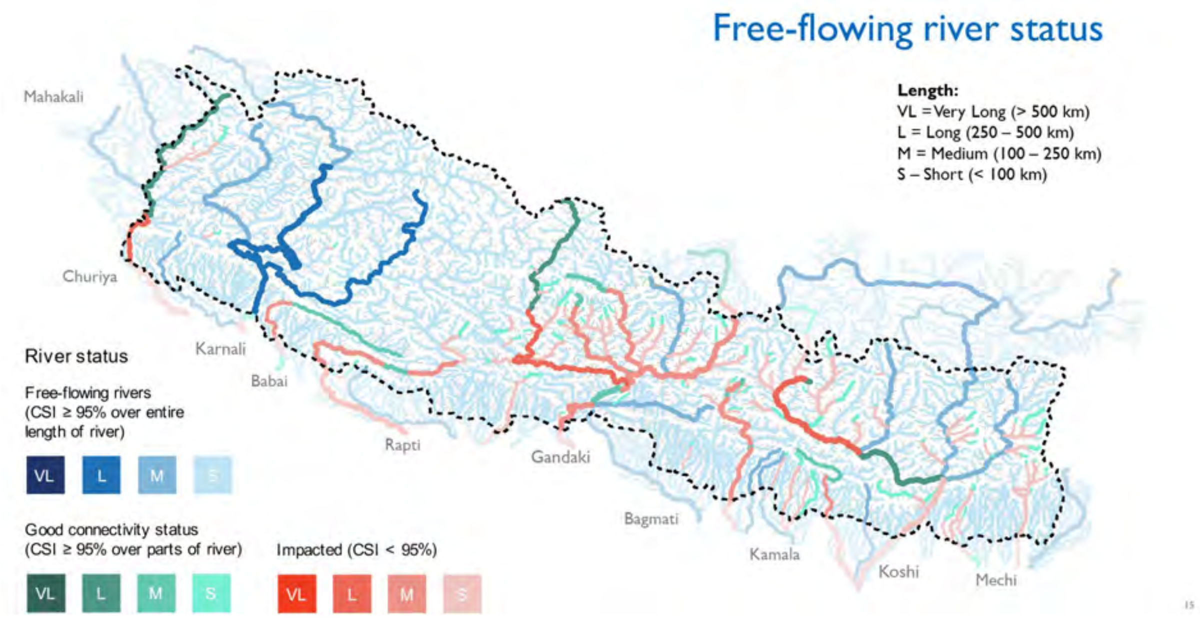


Figure 35: Free-flowing river status in Nepal.

7.1.2 Water quality pressures assessment

The two methods, the machine learning method and spatial accumulation method, provided results for individual indicators and then allowed to create an integrated index (i.e., WQPI).

The machine learning method allowed to predict average nitrate concentrations in all rivers in Nepal and to measure the relative importance of different covariates (i.e., environmental data). Variable importance is measured on a scale from 100 (very important) to 0 (not important) (Figure 36). We found that upstream normalized nitrate application (West et al., 2014) and upstream population are most important covariates. Figure 37 shows the partial variable importance. Thus, it is clear that the model predicts higher nitrate concentrations for reaches with more upstream nitrate application and higher normalized upstream population. For upstream accumulated population, the relation is non-monotonic. I.e., the predicted nitrate increases up to a certain value and decreases thereafter. This is likely because of dilution effects – if we just count upstream population, then large rivers will have very large upstream populations, but also very large drainage areas and discharge, which leads to an increasing dilution.

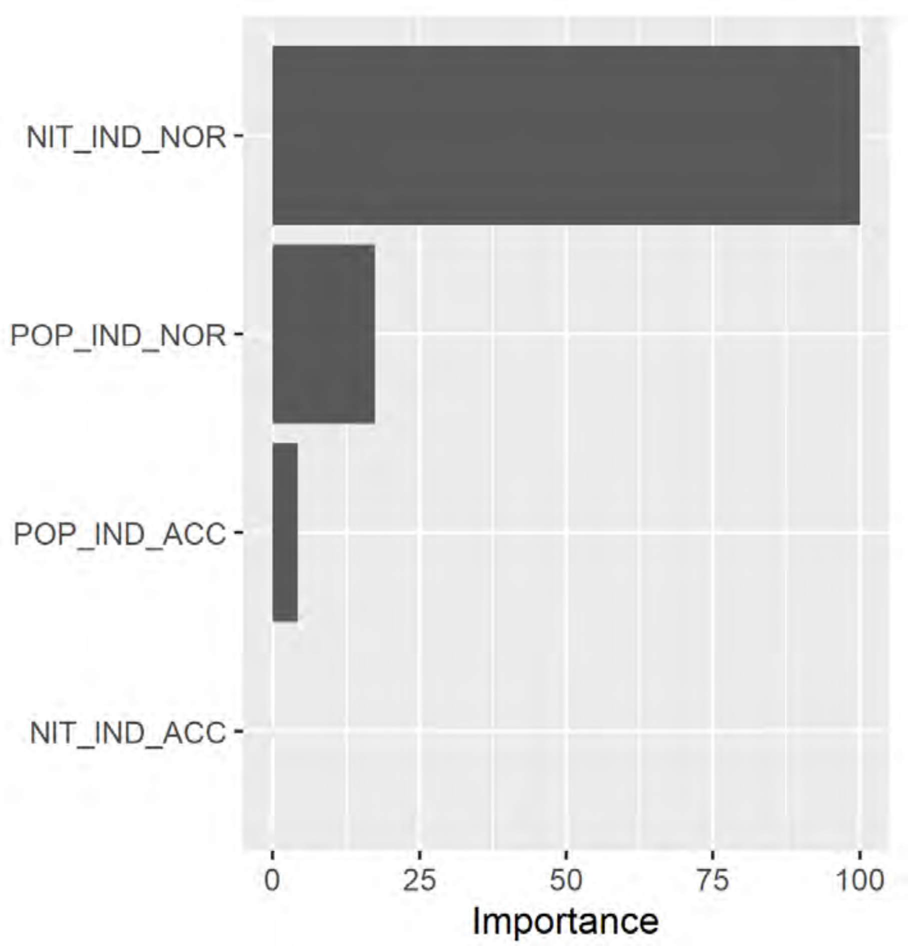


Figure 36: Most important covariates for the nitrate model. The importance score describes how important covariates are to describe observed nitrate. Labels are: Nit_Ind_Nor: Upstream nitrate application rate, normalized by drainage area. Pop_Ind_Acc: Accumulate d upstream populations, Pop_Ind_Nor: Pop_Ind_Acc_normalized by upstream drainage area.

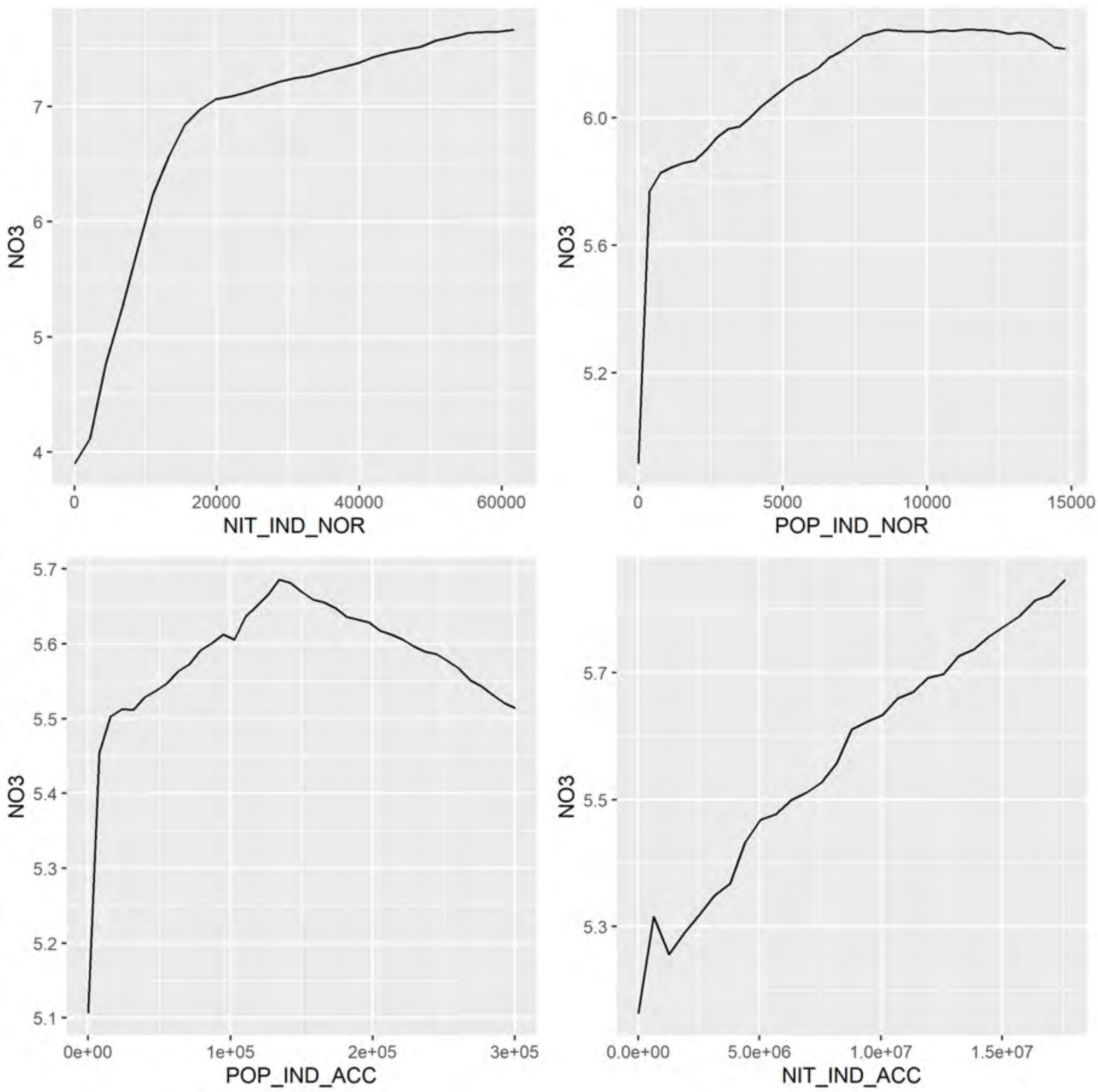


Figure 37: Partial variance importance plots for the nitrate model. Each plot shows the correlation between an individual covariate (ranked by their importance) and the nitrate response.

The results of the normalized index were different for each water pressure indicator (Figure 38). However, in general, the Himalayas region has the lowest WQPI (i.e., least water quality pressure), while the Terai region has the highest index (i.e., highest water quality pressure). The WQPI follows this trend as well (Figure 39). Based on the WQPI, we identified "poor" and "very poor" rivers as "inadequate" to support healthy aquatic systems sustainably (i.e., river stretches with a WPI of 3 or higher; Figure 40). The threshold was used in the HCVR assessment to help distinguish HCVR types. The major rivers that met the threshold of "inadequate" were Babai, Bagmati, Kamala, and Mechi.

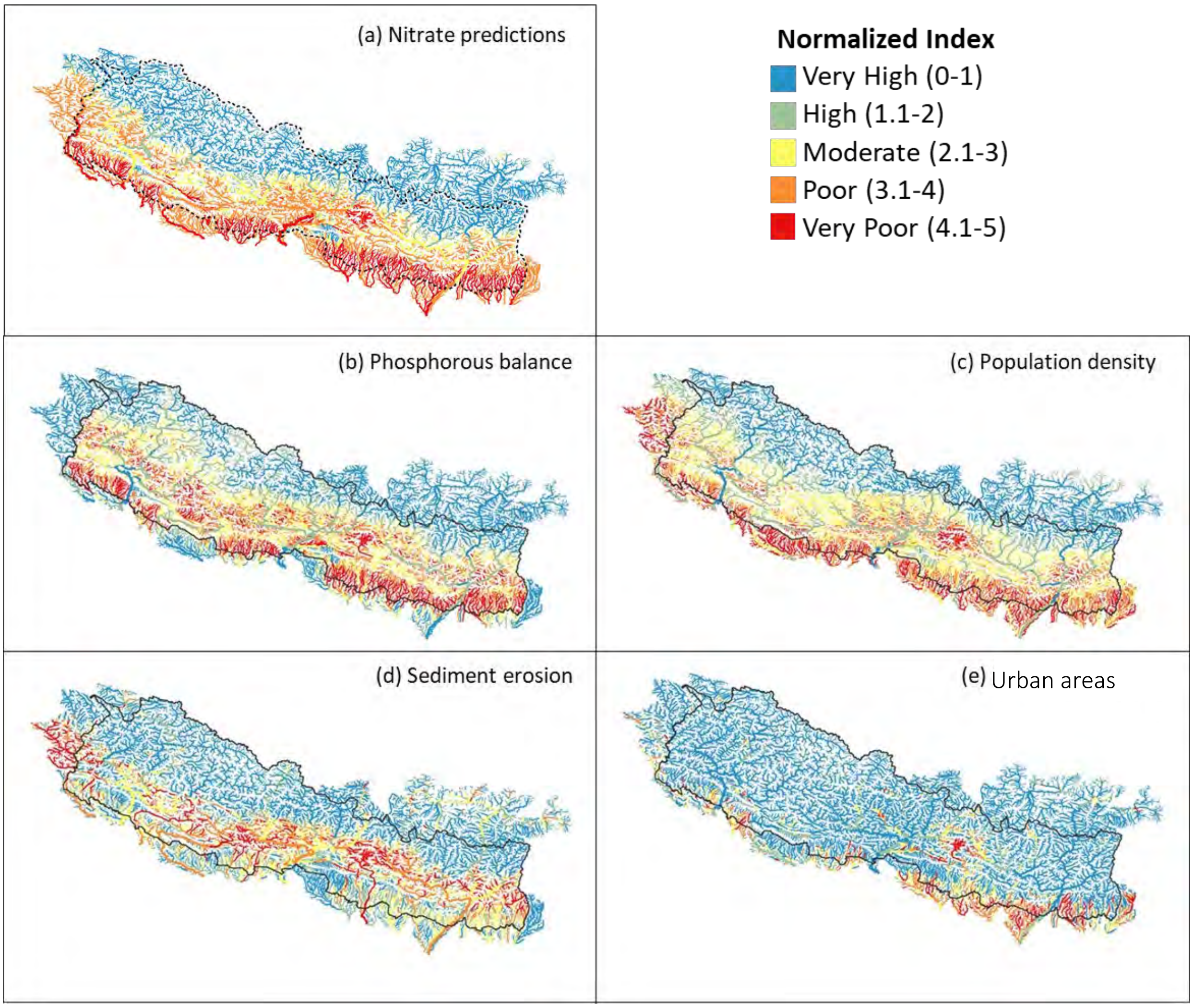


Figure 38. Normalized index for five pressure (a-e) indicators used to calculate WQPI.

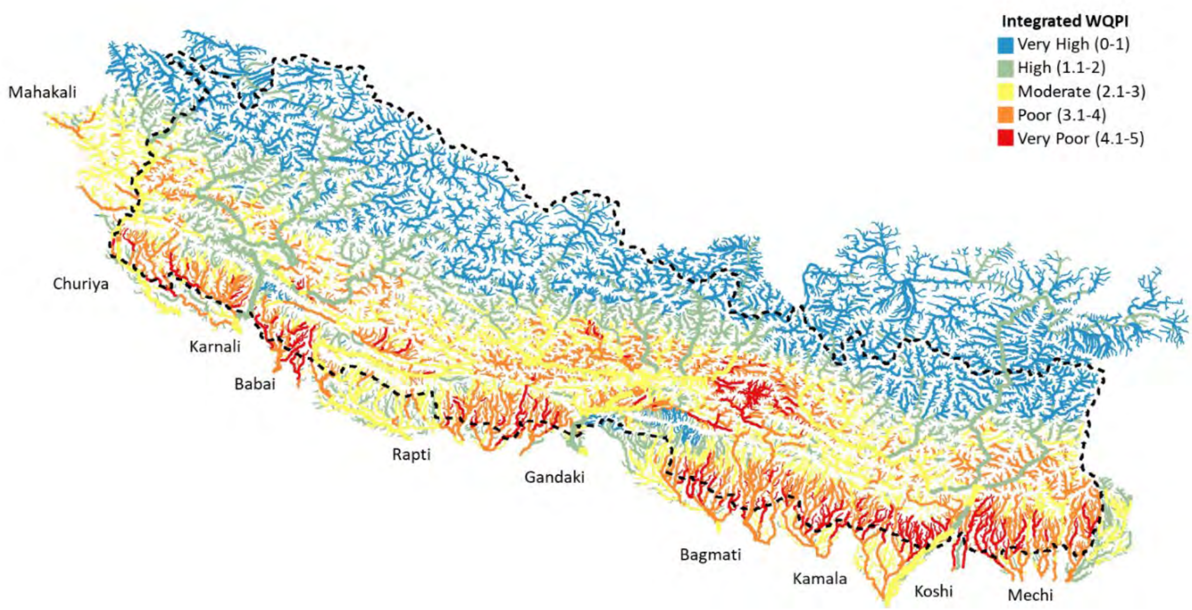


Figure 39. Integrated water quality pressure index (WQPI).

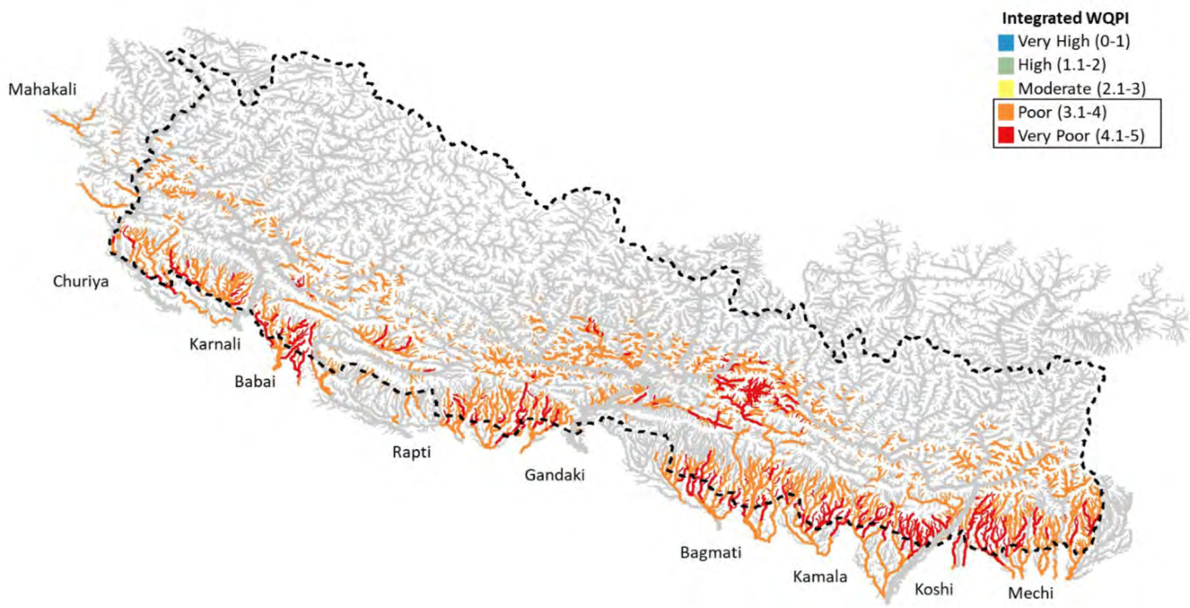


Figure 40. River reaches meeting the “poor” or “very poor” threshold.

7.2 Freshwater values

In this assessment, the Karnali, East Rapti, Sunkoshi, Seti, and Naryani rivers are found to have high freshwater values across both social-cultural and environmental dimensions. The component values that lead to this conclusion are described in the sections that follow.

7.2.1 Biodiversity values

Lowland river reaches of large rivers are found to have high biodiversity value. These include the Koshi, Karnali, Naryani, and East Rapti Rivers. The factors that feed into the biodiversity value score are listed below.

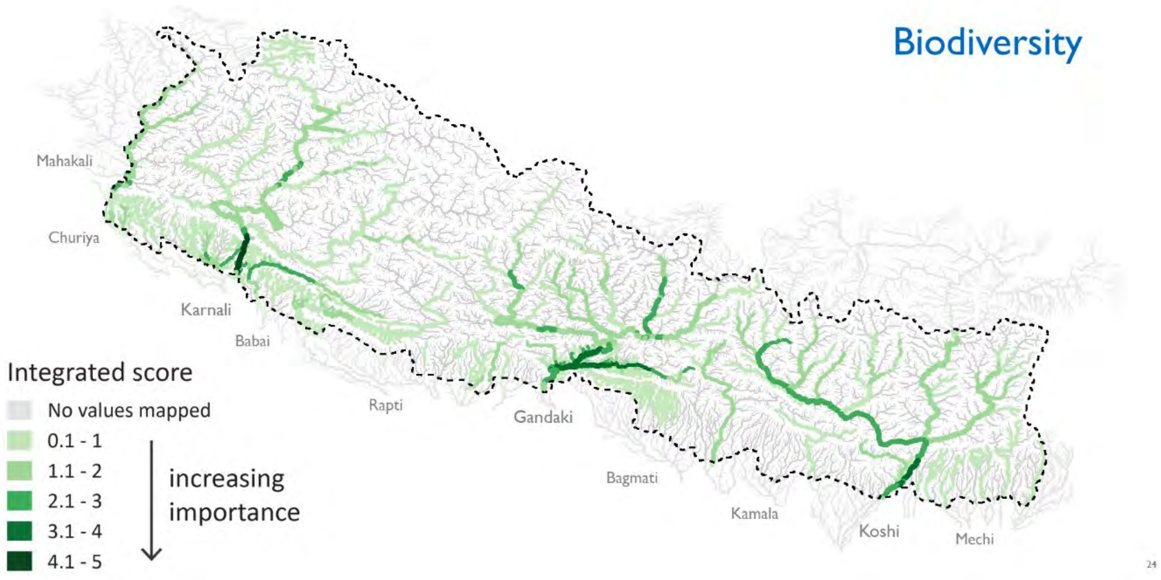


Figure 41: Biodiversity value scores

7.2.1.1 Aquatic Biodiversity

7.2.1.1.1 Fishes

An extensive review of museum and government records showed 256 fish species including both native (n=240), and exotic (n=16) species that belong to 108 genera, 39 families and 14 orders in the river systems of Nepal. Native fish fauna have been recorded from 60m to 3,323m elevation above sea level (Shrestha, 1995). A total of 190 voucher specimens of fish had been recorded in various museums of the country that included Fisheries Research Division of NARC, Central Fisheries Promotion and Conservation Center (CFPCC) of MoALD NARC, Central Department of Zoology-Tribhuvan University, and has recorded in abroad universities (Kansas State University, California Academy of Sciences, Yale University, National Museum of Natural History Smithsonian Institution).

7.2.1.1.2 Fish Richness

Spatial distribution of the fishes showed the major river systems of Karnali, Gandaki, Koshi have a rich fish diversity. Out of the all mapped 256 species of fishes, we recorded up to 201 species of fishes in some river stretches of Nepal, pointing to several hot-spots of fish biodiversity. These include stretches of the Lower Karnali, Narayani, Kaligandaki, Koshi, and Sunkoshi Rivers (Figure 44).Figure 43). Out of 240 native species, Koshi, Gandaki and Karnali river system consist of 211, 208 and 178 species respectively. Similarly, the Mahakali river system also harbors 171 species. The Mahabharat and Churia originated rivers. Similarly, Mechi, Tamor, Kamala, Babai, Lohandra, Dudhkoshi, and Triyuga river have 68, 69, 37, 56, 38, 35 and 71 species respectively which are originated from Mahabharat and Churia region. Endemic fishes have been recorded in the tributaries of the major river system such as *Psilorhynchus pseudecheneis* in Dudhkoshi river, *Pseudecheneis crassicaudata* in Mewa khola, Garra nepalensis in Mardi river, and Balitora eddsi in Geruwa river, a tributary of Karnali. The location of tributaries plays an important role in determining the habitat suitability for fish species. Sharma and Jha (2012) found that the habitat conditions in the upper reaches of the Indrawati sub-basin and its tributaries are suitable habitat for hill stream fishes like *S. richardsonii, S. beavani, P. pseudecheneis* and *M. blythii* that love moderate to high current of water.

The review showed that a total 117 fish species have been reported in the Bagmati river basin. Shrestha (1990) reported 26 species in the upper river stretch in the Bagmati river which included the area between Sundarijal and Kulekhani khola confluence. However, the aquatic environment is deteriorating in the river stretch within the Kathmandu valley which may threaten this diversity. The Bagmati river basin is facing numerous serious environmental and ecological challenges, particularly in the river stretch inside Kathmandu valley since a few decades. Direct discharge of untreated wastewater and solids waste in the Bagmati river in the upper sub basin has degraded the quality of surface water beyond acceptable limits that directly impacted on the aquatic biodiversity of the downstream sub basin. Recent studies have found a large portion of Bagmati river is polluted heavily which has indicated through records of very low dissolved oxygen level (>5 mg/l) and high biological oxygen demand (BOD) (<15 mg/l) (Mishra et al., 2017; Regmi & Mishra,2016). This indicates that the quality of river water is extremely poor and not suitable for aquatic life.

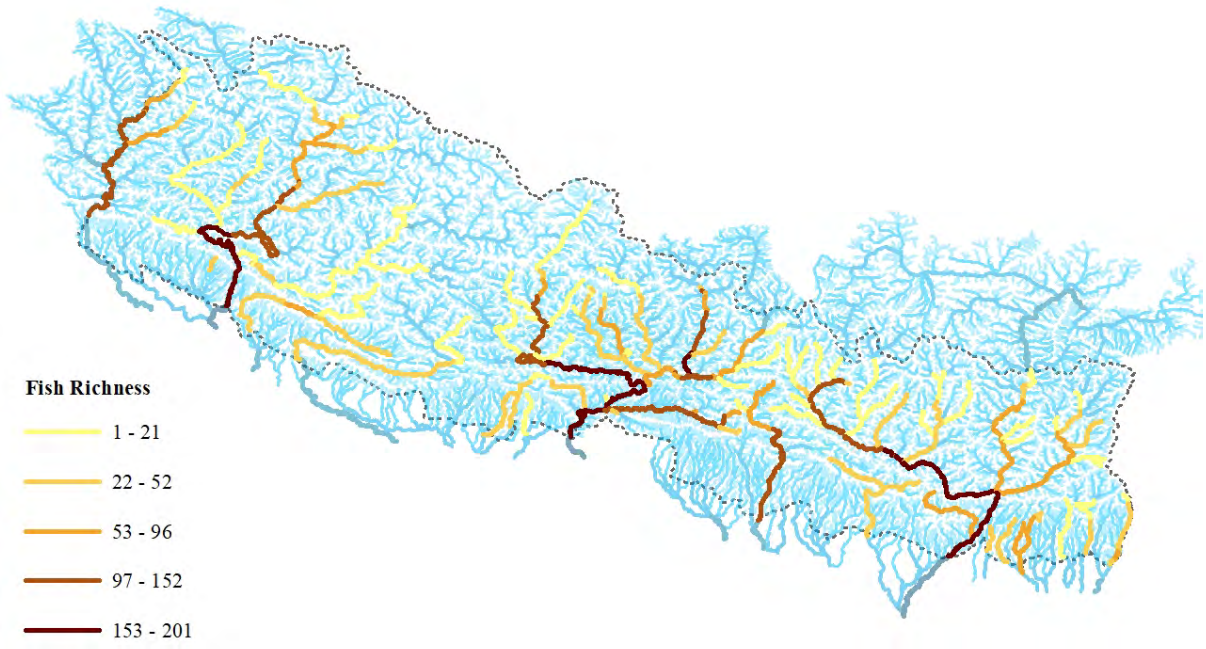


Figure 43: Fish richness in Nepalese rivers.

7.2.1.1.3 Endemic Fishes

This study identified 15 species endemic to Nepal, based on the thorough review and series of consultation with fish experts of the country. Table 9 and Figure 44). Kaligadaki in Midlands, Narayani, Koshi, and lower reaches of Sunkoshi rivers are found to have a higher number of endemic species. Due to lack of nationwide systematic survey of fish, still it is difficult to establish an exact number of the endemic species. Shrestha (2011) has reported 15 endemic species and Rajbanshi (2012) has listed 16 endemic species wherever recently Shrestha (2019) has reported 16 endemic species. Shreatha (2011) has included *Pseudeuotropius murius baterensis* in the list of endemic species but many authors have different views on this aspect e.g., Rajbhanshi (2012) and Shrestha (2019) have not included *Pseudeuotropius murius baterensis* in the as the endemic species. Similarly, *Neoanguilla nepalensis* was reported as endemic species by Shrestha (2019) and Rajbanshi (2012) but Shrestha (2011) has not been included in endemic species. Based on their review of this data, our expert group concluded that these numbers may increase further if systematic surveys on fish fauna were conducted across the entire country.

Psilorhynchus pseudochenesis was the first endemic species described in the Dudhkoshi river (Menon and Dutta 1964). Later Terashima (1984) reported three species of schizothorax in the Rara lake which was synonymized into a single species (Menon 1999) however, Dimmick and Edds (2002) has concluded them as an independent species under genus *Schizothorax* based on DNA barcoding. Many authors such as Ng & Edds (2004 & 2005), Ng (2006), Conwey and Mayden (2008 & 2010), Conwey et al., (2011), Rayamajhi & Arunachalam (2017 a & b) and Rayamajhi et al., (2016) have made significant contributions in exploring the endemic fishes of Nepal.

Table 9: List of Endemic Fishes of Nepal.

SN	Genus	Species	SN	Genus	Species
1	*Psilorhynchus*	*Pseudochenesis*	9	*Pseudochenesis*	*Serracula*
2	*Psilorhynchus*	*Nepalensis*	10	*Erethistoides*	*Ascita*
3	*Schizothorax*	*macrophthalmus*	11	*Erethistoides*	*Cavatura*
4	*Schizothorax*	*Nepalensis*	12	*Balitora*	*Eddsi*
5	*Schizothorax*	*Rarensis*	13	*Turcinoemacheilus*	*Himalaya*
6	*Myersglanis*	*Blythi*	14	*Pseudolaguvia*	*Nepalensis*
7	*Batasio*	*Macronotus*	15	*Garra*	*Nepalensis*
8	*Pseudochenesis*	*Crassicaudata*			

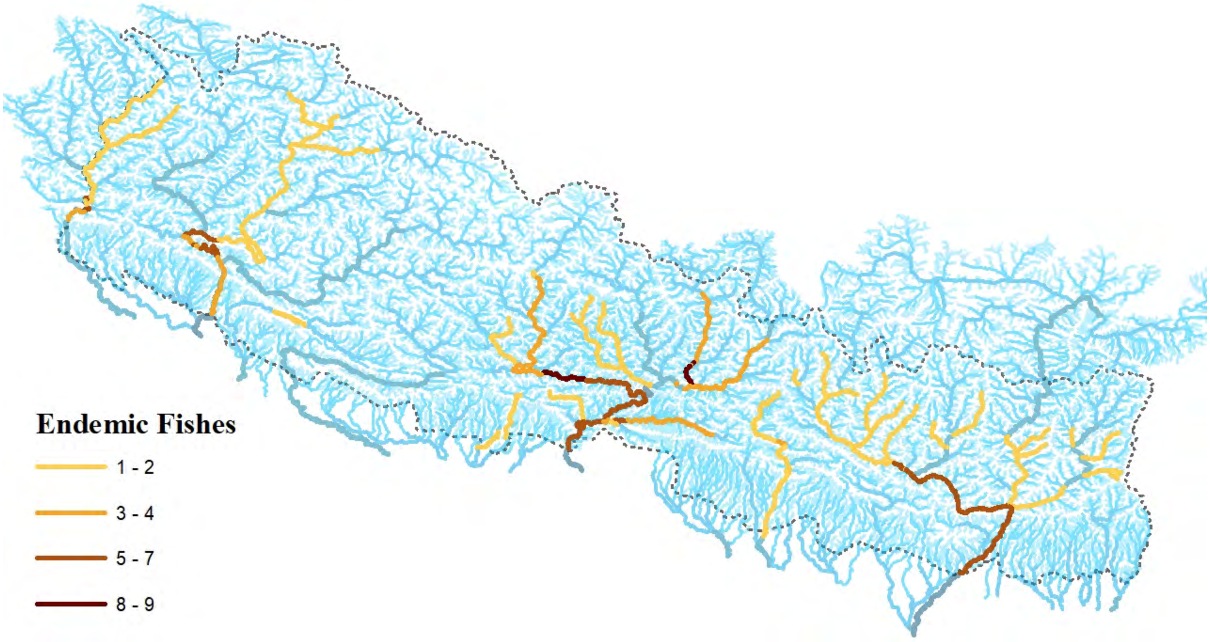


Figure 44: Endemic fish richness in Nepalese rivers.

7.2.1.1.4 Threatened Fishes

Conservation status of indigenous species were assessed based on the IUCN red list of threatened species 2019. The native's species were categorized into Critically Endangered (n=3), Endangered (n=2), Vulnerable (n=5), Nearly Threatened (n=17), Data Deficient (n=24), and Least Concerned (n=163; Figure 46) A further 25 species have not been evaluated by IUCN. The endemic species *Schizothorax nepalensis* and *Schizothorax raraensis* are also listed as critically endangered, and *Systomorhyncus nukta* and *Tor putitora* are listed as endangered species. These fish should be priorities for conservation where they had been recorded.

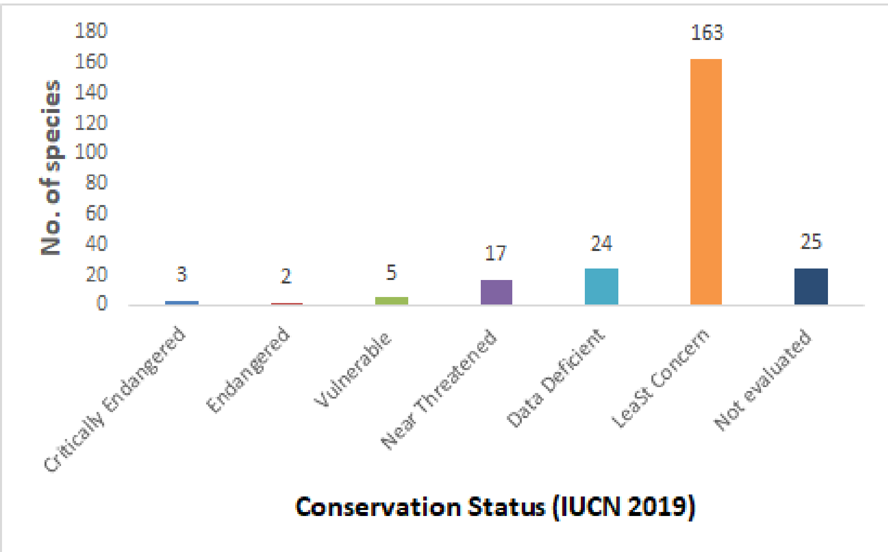


Figure 45: Conservation Status of Native Species of Nepal

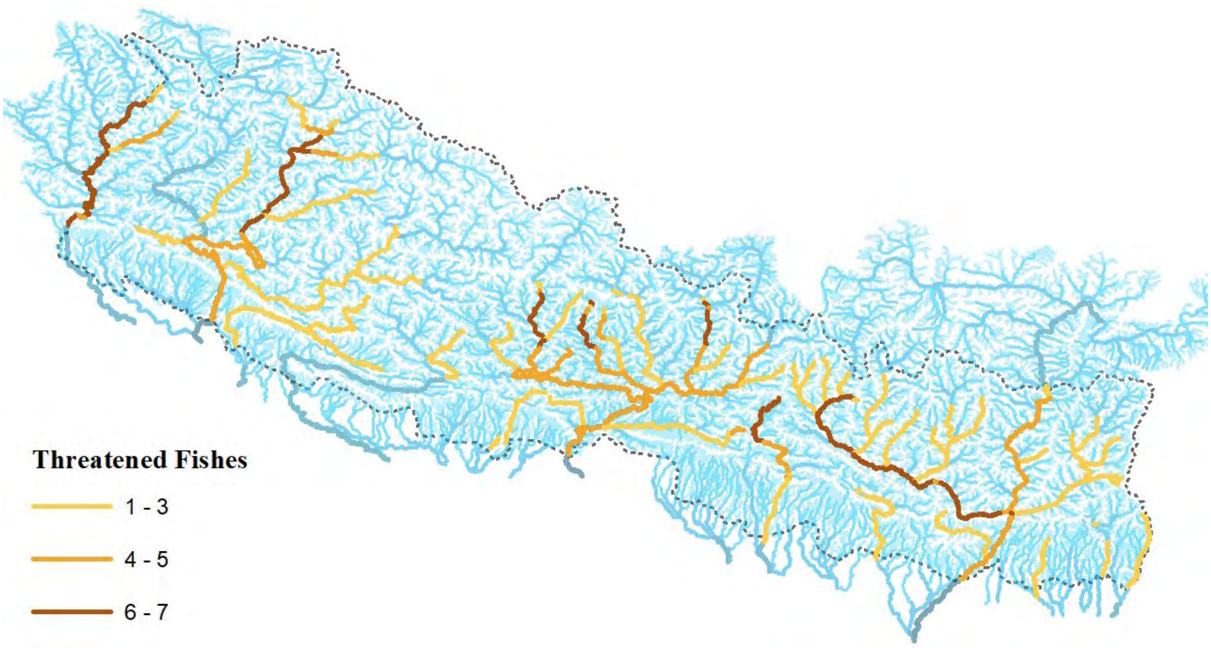
In total, there are three critically endangered species, two endangered and five vulnerable species of fishes found under the threatened category in the rivers of Nepal (Table 10). Sunkohsi, Mahakali, Upper Karnali, Kaligandaki (upper reaches) rivers are highlighted for having greater number of threatened species (Figure 47).

The Mahakali river, the upper section of the Karnali mainstem, as well the Sunkoshi river are examples of prominent rivers with a high number of threatened fish species.

Other sections of the mainstem Karnali, Gandaki and Koshi, show 4-5 threatened species, highlighting these rivers as a refuge and as sensitive to impacts.

Table 10: Critically endangered, endangered and vulnerable fish species of Nepal

SN	Genus	Species	Status
1	*Schizothorax*	*Nepalensis*	Critically Endangered
2	*Schizothorax*	*Rarensis*	Critically Endangered
3	*Glyptothorax*	*kasmirensis*	Critically Endangered
4	*Systamorhynchus*	*Nukta*	Endangered
5	*Tor*	*putitora*	Endangered
6	*Cyprinion*	*Semiplotum*	Vulnerable
7	*Tor*	*Chelynoids*	Vulnerable
8	*Schizothorax*	*Richardsonii*	Vulnerable
9	*Schistura*	*Prashadi*	Vulnerable
10	*Physoschistura*	*Elongate*	Vulnerable



7.2.1.1.5 Migratory Fishes

Information on the migratory behavior of fresh water fishes have not been well documented in Nepal. Nevertheless, the rivers of Nepal are known to be a significant habitat of many resident and short- to long-distance migratory fish species. Some species complete their life cycle within short stretches of river, while others like *Anguilla bengalensis* are believed to travel along the Ganges to the Bay of Bengal for spawning and swim back to the river basins in Nepal to complete their reproductive cycle. A number of fishes show distinct migratory habits in search of suitable spawning and feeding grounds. The distance and direction of migration varies from species to species. Gubhaju (2011) has reported five and nine species as the long and short-mid distance migratory fishes, respectively. This study included migratory species split into two categories- long and short-mid migratory adopted from Gubhaju (2011) due to limited information on the migratory behavior of the native fish species in Nepal. There are five long distance, and eight medium and short distance migratory species that were identified under this study (Table 11). Anguilla bengalensis, Tor putitora, Tor tor, Bagarius Yarelli, Clupisoma garua are long migratory fishes.

Abundant food and increased water volume may attract the long migratory fishes to headwaters during the monsoon while the short migratory fishes move upstream due to the scarcity of food during the rainy season in the lower reaches (Gubhaju, 2002). Sharma, 2001 reported *Schizothorax esocinus* and *S. plagiostomus* in Tinau river at an altitude of 251 m during the flooded condition in July. In many places, fish migration is obstructed due to cumulative impacts from habitat degradation, over-exploitation, pollution, invasive species, flow modification, and climate change. Habitat degradation has caused serious declines of a number of migratory species. Multiple hydropower and irrigation dams reduce the population and number of species. However, in the absence of valid baseline data it is impossible to quantify this reduction. Importantly, illegal extraction of sand and pebbles from the riverbed is also an emerging problem in many rivers that would destroy breeding and spawning grounds of the fishes.

The spatial distribution of migratory species showed that the major river systems are good habitat for both long and short migratory fishes. The Karnali, Narayani, Kaligandaki, Koshi, and Sunkoshi Rivers have been highlighted in terms of distribution of migratory fishes (Figure 48 and Figure 49). However, the construction of dams has hindered migration for the long-distance migrant fishes, preventing them from reaching upstream breeding and feeding ground resulted in decline of these species (Gubhaju, 2011).

Table 11: Long distant, and short to medium distant Migratory Species

S.N	Genus	Species	Migration type
1	*Anguilla*	*bengalensis*	Long distant
2	*Tor*	*putitora*	Long distant
3	*Tor*	*tor*	Long distant
4	*Bagarius*	*bagarius*	Long distant
5	*Clupisoma*	*gaura*	Long distant
1	*Labeo*	*angra*	Medium and Short distant
2	*Labeo*	*dero*	Medium and Short distant
3	*Labeo*	*dyocheilus*	Medium and Short distant
4	*Tor*	*chelyniodes*	Medium and Short distant
5	*Schizothorax*	*plagiostomus*	Medium and Short distant
6	*Monopterus*	*cuchia*	Medium and Short distant
7	*Chagunius*	*chagunio*	Medium and Short distant
8	*Neolissochilus*	*hexagonolepis*	Medium and Short distant

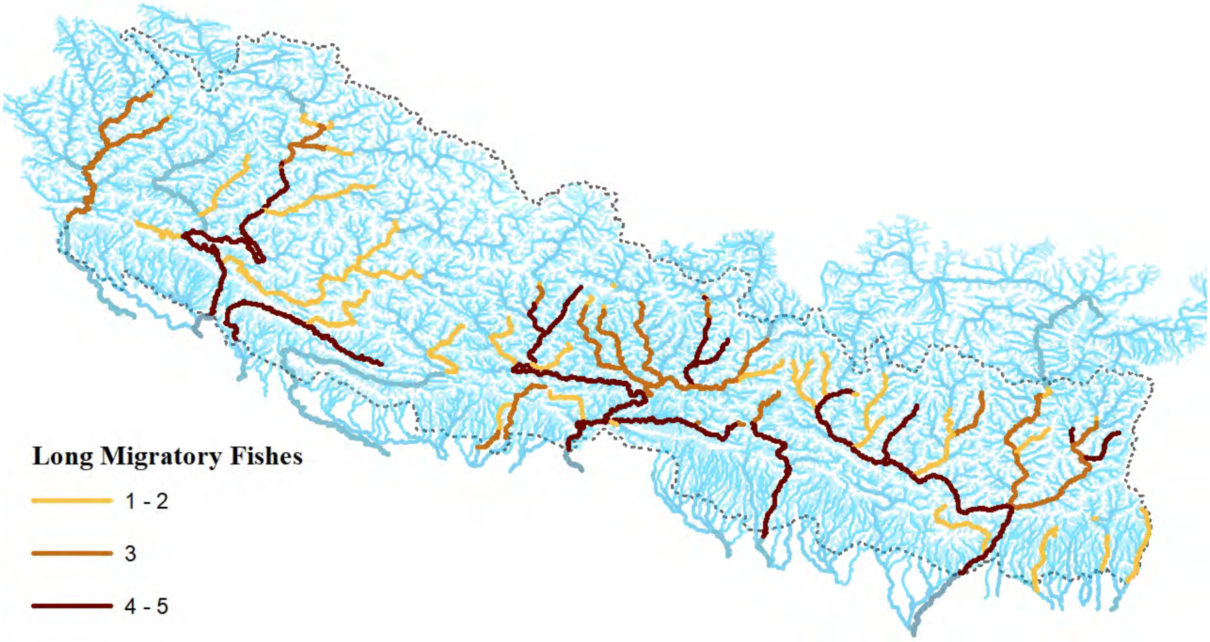


Figure 48: Long migratory fish richness in Nepalese rivers.

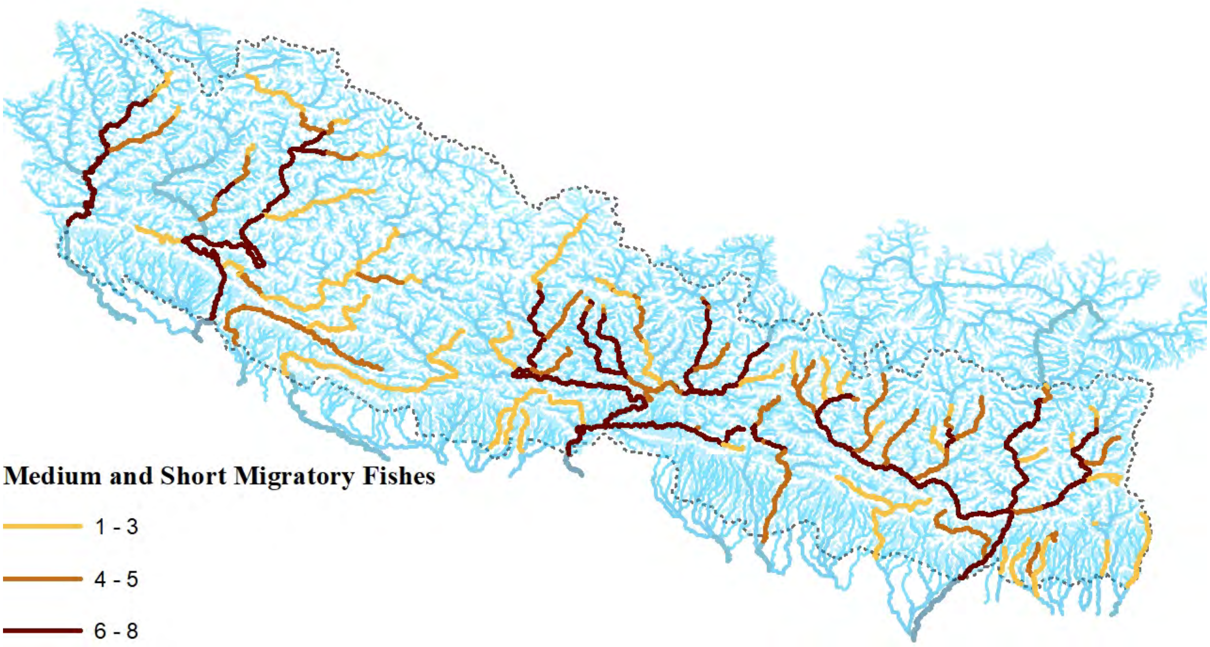


Figure 49: Medium and short migratory fish richness in Nepalese rivers.

7.2.1.2 Flagship Species

7.2.1.2.1 Dolphin

Gangetic River Dolphin (*Platanista gangetica gangetica*) is the only recorded cetacean species and is a legally protected mammal in Nepal. It has been recorded in lowland stretches of Karnali, Koshi, and Naryani rivers. However, it was not recorded in Narayani River in last census of 2016, therefore Narayani has been considered as historical habitat based on the suggestion of Advisory Group (Figure 50).

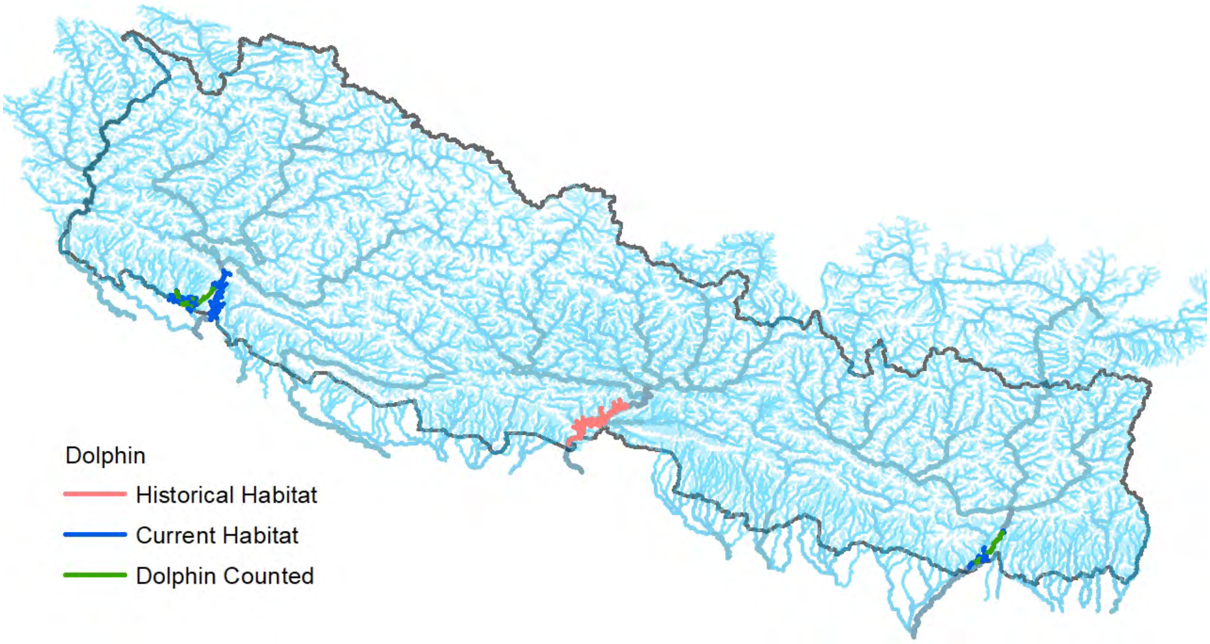


Figure 50: Dolphin habitats in Nepalese rivers.

7.2.1.2.2 Gharial

According to the last census, 198 gharials have been recorded in Babai, Narayani, and East Rapti rivers. Recently in 2019, a gharial has also been spotted in West Rapti River by WWF Nepal (Figure 51).

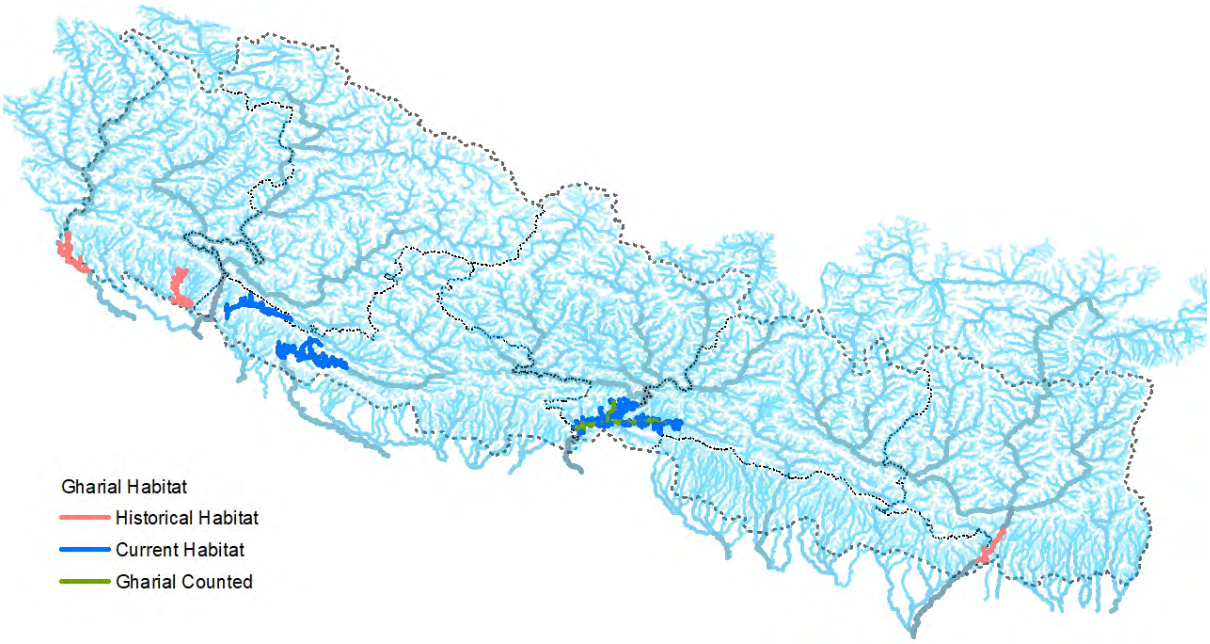


Figure 51: Gharial habitats in Nepalese rivers.

7.2.1.2.3 Mahseer

Four species of mahseer have been mapped under this study (Table 12). Except few mapped rivers including Thuligad, Bheri, Jhimruk, and Bagmati (outside Kathmandu Valley) three to four species of mahseers have been found in the mapped Nepalese rivers (Figure 52). Golden Mahseer is found in fast-moving water, pools, of the Himalayan foothills, especially in rivers like Kaligandaki, Trisuli, Sunkoshi, Narayani, Karnali rivers (Prakritinepal, 2018). Copper Mahseer is recorded from Gandaki, Trisuli, Koshi, Karnali, Mahakali river basins from Nepal (Shrestha 2003 cited by Arunachalam, 2010). Deep Bodied Mahseer is the most widely distributed among other Mahseers.

Table 12: List of Mahseer Species found in Nepal.

SN	Scientific Name	Common Name	Nepali Name	IUCN Status
1	*Neolissochilus hexagonolepis*	Copper Mahseer	Katle	NT
2	*Tor chelynoides*	Dark Mahseer	Halude	VU
3	*Tor putitora*	Golden Mahseer	Sahar/Mahseer	EN
4	*Tor tor*	Deep Bodied Mahseer	Sahar/Mahseer	DD

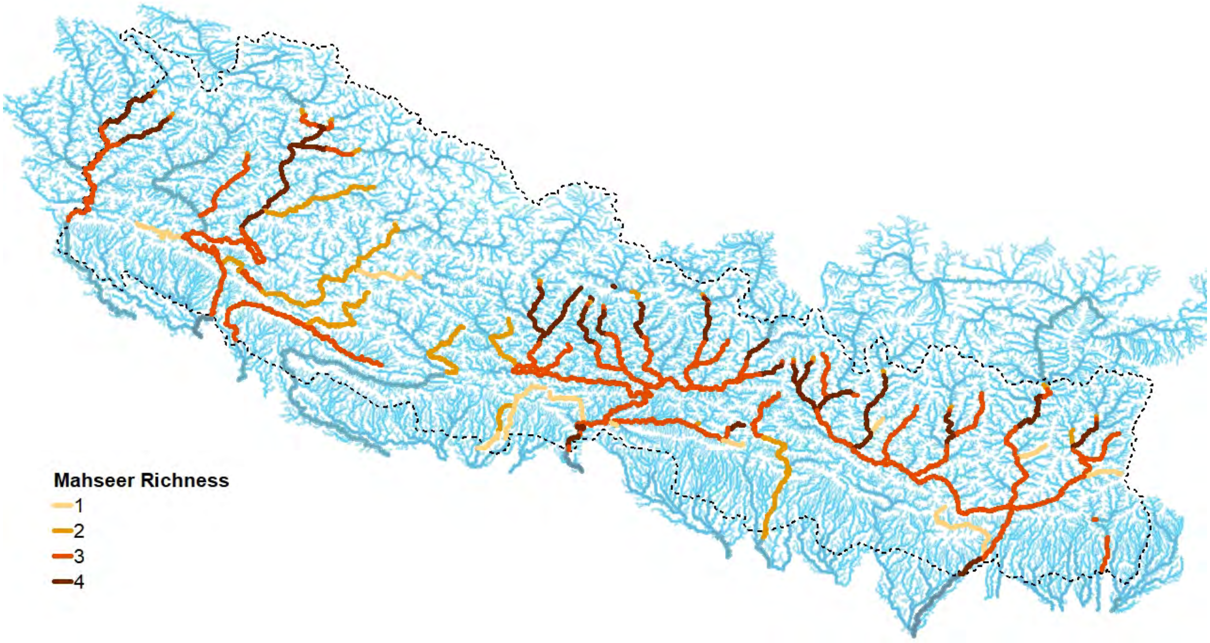


Figure 52: Mahseer richness in Nepalese rivers.

7.2.1.3 Floodplain and riparian biodiversity

7.2.1.3.1 Rhinoceros

Habitat specialists like the one-horned rhinoceros (*Rhinoceros unicornis*) are completely dependent on floodplain grasslands that are governed and maintained by flood dynamics. Protected areas that host rhinos in Nepal include Suklaphanta NP, Bardiya NP, Chitwan NP, Parsa NP, and their buffer zones (Figure 53).

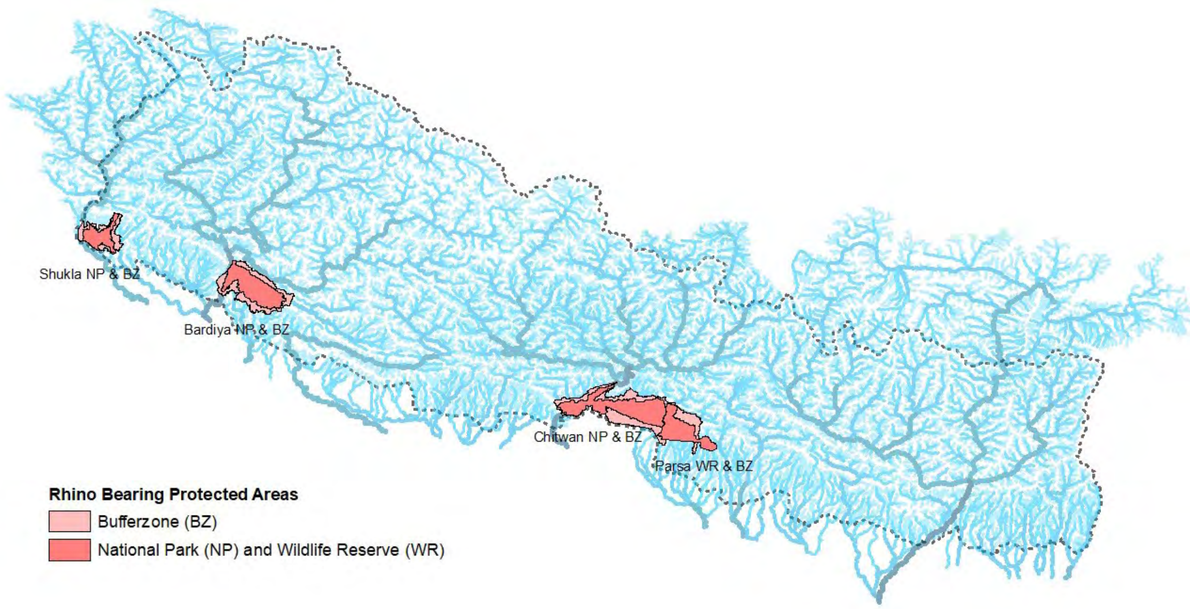


Figure 53: Rhino bearing protected areas in Nepal.

7.2.1.3.2 Tigers

Tigers reach their highest densities on floodplain grasslands. Protected areas that host tigers in Nepal include Suklaphanta NP, Bardia NP, Banke NP, Chitwan NP, Parsa NP, and their bufferzones.

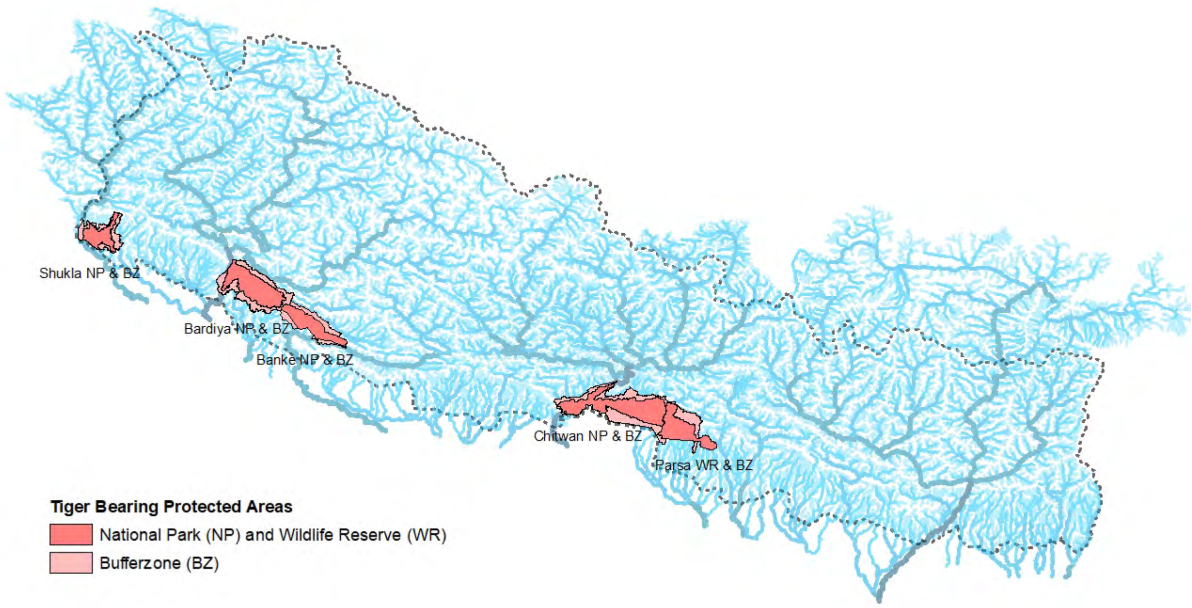


Figure 54: Tiger bearing protected areas of Nepal.

7.2.1.3.3 Otters

According to the Nepal Otter Action Plan (2020-2022), there are three otter species believed to inhabit the rivers and wetlands of Nepal, however their distribution record is poorly documented (Table 13). No Eurasian otter (*Lutra lutra*) has been sighted since 1990, and no Asian Small-clawed otter (*Aonyx cinereus*) has been recorded since 1839 (Kafle, 2009; Acharya and Rajbhandari, 2011).

The Smooth-coated Otter (*Lutrogale perspicillata*) is more common and appears to be confined to the southwestern Terai of Nepal, west to Bardia National Park. Otter scats and tracks have been observed at the Sani Bheri and the Uttar Ganga Rivers in Rukum West and the catchment of the Nalgad River, Jajarkot district as well (Thapa et al., 2020).

Under this study, very few river reaches have found as current habitat in the country (*Figure* 55). Confirmed locations include stretches of the Karnali river and the wetland complex in Suklaphanta National Park, Laukavauka lake, Karyala and Geruwa stretch of Karnali River up to the Bheri confluence, upstream of Sani Bheri River and downstream of Uttarganga River.

Since surveys have not been conducted on many rivers and wetlands in the country, otters most likely inhabit other areas besides the current known distribution (Thapa et al., 2020). In some cases, documented otter populations have disappeared in recent years, for instance in Chitwan National Park and in the Narayani River, where no otters have not been observed since 2013.

We found mention of many potential and historical sites in the literature, and our team validated these locations as best as possible through expert consultations. Our map shows that large parts of the Sunkoshi and Saptakoshi mainstem and major tributaries have formerly been inhabited by otter. Similarly, West Seti and East Rapti rivers have been a confirmed historic habitat.

Important potential sites include the Middle Karnali, Mahakali and Seti rivers, as well as the Northeastern region (Tamor and Arun rivers and tributaries).

Table 13: Otter species documented in Nepal.

SN	Scientific Name	English Name	IUCN Red Data List	CITES Appendix	NPWC Act	Aquatic Life Protection Act
1	*Lutrogale perscipillate*	Semi-coated Otter	VU	II	Not listed	Listed
2	*Lutra lutra*	Eurasian Otter	NT	I	Not listed	Listed
3	*Aonyx cinereal*	Oriental small-clawed Otter	VU	II	Not listed	Not listed

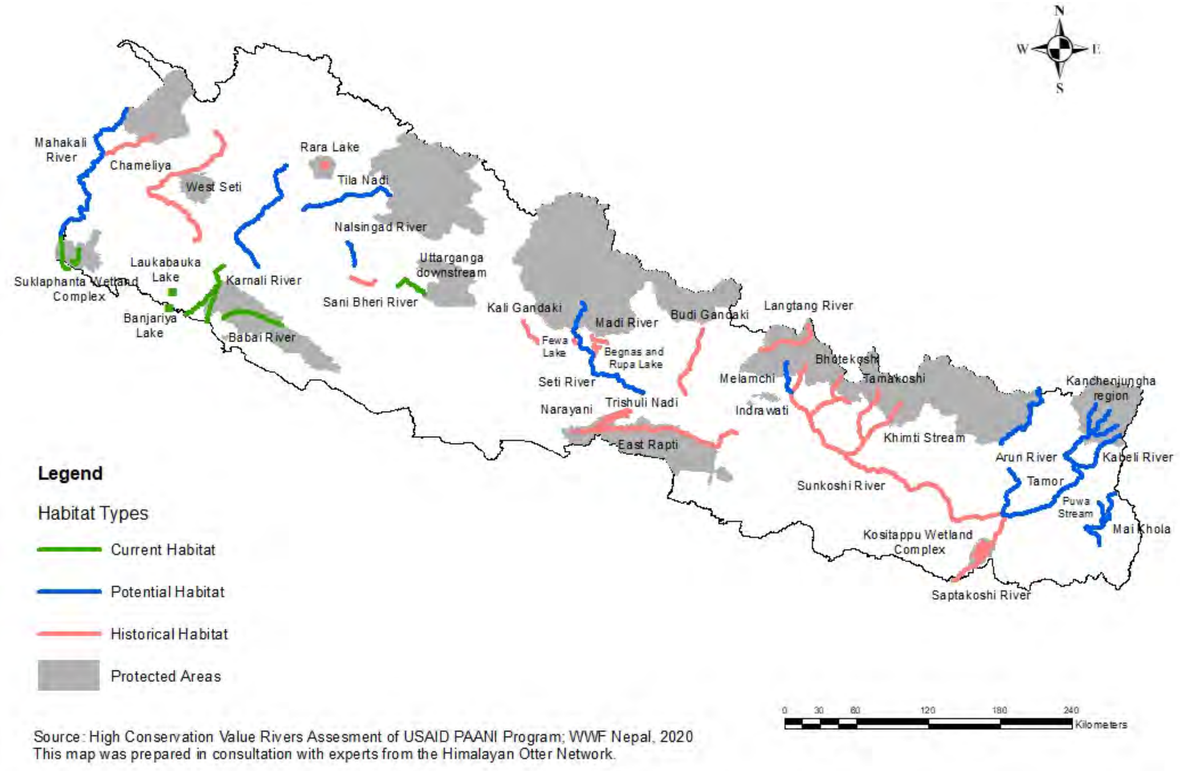


Figure 55: Current, historic, and potential habitat distribution for otters in Nepal. Only the Smooth-coated Otter *(Lutrogale perspicillata)* has been sighted in Nepal in recent years (green). Other otter species inhabited historic sites (red) or may inhabit potential habitats in the future (blue).

7.2.1.3.4 Wetland Birds

In Nepal, there are many important river reaches that are home to several species of wetland birds including Koshi River, Narayani River along Chitwan National Park, Rapti River in Dang, and Karnali River with Bardiya NP.

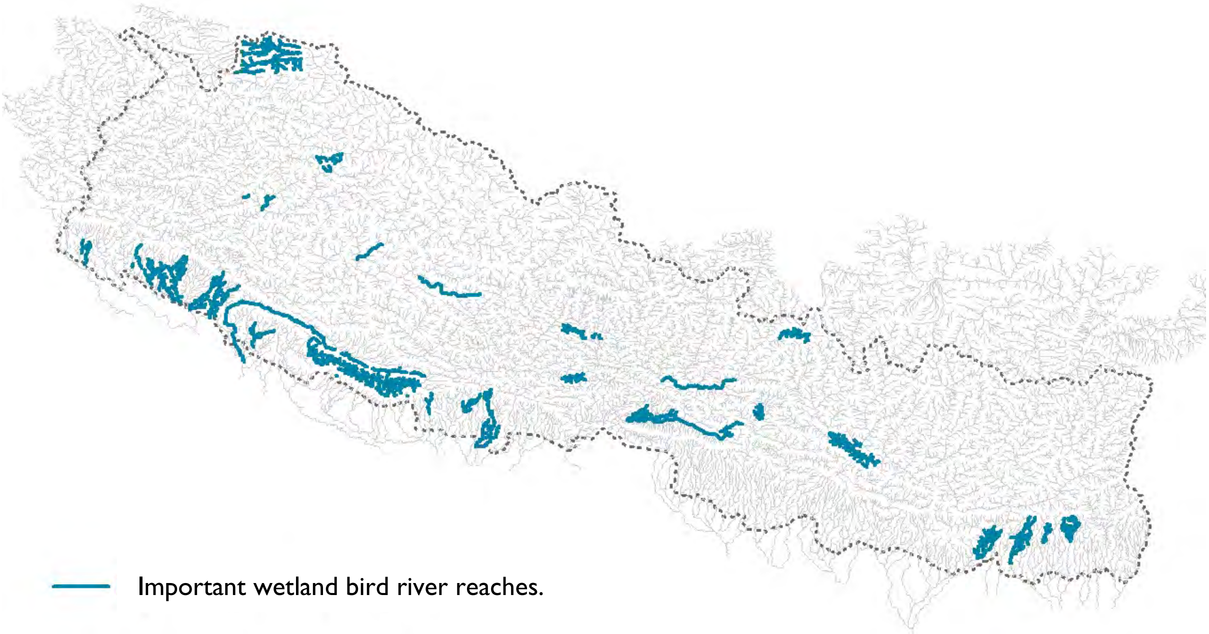


Figure 56: Important river reaches for wetland birds in Nepal.

7.2.1.3.5 Critical Corridors

Critical corridors connect protected areas and facilitate movement and dispersal of wildlife, especially megafauna (Figure 57). Seven such corridors have been identified and managed through a participatory conservation approach, and among them four transboundary corridors have been declared as protected forests. Among others, Karnali River corridor is most important it has been identified as a priority for ecological connectivity between the Churia, Nepal and India's Katerniaghat Wildlife Sanctuary. Frequent use of this corridor by elephant, rhino, and tiger has been reported. Gangetic dolphin and gharial are also found in this corridor.

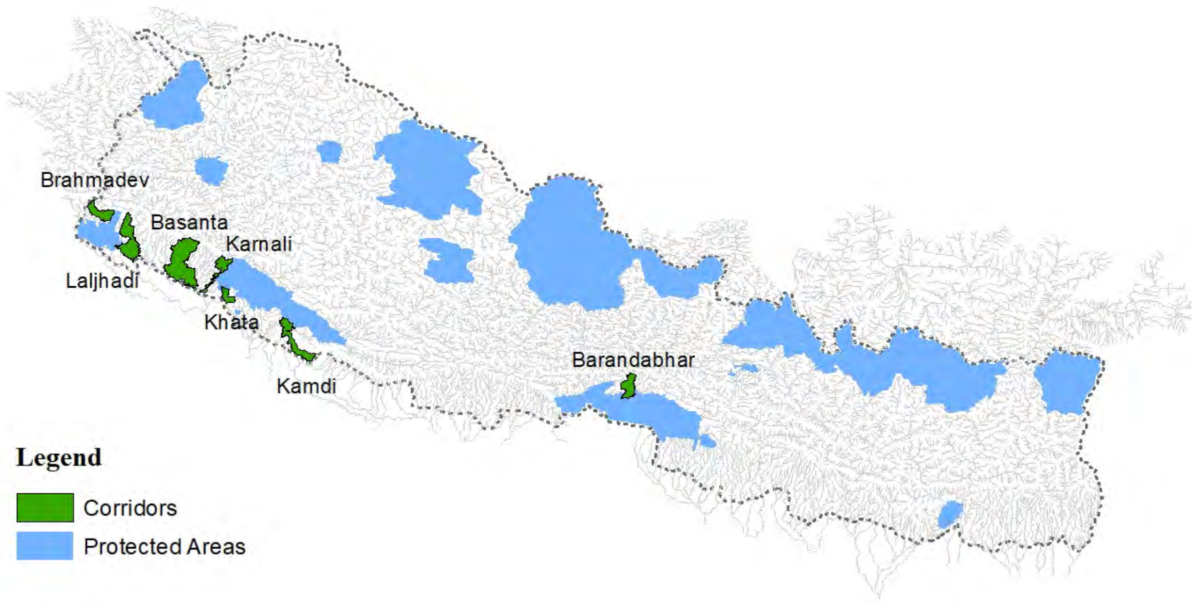


Figure 57: Critical corridors in Nepal.

7.2.2 Recreational values

Generally speaking, more rivers in the Himalayas have recreational values than lowland rivers. The Barun, Arun, West Seti, Dudhkoshi, and Humla Karnali Rivers are found to have high recreational values. Terai and Churia river reaches of Koshi, Gandaki, East Rapti, Karnali, Bheri, and Babai rivers are also important from a recreational perspective.

Combined recreational values are shown in Figure 59, which includes the values 'angling', 'rafting', trekking' and 'protected areas'.

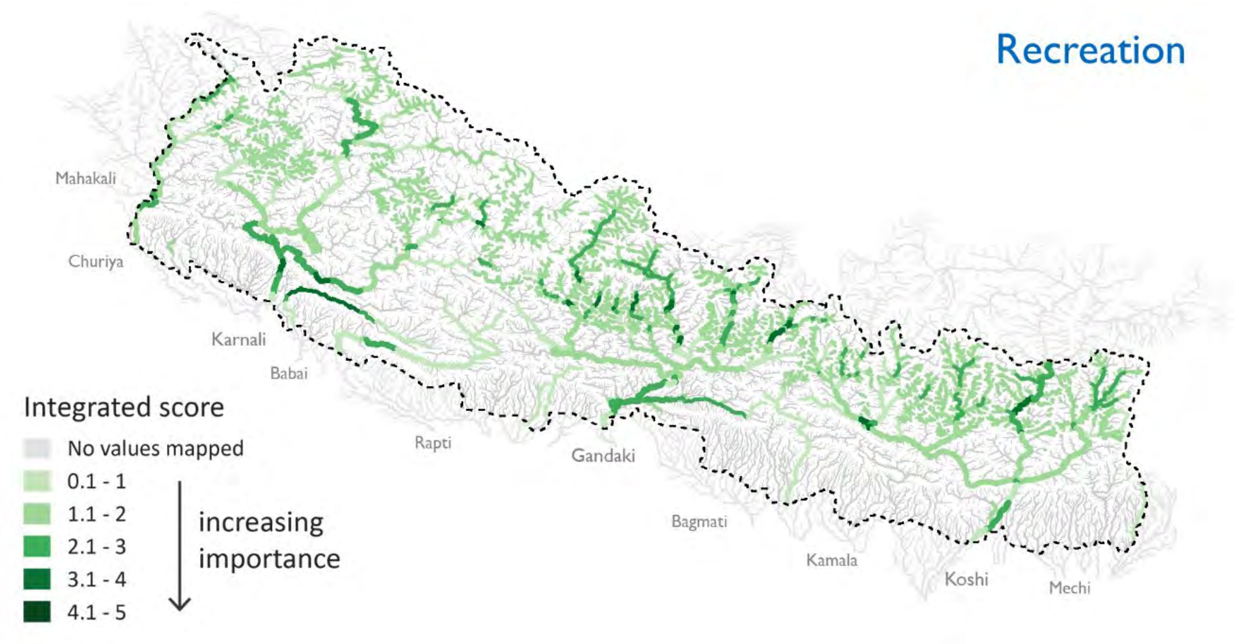


Figure 58. Recreational values in Nepal are composed of an overlay of the freshwater values 'angling', 'rafting', trekking' and 'protected areas'.

7.2.2.1 Angling

Prime angling locations for key species which are most sought after by anglers fishing in Nepal, lowland warmwater river, followed by mid-hills cool-water river, and upland cold-water river. Similarly, lakes are categorized into warmwater and cold-water lakes.

Under this assessment, angling sites have been categorized into 4 categories based on presence of important gamefish species found in rivers that includes Mahseer, Gonch, Warm water species and Asla and their combined presence (Figure 59). Warm water species includes *Channa marulius, Sperata seenghala, Sperata aor, Catla catla, Cirrhinus mrigala, Chitala chitala, Labeo calbasu, Labeo rohita* among others.

Large lowland rivers of Nepal have been found to have high angling value due to the presence of Mahseer, Gonch, Asla and most of the Warm water species in those regions, indicated by river stretches labelled as 'very good' (HCV 5).

Locations further upstream the main arteries of the river are increasingly less attractive for angling. Due to decreasing water temperature, warmwater species such as Asla become rare to encounter, indicated in river stretches with 'good' angling value (HCV 4), or medium angling value, if only Mahseer, Gonch and Alsa are found, but no other warmwater species (HCV 3).

Further upstream and in tributaries of the main arteries, angling value is reduced to a "poor' status (HCV 1-2), due to missing Mahseer and Gonch species, but some recreational value can be derived from fishing Asla or other warmwater species.

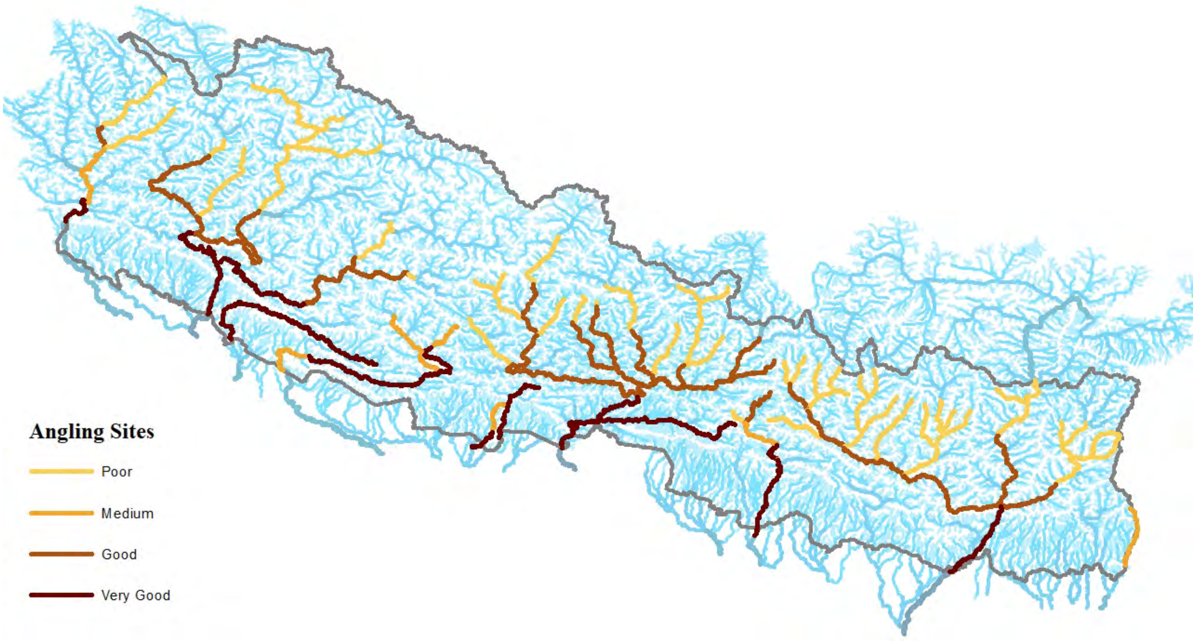


Figure 59: Angling sites in Nepal.

7.2.2.2 Rafting

There are 33 rivers in Nepal that are important for rafting and kayaking (Figure 60). For instance, the Karnali River is famous for its rafting opportunities. It is one of the top ten world class locations for white water rafting. Hydropower development could threaten the success of these recreational opportunities. Within the Karnali basin, the Seti, Upper Seti, and Bheri rivers are also popular tributaries for kayaking and rafting.

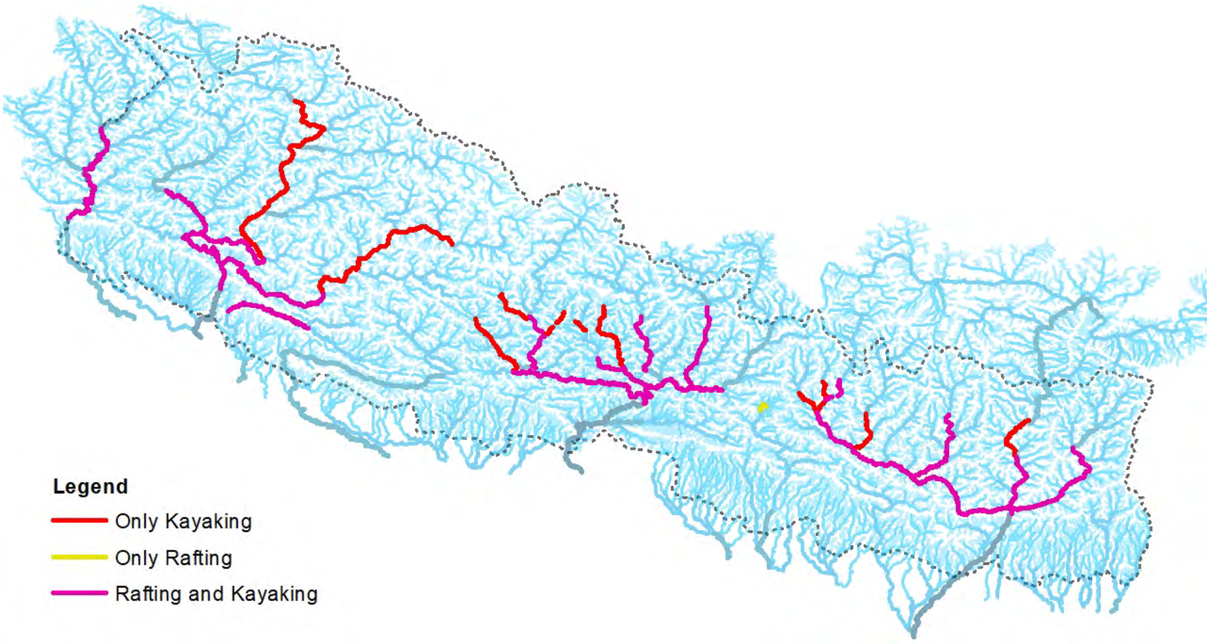


Figure 60: Rivers that are important for kayaking and rafting in Nepal. Note that only a small section in the Bagmati river is found to be suitable for rafting.

7.2.2.3 Trekking

Many upland river reaches of the Himalayas and Midlands have been identified as important river reaches for trekking (Figure 61). These regions include Everest, Annapurna, Langtang and Kanchenjunga.

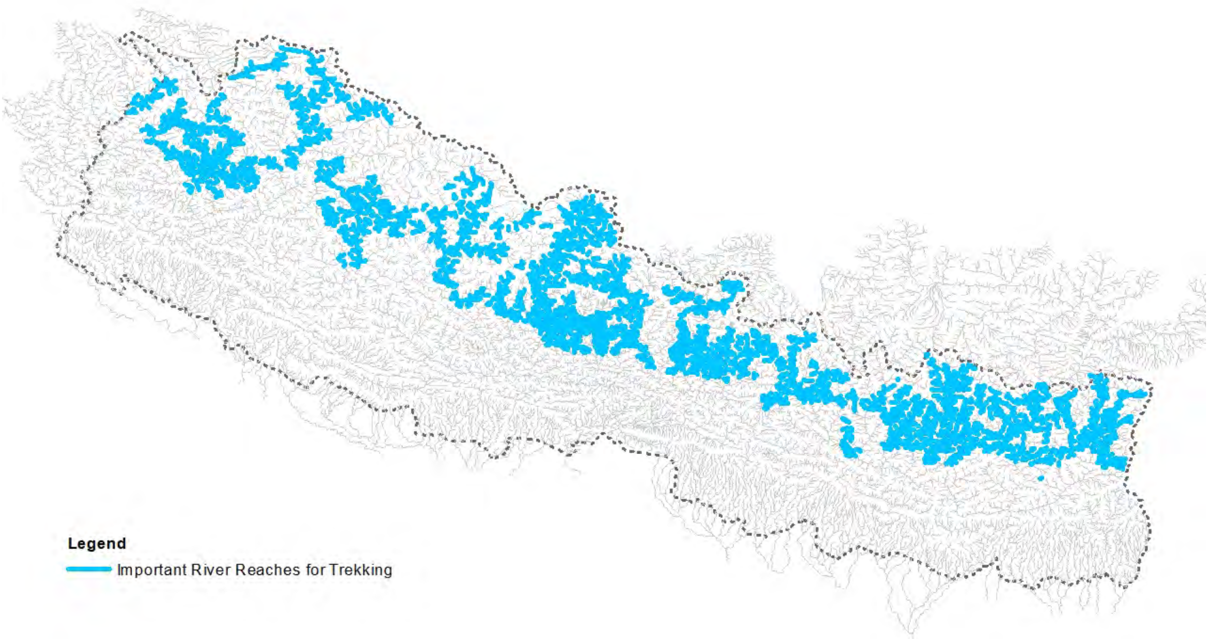


Figure 61: River reaches that are important for trekking.

7.2.2.4 Protected Areas

There are 20 protected areas in Nepal including 12 National Parks and 1 Wildlife Reserve, which also have buffer zones, 6 Conservation Areas, and 1 Hunting reserve conserving a vast assemblage of wild fauna, flora, and other important natural resources of the country (Figure 62). Large rivers (long-term average discharge larger than 10 cubic meters per second) within Protected Areas are targets of recreational activities and therefore important in terms of recreation perspective.

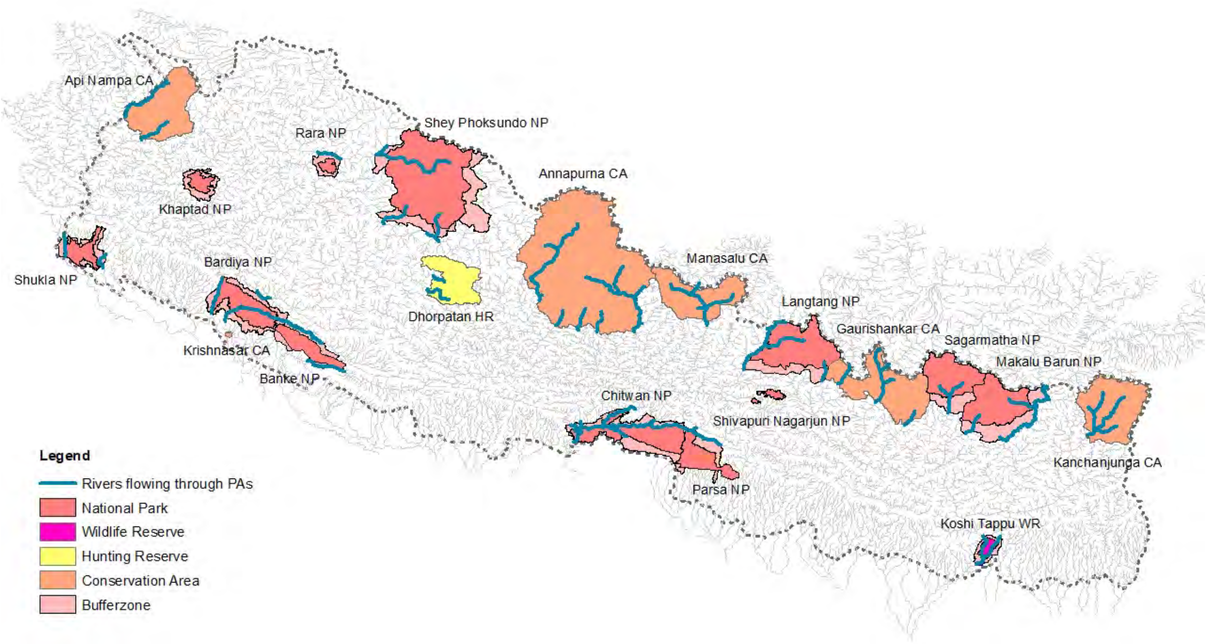


Figure 62. Protected areas in Nepal.

7.2.3 Livelihood values

Livelihood values combine two other values: a) Food and commercial value of fisheries, and b) water provision value.

In terms of livelihood, small rivers or stream are highlighted equally or more than large rivers (Figure 63). Rivers ranked with high livelihood values include Madi khola, Banganga, Sarada, Panar, Jhimruk khola, Mai khola, Ratamata khola, Trijuga, and Kamala rivers.

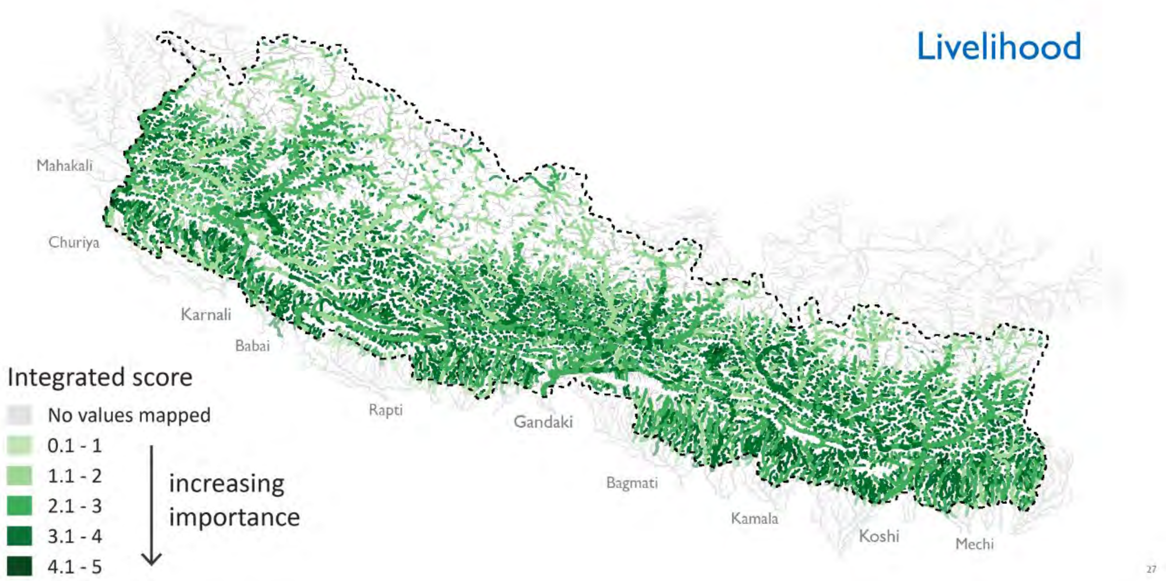


Figure 63. Livelihood values mapped.

7.2.3.1 Food and commercial value

Culturally, fish is considered as an auspicious item in Nepal which has been used during social and religious ceremonies different communities including Newar community. Cold water fish are considered tastier than other fishes. Schizothorax, Schizothoraichthys, Clupisoma, Barilius, Tor and Neolissocheilus are considered exceptionally good quality food. Schizothorax sps. (Asla) and Raimas bola (Jalkapoor) are considered to be highly delicious fish. Up to 220 fish species is considered as a good food value in Nepal. Most of the fishes are eaten and consumed fresh.

Small fishes provide food, nutrition and supplemental income to the great majority of people in the country, particularly the poor and disadvantaged. Marginal people with low income are unable to afford costly species such as carp. Thus, among the fishing communities, small fishes have occupied an important position as a popular food item of protein sources. They are eaten whole; with head, viscera and bones are particularly rich in bioavailable calcium, vitamin A, iron and zinc (Thilsted, 1997).

Out of the 256 fish species found in Nepal, 164 species are SIS, and 152 species of these are preferable. Low land Terai area harbors a large number of SIS, and ethnic communities living there are dependent fully or partially on capturing SIS using traditional fishing gears that are living at the fringe of rivers. Among SIS, A. mola, A. microlepis, Salmostoma bacaila, Nandus nandus, Anabas testudineus, Esomus danrica, Puntius sarana, P. ticto, P chola, P. sophore, Glossogobius giuris, Danio devario are cultivable with high demand, and can be introduced as a candidate species in freshwater aquaculture. Channa marulius, C. striatus, C. punctatus, C. gachua, and C. stewartii are being cultured at minimum scale, mostly based on wild seed collection.

Under this assessment, 165 species have identified as having food and commercial value in Nepal including fish having commercial, food and SIS value, and their distribution have been mapped. Among others Lower Karnali, Narayani, East Rapti, Kaligandaki and Sunkoshi rivers are highlighted as they have 106 – 129 fishes having high commercial and food value.

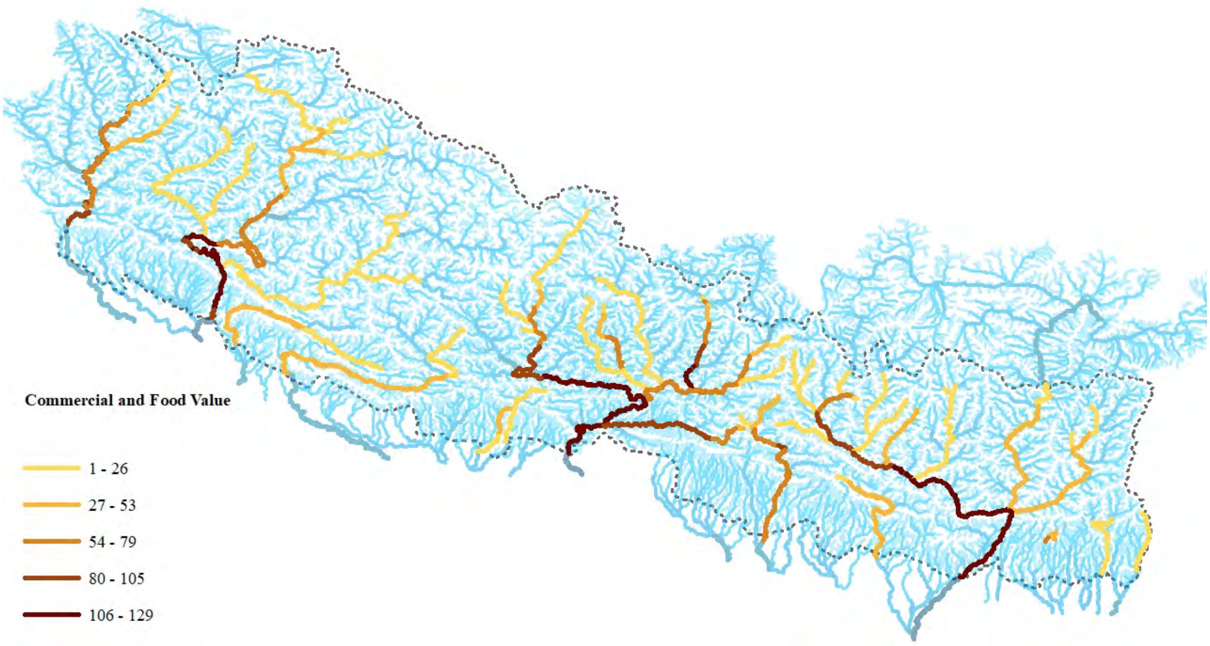


Figure 64. Number of species having "Food and commercial values" or are considered small indigenous species.

7.2.3.2 Water Provision value

The value of rivers for providing water for drinking and indigenous agriculture has been assessed for all river reaches in Nepal (Figure 65). Our methodology was based on the relationship between capacity and demand of human population, which means that the water provision value of a stretch of river increases with higher demand from the local population. Demand from flora and fauna was not taken into account in this assessment, which means that river stretches without local population are shown as having low water provision value.

Large rivers such as Karnali, Gandaki, and Koshi provide large amounts of water, even during the dry season, to a relatively small amount of local population, rendering these rivers as relatively low value (HCV < 2). On the other end of the spectrum, we can see smaller rivers that provide a relatively small amount of river flow to a large amount of people, for example in the Kathmandu Valley, or near other larger aggregations. Many small and medium sized rivers of the Terai region are also shown increased HCV values, due to their relatively low flow and high local demand.

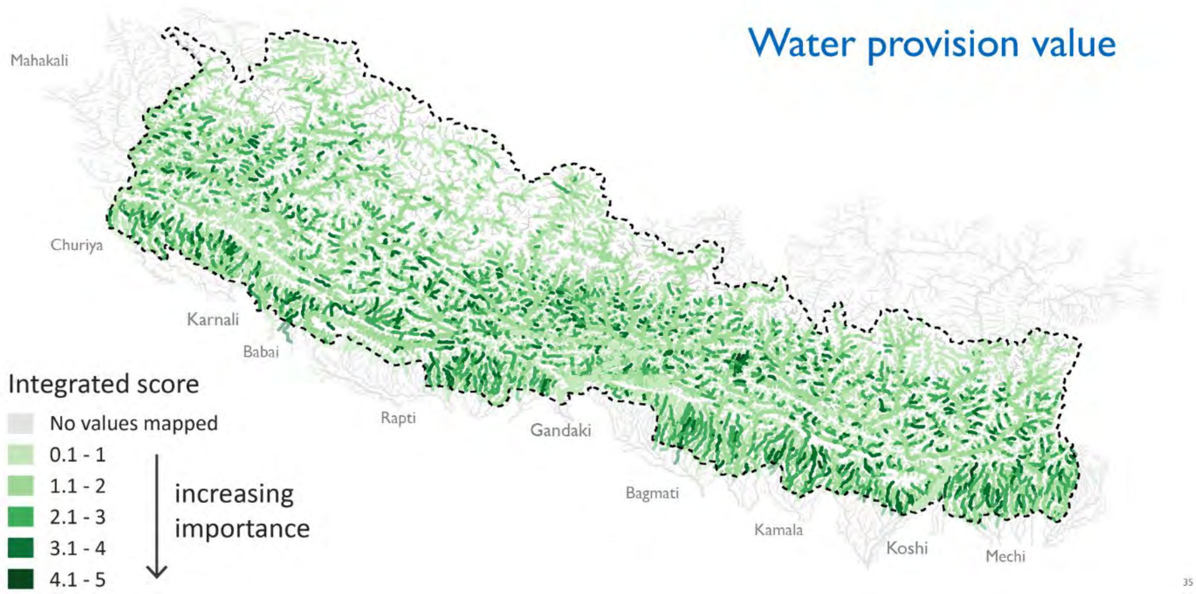


Figure 65: Water provision mapped.

7.2.4 Socio-cultural values

Nepal's rivers provide a variety of social and cultural values to communities across the country. However, due to data limitations, we were only able to map one freshwater value under the socio-cultural component. Religious landmarks in proximity to rivers were mapped as a proxy to identify rivers with value for religious practices (Figure 68). These include the Bakaiya, Kamala, Panar, Madi Khola, Banganga, Ratmata Khola, and Tila rivers.

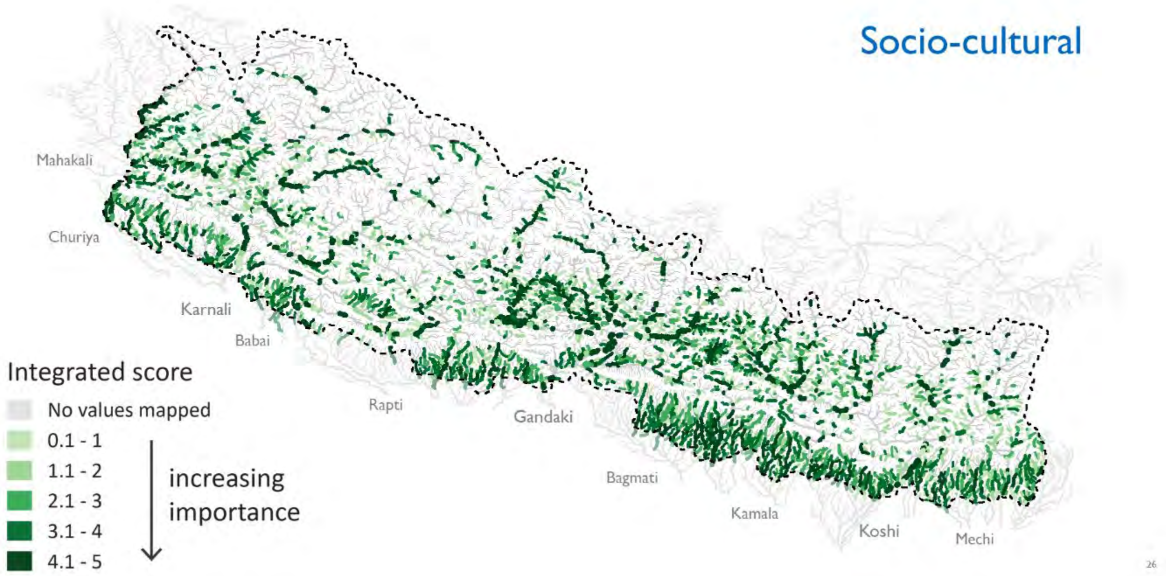


Figure 67: Socio-cultural values mapping

7.2.5 Combining HCV values

7.2.5.1 River reach scale results

The top hierarchical HCV level combines the four main freshwater categories (biodiversity, recreation, livelihood, and socio-cultural) into a final HCV score. As with the other values, we create a weighted average of the four categories using the values assigned in the weighting table. The results are shown in Figure 70.

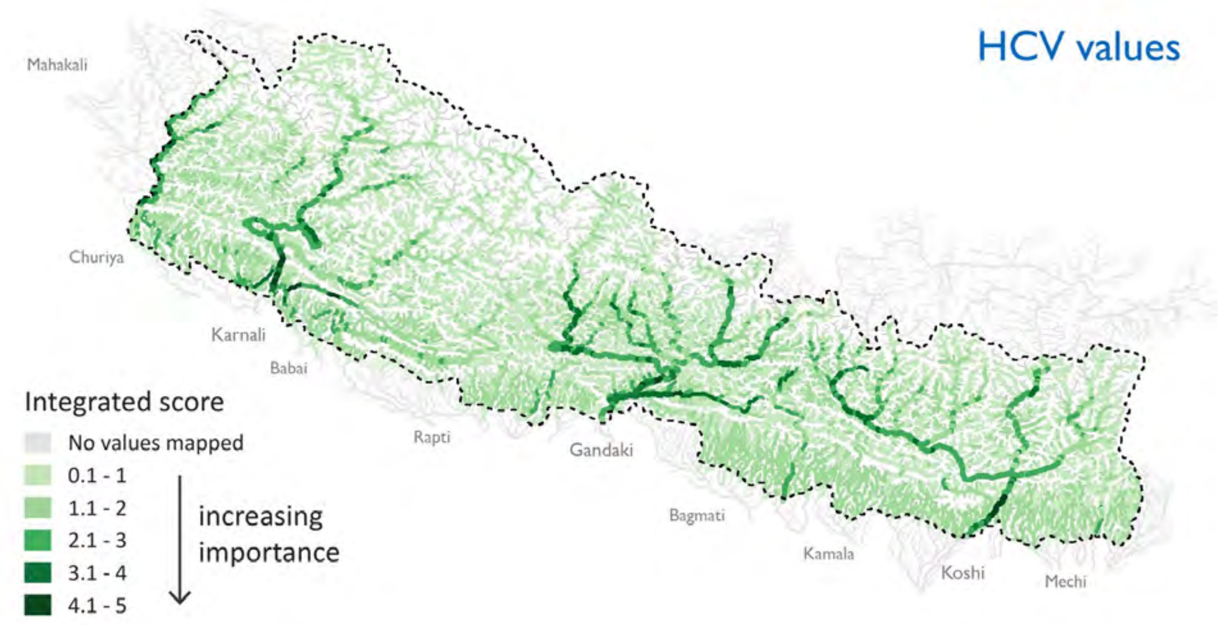


Figure 68: HCV integrated values

The map reflects the weighted combination of all twenty freshwater layers. A typical shortcoming of weighted averages is that the importance of the individual components is somewhat disguised due to the averaging, especially if many variables are included. We therefore also assessed which HCV main component contributed most to calculating the final HCV score. The results of this assessment can be seen in Figure 71.

We can see that mainstem rivers are mainly dominated by biodiversity values, however some stretches, such as on the Behri or West Seti river also show important recreational and socio-cultural values. Livelihood values are driven by food values of fisheries but also by water provision by smaller rivers, especially where population density is high. This value is therefore distributed throughout the Midhills and into the lowland Terai region. Socio-cultural values occur at religious sites, which are located at small sections of the rivers, in close proximity to religious sites. We can observe several important socio-cultural areas dispersed along main rivers; however, many are also concentrated in the Terai region. The dominant values in the Himalaya region are driven by recreational values, specifically trekking and protected area tourism along larger rivers in protected areas.

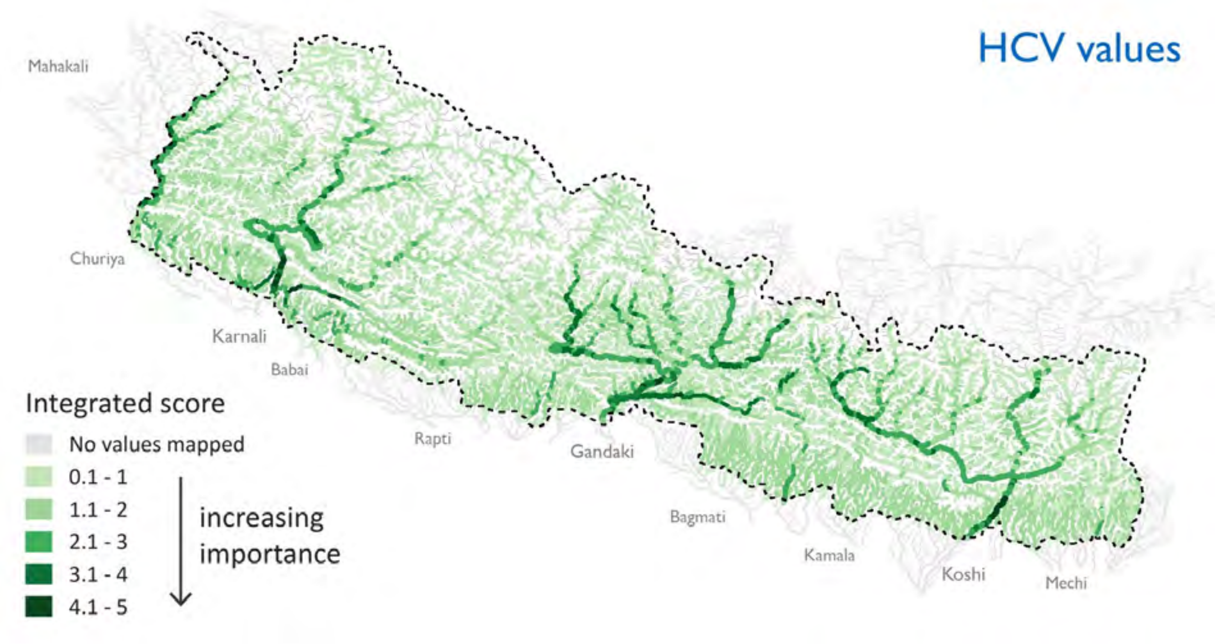


Figure 69: HCV integrated values.

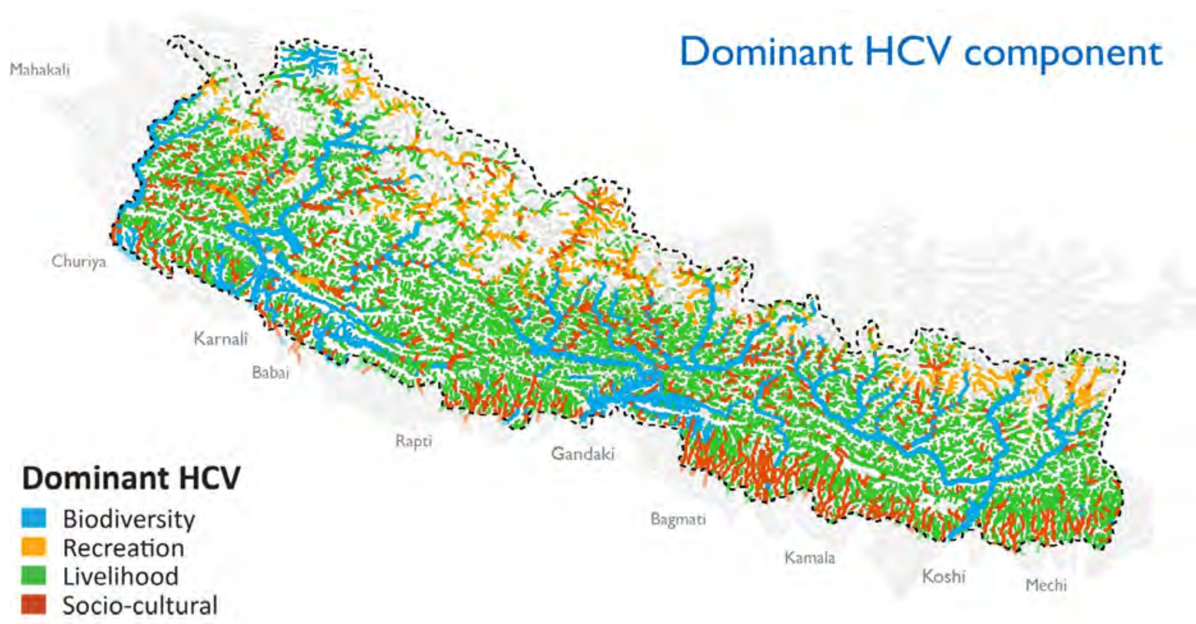


Figure 70: Dominant HCV component

7.2.5.2 River scale results

In addition to calculating the HCV results at the river reach scale, we also created a method to calculate the HCV value of entire rivers as opposed to individual river reaches. As such, decision makers can evaluate entire rivers, in addition to smaller river reaches. In Figure 72, we see that the resulting patterns generally align with the results in Figure 70, because these values were the source of the aggregation. The map appears "cleaner", i.e., with less visible fluctuation between river sections. This is because we used a length-weighted aggregation technique to calculate an average HCV score across the entire length of the rivers. In a final step, we stretched (scaled) the resulting values from 0 to 5.

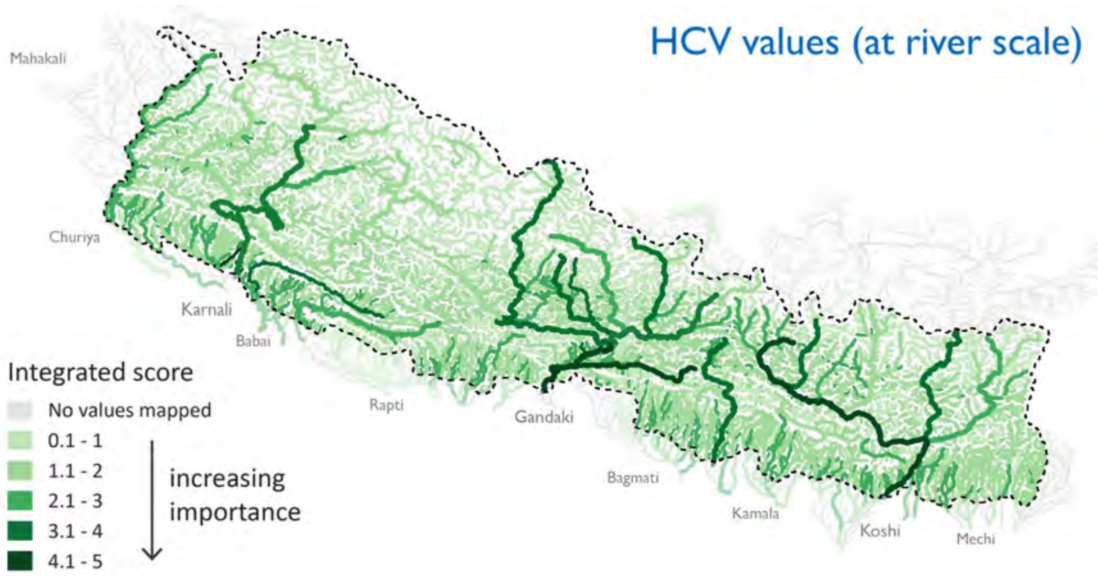


Figure 71: Integrated HCV value at the river scale

A ranked list of rivers is shown in Table 14. It provides the river identifier for establishing a linkage to the GIS database, the river name, as well as its total length in km. Note that a portion of the mainstem Karnali river – the Humla Karnali river, was assessed separately from the Karnali mainstem. Therefore, the Karnali mainstem is shown with a total length of 334 km, instead of the typical 504 km length.

The table also provides information on the four main components biodiversity, recreation, livelihood and socio-cultural. We used the information from the assessment of dominant HCV types (see Figure 71) and calculated the length of each dominant component relative to the total length of the river. As such the four percentage values add up to 100% and provide a measure of the relative importance of each freshwater value component in each river.

Based on this method, the river with the highest HCV score was the East Rapti river, which received a value of HCV 5. Several other rivers also scored high, including the East Rapti, Sunkoshi, Seti and Narayani rivers. The Saptakoshi, Babai, and Tamakoshi also show high HCV values. Note that even though their freshwater value score is high, the freshwater status of some of these is reduced due to loss of connectivity, water quality pressures, or both (see next section 7.3: High-Conservation Value Rivers of Nepal). This highlights the need for urgent action to protect the freshwater values, but also to manage or restore the freshwater status of these rivers.

Other rivers may not score as high in the HCV ranking, because they may not rank high in the biodiversity component. They may nevertheless provide important recreational, livelihood, or sociocultural values, for example the West Seti river, among others.

Table 14. Overview of ranked rivers.

RIVER ID	RIVER NAME	LENGTH (KM)	BIODIVERSITY	RECREATION	LIVELIHOOD	SOCIO-CULTURAL	HCVR VALUE
2085930	Kali Gandaki Nadi	365	42.7	17.1	22.7	17.4	3.2
2085921	Karnali Nadi	334	56.3	13.6	21.5	8.5	3.9
2086024	Bheri Nadi	311	31.1	27.3	22.7	19	1.9
2085791	Sunkoshi Nadi	263	56.3	13.2	22.2	8.3	4.1
2085881	Mahakali Nadi	262	51.4	13.9	21.4	13.4	3.0
2085758	West Seti Nadi	210	24.2	25.8	27.8	22.2	1.4
2086043	Babai Nadi	194	54	16.5	20.1	9.4	3.6
2086037	Bagmati Nadi	188	43.9	7.8	25.9	22.5	3.5
2085825	West Rapti Nadi	182	37.8	13	31	18.2	2.2
2085781	Tamur Nadi	175	49	18.3	25.4	7.4	2.6
2086047	Arun Nadi	158	46.3	21.5	21.3	10.9	3.3
2085762	Trishuli Nadi	156	45.6	14.1	21.7	18.5	3.8
2085875	Marsyangdi Nadi	156	28.1	26.4	19	26.5	2.4
2085980	Dudhkoshi Nadi	140	33	24.9	24.6	17.5	2.0
2085953	Humla Karnali Nadi	139	40.3	21.5	26	12.1	1.7
2085978	East Rapti Nadi	138	61.1	10.9	17.6	10.4	5.0
2085801	Seti Nadi	132	49	13.6	18.5	18.9	3.4
2085929	Kamala Nadi	127	21.5	0	43.5	35	1.6
2086016	Budi Gandaki Nadi	126	48.7	17.3	23.3	10.7	3.1
2085860	Narayani (Sapta Gandaki)	108	66.6	11.4	15.6	6.4	4.8
2040810	Madi Khola	96	0	10.4	56.7	32.9	1.0
2085806	Sarada Nadi	95	37.3	0	37.7	25	1.7
2086033	Bakaiya Nadi	92	0	0	39	61	1.3
2086017	Budhi Ganga Nadi	90	41	10.5	26.1	22.4	2.0
2086029	Banganga River	86	6.3	0	45.8	47.9	1.6
2085784	Tamakoshi Nadi	86	46.9	12.8	17.3	22.9	3.2
2085868	Mohana Nadi	85	32.9	0	33.9	33.2	1.9
2085945	Jhimruk Khola	84	35.6	12.6	45.9	5.9	1.7
2086008	Chameliya Nadi	83	47.7	11.5	22.9	17.9	2.7
2085891	Likhu Khola	80	46.4	16.9	28	8.7	2.0
2085807	Saptakoshi Nadi	77	58.6	9.3	17.4	14.8	4.7
2085877	Mai Khola	77	25.9	0	50.5	23.6	1.2
2085866	Mugu Karnali Nadi	75	50.2	11	29.9	8.9	2.0
2085882	Madi Nadi	75	40	18.7	21.7	19.6	3.4
2085847	Panar	67	0	0	55.3	44.7	1.5
2086028	Barun Khola	65	0	43.8	30.5	25.7	0.7
2085771	Tila Nadi	64	37.4	2.5	26	34.2	2.6
2085764	Trijuga Nadi	64	37.4	1.3	42.9	18.5	2.0
2085876	Marin Khola	64	0	0	64.8	35.2	0.9
2085974	Ganga Nadi	63	33.4	17.6	42.4	6.6	1.4
2086056	Thuli Bheri Nadi	62	0	40.3	39.3	20.4	1.1
2085823	Ratmata Khola	62	9.8	0	39.5	50.7	1.7
2085873	Mechi Nadi	62	25.3	4.8	35.1	34.8	1.7
2085966	Ghunse Khola	61	11	53.8	24.1	11.1	1.0
2085988	Daraudi Khola	61	0	29.9	57.9	12.3	0.8
2085927	Kandra Nadi	61	50.8	0	28.5	20.7	2.2

7.3 High-Conservation Value Rivers of Nepal

The HCVR typology combines the HCV values of the mapped freshwater values and the freshwater status into the High-Conservation Value River Typology. The typology consists of four principal types based on freshwater status and within these, we mapped HCV in increasing order. The HCVR types are described in the section 0 in more detail.

The map in Figure 73 shows the distribution and extent of the HCVR types throughout Nepal and Table 15 show some basic statistics for the distribution of HCVR types by river basins.

A total of 50,531 km of rivers are included in our database in Nepal. Out of these, most rivers — 31,252 km or close to 62% — are classified as HCVR type 1 and can be described as both free-flowing and with potentially high water quality. The Karnali river basin stands out as the basin with the highest number of HCVR type 1 rivers, followed by the Gandaki, Koshi and Mahakali, and the West Rapti river basins, which all show more HCVR type 1 rivers than other types. Smaller basins, such as the Bagmati, Babai, Kanakai, and Mechi river basins, show only 40, 34, 23, and 4% of rivers in this category.

The second largest category are HCVR type 3 rivers that make up 27.8% (14,054 km) of the total river length in Nepal. These rivers can be described as free-flowing but they show lower water quality pressure index scores. River basins such as Mechi, Babai and Bagmati river are the three most prominent examples of this category. Many rivers of the Terai, and to a certain extent in the mid-hills, are also included in this category, possibly due to water quality pressures from pollutants from agricultural fertilizers.

HCVR type 2 rivers make up 7% (3,527 km) of rivers of Nepal. These rivers show losses of connectivity (river not described as “free-flowing”) however they still show potentially good water quality (low water quality pressures). The Mahakali, Kankai, Koshi, and West Rapti river basins include many of such river stretches.

Finally, the fourth category, HCVR type 4 are rivers where both losses of connectivity and reduced water quality occur. The Kanakai, Bagmati, and Babai rivers can be classified as such, and a total of 3.4% (1,698 km) are included in this category.

Any HCVR river type can harbor several freshwater values. For example, the Bagmati river is primarily composed of HCVR type 3 and 4 river reaches and therefore its freshwater status is disturbed, yet it harbors important biodiversity and recreation values along its course.

Each HCV type aligns with specific recommendations for protection, management, or restoration. HCVR type 1 require protection, whereas the other types require management or restoration measures (see section 6.3.7).

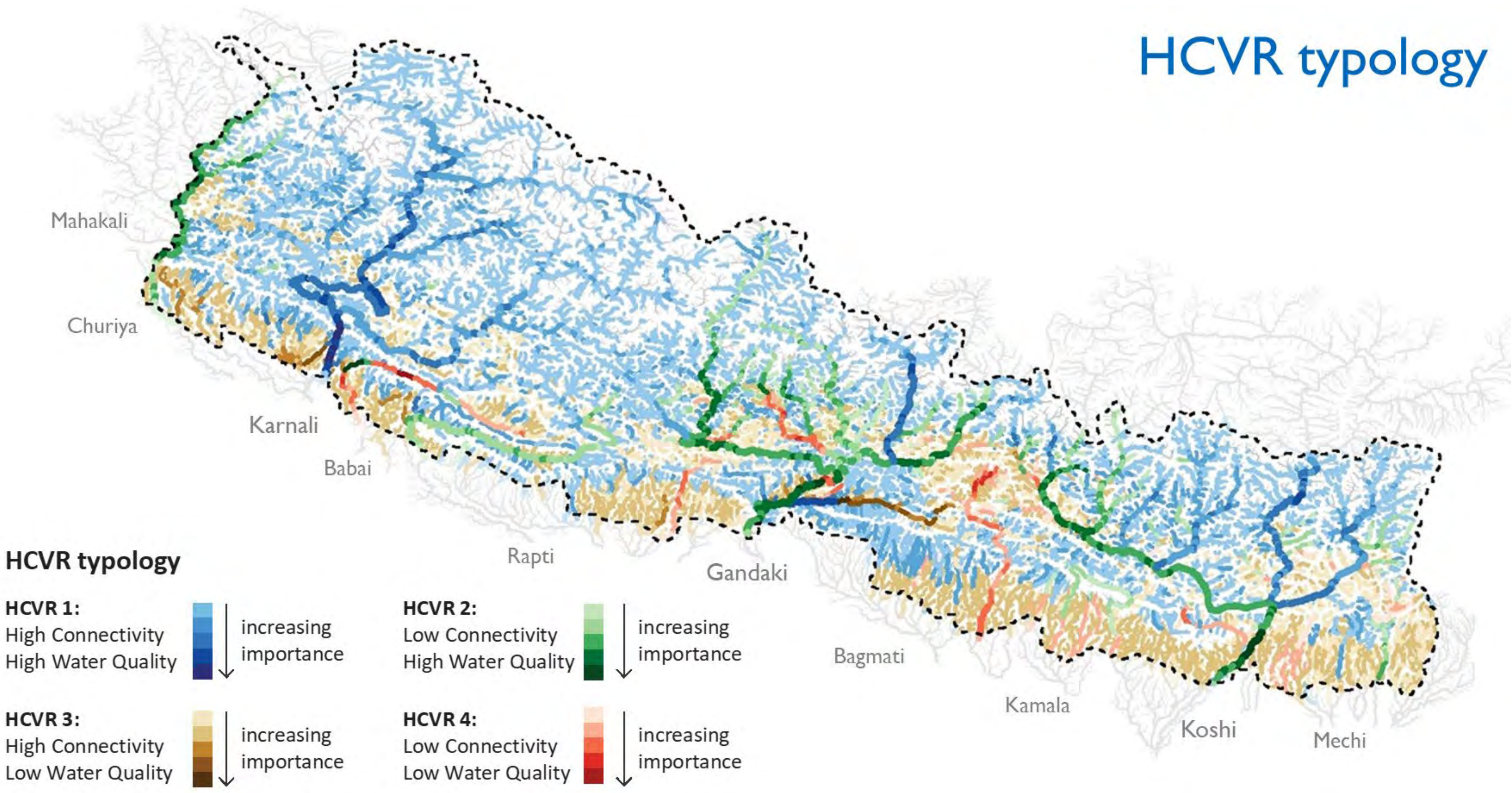


Figure 72: High Conservation River Typology. The increasing color saturation within each of the HCVR types indicate increasing HCV value scores.

Table 15: Overview statistics of the HCVR analysis. The table shows a) total sum of river kilometers in each HCVR type by river basin.

a) Percent of kilometers attributed to HCVR type by river basin

	HCVR Type				
River basin	**HCVR 1**	**HCVR 2**	**HCVR 3**	**HCVR 4**	**Total**
Babai basin	34.2%	2.7%	51.4%	11.6%	100%
Bagmati basin	39.5%	0.1%	40.6%	19.8%	100%
Gandaki basin	63.1%	12.7%	21.7%	2.5%	100%
Kankai basin	23.0%	16.3%	40.6%	20.1%	100%
Karnali basin	86.1%	0.3%	13.6%		100%
Koshi basin	60.3%	10.4%	26.4%	2.9%	100%
Mahakali basin	55.5%	17.8%	26.1%	0.5%	100%
Mechi basin	3.5%		96.5%		100%
Other Southern Basins	28.7%	1.5%	61.5%	8.4%	100%
West Rapti basin	58.5%	13.8%	27.6%		100%
Grand Total	**61.8%**	**7.0%**	**27.8%**	**3.4%**	**100%**

b) Total river kilometers attributed to HCVR type by river basin.

	HCVR Type				
River basin	**HCVR 1**	**HCVR 2**	**HCVR 3**	**HCVR 4**	**Total**
Babai basin	501	40	753	170	1,464
Bagmati basin	666	1	684	334	1,685
Gandaki basin	7,573	1,525	2,603	306	12,007
Kankai basin	117	83	206	102	508
Karnali basin	12,057	43	1,908		14,007
Koshi basin	6,270	1,080	2,744	300	10,394
Mahakali basin	1,164	373	548	11	2,095
Mechi basin	20		542		562
Other Southern Basins	1,618	83	3469	474	5,644
West Rapti basin	1,267	300	598		2,164
Grand Total	**31,252**	**3,527**	**14,054**	**1,698**	**50,531**

7.4 Ecosystem representation

7.4.1 River classification

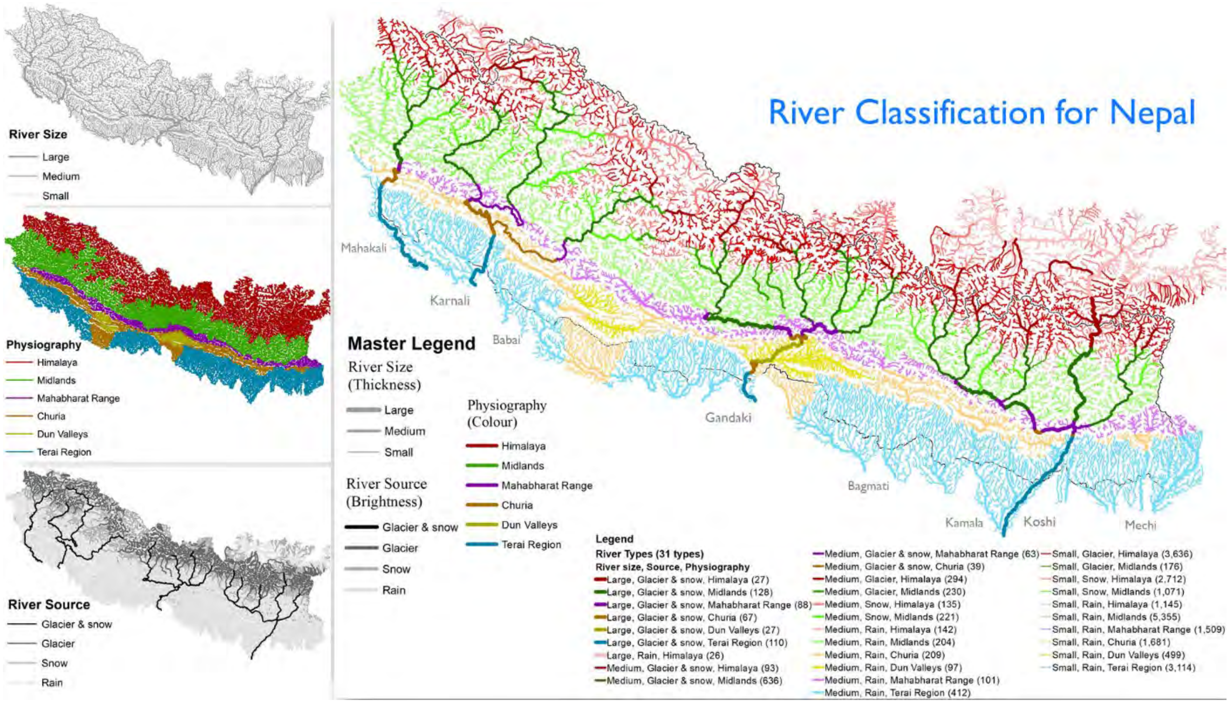
We conducted a river classification at the river reach scale for Nepal based on river size, physiography, and river source/influence. A total of 31 unique types of river have been Analysis of ecosystem representation identified under this assessment among them 29 river types occur within Nepal including large, glacier- and snow-influenced Himalayan rivers to small, rain-influenced Terai rivers (Figure 74).

The main objective of creating a river classification was to assess whether the diverse types of rivers in Nepal were well captured in the results of the HCV assessment. The river types classification was compared with the combined HCV score of the river reaches: no freshwater values mapped' (HCV 0; in places where values could not be identified), 'very low' (HCV < 1), 'low' (HCV 1-2), 'medium' (HCV 2-3), 'high' (HCV 3-4), and 'very high (HCV 4-5). We calculated how many river reaches of each river type falls within each of the six HCV value categories (Table 16).

The results show that all 29 river types identified in the river classification for Nepal are represented in at least one or more of the HCV value categories with a score $\geq$ 1. Large, Glacier & Snow, Dun; Large, Glacier & Snow, Terai; Large Glacier & Snow, Churia; Medium, Rain, Dun; and Medium, Glacier & Snow, Midland rivers have been represented in medium to very high HCV value categories and others have been found in at least one or several other categories. These results confirmed that the identified river types are well represented in the results of the HCV assessment, which was the primary objective of this assessment.

Additionally, the results also show some other interesting patterns. River types in Table 17 are sorted in increasing order of abundance, with the total number of river reaches reflecting their extent. We can see that ten river types are found in less than 100 river reaches throughout Nepal, making these river types very rare. Many of these rivers are medium-to-large rivers that are typically less abundant than smaller rivers. For example, large, glacier-influenced rivers flowing through the Terai region are only found in 37 locations throughout Nepal, yet all of these locations show medium to very high HCV values, marking these rivers as critically important for conservation. Other rivers are also rare, yet show lower HCV values, which could be the result of mapping a specific set of values, or due to gaps in the mapping methodology, i.e., fish species in smaller river reaches have not been mapped in Nepal yet.

We developed this river classifications for a specific purpose within the HCVR assessment, however we consider the results useful beyond that. It is to our knowledge the best currently available river classification for Nepal. It can be used as baseline data for research, environmental assessments, and applications in Nepal and can serve as a blueprint for other regional classifications. A valuable future next step would be to validate and update the classification based on field visits.



Large, Glacier & snow, Churia	Medium, Rain, Midlands
Large, Glacier & snow, Dun Valleys	Medium, Rain, Terai Region
Large, Glacier & snow, Himalaya	Medium, Snow, Himalaya
Large, Glacier & snow, Mahabharat Range	Medium, Snow, Midlands
Large, Glacier & snow, Midlands	Small, Glacier, Himalaya
Large, Glacier & snow, Terai Region	Small, Glacier, Midlands
Medium, Glacier, Himalaya	Small, Rain, Churia
Medium, Glacier, Midlands	Small, Rain, Dun Valleys
Medium, Glacier & snow, Churia	Small, Rain, Himalaya
Medium, Glacier & snow, Himalaya	Small, Rain, Mahabharat Range
Medium, Glacier & snow, Mahabharat Range	Small, Rain, Midlands
Medium, Glacier & snow, Midlands	Small, Rain, Terai Region
Medium, Rain, Churia	Small, Snow, Himalaya
Medium, Rain, Dun Valleys	Small, Snow, Midlands
Medium, Rain, Mahabharat Range	

Figure 73: Final River Classification for Nepal. The left side shows the three different components that were combined to create the final river types classes (right). List of identified river classes (bottom).

Table 16: Representation of River Types in HCV Value Categories. Number of river reaches mapped to each river type and HCV value category.

	Number of River Reaches	**HCV Value Categories (HCV Value range)**						**Total**
SN	**River Types**	**No Value mapped (0)**	**Very low (<1)**	**low (1-2)**	**medium (2-3)**	**high (3-4)**	**very high (4-5)**	
1	Large, Glacier/snow, Himalaya			7	7			14
2	Large, Glacier/snow, Dun Valleys					20	7	27
3	Large, Glacier/snow, Terai Region				6	22	9	37
4	Medium, Glacier/snow, Churia			38	1			39
5	Large, Glacier/snow, Churia				2	56	4	62
6	Medium, Glacier/snow, Mahabharat Range			21	18	24		63
7	Medium, Snow, Himalaya	19	44	1				64
8	Medium, Glacier/snow, Himalaya	3	24	42	5			74
9	Large, Glacier/snow, Mahabharat Range				9	73	4	86
10	Medium, Rain, Mahabharat Range	28	38	5	18	8		97
11	Medium, Rain, Dun Valleys	2	2	11	34	14	34	97
12	Large, Glacier/snow, Midlands				34	70	18	122
13	Medium, Rain, Terai Region	33	2	31	45	10	2	123
14	Small, Glacier, Midlands	51	71	11	12	2		147
15	Medium, Rain, Midlands	46	55	27	10	15	1	154
16	Medium, Glacier, Himalaya	18	98	44	9			169
17	Medium, Rain, Churia	50	25	33	48	16		172
18	Medium, Glacier, Midlands	14	95	25	35	15	2	186
19	Medium, Snow, Midlands	38	74	58	42	4		216
20	Small, Rain, Himalaya	211	152	1	9			373
21	Small, Rain, Dun Valleys	147	4	121	139	88		499
22	Medium, Glacier/snow, Midlands		37	162	223	169	15	606
23	Small, Snow, Midlands	495	402	39	11			947
24	Small, Rain, Churia	1157	28	126	49	10		1370
25	Small, Rain, Mahabharat Range	1354	58	40	8	3		1463
26	Small, Rain, Terai Region	1146	54	279	94	154	5	1732
27	Small, Snow, Himalaya	1103	645	31	23			1802
28	Small, Glacier, Himalaya	1516	707	117	30			2370
29	Small, Rain, Midlands	3461	1340	69	36	3		4909
	Grand Total	**10892**	**3955**	**1339**	**957**	**776**	**101**	**18020**

8 Recommendations & next steps

In 2015, the United Nations agreed on a set of 17 Sustainable Development Goals (SDGs) encompassing 169 targets by 2030. These goals recognize that economic, social and environmental values are fundamentally connected and that policies and management need to pursue these goals in a coordinated fashion in order to be successful (Opperman et al., 2018). Under SDGs, the 6th goal is focused on water "to ensure availability and sustainable management of water and sanitation for all" and through SDG 6.6 explicitly focused on maintaining or restoring freshwater ecosystem extent, including rivers. The HCV Rivers of Nepal will be useful for long term and national scale management of freshwater ecosystems in Nepal and will contribute to SDG 6 and other freshwater-related goals und SDGs.

In Nepal, water resources management is largely focused on water quantity and quality, with little focus on conservation and restoration of rivers. There are a variety of policies with provisions related to freshwater conservation (Annex 10.3). The Constitution of Nepal, 2015 provides the right to every citizen to live in a clean and healthy environment, and it also provides different powers related to water use to federal, provincial, local governments; and now the Nepalese government is preparing legal instruments to use the power provided in the Constitution.

Recommendations

This is the first time that HCVRs have been identified and categorized in Nepal. The datasets and maps provide new understanding of the location of high conservation value areas, both for individual indicators and for summarized levels of value. World Wildlife Fund (WWF) and USAID Paani program worked alongside Nepalese experts from multiple organizations to identify and synthesize data for biodiversity, recreational, livelihood, and social and cultural values. The resulting national-level HCVR assessment is the first of its kind in Nepal and will be a key source for government agencies and other stakeholders. Identification of HCVRs provides critical information for planning at different levels through quantitative evaluation and spatial mapping of the values that rivers provide to society. Understanding where areas of high conservation value - i.e., those that support high levels of biodiversity, recreation, fisheries, or other socio-cultural values - occur within a country allows for more scientifically grounded decisions on river management. Natural resources managers and others involved with conservation efforts benefit from the identification of freshwater conservation priorities, which can guide decisions on where to focus their limited resources.

Under the Convention of Biological Diversity (CBD), National Biodiversity Strategy Action Plan (NBSAP, 2003) for Nepal there is a recognition of the importance of north-south biological connectivity for fish assemblages and ecological integrity of the river systems. Therefore, one of the objectives in the NBSAP was to maintain unhindered north-south biological connectivity in at least three major rivers each in central, eastern, and western parts of Nepal by 2020. The National Strategic Framework for Sustainable Development (2015-2030) also prioritized maintaining river connectivity in Nepal. Until now, however, there was no progress towards these targets. A national assessment identifying and ranking the relative conservation values of Nepali rivers has been lacking until now. The HCVR assessment can provide scientifically grounded information to help prioritize which rivers to keep free flowing or with high levels of river connectivity to meet the objectives of the NBSAP.

Identification of HCVR can also guide hydropower development decisions. Hydropower development is being proposed on all the major rivers across Nepal and is a significant threat to river systems. HCVR maps can provide insights on where those threats are most serious and provides opportunities for mitigation of development impacts. Avoidance, minimization, restoration and offsetting are options to mitigate the potential negative impacts of hydropower on river biodiversity and other values. The results can provide quantitative assessment of rivers to avoid and rivers to protect or restore, to compensate for impacts. For example, the high values of the main channel of the Karnali and its tributaries would conflict with several large-scale projects proposed for this basin. If these projects were developed, the impacts on the river ecosystem and its conservation values would be significant. The Karnali is one of the last free-flowing rivers in Nepal, with unique values such as providing a home for the critically endangered Ganges River dolphin and endangered, native Golden Mahseer and critically endangered, endemic snow trout Rara Asala (*Schizothorax macrophthalmus*).

This assessment can also contribute to and influence ongoing processes for developing a River Basin Plan, a Hydropower Master Plan and a Strategic Environmental and Social Assessment (SESA) of all the river basins of Nepal that are being developed under the leadership of the Water and Energy Commission Secretariat (WECS) - an apex body of Government of Nepal whose mandate is to formulate plans and policies related to water and energy resources sector. Similarly, these results can support the Ministry of Forests and Environment and National Planning Commission to implement their prioritized actions specified in Nepal's National Biodiversity Strategy and Action Plan and the National Strategic Framework for Sustainable Development. As well, this work can be instrumental in supporting the preparation of the National Integrated River Basin Strategy and Action Plan, and associated River Conservation Bills and Aquatic Biodiversity Conservation Bills.

Next Steps

Moving forward, the highest priority next step is to conduct capacity building activities for water resource managers and stakeholders on both the available data and resources and how they can be used and updated into the future. Ideally, the HCVR data can become incorporated into multiple Nepalese data systems -including those of academic, governmental, private sector and civil society organizations. Due to Covid, the project team was unable to complete field validation studies and these are recommended as another priority next step. Scientific publications of available data and information have been planned for further disseminating and validating this assessment within the academic literature and providing broad accessibility. Translation of the report as well as policy briefs and summary documents into Nepali language is important for making it available to managers and readers at the local and provincial levels.

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10 Annexes

10.1 Workshops, advisory group meetings and impressions

10.1.1 Workshops

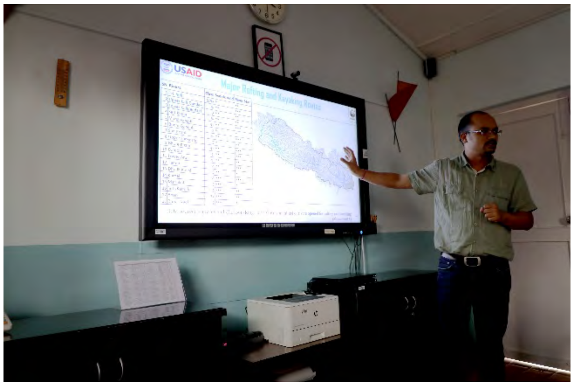
Workshop 1, July 2019, Kathmandu and Surkhet, Nepal

Workshop 2, March 2020 (virtual)

Workshop 3, October 2020 (virtual)

10.1.2 Advisory group meetings

Number	Date	Venue	No. Of Participants
1st	27th Sept 2019	WWF Nepal	19
2nd	6th Nov 2019	WWF Nepal	19
3rd	6th Dec 2019	Paani Office	15
4th	11th Feb 2020	Paani Office and Zoom	20
5th	27th May 2020	Zoom	31
6th	7th Oct 2020	Zoom	38


USAID



Emergency Exit


USAID
Integrating Values and Status into HCVR
Option 2: Classification approach


Emergency Exit

10.2 Freshwater Values and Status

10.2.1 Justification and Data description and source

Value Category	Biodiversity
Sub-category	Aquatic Biodiversity>Fish
Value ID	1.1.1.1, 1.1.1.2, 1.1.1.3, and 1.1.1.4
Value Name	Fish Species (Species Richness, Endangered, Threatened, Migratory)
Justification	Freshwater ecosystems and their associated biodiversity are invaluable resources in Nepal. There are at least 256 species in Nepal. Maintaining adequate habitat for fish species requires connected river corridors without barriers to their dispersal. Dams and barrages can temporarily or permanently block habitat space that is required to complete the life cycle of fishes. Dams and barrages can also affect the flow regime of the downstream communities, leaving significant stretches with less, or without water. Diversion structures and their turbines further increase the risk of mortality for river species.
Data description	Number of fish species (migratory, endemic, threatened, species richness) distributed in Rivers
Data source	USAID Paani Program/WWF Nepal, 2020

Value Category	Biodiversity
Sub-category	Aquatic Biodiversity>Flagship Species
Value ID	1.1.2.1
Value Name	River Dolphins
Justification	Gangetic River Dolphin is the only recorded cetacean species and legally protected mammal in Nepal. The River Dolphin- freshwater indicator species plays an important role in food chain and thus balances the freshwater ecosystem. Though it is regarded as an endangered flagship species, its habitat is highly degraded and destructed by human interference thereby shrinking its distribution range and lowering its population. Maintaining adequate habitat for river dolphins requires connected river corridors without barriers. Dams and barrages can temporarily or permanently block habitat space that is required for river dolphins to survive. Dams and barrages can also affect the flow regime downstream, leaving river stretches with less, or without water, further affecting the river dolphins.
Data description	Number of dolphins distributed in rivers and the type of dolphin habitat (current/potential/historical)

Data source	IUCN Nepal, 2017; Advisory meetings

Value Category	Biodiversity
Sub-category	Aquatic Biodiversity>Flagship Species
Value ID	1.1.2.2
Value Name	Gharials
Justification	Gharials (*Gavaialis gangeticus*) are critically endangered species and considered as habitat specialist and indicator species of healthy freshwater ecosystems. It is one of the protected reptiles of Nepal under the Schedule I of National Parks and Wildlife Conservation Act, 1973. According to the last census, 198 number of gharials have been recorded in Babai, Narayani and East Rapti rivers of Nepal. However, recently a gharial has also been spotted in West Rapti river. Maintaining adequate habitat for gharials requires connected river corridors without barriers.
Data description	Number of gharials distributed in rivers and the type of gharial habitat (current/potential/historical)
Data source	DNPWC, 2018 (Crocodile Survey, 2016); Acharya et al., 2017; Advisory Meetings Crocodile Survey, 2016; DNPWC, 2018; Acharya et al., 2017; Record of WWF Nepal, 2019; Advisory Meetings

Value Category	Biodiversity
Sub-category	Aquatic Biodiversity>Flagship Species
Value ID	1.1.2.3
Value Name	Mahseer
Justification	Mahseer are called as tigers of rivers, mahseer was also included in flagship category as this species is also important for gharial and dolphin to survive in Nepalese rivers. Mahseer are commercially important game fish as well as highly esteemed food fish. There are four species of mahseer found in Nepal. Golden Mahseer is one of the most highly popular sport fish attracting anglers from around the world. It is also an important food fish harvested for both commerce and subsistence throughout its range often using unsustainable fishing methods. Copper Mahseer is also a highly valued food and game fish. Major threats to Mahseer include habitat loss due to deforestation and erosion, urbanization, including road construction, overfishing, decline in quality of habitat resulting in loss of breeding grounds, and other anthropogenic effects.
Data description	Number of mahseer distributed in rivers
Data source	USAID Paani Program/WWF Nepal, 2020

Value Category	Biodiversity
Sub-category	Floodplain Biodiversity
Value ID	1.2.1
Value Name	Rhinoceros
Justification	Maintaining adequate habitat for rhinos requires healthy functioning floodplain systems that have natural variability with the seasons. Dams and barrages can affect the flow regime of the floodplains, affecting the species that depend on the natural ecosystem function for their survival. Habitat specialists like one-horned rhinoceros are completely dependent on floodplain grasslands that are governed and maintained by flood dynamics.
Data description	Important river reaches for Rhinos
Data source	DNPWC, 2015 (National Rhino Count, 2015)

Value Category	Biodiversity
Sub-category	Floodplain Biodiversity
Value ID	1.2.2
Value Name	Tigers
Justification	Maintaining adequate habitat for tiger's prey species requires healthy functioning floodplain systems that have natural variability with the seasons. Dams and barrages can affect the flow regime of the floodplains, affecting the species that depend on the natural ecosystem function for their survival. Tigers, though generalist species, reach their highest densities on floodplain grasslands.
Data description	Important river reaches for Tigers
Data source	DNPWC and DFSC, 2018 (National Tiger Survey, 2018); Dhakal et al, 2014; National Tiger Survey, 2018; Dhakal et al., 2014; Poudyal et al., 2018

Value Category	Biodiversity
Sub-category	Floodplain Biodiversity
Value ID	1.2.3
Value Name	Otters
Justification	Representing the top of the food chain of the freshwater ecosystem, otters are often regarded as indicator species for intact healthy wildlife

	habitat. Hydropower and Infrastructures development is considered as one of the major threats to this species.
Data description	Important river reaches for Otter
Data source	USAID Paani Program/WWF Nepal, 2020

Value Category	Biodiversity
Sub-category	Floodplain Biodiversity
Value ID	1.2.4
Value Name	Wetland Birds
Justification	A total of 863 species of birds has been reliably recorded in Nepal (BCN, 2008). Of these nearly 200 species of birds are considered to be heavily dependent on wetland habitats (Grimmett et al., 2000 cited by Baral, 2009)). Wetland birds comprise significant portion of avian fauna of Nepal. Wetlands in Nepal are rich in biological diversity and are known to regularly support more than 20,000 waterfowl during the peak period between December-February. Rivers are home to many bird species: some got there to eat, or to next or to rest, others follow the course of a river, using it as a migratory route. In Nepal, there are many important rivers reaches that are home to several species of wetland birds including Koshi River, Narayani River along Chitwan National Park, Rapti River in Dang Deukhuri IBA, Karnali River, and Babai River
Data description	Important river reaches for wetland birds with species diversity index information of each sites
Data source	USAID Paani Program/WWF Nepal, 2020

Value Category	Recreation
Value ID	2.1
Value Name	Rafting and Kayaking
Justification	The Karnali river is famous for its rafting opportunities. It's considered to be one of the top ten world class locations for white water rafting. Hydropower development could threaten the success of these recreation opportunities. Within the Karnali basin, the Seti, Upper Seti, and Bheri rivers are popular tributaries for kayaking and rafting. Hydropower dams that are constructed on popular stretches of river for rafting are physical barriers negatively disrupting the tourism opportunities. Downstream flow alteration from dams could also impact rafting by changing the white-water rapids and the overall experience on the river.
Data description	Important river reaches for Rafting and Kayaking

Data source	White Water Nepal Book by Knowles and Clarkson-King, 2011; Advisory Meetings

Value Category	Recreation
Value ID	2.2
Value Name	Trekking
Justification	The diversity of trekking trails in Nepal cannot be found in any other part of the world. Trekking has been the leading activity of tourists in Nepal and thousands take to the Himalayas, some doing a few days of hiking while others take on a month-long trek through valleys and high mountain passes. There are many trekking regions including Everest, Annapurna, Langtang and Kanchenjunga regions. There are important trekking sites near rivers and peoples love to do bird watching and George walk and other recreational activities in these sites.
Data description	River reaches passed by trekking routes
Data source	Great Himalayan Trail Map (Maharjan et al., 2017); Advisory Meetings

Value Category	Recreation
Value ID	2.3
Value Name	Protected Areas
Justification	Maintaining the natural flow regime of rivers within protected areas is critical to ensure that the natural ecosystem function continues. Protected areas are set aside due to high biodiversity or natural significance. Dams and barrages can temporarily or permanently change the flow regime of rivers, affecting the ecosystem functioning within protected areas. This will negatively affect the fauna and flora living in the protected areas.
Data description	Big rivers passing through Protected Areas
Data source	Department of National Parks and Wildlife Conservation (DNPWC), 2020

Value Category	Livelihood
Value ID	3.1
Value Name	Commercial and Food Value of Fisheries
Justification	Freshwater biodiversity plays a significant role in supporting the livelihoods of human communities particularly people in rural and poor communities. Indigenous fishes are a key source of nutrition and income

	for much of the rural and fisher communities. As the riverine fisheries have various opportunities for development of fisheries and aquaculture, they are generally unrecognized and undervalued. Majority of fish species are used as food value with multiple use. Overfishing, damming, habitat degradation and destructive fishing practices are reported to have contributed to reduction in stocks. Marginal people and fishers with low income are unable to afford costly farm fishes, the capture fisheries benefit directly by increasing income and improving nutritional status. Some riverine fishes have considered more delicious than cultured species so have high demand with good market price. The species that have high livelihoods value must be protected from threats.
Data description	Number of high commercial and food value fish species in rivers
Data source	USAID Paani Program/WWF Nepal, 2020

Value Category	Livelihood
Value ID	3.2
Value Name	Water Provision
Justification	Water provision has included under the livelihood category is to represent importance of Nepalese rivers in terms of drinking water, indigenous irrigation, other household uses and waste disposal services they provide. The river reaches have been mapped based on the less water available in rivers and population nearby. Therefore, based on this analysis: low lying, seasonal and small rivers possess greater water provision value than highland, perennial, and large rivers.
Data description	Categories of river reaches based on water provisioning value
Data source	USAID Paani Program/WWF Nepal, 2020

Value Category	Socio-cultural
Value ID	4.1
Value Name	Religious and Symbolic Sites
Justification	There are many rivers reaches in Nepal that are equally important for religious and cultural activities including cremation, sacred bathing, and other cultural and regions events. Maintenance of river flow and water quality are important to continue the socio-cultural services.
Data description	Rivers reaches nearby to locations of religious sites (Temple, Stupa, Mane, Church, Mosque, Cemetery and Crematorium)
Data source	Topographic Map of Nepal (Department of Survey, 2001); Advisory meeting

Value Category	Freshwater Status
Value ID	5
Status Name	Connectivity
Justification	The connectivity of rivers captures many of the other values that are listed here. The connectivity of rivers allow species to move upstream, downstream, and laterally, transport sediments, supports tourism activities, and maintains the natural state of the rivers.
Data description	Connectivity Status Index (CSI, %) classes, please see detail method and data requirement in Grill et al, 2019
Data source	Dam database from Government of Nepal, WWF-Nepal, and PANI; hydrologic network from HydroSHEDS
Remarks	Data will be updated based on new information on dams

Value Category	Freshwater Status
Value ID	6
Status Name	Water Quality
Justification	Many peoples in rural and urban areas depend directly or indirectly on water from rivers and streams. In addition, species that both live and use water in rivers can also suffer from poor water quality.
Data description	Water Quality classes
Data source	Esch et al. 2014; West et al. 2014; Vogl et al. 2019; OSM 2020; Gaughan et al. 2013; USAID Paani Program/WWF Nepal, 2020

Category	Ecosystem Representation
ID	7
Name	River Classification
Justification	River classifications can provide opportunities to better understand river ecosystems and their function, highlight similarities or differences between climatic or physiologic regions, allow for international comparisons of freshwater resources, enable assessments of the representation of system types, and frame other analyses. Some general river classifications have been made in Nepal for instance based on the river/stream origin and stream order. However, so far there has been no national level classification of rivers in Nepal based on number of characteristics.
Data description	River Reach Types
Data source	USAID Paani Program/WWF Nepal, 2020

10.3 Important policies related to freshwater conservation in Nepal

1. Constitution of Nepal, 2015

The constitution provides the right to every citizen to live in a clean and healthy environment. The constitution provided following powers related to water resources to respective level of governments:

Federal Power:

- Policies relating to conservation and multiple uses of water resources
- Mines excavation
- National and international environment management, national parks, wildlife reserves and wetlands, national forest policies, carbon services
- Any matter not enumerated in the Lists of Federal Powers, State Powers and Local level Powers or in the Concurrent List and any matter not specified in this Constitution and in the Federal laws

State power:

- State level electricity, irrigation and water supply services, navigation
- Exploitation and management of mines
- Use of forests and waters and management of environment within the State

Concurrent powers of Federal and state

- State boundary river, waterways, environment protection, biological diversity
- Tourism, water supply and sanitation
- Utilization of forests, mountains, forest conservation areas and waters stretching in inter-State form

Local level power:

- Local market management, environment protection and biodiversity
- Local roads, rural roads, agro-roads, irrigation
- Water supply, small hydropower projects, alternative energy
- Protection of watersheds, wildlife, mines and minerals

Concurrent Powers of Federation, State and Local Level:

- Services such as electricity, water supply, irrigation
- Service fee, charge, penalty and royalty from natural resources, tourism fee
- Forests, wildlife, birds, water uses, environment, ecology and biodiversity
- Mines and Minerals
- Royalty from natural resources

2. Aquatic Animals Protection Act, 1961

This Act is one of the oldest acts in Nepal that recognizes the value of wetlands and aquatic animals. Under the Act, any party is punishable for introducing poisonous or explosive materials into a water source or destroying any dam, bridge or water system with the intent of catching or killing aquatic life. It also defines "private water" as a lake, pond, ditch, pool or reservoir that is on land used by a person who has been paying land tax to the government. Although the Act has been in effect for quite some time there is no designated agency to administer it.

3. Soil Conservation and Watershed Management Act 1982 and Regulation 1985

The Soil and Watershed Conservation Act empowers the government to declare any area as a protected watershed to limit degradation of land by floods, waterlogging, salinity in irrigated areas and acceleration of siltation in storage reservoirs, and to properly manage the watersheds of Nepal. The Act of 1982 and its regulations of 1985 together provide the legal basis for managing watersheds. The Act also outlines the essential parameters necessary for proper watershed management (including both rivers and lakes). Department of Soil Conservation and Watershed Management (DSCWM)[1] (authorized body to implement the act) has taken some actions to declare Fewa Watershed as protected watershed area regarding formation of high-level conservation committee, however due to the inability of doing so the act and regulation remain unimplemented.

4. National Conservation Strategy, 1988

It recognizes that increasing urbanization and an expanding industrial base are major contributors to air, noise, and water pollution, and that the quality of human life and health is adversely affected by this pollution. It recommends formulating national policy and legislation on air, noise, and water pollution monitoring and control.

5. Water Resources Act 1992, Water Resources Regulation, 1993, and Water Resource Strategy, 2002

The act was formulated to ensure the rational utilization, conservation, management and development of water resources in Nepal. The Act legally defined the process for determining beneficial uses of water, preventing environmental and hazardous effects, and keeping water resources free from pollution. It requires the use of environmental impact assessments in order to minimize environmental damage to wetland, lakes, rivers. The hierarchy of water resource use in Nepal was giver as: 1) Drinking water and domestic use, 2) Irrigation, 3) Agricultural animal husbandry, 4) Fisheries, 5) Hydroelectricity, 6) Cottage Industry, 7) Industrial enterprises and mining, 8) Navigation, 9) Recreational Use, and 10) Other Uses. Nepal has quite comprehensive water quality standards for drinking water, Irrigation, Livestock Watering, Protection of Aquatic Ecosystems, Aquaculture, Industrial Use, Industrial Effluents, and Recreation. Even with these data available, however, there does not appear to be a comprehensive water quality monitoring program or national database for water quality records. There also does not appear to be any regulatory system in place which would enforce water quality standards and ensure that they are being met. As a result, there is no impetus to implement the existing water quality standards.
The Water Resources Regulation, 1993 makes it mandatory to take appropriate measures to minimize the adverse effects of water resource development projects on the overall environment. Measures must be taken for the conservation of aquatic life and water quality.

[1] DSCWM has merged into Department of Forest and Soil Conservation (DoFSC)

The National Water Resource Strategy of Nepal 2002 recognizes the need for sustainable management of watersheds and aquatic ecosystems. The strategy introduces a three-prong approach to water resource management which includes the following: 1. Ensuring security; 2. Protecting and regulating key water uses; and 3. Developing mechanisms for deployment of a Water Resource Management Program.

6. Electricity Act, 1992

The Electricity act states that while generating, transmitting, or distributing electricity, it is forbidden to negatively impact the environment by causing soil erosion, flooding, landslides, or air pollution. The act prohibits blocking, diverting, or placing hazardous or explosive materials in the river, streams, or any other water source.

7. Nepal Environmental Policy and Action Plan, 1993

The plan recommends the finalization of draft EIA guidelines for water resources, the development of EIA guidelines for road construction, and the use of EIA when designing hydroelectric projects. The Government of Nepal endorsed national EIA guidelines in 1993.

8. Environment Protection Act and Regulation, 1997

The act obliges the proponents of development projects to prepare an initial environmental examination and/or EIA based on threshold values. The act does not cover strategic environmental assessment and is not made obligatory for policies and strategies.

9. Drinking Water Regulation, 1998

The regulation requires a license from the District Water Resource Committee to use water resources. The committee must publish a notice with details for public information. The committee may prescribe some conditions for minimizing the adverse effect if there are suggestions from the public. The supplier must not construct or conduct any activity that may pollute the water resources and environment.

10. Hydropower Development Policy, 2001

The policy sets minimum environmental flow for hydropower projects as the higher of 10% of minimum monthly discharge or as identified in the EIA.

11. National Wetland Policy 2012

National wetland policy (2012)'s vision is "Healthy wetlands for sustainable development and environmental balance" It aims at conserving and managing wetlands resources sustainably and wisely. Its objectives are to conserve and protect biodiversity and the environment through the conservation of wetlands by (i) involving locals in the management of wetlands and the conservation, rehabilitation, and effective management areas; (ii) supporting the well-being of wetland development communities; and (iii) enhancing the knowledge and capacity of stakeholders along with maintaining good governance in the management of wetland areas.

It emphasizes (i) identifying and prioritizing wetlands on the basis of ecological, social, and economic importance and the conservation, rehabilitation, and management of such areas (this policy is very much related to HCVR); (ii) identifying, respecting, and utilizing traditional knowledge and skills of wetland dependent communities; (iii) making provisions for equitable distribution of the benefits arising from the utilization of wetland-based resources; and (iv) promoting good governance. However, it seems like the policy, has introduced to conserve stagnant water bodies like lakes and ponds only.

12. Irrigation Policy, 2013

The policy promotes the implementation of strategy relating to the management of climate risks, and mitigation and adaptation to the effects of climate change. It highlights the construction of irrigation projects and/or systems in a manner that minimizes negative environmental effects. It commits to using only the portion of water for irrigation from any river after releasing minimum water in the river to sustain aquatic biodiversity.

13. Nepal Biodiversity Strategy (NBS), 2003, Nepal National Biodiversity Strategy and Action Plan (NBSAP) 2014-2020 and Nepal's Sixth National Report on Convention on Biological Diversity (December 2018)

NBS provides a strategic planning framework for the conservation of biological maintenance of ecological processes and systems, and equitable sharing of the benefits accrued. The NBSAP recognizes the importance of north-south biological connectivity for fish assemblage and ecological integrity of the river system, therefore, it has planned for maintaining unhindered north-south biological connectivity in at least three major rivers each in central, eastern and western part by 2020. However, no rivers are declared as unhindered N-S biological connectivity. Till now, there was no progress towards the target. The sixth national report on CBD (2018) stated country's hydropower potential and hydropower companies' ignorance to implement remedial measures for aquatic biodiversity conservation as the cause of not maintaining north-south connectivity of rivers.

NBSAP has also envisioned the establishment and management of fish sanctuaries, however in the context of limited legislation and intense fishing pressure and use rights of communities; no wetlands have been declared and managed as fish sanctuaries (MoFSC, 2018). Certain stretch of river in Koshi inside KTWR, designated area of Phewa Lake and stretch near dam side of Kulekhani River are restricted for fishing.

14. National Forest Policy, 2075

Vision of this policy is to contribute on economic, social, and cultural wellbeing of Nepal by management of forest area and ecosystem balance. The goal is to sustainable and participatory management of forest, protected area, watershed, biodiversity, wildlife, and vegetation, thereby production and value addition of forest products and services and equitable benefit sharing. Under 8.5: Watershed, environmental services, and REDD+: three policies are stated, they are: 1) Maintenance of watershed health by integrated water and soil conservation and management, thereby increase in land productivity, 2) Conservation and management of watersheds of Churey area on the basis of upstream and downstream linkage, and 3) Conservation, management and sustainable use of wetlands. All three policies are directly or indirectly related to river conservation.