



COVER PHOTO CREDIT: RAJESH SADA/WWF-NEPAL

PAANI PROGRAM | पानी परियोजना

HIGH CONSERVATION VALUE RIVER ASSESSMENT - METHODOLOGY AND RESULTS

This publication is made possible by the support of the American People through the United States Agency for International Development (USAID.) The contents of this plan are the sole responsibility of DAI Global and WWF and do not necessarily reflect the views of USAID or the United States Government.

PAANI PROGRAM | पानी परियोजना

HIGH CONSERVATION VALUE RIVER ASSESSMENT - METHODOLOGY AND RESULTS

Program Title:	USAID Paani Program
DAI Project Number:	1002810
Sponsoring USAID Office:	USAID/Nepal
IDIQ Number:	AID-OAA-I-14-00014
Task Order Number:	AID-367-TO-16-00001
Contractor:	DAI Global LLC
Date of Publication:	December 2020
Authors:	Günther Grill (McGill University), Michele Thieme (WWF-US), Jibesh Kumar K.C. (WWF Nepal), Natalie Shahbol (WWF-US), Rajesh Sada (WWF-Nepal), Rafael Schmitt (Stanford University), Jeff Opperman (WWF-US), and Erik Martin (TNC)

COVER PHOTO CREDIT: RAJESH SADA/WWF-NEPAL

ACKNOWLEDGEMENTS

We would like to thank the following organizations and people for their contribution to the High Conservation Value Rivers assessment: USAID Paani Program for their funding, feedback and support on this assessment; High Conservation Value Rivers Advisory Group members for their many contributions and advice throughout the project; experts from the Himalayan Otter Network, including Paras Mani Acharya; GEEC Pvt. Ltd. for consolidating and providing fisheries data; FEED Pvt Ltd for their expertise on river classification; Hari Krishna Dhonji for his work on the webtool; Ministry of Forests and Environment, Water and Energy Commission Secretariat, and Tractebel for their inputs; and guest attendees for their feedback during the July, March, and November workshops.

TABLE OF CONTENTS

i.	ADVISORY GROUP.....	ix
ii.	ABBREVIATIONS.....	x
iii.	GLOSSARY.....	xi
1.	EXECUTIVE SUMMARY.....	1
2.	BACKGROUND & PURPOSE.....	4
3.	ACCOMPLISHMENTS, OUTPUTS & DELIVERABLES.....	5
4.	INTRODUCTION.....	6
4.1	OVERVIEW: FRESHWATER RESOURCES & ECOSYSTEMS.....	6
4.2	NEPALESE FRESHWATER RESOURCES & ECOSYSTEMS.....	6
4.3	THREATS TO FRESHWATER ECOSYSTEMS IN NEPAL.....	7
4.4	VALUES OF RIVERS.....	9
4.5	DEFINITIONS AND APPLICATIONS: FFR AND WILD RIVERS.....	10
4.6	CONCEPT OF FREE-FLOWING RIVERS (RIVER CONNECTIVITY).....	11
5.	OVERVIEW.....	13
5.1	PROJECT COMPONENTS.....	13
5.1.1	Freshwater status.....	14
5.1.2	Freshwater value mapping.....	15
5.1.3	High-Conservation Value rivers.....	15
5.1.4	Ecosystem representation analysis.....	15
6.	METHODOLOGY.....	16
6.1	DATA SOURCES AND MATERIALS.....	16
6.2	ASSESSING THE FRESHWATER STATUS OF NEPALESE RIVERS.....	17
6.2.1	Free-flowing river assessment.....	17
6.2.2	Water quality pressures assessment.....	26
6.3	ASSESSING THE FRESHWATER VALUES OF NEPALESE RIVERS.....	29
6.3.1	Identification and selection for freshwater values.....	29
6.3.2	Data collection and review.....	29
6.3.3	Mapping of freshwater values to the river network.....	29
6.3.4	Standardization of freshwater values.....	30
6.3.5	Weighting Values.....	32
6.3.6	Combining HCV values.....	33
6.3.7	HCVR typology.....	34
6.4	MAPPING OF FRESHWATER VALUES.....	36
6.4.1	Biodiversity values.....	36
6.4.2	Recreational values.....	42
6.4.3	Livelihood values.....	46
6.4.4	Socio-cultural values.....	48
6.5	ECOSYSTEM REPRESENTATION ANALYSIS.....	48
6.5.1	Objective.....	48
6.5.2	Introduction to river classifications.....	49
6.5.3	Methodology.....	50
7.	RESULTS.....	56
7.1	FRESHWATER STATUS.....	56
7.1.1	Free-Flowing Rivers Assessment.....	56
7.1.2	Water quality pressures assessment.....	60

7.2 FRESHWATER VALUES	65
7.2.1 Biodiversity values	65
7.2.2 Recreational values	78
7.2.3 Livelihood values.....	81
7.2.4 Socio-cultural values.....	83
7.2.5 Combining HCV values	84
7.3 HIGH-CONSERVATION VALUE RIVERS OF NEPAL	88
7.4 ECOSYSTEM REPRESENTATION	92
7.4.1 River classification.....	92
8. RECOMMENDATIONS & NEXT STEPS.....	95
8.1 RECOMMENDATIONS.....	95
8.2 NEXT STEPS	96
9. REFERENCES	97
10. ANNEXES.....	104
10.1 WORKSHOPS, ADVISORY GROUP MEETINGS AND IMPRESSIONS.....	104
10.1.1 Workshops	104
10.1.2 Advisory group meetings	105
10.2 FRESHWATER VALUES AND STATUS	107
10.2.1 Justification and Data description and source.....	107
10.3 IMPORTANT POLICIES RELATED TO FRESHWATER CONSERVATION IN NEPAL	113
10.4 USAID PAANI PROGRAM/WWF STUDIES	117

TABLES

Table 1: Overview of pressure factors.....	18
Table 2: Local adjustments of the discharge range factor (DRF).	21
Table 3. Estimated road width for road types in Nepal.	22
Table 4: Data sources used to predict the water quality pressures index for Nepali rivers.	27
Table 5: Overview of high conservation values (HCV).	31
Table 6: Primary fish species important for angling (Rana, 2020).	43
Table 7: Rafting and Kayaking summary of Nepalese rivers.	44
Table 8: Expert evaluation of the capacity of the river in relation to demand (m ³ person / day).....	47
Table 9: Number of fish species in Nepal’s rivers	66
Table 10: List of Endemic Fishes of Nepal.	67
Table 11: Critically endangered, endangered and vulnerable fish species of Nepal.....	69
Table 12: Long distance, and short to medium distance migratory species.	70
Table 13: List of Mahseer Species found in Nepal.	73
Table 14: Otter species documented in Nepal.....	75
Table 15: Overview of ranked rivers	87
Table 16: Overview statistics of the HCVR analysis.	91
Table 17: Representation of River Types in HCV Value Categories.	93

FIGURES

Figure 1: Major Rivers of Nepal.	7
Figure 2: Gradient of disturbance.	11
Figure 3: Tree-diagram identifying the freshwater status and value components.....	14
Figure 4: Tree-diagram identifying freshwater status.....	14
Figure 5: Tree-diagram identifying freshwater values.....	15
Figure 6: Concept diagram of Connectivity Status Index (CSI).....	18
Figure 7: Relationship between river reaches and rivers	19
Figure 8: Estimation of storage volume.	22
Figure 9: Road types in Nepal, based on OpenStreetMap (OSM, 2020).....	23
Figure 10: Benchmark rivers selected by advisory group for FFR assessment validation.	24
Figure 11: Overview of main rivers of Nepal.....	25
Figure 12: Steps for assessing the freshwater values of Nepalese rivers.	29
Figure 13: Freshwater values identified for Nepal	30
Figure 14: Quantitative value score for freshwater values	33
Figure 15: Illustration of integrating HCV values	34
Figure 16: Classification scheme for final HCVR river typology	35
Figure 17: Flowchart on distribution mapping of fishes.....	37
Figure 18: Fish distribution data	38
Figure 19: Flagship fish species of Karnali river basin.....	39
Figure 20: Methodological framework for river classification.....	51
Figure 21: Physiographic Classification for River Classification of Nepal.....	52
Figure 22: Glacial and snow cover in Nepal.....	53
Figure 23: River classification based on source.	54
Figure 24: Geomorphic component of river classification based on size.....	55
Figure 25: Connectivity Status Index (CSI).....	56
Figure 26: Dominant Pressure Factor (DOM).....	57
Figure 27: Free flowing river status in Nepal.....	59
Figure 28: Most important covariates for the nitrate model.	60
Figure 29: Partial variance importance plots for the nitrate model.....	61
Figure 30: Normalized index for five pressure (a-e) indicators.....	62
Figure 31: Integrated water quality pressure index (WQPI).....	63
Figure 32: River reaches meeting the “poor” or “very poor” threshold.....	64
Figure 33: Biodiversity value scores.	65
Figure 34: Fish richness in Nepalese rivers.....	66
Figure 35: Endemic fish richness in Nepalese rivers.....	68
Figure 36: Conservation Status of Native Species of Nepal.....	68
Figure 37: Threatened fish species in Nepalese rivers.....	69
Figure 38: Long-distance migratory fish richness in Nepalese rivers.	71
Figure 39: Medium and short-distance migratory fish richness in Nepalese rivers.	71
Figure 40: Dolphin habitats in Nepalese rivers.....	72
Figure 41: Gharial habitats in Nepalese rivers.	72
Figure 42: Mahseer richness in Nepalese rivers.....	73
Figure 43: Protected areas that host rhinoceros in Nepal.	74
Figure 44: Protected areas that host tigers in Nepal.	74
Figure 45: Current, historic, and potential habitat distribution for otters in Nepal.	76
Figure 46: Important river reaches for wetland birds in Nepal.....	77
Figure 47: Critical corridors in Nepal.....	78
Figure 48: Recreational values in Nepal	78

Figure 49: Rating of rivers for Angling value based on number of angling species.....	79
Figure 50: Rivers that are important for kayaking and rafting in Nepal.....	80
Figure 51: River reaches that are important for trekking.....	80
Figure 52: Protected areas in Nepal.....	81
Figure 53: Livelihood values overlay map.....	81
Figure 54: Number of fish species providing food or commercial value.....	82
Figure 55: Water provision values.....	83
Figure 56: Socio-cultural values mapping based on religious sites in proximity to rivers.....	84
Figure 57: HCV integrated values.....	84
Figure 58: Dominant HCV component.....	85
Figure 59: Integrated HCV value at the river scale.....	86
Figure 60: High Conservation River Typology.....	90
Figure 61: Final River Classification for Nepal.....	93

I. ADVISORY GROUP

S.N.	NAME	EXPERTISE	ORGANIZATION
1	Dr. Ram Devi Tachamo Shah	Freshwater Ecology	Kathmandu University (KU)
2	Dr. Tej K. Shrestha	Fish and Dolphin	Himalayan Biome Research Institute (HBRI)
3	Dr. Tek B. Gurung	Limnology	Nepal Fisheries Society (NEFIS)
4	Dr. Vishnu Prasad Pandey	Hydrology	International Water Management Institute (IWMI) - Nepal
5	Karen Bennett	Geo-science	Nepal River Conservation Trust (NRCT)
6	Sanita Dhaubanjari	Hydrologic Modeling	International Centre for Integrated Mountain Development (ICIMOD)
7	Arun Rana	Tourism and Angling	Asian Development Bank (ADB)
8	Shiva Adhikari	Tourism-rafting	Nepal Association of Rafting Agencies (NARA)
9	Krishna Bhusal	Bird	Bird Conservation Nepal (BCN)
10	Mohan Bikram Shrestha	Bird and Otter	Bird Conservation Nepal (BCN)
11	Megh Ale	Tourism	Nepal River Conservation Trust (NRCT)
12	Asha Raymajhi	Fish Diversity	Nepal Agriculture Research Council (NARC)
13	Santoshi Shrestha	Fish Biology	Tribhuvan University- Central Department of Zoology (TU-CDZ)
14	Dr. Shanta Raj Jnawali	Gharial, Dolphin and other wildlife	Hariyoban II, WWF Nepal
15	Sabita Malla	Wildlife Biologist	WWF Nepal
16	Dr. Kashmiri Kakati	Environment	USAID Nepal
17	Christopher Dege	Environment	USAID Nepal
18	Shanker Khagi	Environment and Energy	USAID Nepal
19	Netra Sharma	Environment and Climate Change	USAID Nepal
20	Jeremy Keeton	Freshwater	USAID TAYAR Nepal Disaster Risk Reduction Project
21	Nilu Basnyat	Freshwater	USAID Paani Program
22	Narayan Belbase	Environment Policy	USAID Paani Program
23	Suresh Wagle	Fish Population Dynamics	USAID Paani Program
24	Arun Paudel	GIS	USAID Paani Program
25	Dr. Deepak Rijal	Ecology	USAID Paani Program
26	Pradip Gautam	Hydropower	USAID Paani Program

II. 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
GEEC	Greenwich Environmental & Engineering Consultant, Pvt LLC
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
SIS	Small indigenous fish species
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

III. GLOSSARY

Connectivity Status Index (CSI)	An index that 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.
Consumptive water use (USE)	A pressure factor used to calculate the longitudinal, lateral, and vertical impacts from water consumption.
Degree of Fragmentation (DOF)	A pressure factor used to calculate the longitudinal impact from river fragmentation.
Degree of Regulation (DOR)	A pressure factor used to calculate the lateral and temporal impacts from flow regulation.
Dominant Pressure Factor (DOM)	The main pressure factors responsible for the loss of connectivity in each river reach
Free-flowing river	A river where its 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.
Free-flowing river assessment	An assessment developed by Grill et al. (2019) that shows three types of results for rivers: (1) Connectivity Status Index (CSI) showing a quantitative measure of each river reach; (2) Dominant Pressure Factor showing the driving force for calculation of CSI index; and (3) classification of rivers into either free-flowing or non-free-flowing rivers using a CSI threshold.
Free-flowing river status	Categorization of rivers as free-flowing or non-free-flowing using a Connectivity Status Index threshold.
Freshwater status	Assessment of river health based on river and floodplain connectivity and water quality pressures on rivers and floodplains.
Freshwater values	Values of biodiversity, recreation, livelihood, and socio-cultural, identified by stakeholders, used for identifying High Conservation Value Rivers.
High Conservation Value River (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-cultural values (Nepali context).

High Conservation Value River typology	A classification of rivers based on integration of freshwater status and freshwater values used to determine the High Conservation Value Rivers.
Nightlight intensity in urban areas (URB)	A pressure factor used to calculate the lateral impact from infrastructure development in riparian and floodplain areas.
Peaking run-of-river dam	A type of dams that uses a storage and release cycle, which follow a daily schedule and typically store about one day of water.
Pressure factor (IND)	A representation of the main human interferences in the FFR assessment, including river fragmentation, flow regulation, sediment trapping, water consumption, and infrastructure development in riparian areas and floodplains.
River	An aggregation of river reaches that form a single-threaded, contiguous flowpath from headwater source to river outlet.
River connectivity	The four dimensions that determine the connectivity status of a river: 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 reach	A stretch of river between consecutive tributaries—with a minimum average discharge of 100 l/second (0.1 m ³ /second).
Road density (RDD)	A pressure factor used to calculate the longitudinal and lateral impacts from infrastructure development in riparian and floodplain areas.
Run-of-river (PoR) project	A non-storage dam that diverts water from a river through a channel to generate electricity.
Sediment trapping index (SED)	A pressure factor used to calculate the longitudinal, lateral, and vertical impacts from sediment trapping
Storage dam	A type of dam that stores large amounts of water during the rainy season and releases the water during the dry season.
US Wild and Scenic Rivers Act	A law passed in 1968 by the United States Congress to preserve certain rivers with outstanding natural, cultural, and recreational values in a free-flowing condition for the enjoyment of present and future generations.
Water Quality Pressure Index (WQPI)	An index that uses water quality proxy indicators to estimate water quality pressures in rivers.

I. EXECUTIVE SUMMARY

Key Points

- This is the first time that High Conservation Value Rivers (HCVRs) have been identified and categorized in Nepal.
- Hydropower development is being proposed on all the major rivers across Nepal and is a significant threat to the diverse values of river systems.
- 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.
- Identification and ranking of Nepal's HCVRs can also help the country in meeting its national and international commitments, such as those under its National Biodiversity Strategic Action Plan.
- HCVR maps can provide insights into opportunities for mitigation of development impacts.

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 or

river reaches (i.e., the river segment between two tributaries) 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.

Hydropower development is being proposed on all the major rivers across Nepal and is a significant threat to the diverse values of river systems. The HCVR maps show where those threats are most serious. 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 critically endangered dolphin and fish species such as Golden Mahseer and snow trout.

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 is very important to 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 in which to avoid hydropower development 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 feedback 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 country with abundant water resources with approximately 225 billion cubic meters of surface water available within the country annually (WECS, 2011). There are more than 11,614 km of rivers and rivulets (EDC 2016) that have 76% of their watersheds lying within national boundaries; a channel spacing of 0.3km/km²; and an average discharge of 7,125 m³/s (WECS, 2011).

Given the abundant freshwater resources in Nepal, the economically feasible 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).

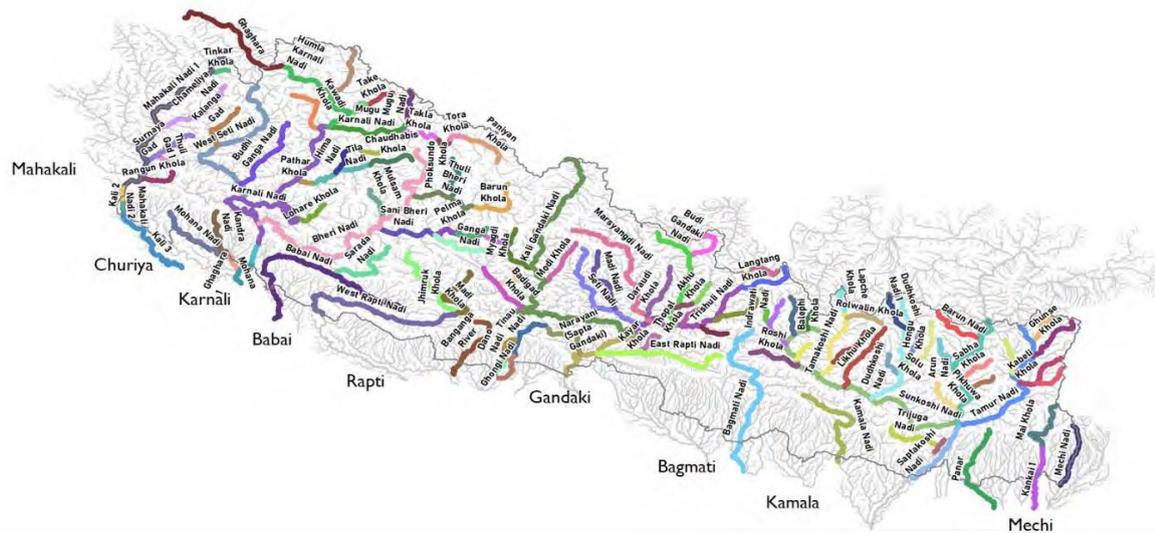


Figure 1: Major Rivers of Nepal.

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 thousands of rivers and streams that have their source in remote mountainous areas that eventually merge and form significant streams several hundreds of kilometers long that break through the Himalayan mountains and continue their journey through the Terai region towards India. Nepal also features thousands of lakes, including ten 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. 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).



Picture 1: Dam on Babai River, Nepal. (Photo credit: WWF)

Dams 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 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 Asala (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).

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 aquatic life and other wildlife that eats aquatic life, e.g., piscivorous birds); and water pollution from agricultural runoff and from households and industrial discharges (particularly urban rivers such as Bagmati).

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).

Rivers are important from social, cultural and livelihood perspectives. Some communities including Hindus in Terai, Nepal pray to rivers as goddesses during the Chhath 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.



Picture 2. 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 2). 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.”

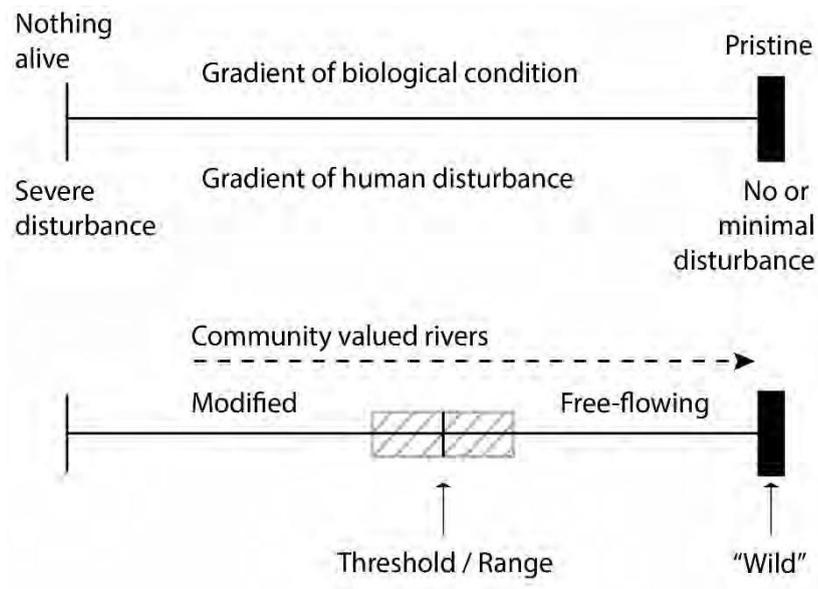


Figure 2: Gradient of disturbance. Conceptual graph showing a continuum of anthropogenic disturbance between “nothing alive” to “Pristine” (top panel). The lower panel proposes a conceptual framework to locate modified, free-flowing, and wild rivers on a continuum of human disturbance. A threshold or 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. OVERVIEW

The definition of High Conservation Value Rivers of Nepal was developed through a 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 3 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 include all types of riverine and aquatic ecosystems across the diverse river types and regions of Nepal. More detail on the full list of ecosystem types that were included in the assessment and their representation in the final results is given in sections 6.5 and 7.3.

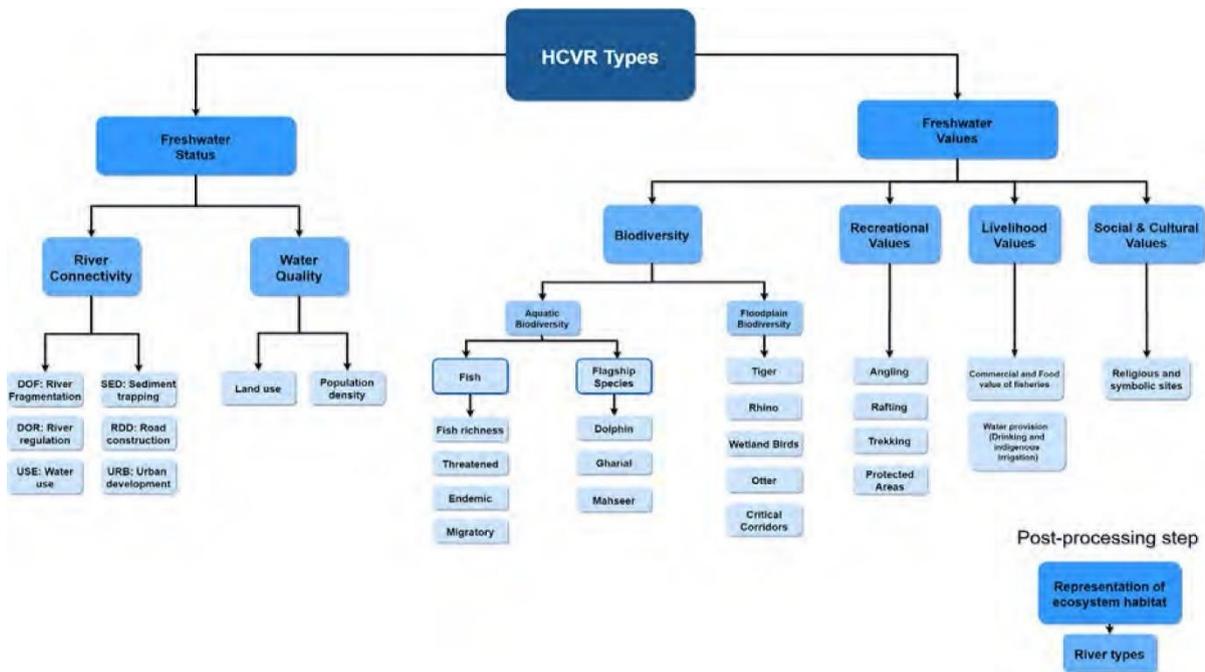


Figure 3: Tree-diagram identifying the freshwater status and value components. Representation of ecosystem habitat, using river types was an important post-processing step to ensure representation of diverse river types across Nepal.

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 4). 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.

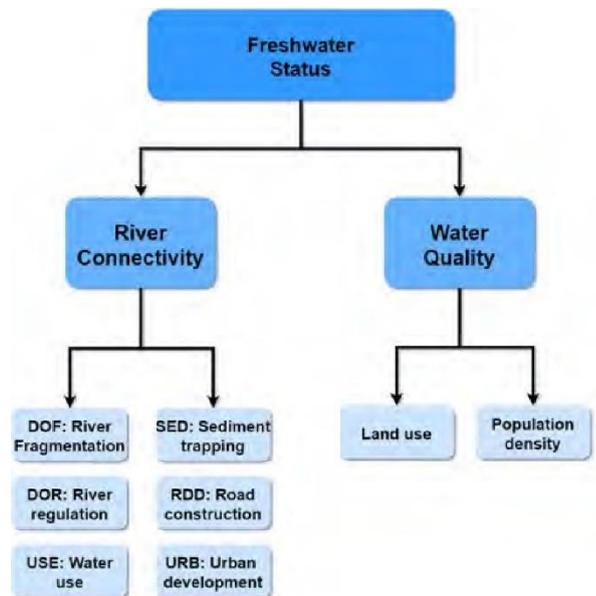


Figure 4: Tree-diagram identifying freshwater status.

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 5).

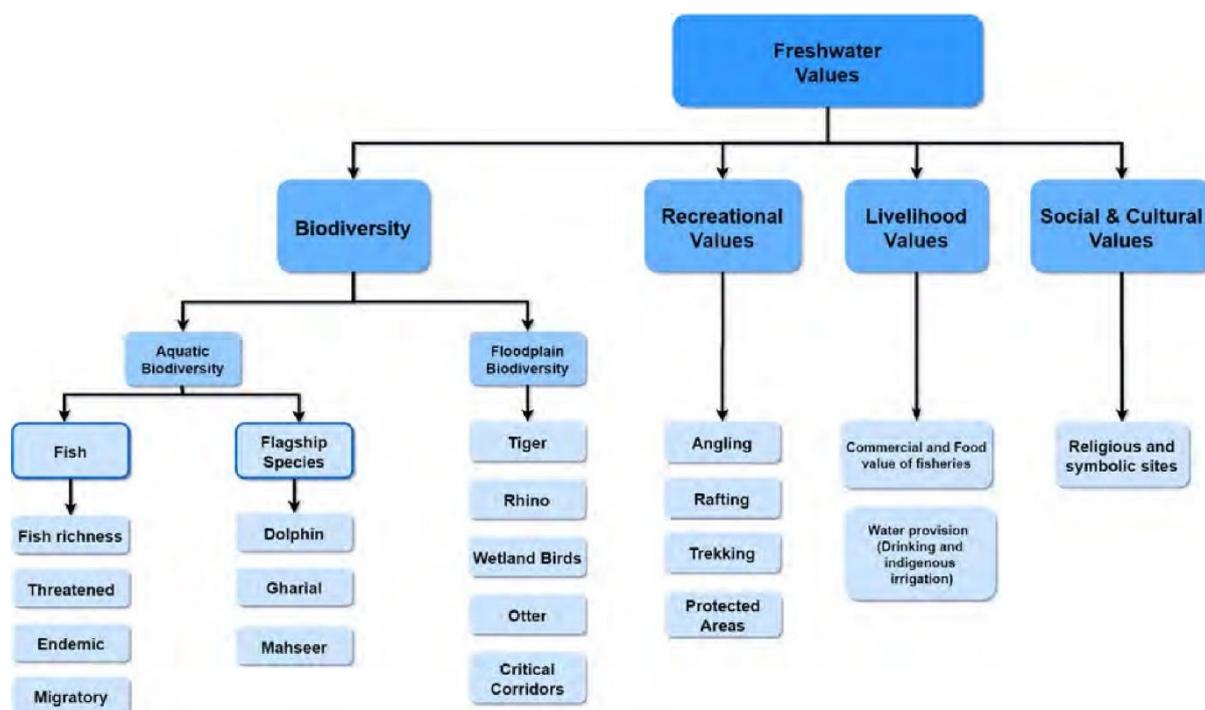


Figure 5: Tree-diagram identifying freshwater values.

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 90m at 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 60 northern 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 contributing or connected hydrological areas outside of Nepal to form a gapless, hydrologically connected study area. A total of 50,531 km flow inside Nepal's country boundaries.

We define a river reach as a stretch of river between consecutive tributaries—with a minimum average discharge of 100 l/second (0.1 m³/second). Rivers smaller than this minimum average discharge 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. The river reaches have an average length of 2.7 km 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. Based on the criteria above (i.e., only including river reaches with a minimum average discharge of 0.1 m³/second, we identified 9,519 rivers with a total length of 50,531 km in Nepal. 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 (see also Table 16).

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)

- a) 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).

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).

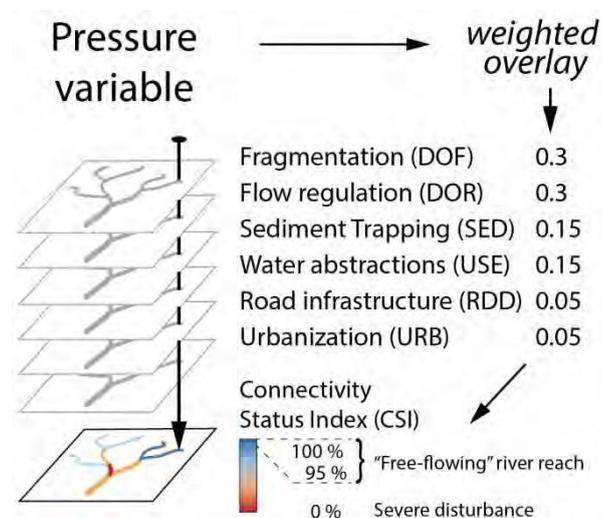


Figure 6: Concept diagram of Connectivity Status Index (CSI).

Using this conceptual approach, CSI values are calculated for every river reach by producing a weighted average of the six individual pressure indicators (Figure 6).

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); DoFD 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; Messenger 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; Messenger 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)

PRESSURE FACTOR	PRESSURE INDICATOR	DESCRIPTION	CONNECTIVITY ASPECT AFFECTED	SOURCE DATA
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 7) 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.’

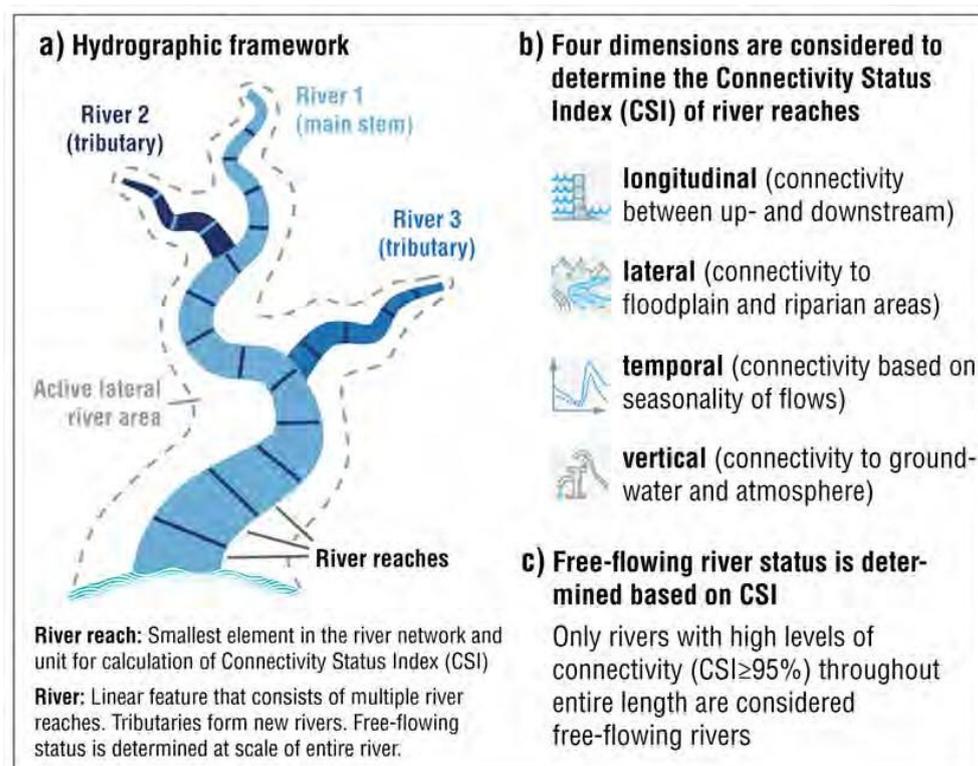


Figure 7: Relationship between river reaches and rivers in the context of the FFR assessment.

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 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, otherwise – in less than 5% of cases – we used auxiliary information such as river names or distance to villages, or assigned the location of the nearest river.

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, which is a diversion project that does not have a structure across the river. 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, flowing from very high to very low altitudes, and are relatively small in volume (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, such as during the low flow season when the gates of the barrage are closed.

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 meters above sea level), 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 m asl), the DOF effect was reduced to 3 times in the upstream direction, and to 7 times in the downstream direction.

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 disruption 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 8). 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 or longer stretches of rivers. 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.

Table 2: Local adjustments of the discharge range factor (DRF) in the upstream and downstream direction for different barrier.

BARRIER TYPE	UPSTREAM DRF	DOWNSTREAM DRF
Barrage	1.07	1.5
Dams > 1000 msl	1.5	3
Dams < 100 msl	3	7

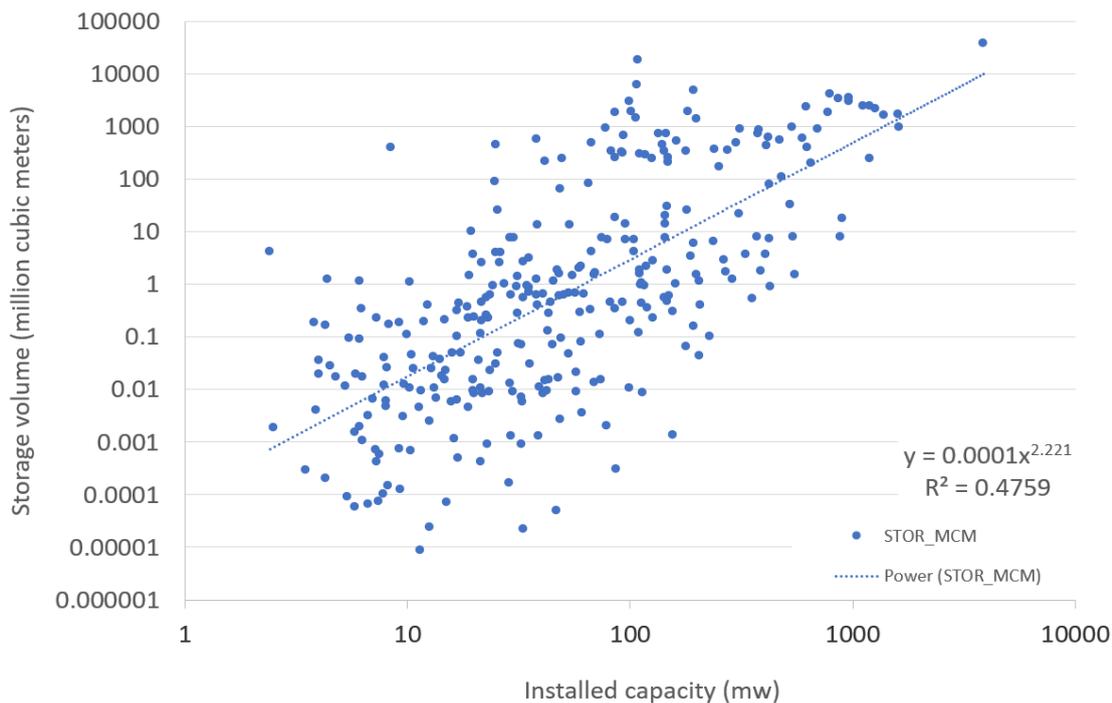


Figure 8: Estimation of storage volume using a power relationship based on data from Tractebel (2020).

6.2.1.3.4 ROAD DENSITY

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 9).

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.

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



Figure 9: 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 10). 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.

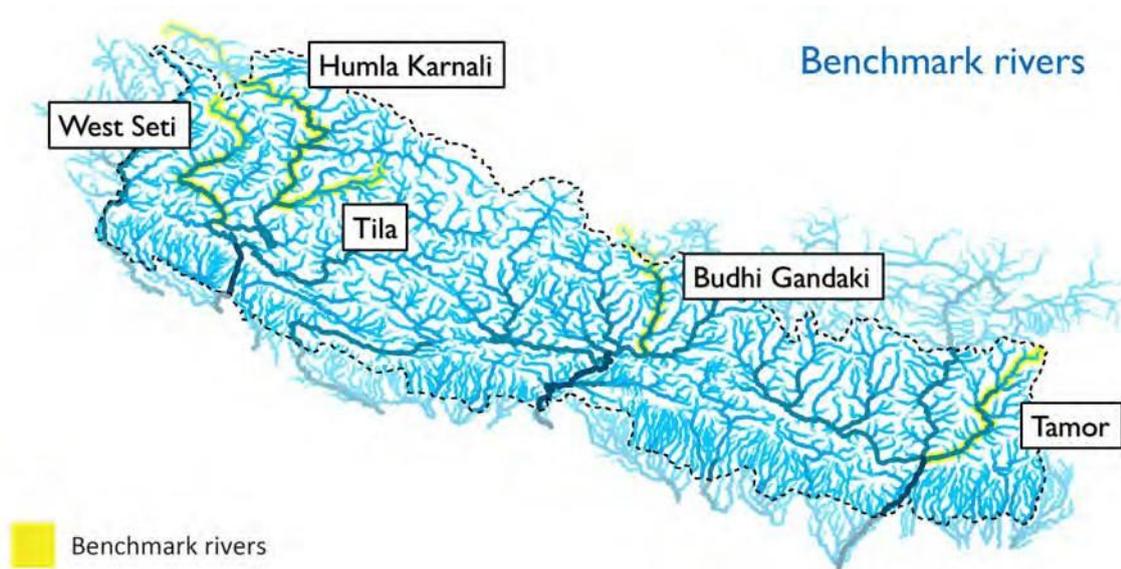


Figure 10: Benchmark rivers selected by advisory group for FFR assessment validation.

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 11 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.

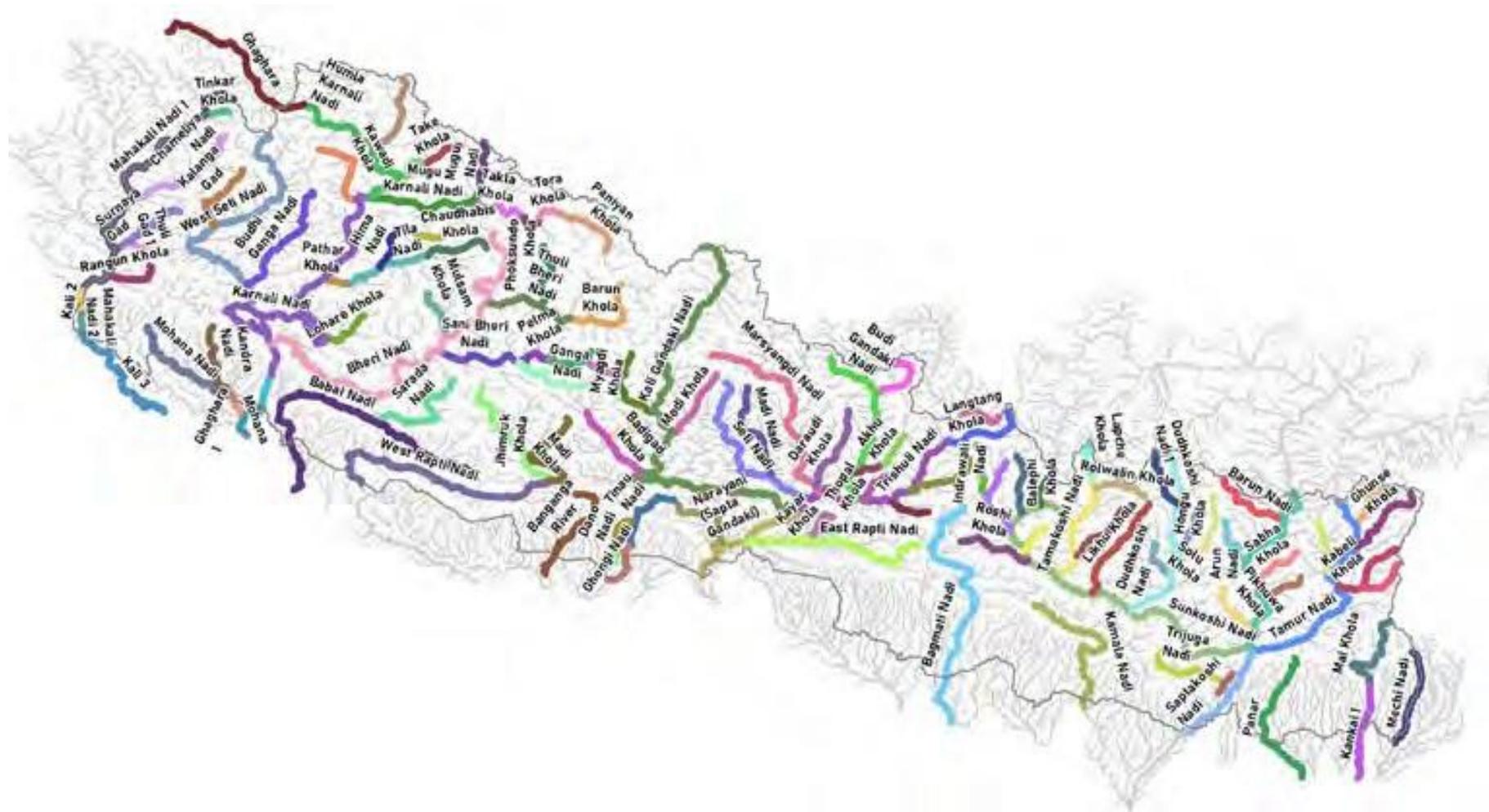


Figure 11: Overview of main rivers of Nepal.

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 Bagmati 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.



Photo 3: 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 the 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 constant source of sediment delivery through ongoing erosion	World Bank study (Vogl, Schmitt, et al. 2019); own calculations using river- OpenStreetMap (2020)	Calculated on 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.
- (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.

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 12.

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 13). A more detailed description and the justification for including each freshwater value can be found in section 7.2 and in Annex 10.2.1.

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.

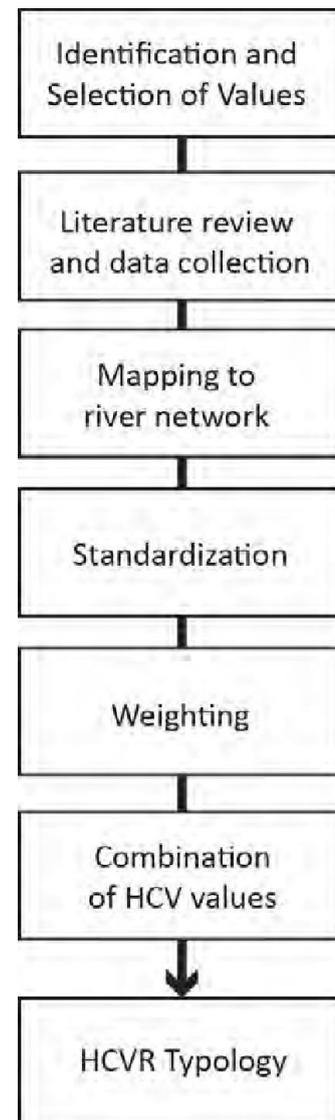


Figure 12: Steps for assessing the freshwater values of Nepalese rivers.

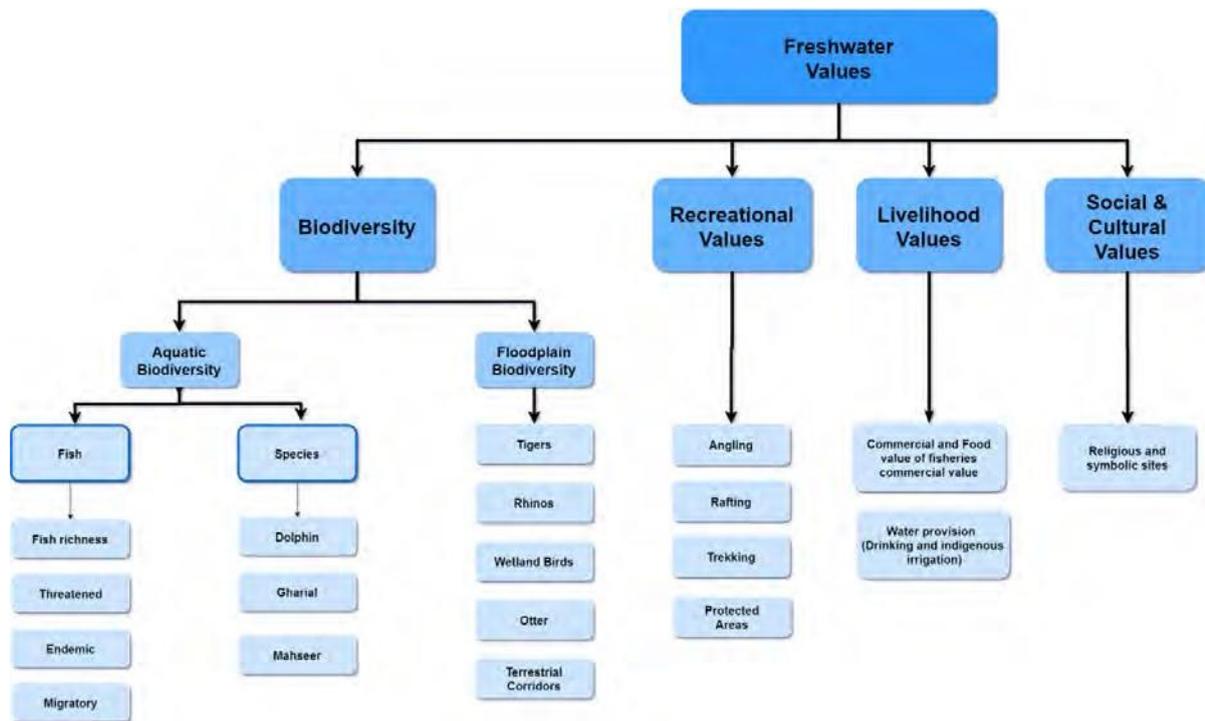


Figure 13: Freshwater values identified for Nepal.

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.
- 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 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
I	Biodiversity	Quantitative	n.a.	
I.1	Aquatic Biodiversity	Quantitative	n.a.	
I.1.1	Fish	Quantitative	n.a.	
I.1.1.1	Fish richness	Quantitative	Quintile mapping	0 - 5
I.1.1.2	Threatened	Quantitative	Quintile mapping	0 - 5
I.1.1.3	Endemic	Quantitative	Quintile mapping	0 - 5
I.1.1.4	Migratory	Quantitative	n.a.	0 - 5
I.1.1.4.1	Long Migratory	Quantitative	Quintile mapping	0 - 5
I.1.1.4.2	Medium and Short Migratory	Quantitative	Quintile mapping	0 - 5
I.1.2	Mahseer	Categorical	Expert mapping	
			1 species identified	2
			2 species identified	3
			3 species identified	4
			4 species identified	5
I.1.3	Dolphin	Categorical	Expert mapping	
			Historical, non-viable or seasonal population	3
			Known population occurrence from other sources	4
			One or more dolphins documented in latest census	5
I.1.4	Gharial	Categorical	Expert mapping	
			Historical presence	2
			Recently sighted but needs verification	3
			Known population occurrence from other sources	4
			One or more gharial documented in latest census	5
I.2	Floodplain/Wetland-Dependent Biodiversity	Quantitative	n.a.	
I.2.1	Tigers	Binary	Presence/absence mapping	0 / 5
I.2.2	Rhinos	Binary	Presence/absence mapping	0 / 5
I.2.3	Wetland Birds	Binary	Presence/absence mapping	0 / 5
I.2.4	Otter	Categorical	Expert mapping	
			Probable habitat	3

SN	VALUE CATEGORY	HCV VALUE TYPE	DATA STANDARDIZATION TECHNIQUE	HCV VALUE MAPPING
			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	
			Asala species	1
			Warmwater species	1.5
			Mahseer	2
			Mahseer + Asala	3
			Mahseer + Warmwater species	4
			Mahseer + Asala + 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 (m ³ 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 14. 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_v1 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 14: Quantitative value score for freshwater values. 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 definitions, please see the Glossary, and for a discussion on the distinction between river and river reach, please see section 6.1 and Figure 7.

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 is 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 15: Illustration of integrating HCV values from the river reach scale to the river scale using length-weighted averages.*, 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.

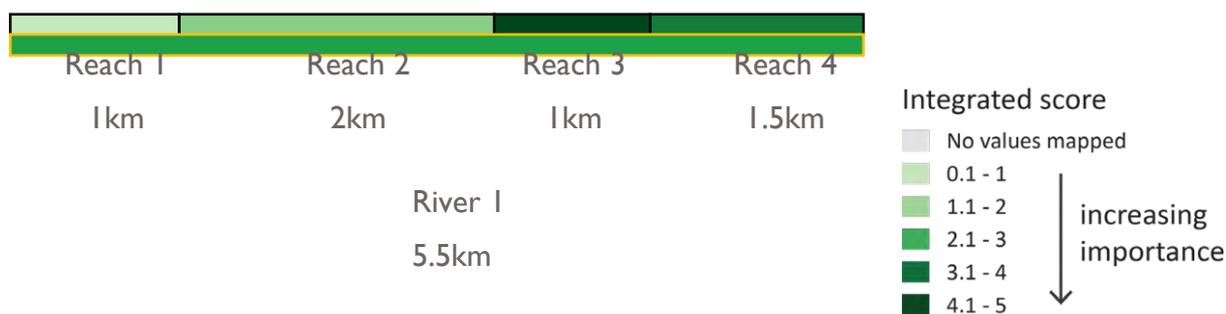


Figure 15: Illustration of integrating HCV values from the river reach scale to the river scale using length-weighted averages.

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 16).

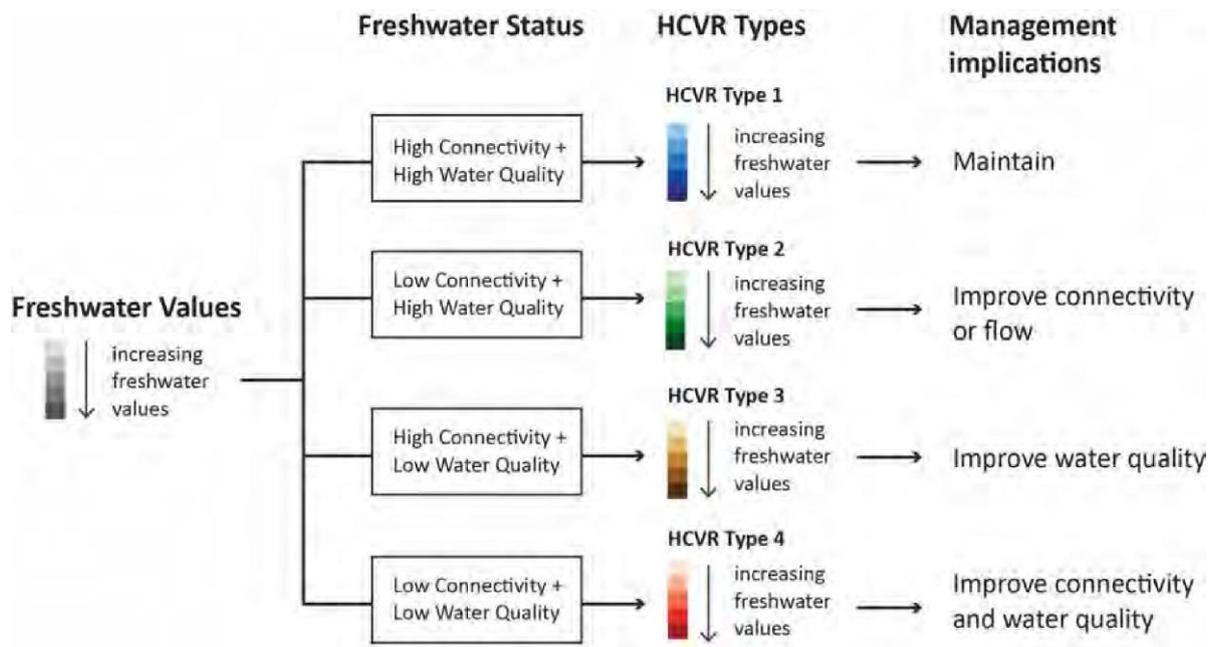


Figure 16: Classification scheme for final HCVR river typology. The corresponding map is shown in Figure 59.

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.

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

6.3.7.2 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 water quality pressures.

6.3.7.3 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 nor 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 floodplains 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

The aquatic biodiversity category includes species groups that are strictly dependent on freshwater environments. The data were identified based on inputs provided during the July 2019 workshop and subsequent advisory group meetings.

6.4.1.2 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. Greenwich Environmental & Engineering Consultant Pvt. Ltd (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 17. The data has been provided through GIS with River ID and River Name attributes. Based on this information, 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 several consultations with fisheries experts.

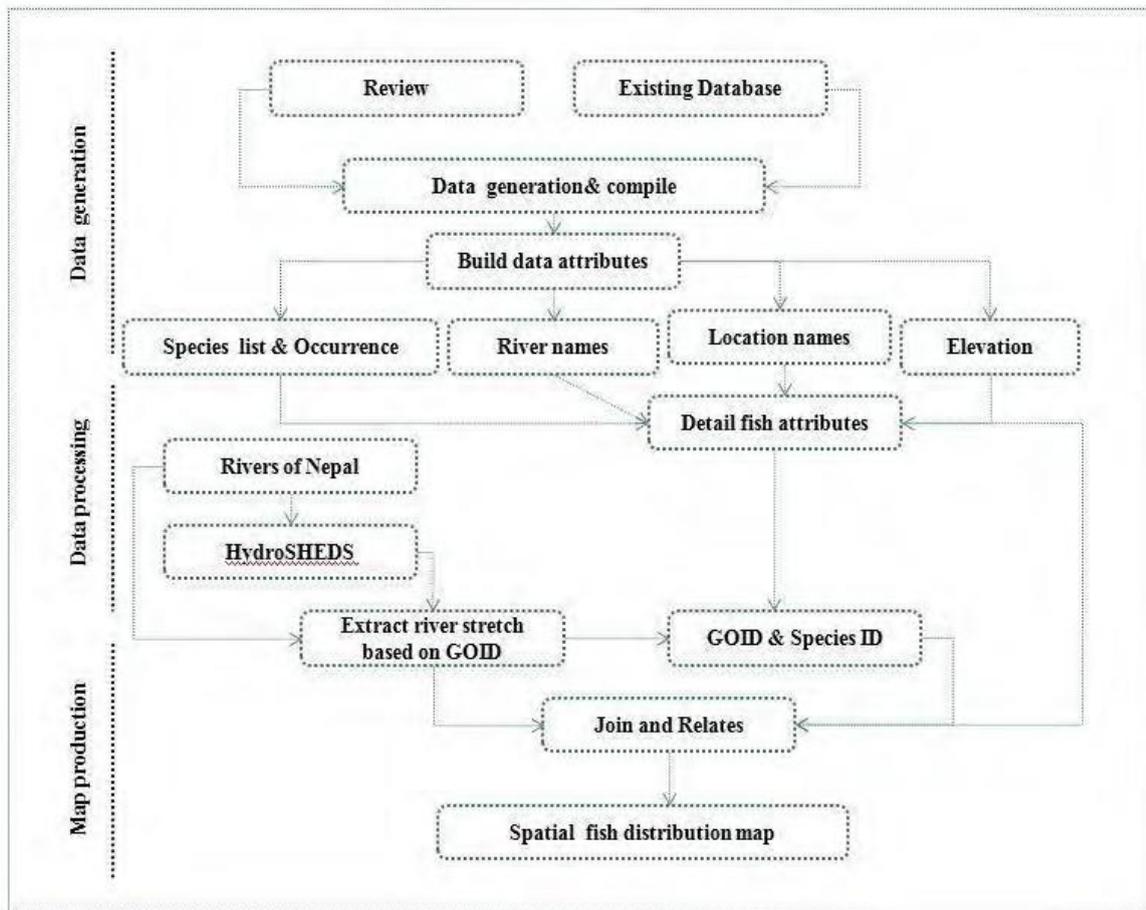


Figure 17: Flowchart on distribution mapping of fishes.

A total of 256 fishes were mapped – some of this distribution information was a revision of existing distribution maps from Bennett et al. (2016); however, new data has also been included for additional 30 rivers of Nepal including Thuligad, Tila, Sarada, Modi, Badigad, and Trijuga Rivers (Figure 18). The data 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 the recreation component, and commercial and food value under the livelihood component.

Fish richness and endemism, as well as migratory and threatened fish distribution have been mapped as the number of each of these types 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 listed as critically endangered, endangered, or vulnerable in the IUCN Red Data list.

We classified migratory fishes into two categories – those making long (hundreds of km) or short and medium migratory movements. Among these two categories more weight has been given 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).

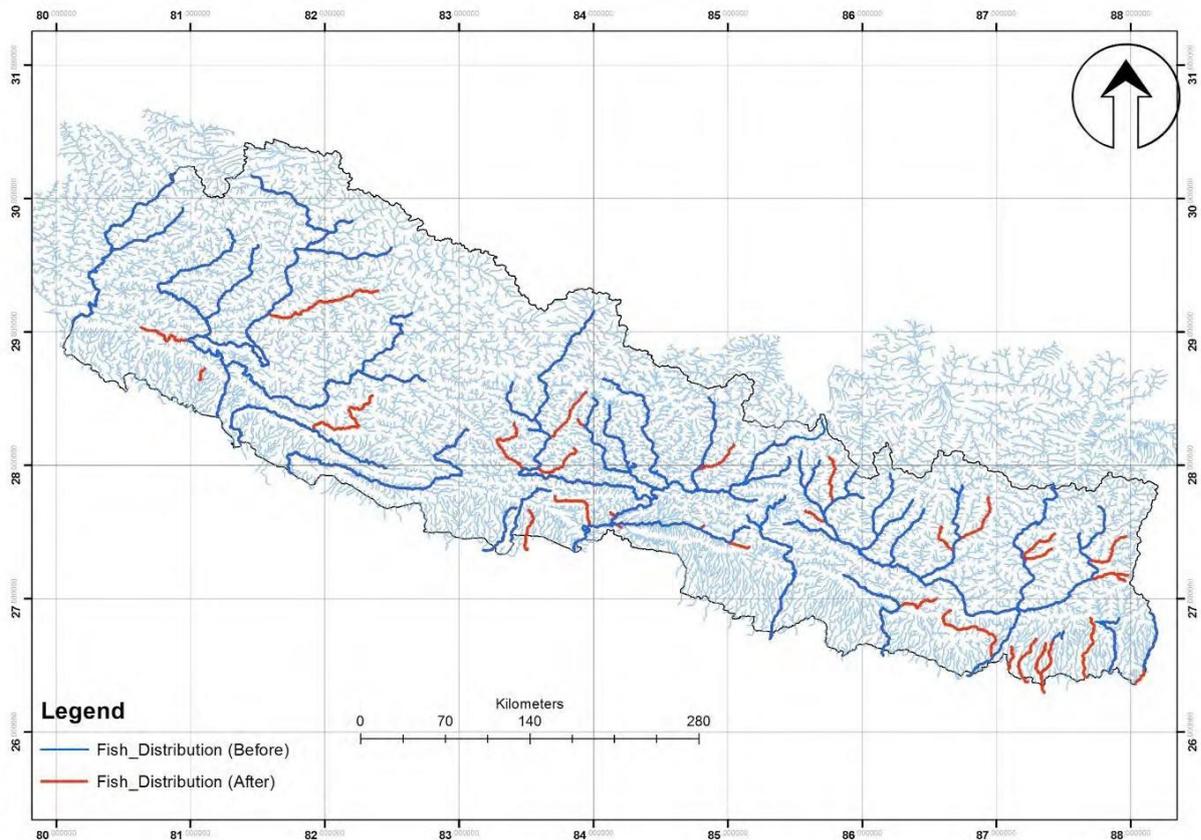


Figure 18: Fish distribution data was originally mapped by Bennett et al. (2016) based on Shrestha et al. (2008; blue locations), and then updated by the project team (red locations).

6.4.1.3 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 affect the types and number of other species in their environment and without them the balance in that environment may be 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 been identified for the Mahakali and Karnali river basin based on their high economic and ecological value. These include Sahar or Golden Mahseer (*Tor putitora*), Bucheche Asala or Alwan Snowtrout (*Schizothorax richardsonii*), Thend, Thunde, Klanch, or Angra Labeo (*Labeo angra*), Gardia or Bajeo (*Labeo dero*) for Mahakali and *Tor putitora*, *Schizothorax richardsonii*, *Labeo angra*, *Labeo dero* and Katle, Vadalke, or Copper Mahseer (*Acrossocheilus hexagonolepis*) in Karnali (Figure 19).

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, mahseer was also included in this category.

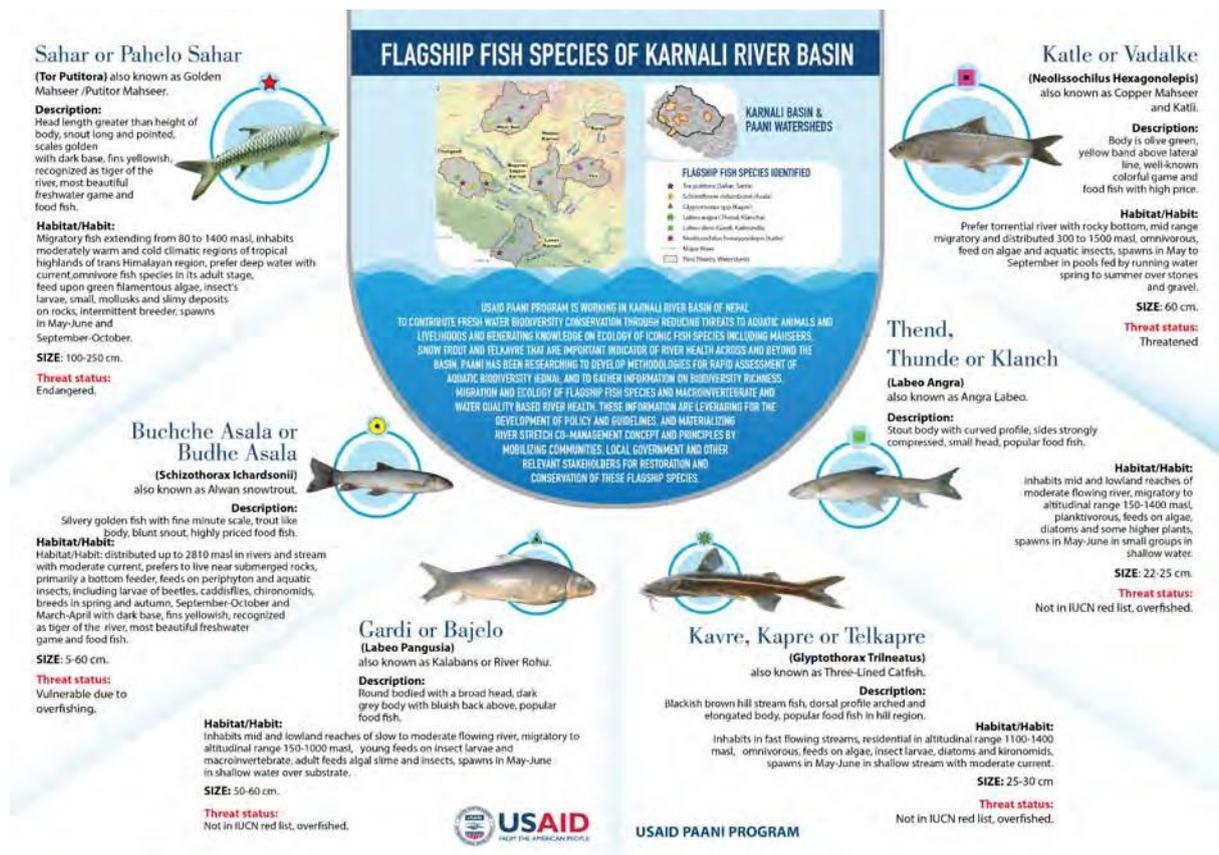


Figure 19: Flagship fish species of Karnali river basin. Source: USAID PAANI Program, 2020.

6.4.1.3.1 DOLPHINS

Gangetic River Dolphin (*Platanista gangetica*) is the only recorded cetacean species and is a legally protected mammal in Nepal. The River Dolphin plays an important role in the riverine food chain. Despite being 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 dolphins 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.

6.4.1.3.2 GHARIAL

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

The number of gharials 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 gharial 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 other available information. These locations were given an HCV value of 4.
- Locations (river reaches) considered where a gharial was recorded in 2019 by WWF Nepal, which received an HCV value of 3. Proper surveys need to be conducted to verify presence in these locations therefore, these locations were given a lower rating; and
- Known historical gharial habitat confirmed by studies and the Advisory Group, which received an HCV value of 2.

6.4.1.3.3 MAHSEER



Picture 4. Golden Mahseer (*Tor putitora*). It is categorized as 'Endangered' in the International Union of Conservation of Nature Red List. (Photo credit: Juha Rouhikoski).

Mahseer are commercially important game fish as well as highly esteemed food fish. Golden Mahseer (*Tor putitora*) and Dark Mahseer (*Tor chelynoides*) are Endangered according to the 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 habitat resulting in loss of breeding grounds, and from other anthropogenic threats that have resulted in declines in harvest in several locations (Rayamajhi et al., 2018a).

Deep bodied mahseer (*Tor tor*) is considered to be the most widely distributed among the mahseers, and 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 to 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 an HCV value of 4, 3, and 2, respectively. 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.

6.4.1.3.4 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.

Data on rhino distribution has been sourced from the Nepal National Rhino Count conducted 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.

6.4.1.3.5 TIGERS

Maintaining adequate habitat for tiger's prey species requires healthy functioning floodplain systems that have natural seasonal variability. Impacts on the flow regime affect floodplains and 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.



Picture 5. Chitwan National Park is home to the second largest population of greater one-horned rhinoceros. (Photo Credit: Sameer Singh / WWF Nepal).



Picture 6. A tiger in Bardia National Park, Nepal. (Photo Credit: Emmanuel Rondeau / WWF-US).

Data on tiger distribution has been compiled from the National Tiger Survey in 2018, Dhakal et al. (2014), and Poudyal et al. (2018). Available data on tiger distribution associated with floodplain river reaches have been mapped 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.

6.4.1.3.6 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. Sustainance of this species in an aquatic ecosystem requires a connected river network and a virgin ecosystem. River otters in Nepal historically included Smooth-coated otter (*Lutrogale persillata*), Eurasian Otter (*Lutra lutra*) and Asian Small-clawed otter (*Aonyx cinerea*). However, there is no strong evidence of existence of Asian Small-clawed otter 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 (2015b), Kafle (2009) and Acharya and Rajbhandari (2009) and further review and validation was done through consultations with experts from the Himalayan Otter Network (HON). River reaches where otters were found received an HCV value of 5.

6.4.1.3.7 WETLAND BIRDS

A total of 863 species of birds has been reliably recorded in Nepal (DNPWC and BCN 2008). Of these nearly 23% or 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 biodiversity and support more than 20,000 waterfowl during the peak period between December-February (HMG/N/MFSC, 2002). 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), Dang Deukhuri Important Bird Area (IBA) on the Rapti river, 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.

6.4.1.3.8 CRITICAL CORRIDORS

Critical corridors were included as 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

Recreation-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 sport 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 adequately developed in Nepal (Rana 2020).

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 snow trout or Asala species (Table 6). According to Arun Rana, a Nepalese angler, the golden mahseer is the most sought-after gamefish of the Himalayan waters. It migrates upstream to their spawning grounds in the smaller tributaries of the major rivers in the spring, the prime fishing season. After spawning, they move back downstream to the main river.

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	<i>Tor putitora</i> (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	<i>Tor tor</i> (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	<i>Bagarius bagarius</i> (Hamilton, 1822)	Goonch	Goonch; Thed (western Nepal)	75.00 kg (165 lb 5 oz) caught by Jakub Vagner on 06-Mar-2009, Ramganga River, India
4	<i>Neolissochilus hexagonolepis</i> (McClelland, 1839)	Copper Mahseer	Katle	Unlisted
5	<i>Channa marulius</i> (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	<i>Wallago attu</i> (Bloch & Schneider, 1801)	Wallago Catfish	Buhari	18.6 kg (41 lb 0 oz) caught by Kasem Lamaikul on 4-Dec-2004, Khaolam Dam, Sangklaburi, Thailand
7	<i>Raiamas bola</i> (Hamilton, 1822)	Trout Barb	Galara	Unlisted
8	<i>Schizothorax progastus</i> (McClelland, 1839)	Dinnawah Snowtrout	Chuche Asala	Unlisted
9	<i>Sperata seenghala</i> (Sykes, 1839)	Long-whiskered Catfish	Kanti	Unlisted
10	<i>Sperata aor</i> (Hamilton, 1822)	Long-whiskered Catfish	Kanti	Unlisted
11	<i>Catla catla</i> (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	<i>Cirrhinus mrigala</i> (Hamilton, 1822)	Mrigal	Naini	8.0 kg (17 lb 10 oz) caught by Eddie Grey n 03-Jan-2012, Gillhams Fishing Resorts, Krabi, Thailand

S.N.	SCIENTIFIC NAME	ENGLISH NAME	NEPALI NAME	CURRENT IGFA ALL TACKLE WORLD RECORD
13	<i>Chitala chitala</i> (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	<i>Labeo calbasu</i> (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	<i>Labeo rohita</i> (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 the snow trouts or Asala, and other warmwater species.

Each category has been assigned an HCV value based on perceived recreational value: If only snow trout (Asala) 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/Goonch were given HCV value 2, locations with Mahseer/Goonch and Asala received HCV 3, Mahseer/Goonch and other warmwater species HCV 4, and locations with Mahseer/Goonch, Asala, and other warmwater species received the highest HCV value of 5.

6.4.2.2 RAFTING & KAYAKING

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 (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 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. White water class is the international scale of river difficulty, and there are the six grades identified to measure difficulty in white water rafting. They range from 1 (simple) to 6 (very dangerous and possess risk of potential death or serious injuries). Rivers are assigned as raft class or kayak class to denote difficulty within each of the categories. The rafting and kayaking summary of Nepalese rivers has been provided in Table 7.

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.

Table 7: Rafting and Kayaking summary of Nepalese rivers. Scenic/Wild subjective rating for scenery and wildlife for each particular route. Kayak or Raft 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 Minbhawan to Chovar has been added as rafting route from the suggestion of Advisory group. The rafting is done in the river every year as part of the Bagmati Cleaning Campaign, 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	RAFT STAR
1	Arun Gorges	5	**	***			
2	Babai Nadi	2	**	*	2	***	*
3	Badi Gad	4-	**	*			

SN	RIVER NAME	KAYAKING			RAFTING		
		KAYAK CLASS	SCENIC/WILD	KAYAK STAR	RAFT CLASS	SCENIC/WILD	RAFT STAR
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+	**	**			

6.4.2.3 TREKKING

The diversity of trekking trails found in Nepal are among the best in 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 month-long treks 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.

Trekking routes that follow rivers have been mapped as important river reaches for trekking. The trekking routes have been digitized from the Great Himalayan Trail Map of Nepal (Maharjan et al., 2017), however great Himalayan trail has not been included in this analysis as this is accessible to only very few trekkers. 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 one Wildlife Reserve with their Buffer zones, six Conservation Areas, and one 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 to 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 ('large').

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 those in rural and poor communities. Indigenous fishes are a key source of nutrition and income for much of the rural and fisher communities. Most fish species are used as food either for in-home use or for sale. Overfishing, damming, habitat degradation and destructive fishing practices are reported to have contributed to reduction in stocks. Since marginal people and fishers with low income are unable to afford costly farmed fishes, fishers who sell locally benefit directly by increasing income, while also improving nutritional status. Some riverine fishes are considered more delicious than cultured species so that they are in high demand. The species that have high livelihoods value must be protected from threats.

The fish consultancy group updated the list of fish that qualified and the range maps of 165 species that had food and commercial value in Nepal based on previous work by Shrestha et al. (2008). 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, vitamins and minerals that are not commonly available in other foods. Many SIS are consumed as entire fish, thus contributing calcium, phosphorus and vitamins to the human diet. All small fish contain large amounts of calcium and phosphorus. SIS play an important role in livelihoods 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 they benefit directly from fishing as an alternate activity by increasing their 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 disproportionately. As such, the value for water provision was essentially a function of capacity to provide versus local demand:

$$Value = \frac{River\ Flow\ (\frac{m^3}{day})}{Population\ count}$$

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 m³ per person / day to millions of m³. 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 evaluation of the capacity of the river in relation to demand (m³ 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 religious 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:

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

where $religious_value_i$ 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 resulting seven different stream types include: 1. Antecedent Stream, 2. Glacial-fed streams, 3. Intermittent Streams, 4. Snow-fed Streams, 5. Rain-fed streams, 6. Siwalik Streams and 7. Terai spring-fed 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 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. River classification is important for both water management and ecosystem management. Zhao and Ding (2016) highlighted the following reasons that river classification is valuable, as it:

- *Provides a basic unit for river management by dividing the river network into reaches with similar structures and functions*
- *Facilitates resource cataloging according to river types, and to target different management goals for each river type*
- *Facilitates biological/ecological monitoring research design*
- *Promotes communication between scholars and administrators with different backgrounds*
- *Establishes a 'reference state' for each river type, i.e., the basis of river design.*

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

Forum for Energy and Environment Development (FEED Pvt. Ltd.) completed the first iteration of the river classification, and further revision was then made based on comments from experts during the 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 assessed for their usefulness to contribute to a river type classification in the context of a data-scarce situation. Data from the GloRiC database such as annual (mean) river discharge, river order, stream-power, were reviewed or enhanced to contribute to a river type classification appropriate for Nepal.

GIS, RS, and empirical methods were applied (Figure 20) to classify river network in terms of hydrologic, physio-climatic and geomorphic classes.

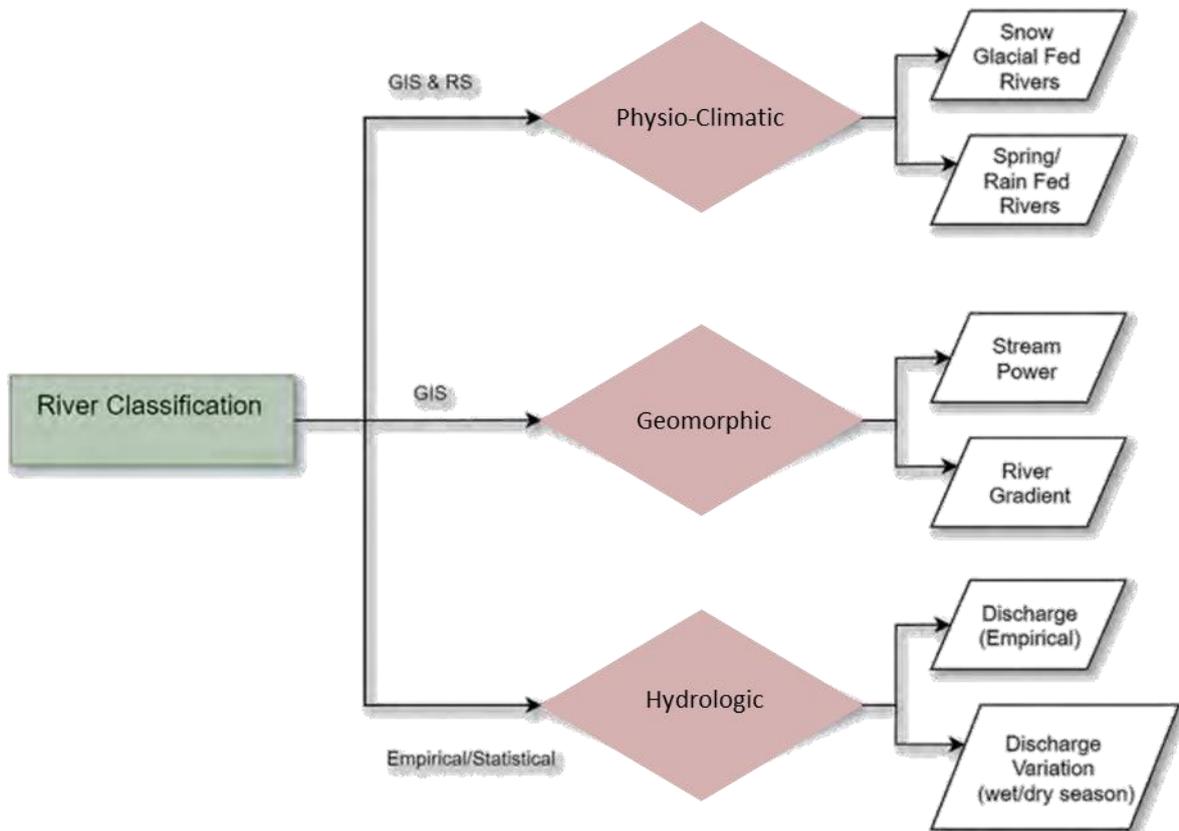


Figure 20: Methodological framework for river classification.

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. We further grouped Inner and Trans Himalaya, Fore Himalaya, and Higher Himalaya into a Himalaya physiographic region as these three regions possess similar physiography.

The Himalayan region of Nepal is the origin of its major rivers that run through several different physiographic zones until they reach the River Ganga in northern India. Depending on their location, rivers in Nepal have been classified according to their physiographic location as: Himalayan Rivers, Midland Rivers, Mahabharat Rivers, Churia Rivers, Dun Valley Rivers, and Terai Rivers (Figure 21).

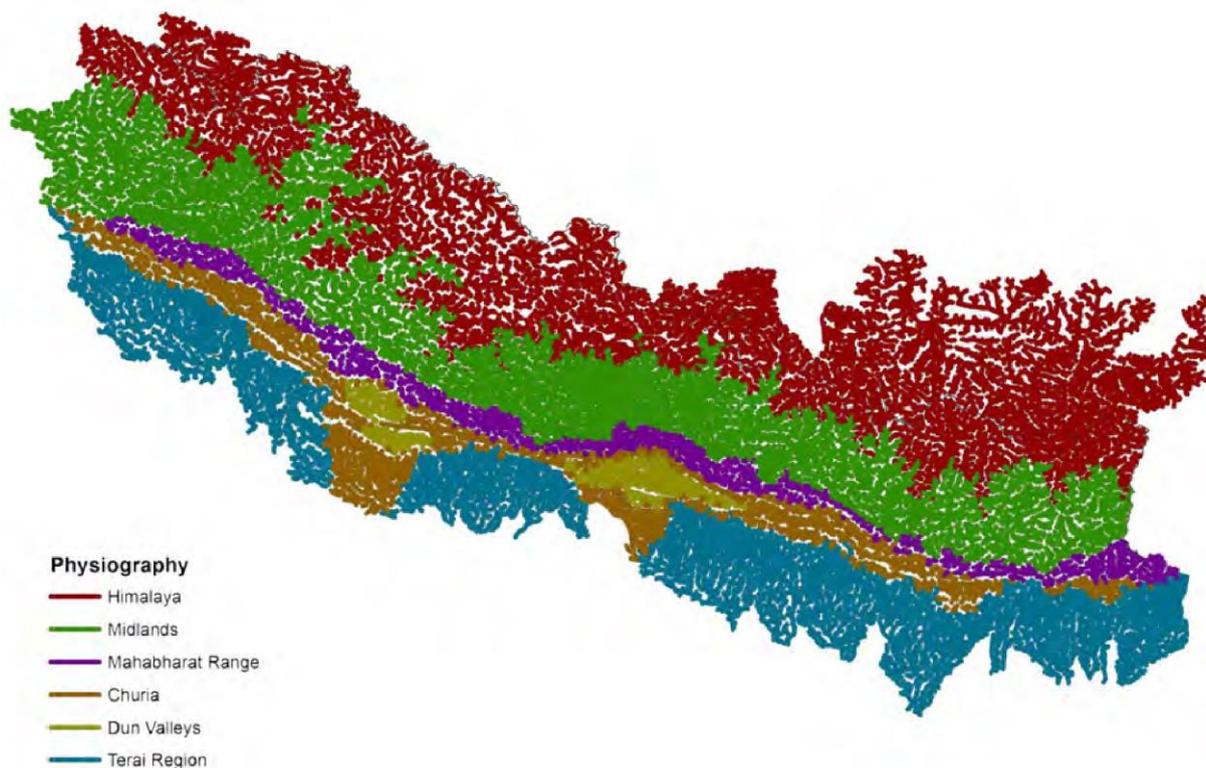


Figure 21: Physiographic Classification for River Classification of Nepal.

6.5.3.2 RIVER SOURCE / INFLUENCE

Rivers in Nepal can also be classified into three broad groups based on the origin of their waters (WECS, 2005; Figure 22). 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 sustained flow during the dry season. These rivers are reliable source of water and also provide potential opportunities for hydropower generation, and irrigation.

In 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 150 km 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, also known as the Kali River, flows along the Nepal-India border in the 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 maintains the minimum flow level and prevents them 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 the Siwalik or Chure 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 during which about 60-85% of annual runoff occurs in

all river systems in Nepal. The rivers originating in the Siwalik Hills and further south in the Terai region are seasonal and mostly depend on the monsoonal rain (Jun-Sep) and remains dry rest of the year.

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 22. 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 comparison with 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 'glacial'. 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 it is difficult to separate the two components conclusively into either a snow or a glacial category.

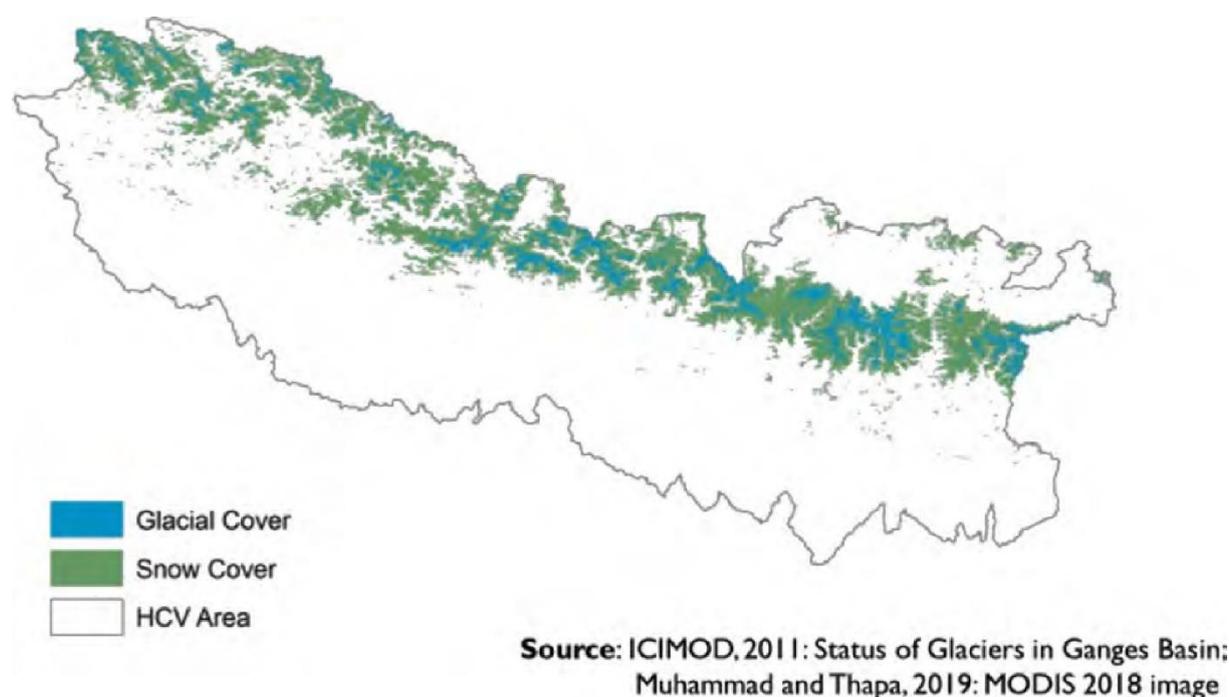


Figure 22: Glacial and snow cover in Nepal.

The results of this classification are displayed in Figure 23. The rivers draining from the Himalayas and High-hills are mostly snow fed and contain 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. As these lower order channels drain downstream, they merge with other channels, subsequently increasing the order and discharge. The snow-fed rivers are perennial and contain 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 contributed to by rain.

River source / influence

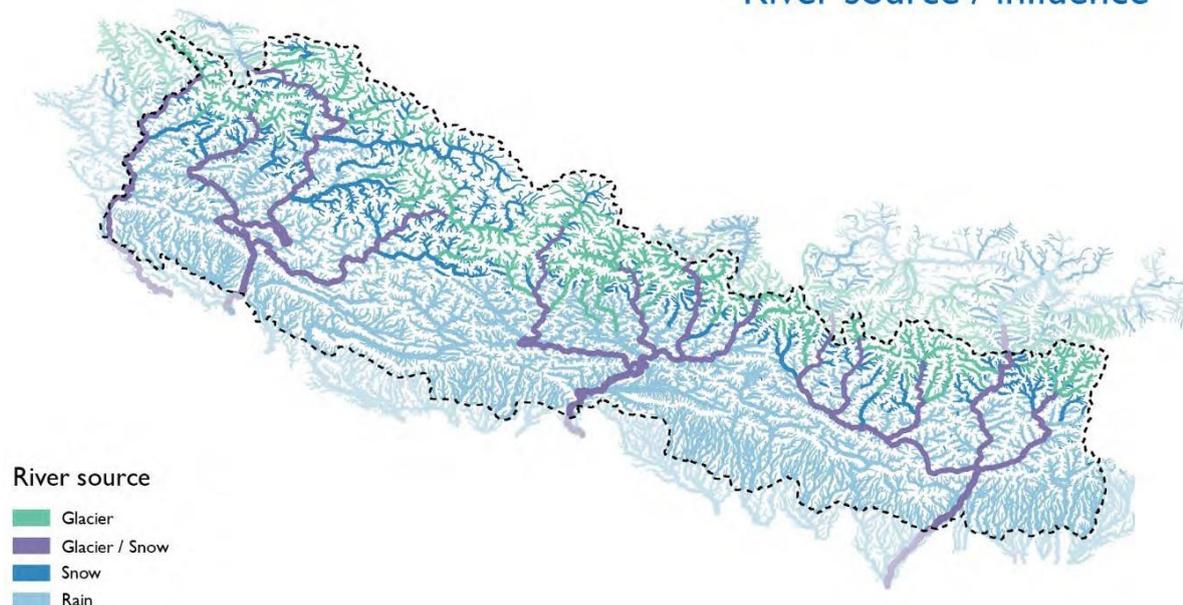


Figure 23: River classification based on source.

6.5.3.3 GEOMORPHIC CLASSIFICATION

River order (i.e., Strahler river order) has also been included in the river classification. According to the "top down" system of river orders devised by Strahler, rivers of the first order are the smallest 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 into 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 originating in the Himalayan region are first order streams or the headwater rivers. As these first order streams merge with others, the river order number and discharge increase (Figure 24).

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.

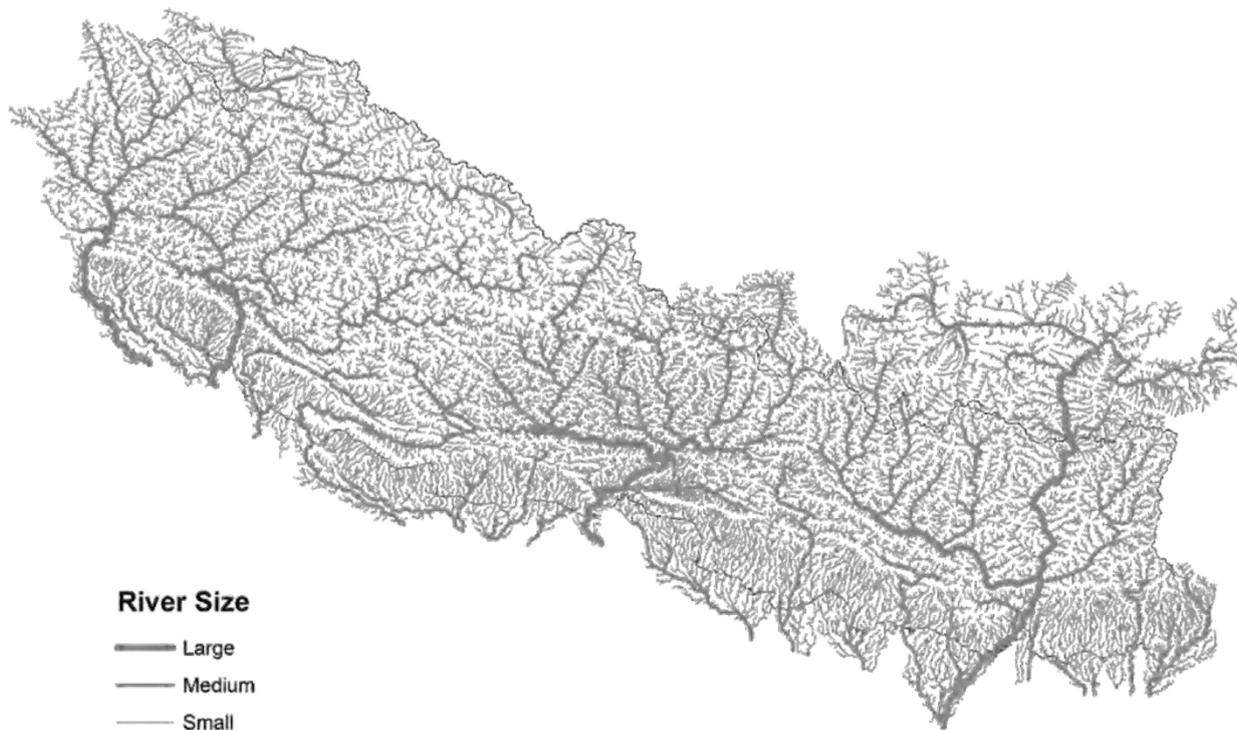


Figure 24: Geomorphic component of river classification based on size (Strahler stream order system)

7. RESULTS

7.1 FRESHWATER STATUS

7.1.1 FREE-FLOWING RIVERS ASSESSMENT

The Free-flowing river assessment shows three major results for the rivers of Nepal. The first 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 is related to the CSI and shows which of the six 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 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). The classification of rivers into free-flowing or non-free-flowing feeds into the Freshwater status (Connectivity) assessment and is incorporated into the final HCVR typology.

7.1.1.1 CONNECTIVITY STATUS INDEX

The results of the Connectivity Status Index (CSI) assessment are shown in Figure 25. 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 the 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 for more details).

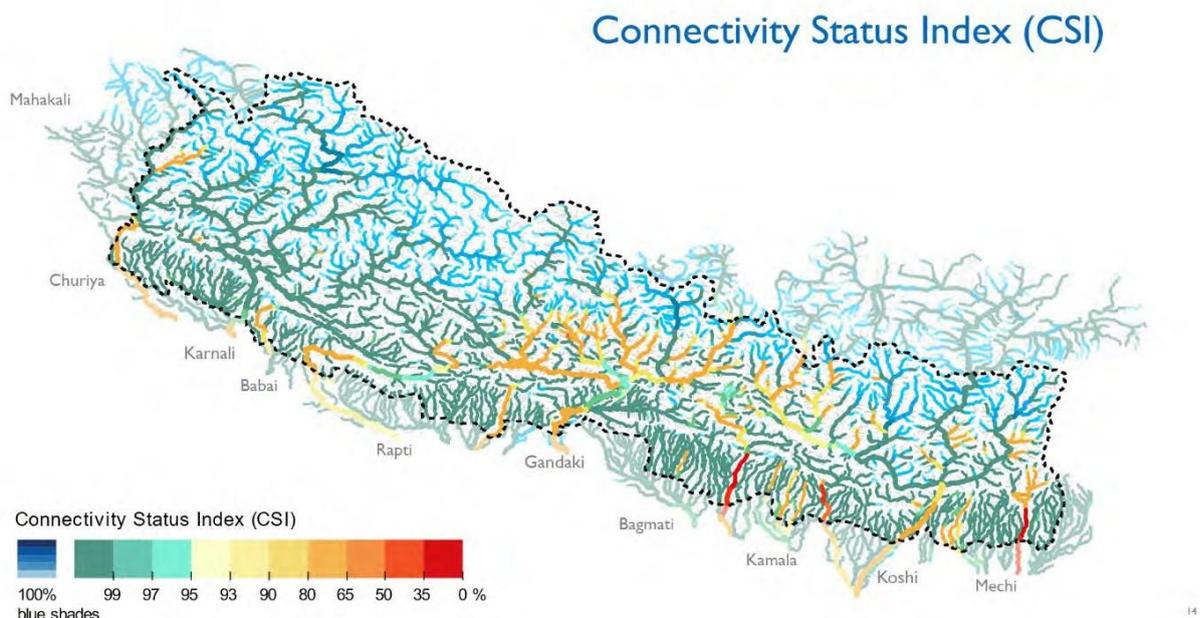


Figure 25: Connectivity Status Index (CSI).

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 are river stretches that were affected by dams via river fragmentation, flow regulation, sediment capture, or a combination of the three. The other three pressure factors may also contribute to further reduce the CSI in these river stretches. We see from the maps that these river stretches correspond to stretches upstream or downstream of existing hydropower or other dams. Rivers most impacted by a decline of CSI are major sections of the 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, describes the main pressure factor responsible for the loss of connectivity in each river reach (Figure 26: Dominant Pressure Factor (DOM)). *DOF=Degree of Fragmentation, DOR=Degree of Regulation, SED=Sedimentation, RDD=Roads, USE=Water use, URB=Urban areas*). The DOM does not indicate the magnitude of impacts, only which type of impact was dominant, and should therefore be interpreted together with the CSI results, which show the magnitude of impacts. Like in the CSI map, the blue shades refer to rivers that are unaffected by the loss of connectivity.

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

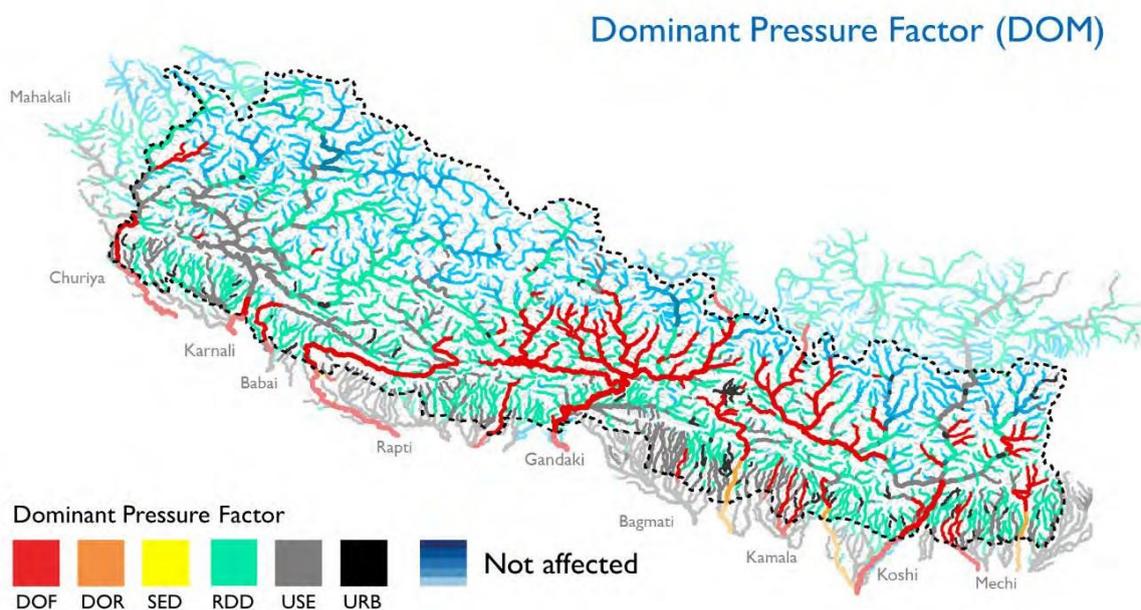


Figure 26: Dominant Pressure Factor (DOM). *DOF=Degree of Fragmentation, DOR=Degree of Regulation, SED=Sedimentation, RDD=Roads, USE=Water use, URB=Urban areas*.

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 individual reaches nearby other urban centers.

If major losses of connectivity occur, the reason is typically due to 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 flows in a major way. Similarly, due to the small reservoir size, sediment capture does not play a major role in most river systems but can significantly contribute to reducing river connectivity.

7.1.1.3 FREE-FLOWING RIVER STATUS

The map in Figure 27 shows the result of the categorization of rivers into free-flowing, or non-free-flowing. Free-flowing rivers are shown in blue on 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 of the river to where it met 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, including the Karnali river, can be considered free-flowing.

If major impacts occur anywhere within a river (CSI <95%), the river is non-free-flowing and will show sections that are “impacted” (red) or “good connectivity”. The red sections are with a CSI below 95% and are typically those with dams and major impacts can occur both upstream and downstream of a barrier, 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 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 rarity among Himalayan rivers and in Southeast Asia.

Free-flowing river status



Figure 27: Free flowing river status in Nepal.

7.1.2 WATER QUALITY PRESSURES ASSESSMENT

Two methods, the machine learning method and spatial accumulation method, were deployed to provide results for individual indicators. These two indicators were then integrated into a single index (i.e., WQPI).

The machine learning method was used to predict the average nitrate concentration 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 28). We found that upstream normalized nitrate application (West et al., 2014) and upstream population were the most important covariates. Figure 29 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 increasing dilution.

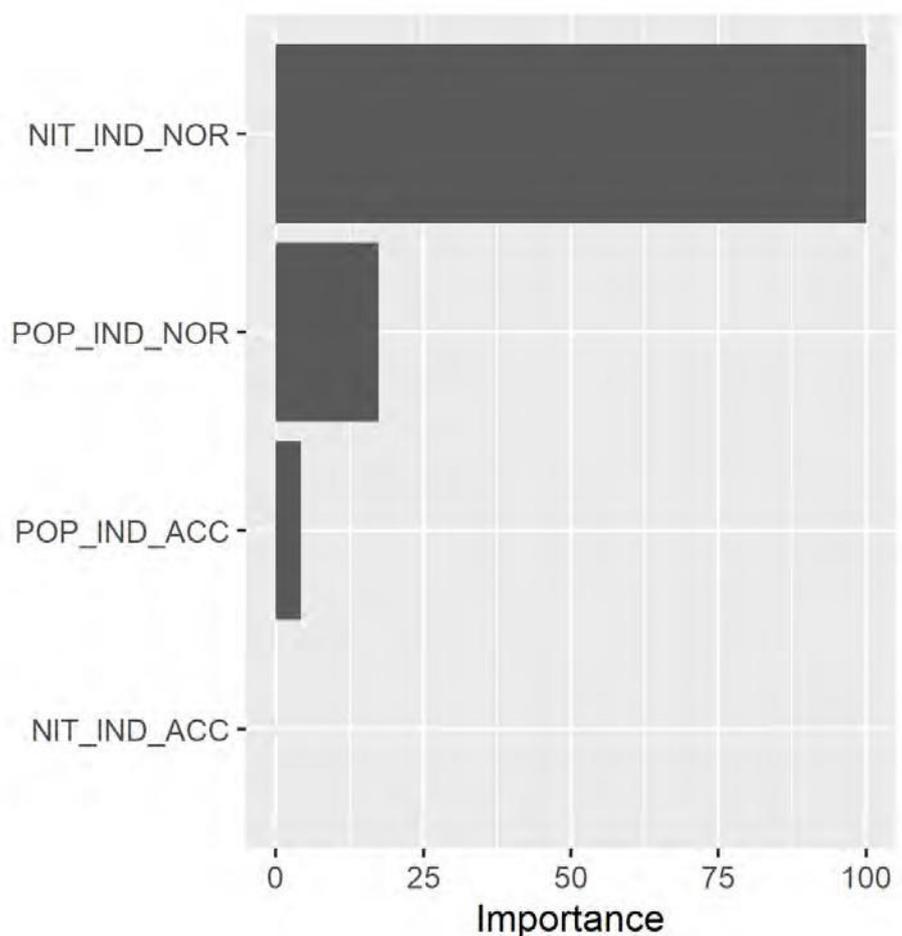


Figure 28: Most important covariates for the nitrate model. The importance score describes how important covariates are to describe observed nitrate. Labels are: Nit_Ind_Nor: Upstream nitrate application rate, normalized by drainage area. Pop_Ind_Acc: Ac

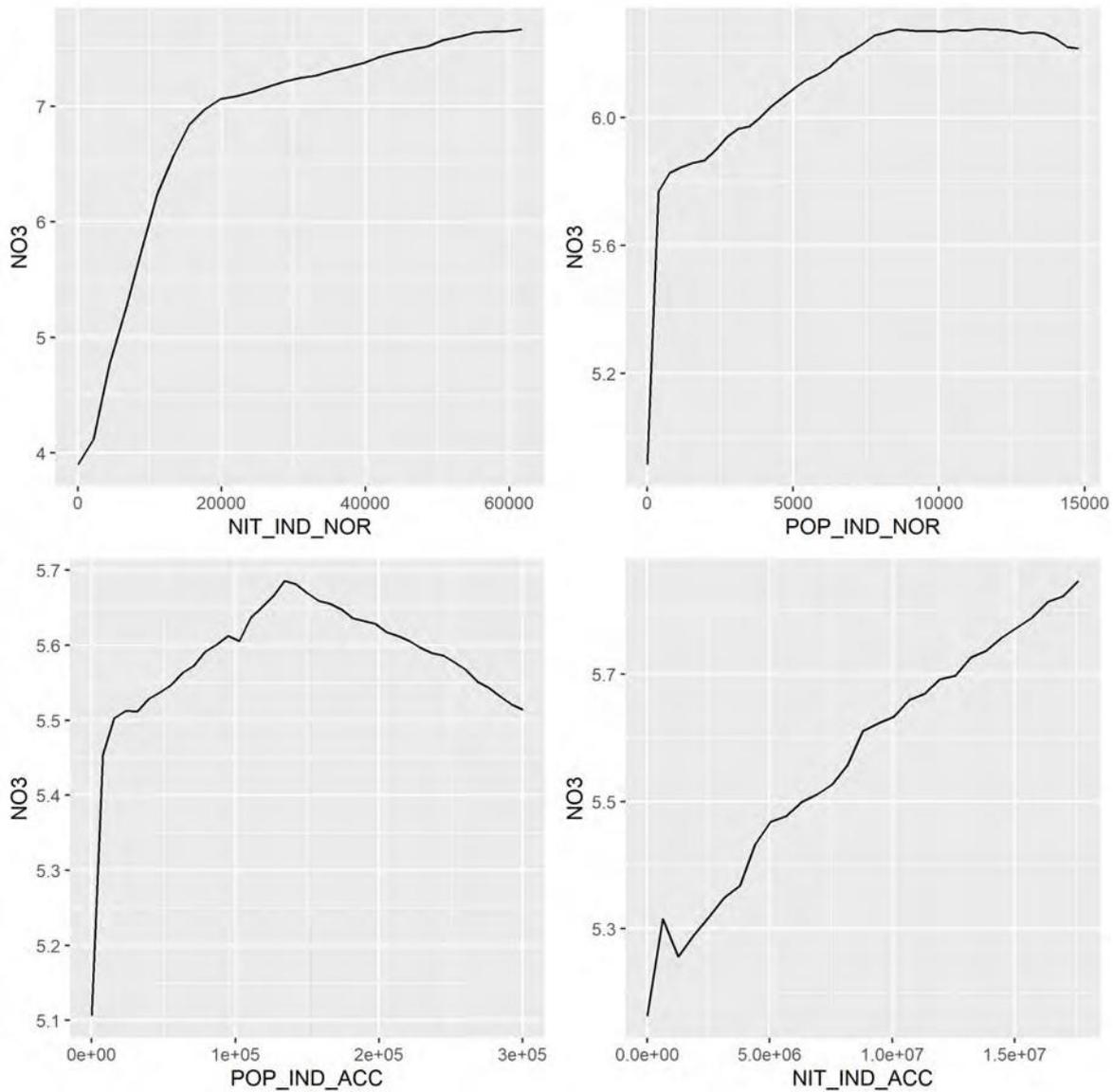


Figure 29: Partial variance importance plots for the nitrate model. Each plot shows the correlation between an individual covariate (ranked by their importance) and the nitrate response.

The results of the normalized index were different for each water pressure indicator (Figure 30). 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 31). 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 32). The threshold was used in the HCVR assessment to help distinguish HCVR types. Rivers that met the threshold of “inadequate” included the Babai, Bagmati, Kamala, and Mechi (Figure 32).

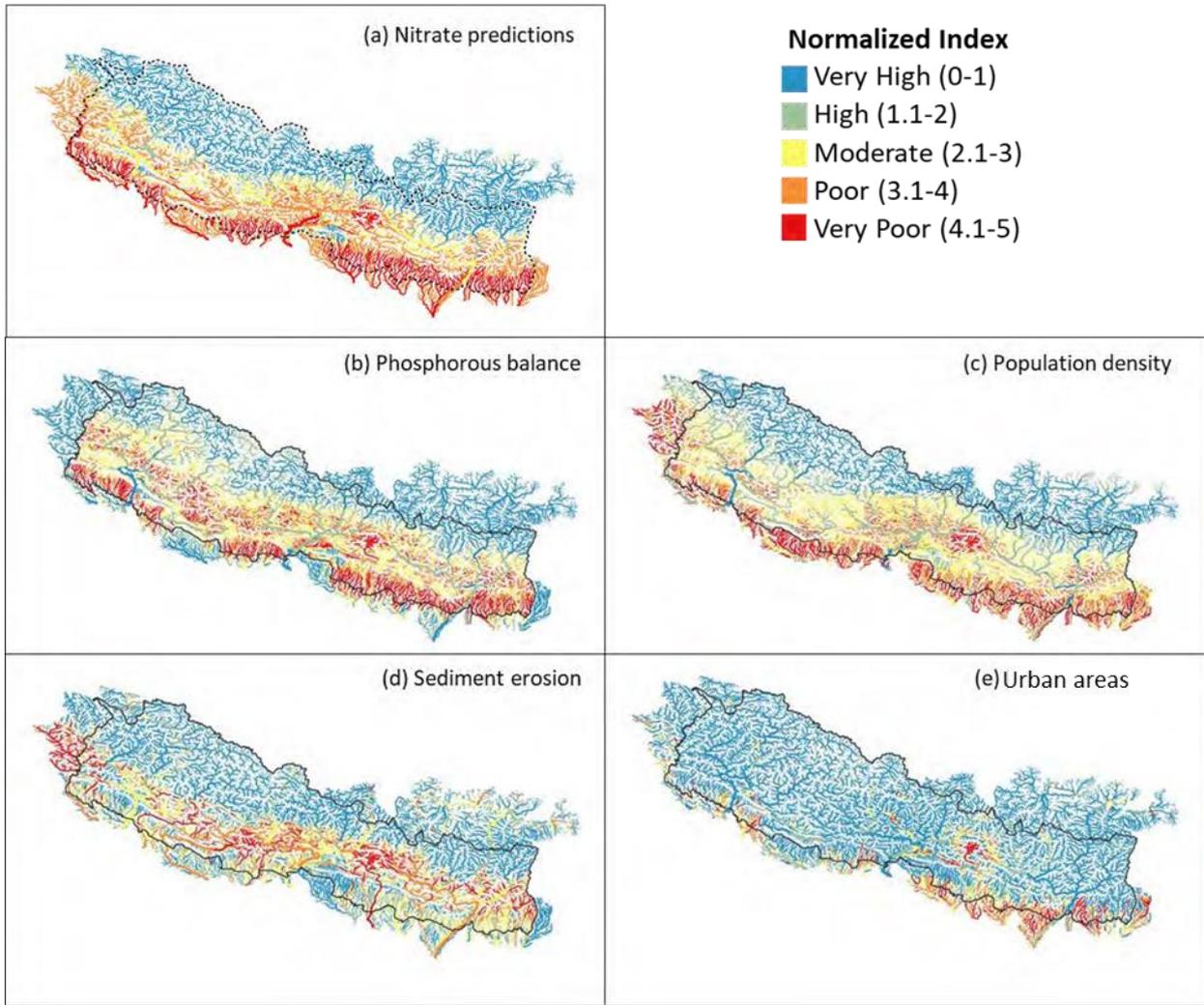


Figure 30: Normalized index for five pressure (a-e) indicators used to calculate WQPI.

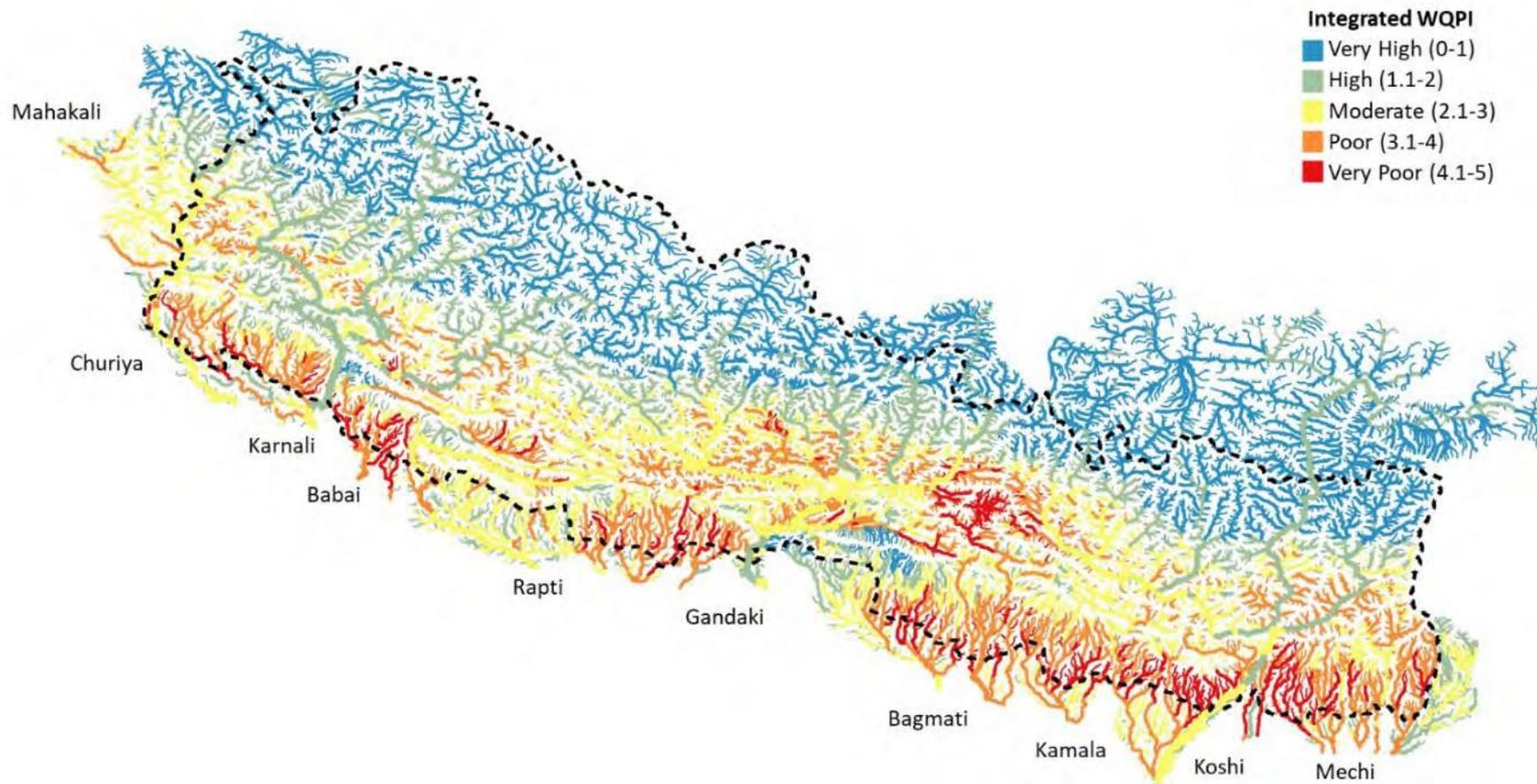


Figure 31: Integrated water quality pressure index (WQPI).

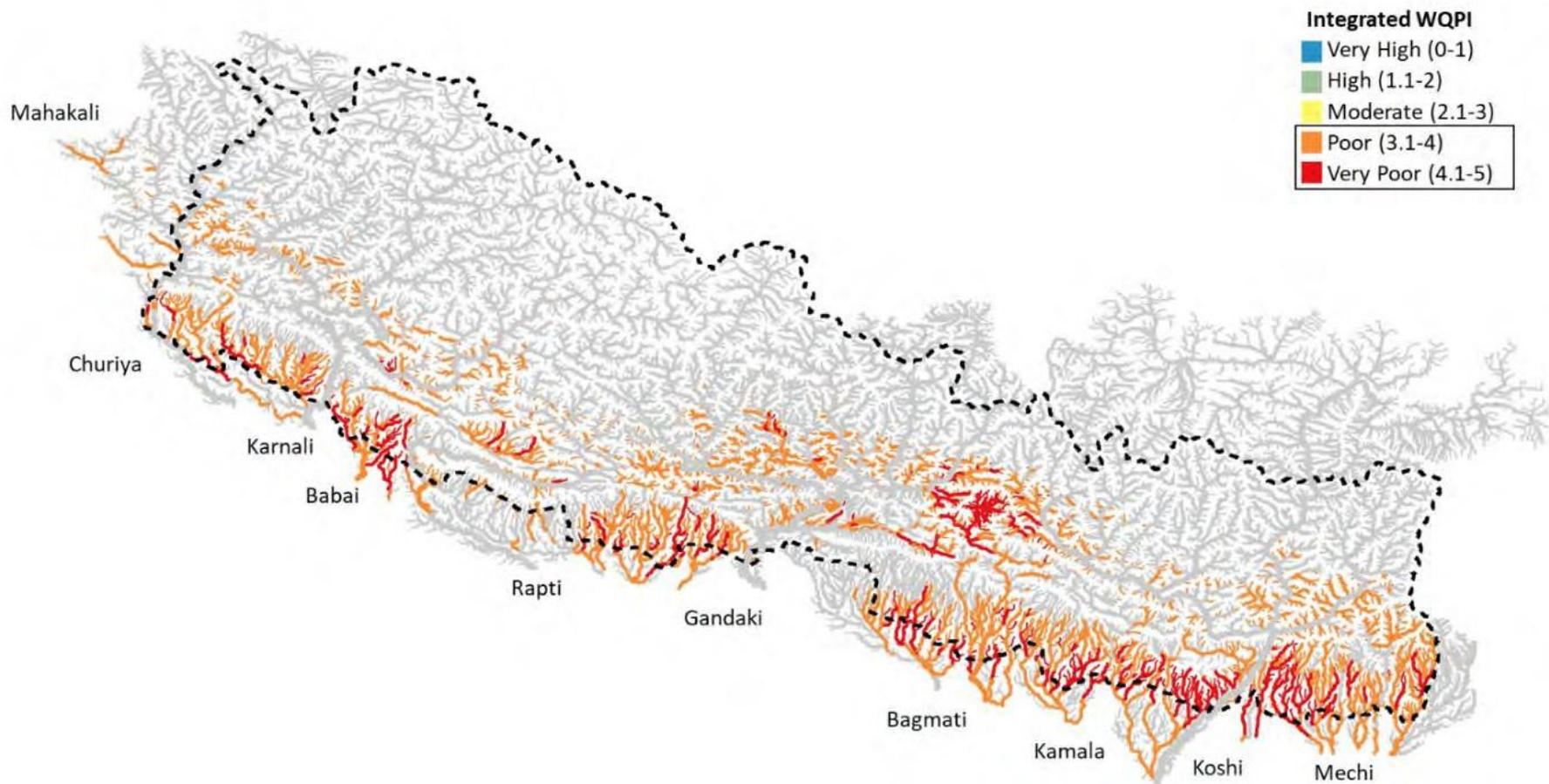


Figure 32: River reaches meeting the “poor” or “very poor” threshold.

7.2 FRESHWATER VALUES

Rivers across Nepal were found to host a variety of different values. The Karnali, East Rapti, Sunkoshi, Seti, and Narayani rivers were among the major rivers 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 (Figure 33: Biodiversity value scores.). These include the Koshi, Karnali, Narayani, and East Rapti Rivers. The factors that feed into the biodiversity value score are listed below.

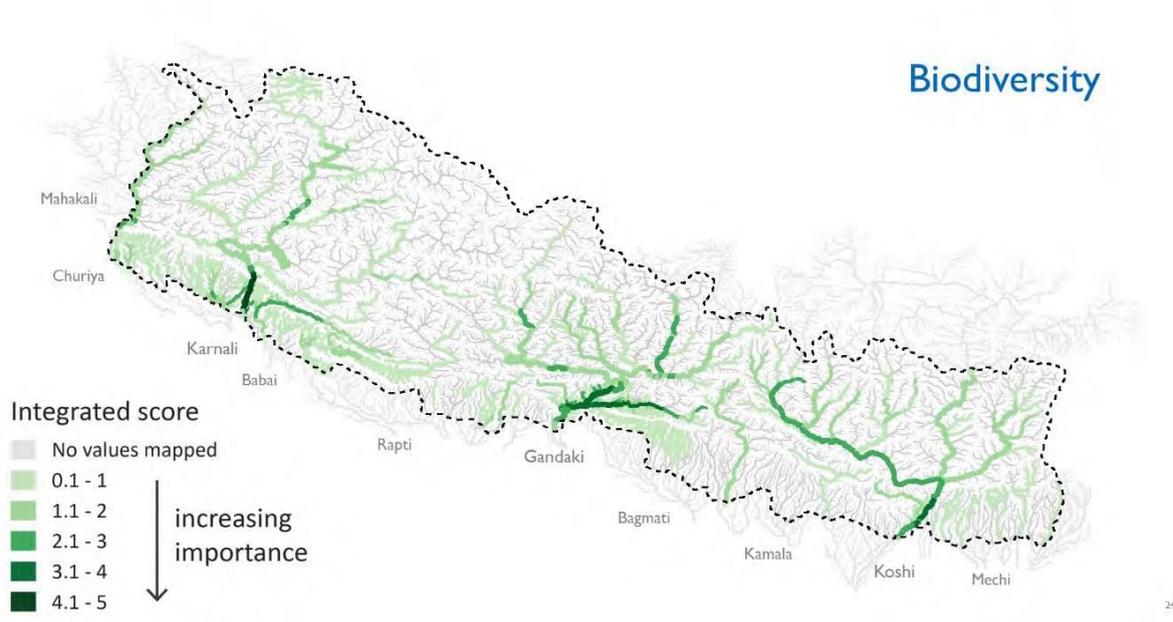


Figure 33: Biodiversity value scores.

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 have been deposited at universities abroad (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 total 256 species of fishes mapped, 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 34: Fish richness in Nepalese rivers.* shows the number of fish species in major rivers of Nepal.

Endemic fishes have been recorded in the tributaries of the major river system such as Nepalese minnow *Psilorhynchus pseudecheneis* in Dudhkoshi river, a catfish *Pseudecheneis crassicaudata* in Mewa khola, *Garra nepalensis* in Mardi river, and a river loach *Balitora eddsi* in Geruwa river, a tributary of Karnali. 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 water currents.

Table 9: Number of fish species in Nepal's rivers

RIVER	NUMBER OF SPECIES
Koshi	211
Gandaki	208
Karnali	178
Mahakali	171
Mechi	68
Tamor	69
Kamala	37
Babai	56
Lohandra	38
Dudhkoshi	35
Triyuga	71

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 solid waste in the Bagmati river in the upper sub basin has degraded the quality of surface water beyond acceptable limits that directly impacts on the aquatic biodiversity of the downstream sub basin. Recent studies have found a

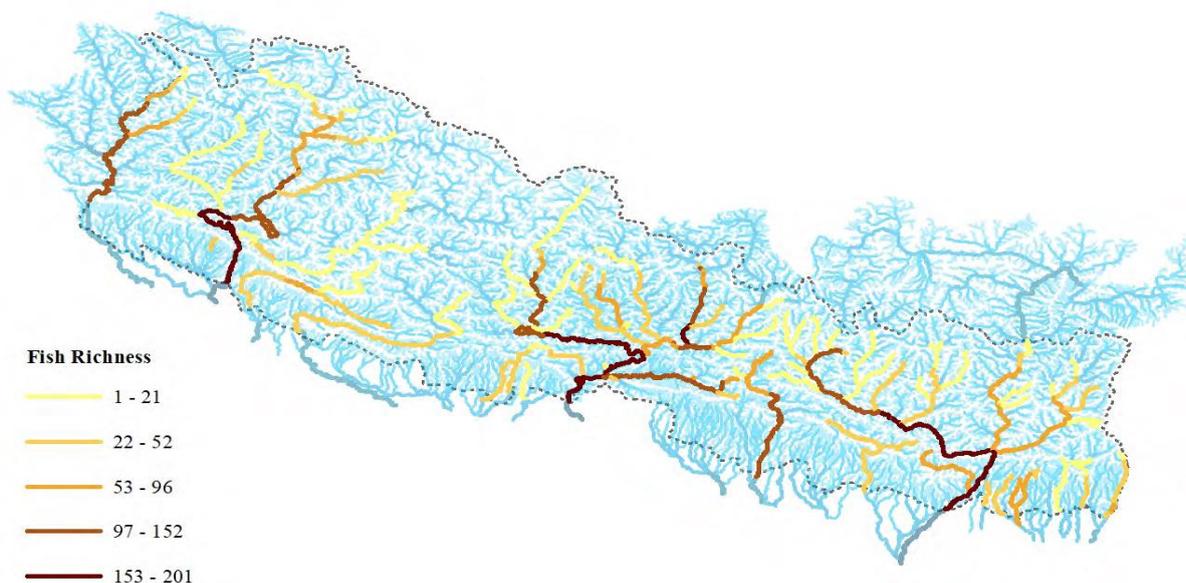


Figure 34: Fish richness in Nepalese rivers.

large portion of the Bagmati river is polluted heavily and there have been 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.

7.2.1.1.3 ENDEMIC FISHES

Due to lack of nationwide systematic survey of fish, it is difficult to establish an exact number of endemic species. Shrestha (2011) has reported 15 endemic species, whereas Rajbanshi (2012) and Shrestha (2019) have listed 16 endemic species. For example, Shrestha (2011) had included *Pseudeutropius murius baterensis* in the list of endemic species but other authors have disagreed. Thus, Rajbanshi (2012) and Shrestha (2019) have not included *Pseudeutropius murius baterensis* as an endemic species. Similarly, Shrestha (2011) and Rajbanshi (2012) did not list *Neoanguilla nepalensis* as an endemic species, but Shrestha (2019) does. Based on thorough review of the literature and a series of consultations with senior fisheries experts in Nepal, this study concluded that there are 16 species endemic to Nepal (Table 10 and Figure 35). Kaligadaki in Midlands, Narayani, Koshi, and lower reaches of Sunkoshi rivers are found to have a higher number of endemic species. These numbers may increase further if systematic surveys on fish fauna is conducted across the entire country.

Psilorhynchus pseudochenensis 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 10: List of Endemic Fishes of Nepal.

SN	GENUS	SPECIES	COMMON NAME	SN	GENUS	SPECIES	COMMON NAME
1	<i>Psilorhynchus</i>	<i>pseudochenensis</i>	Nepalese minnow/Stone carp	9	<i>Pseudochenensis</i>	<i>serracula</i>	Kabre
2	<i>Psilorhynchus</i>	<i>nepalensis</i>	N/A	10	<i>Pseudochenensis</i>	<i>eddsi</i>	Kabre
3	<i>Schizothorax</i>	<i>macrophthalmus</i>	Nepalese snowtrout	11	<i>Erethistoides</i>	<i>ascita</i>	Kabre
4	<i>Schizothorax</i>	<i>nepalensis</i>	Asla snowtrout	12	<i>Erethistoides</i>	<i>cavatura</i>	Kabre
5	<i>Schizothorax</i>	<i>rarensis</i>	Rara snowtrout	13	<i>Balitora</i>	<i>eddsi</i>	N/A
6	<i>Myersglanis</i>	<i>blythi</i>	Pharping catfish	14	<i>Turcinoemacheilus</i>	<i>himalaya</i>	N/A
7	<i>Batasio</i>	<i>macronotus</i>	Batasio	15	<i>Pseudolaguvia</i>	<i>nepalensis</i>	N/A
8	<i>Pseudochenensis</i>	<i>crassicaudata</i>	Kabre	16	<i>Garra</i>	<i>nepalensis</i>	N/A

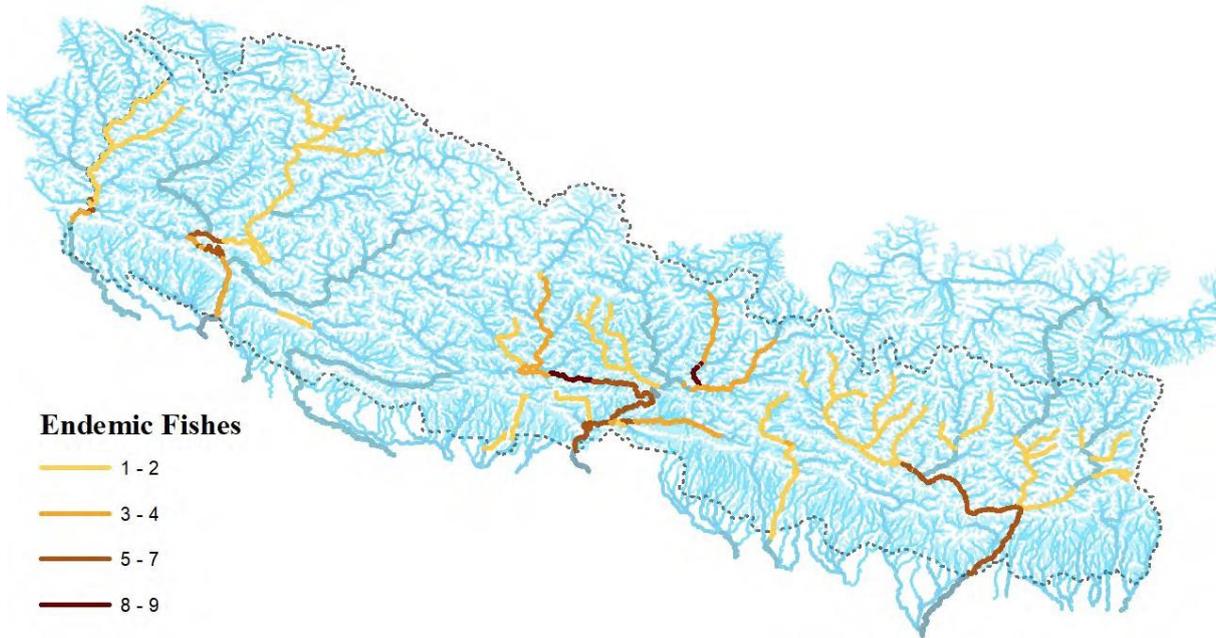


Figure 35: Endemic fish richness in Nepalese rivers.

7.2.1.1.4 THREATENED FISHES

Conservation status of indigenous species were assessed based on the IUCN red list of threatened species 2019. Native species were categorized into Critically Endangered (n=3), Endangered (n=2), Vulnerable (n=5), Nearly Threatened (n=17), Data Deficient (n=24), and Least Concern (n=163; Figure 36) A further 25 species have not been evaluated by IUCN. The species *Schizothorax nepalensis* *Glyptothorax kasmirensis* and *Schizothorax raraensis* are also listed as critically endangered, and *Systemorhyncus nukta* and *Tor putitora* are listed as endangered species. These fish should be priorities for conservation where they remain.

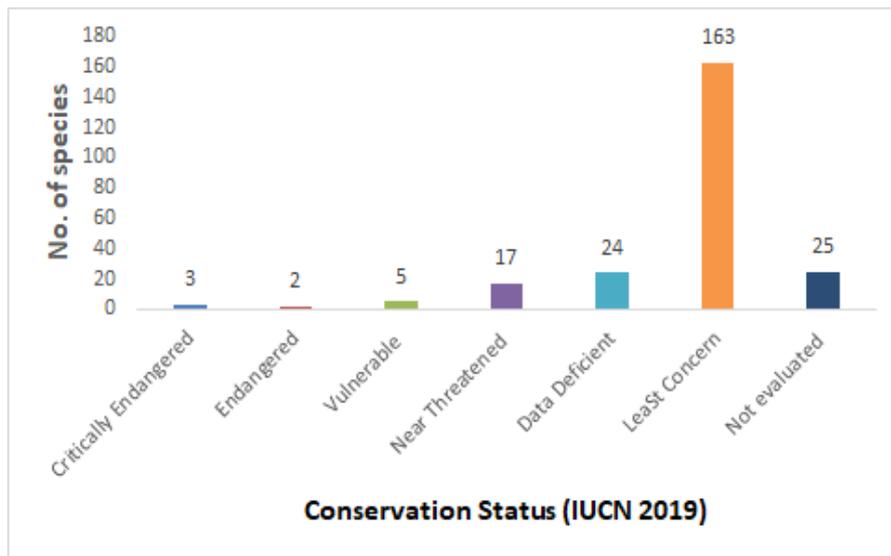


Figure 36: Conservation Status of Native Species of Nepal.

In total, there are three critically endangered species, two endangered and five vulnerable species of fishes found under the threatened category in Nepal (Table II).

The Sunkossi, Mahakali, Upper Karnali, Kaligandaki (upper reaches) rivers are highlighted for having higher numbers of threatened species (Figure 37).

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 II: Critically endangered, endangered and vulnerable fish species of Nepal.

SN	GENUS	SPECIES	STATUS
1	<i>Schizothorax</i>	<i>nepalensis</i>	Critically Endangered
2	<i>Schizothorax</i>	<i>rarensis</i>	Critically Endangered
3	<i>Glyptothorax</i>	<i>kasmirensis</i>	Critically Endangered
4	<i>Systemorhynchus</i>	<i>nukta</i>	Endangered
5	<i>Tor</i>	<i>putitora</i>	Endangered
6	<i>Cyprinion</i>	<i>semiplotum</i>	Vulnerable
7	<i>Tor</i>	<i>chelynoids</i>	Vulnerable
8	<i>Schizothorax</i>	<i>richardsonii</i>	Vulnerable
9	<i>Schistura</i>	<i>prashadi</i>	Vulnerable
10	<i>Physoschistura</i>	<i>elongate</i>	Vulnerable

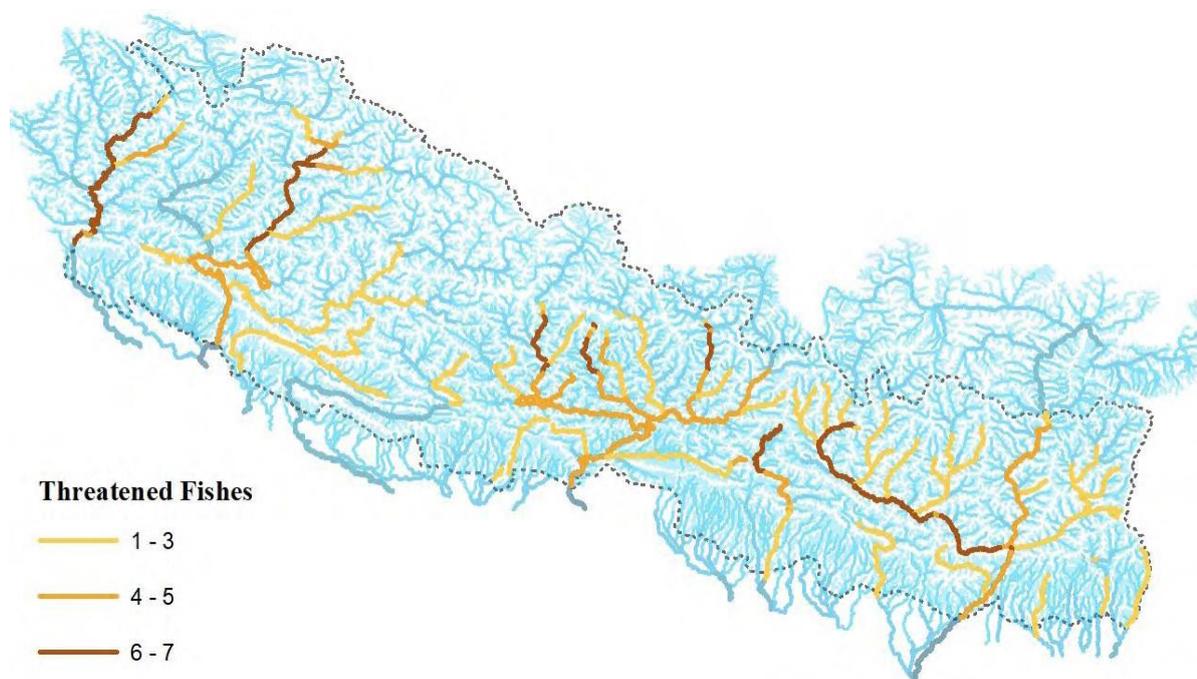


Figure 37: Threatened fish species in Nepalese rivers.

7.2.1.1.5 MIGRATORY FISHES

Information on the migratory behavior of freshwater fishes have not been well documented in Nepal. Nevertheless, the rivers of Nepal are known to provide significant habitat for 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. Those in the long distance category travel distances of hundreds of kilometers. 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. In this study we split migratory species 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 12). *Anguilla bengalensis*, *Tor putitora*, *Tor tor*, *Bagarius yarrelli*, and *Clupisoma garua* are the 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 plagiostomus*, considered a short to medium distance migrant, in Tinau River at an altitude of 251 m during the flood season 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 constructed in different rivers and their tributaries can reduce the populations and number of species, however, in the absence of valid baseline data it is impossible to quantify the reduction rate. 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 migratory species showed that the major river systems are good habitat for both long and mid-short migratory fishes. The Karnali, Narayani, Kaligandaki, Koshi, and Sunkoshi Rivers have been highlighted in terms of distribution of migratory fishes (Figure 38 and Figure 39). However, the construction of dams has hindered migration for the long-distance migrant fishes, preventing them from reaching upstream breeding and feeding grounds resulting in declines of these species (Gubhaju, 2011).

Table 12: Long distance, and short to medium distance migratory species.

S.N	GENUS	SPECIES	COMMON NAME	MIGRATION TYPE
1	<i>Anguilla</i>	<i>bengalensis</i>	Mottled eel	Long distant
2	<i>Tor</i>	<i>putitora</i>	Golden mahseer	Long distant
3	<i>Tor</i>	<i>tor</i>	Tor mahseer	Long distant
4	<i>Bagarius</i>	<i>bagarius</i>	Devil catfish	Long distant
5	<i>Clupisoma</i>	<i>gaura</i>	Garua Bachcha	Long distant
1	<i>Labeo</i>	<i>angra</i>	N/A	Medium and Short distant
2	<i>Labeo</i>	<i>dero</i>	Indian major carp	Medium and Short distant
3	<i>Labeo</i>	<i>dyocheilus</i>	Gardi	Medium and Short distant
4	<i>Tor</i>	<i>chelynoides</i>	Dark mahseer	Medium and Short distant
5	<i>Schizothorax</i>	<i>plagiostomus</i>	Snow trout	Medium and Short distant

S.N	GENUS	SPECIES	COMMON NAME	MIGRATION TYPE
6	<i>Monopterus</i>	<i>cuchia</i>	Gangetic mud eel	Medium and Short distant
7	<i>Chagunius</i>	<i>chagunio</i>	N/A	Medium and Short distant
8	<i>Neolissochilus</i>	<i>hexagonolepis</i>	Chocolate mahseer	Medium and Short distant

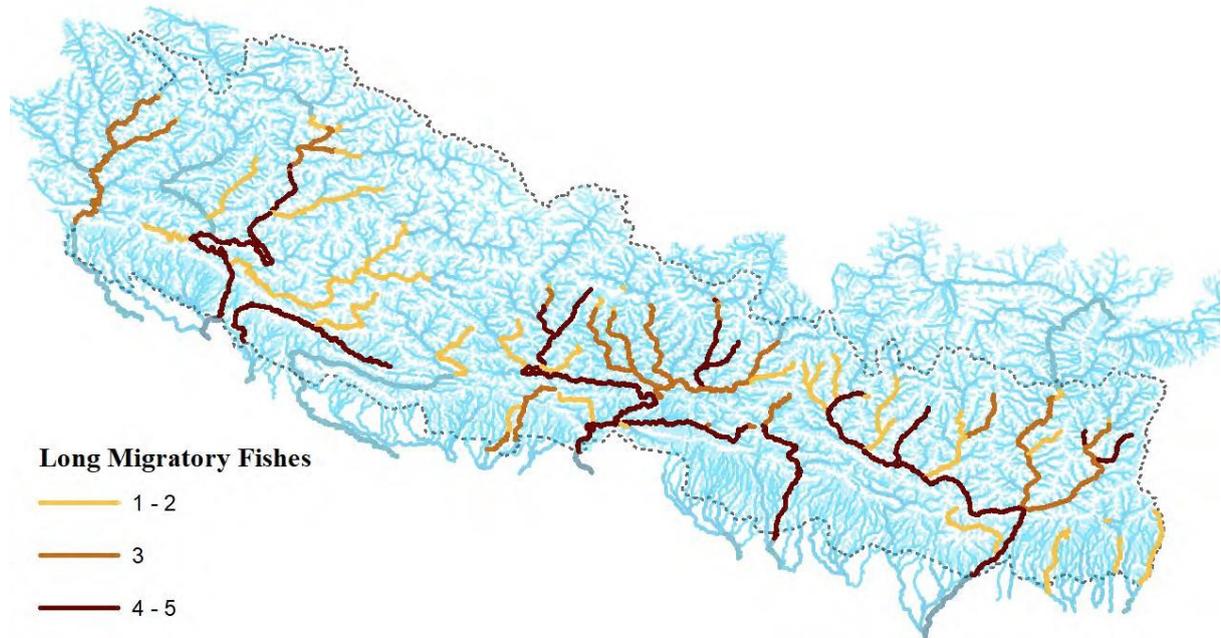


Figure 38: Long-distance migratory fish richness in Nepalese rivers.

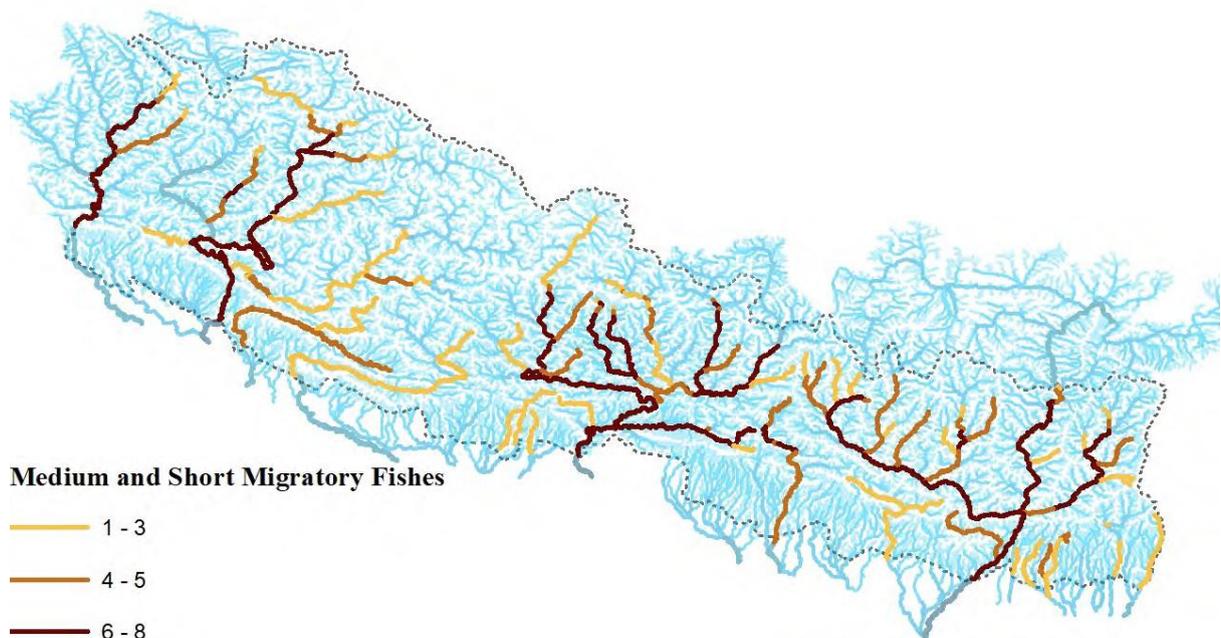


Figure 39: Medium and short-distance migratory fish richness in Nepalese rivers.

7.2.1.2 FLAGSHIP SPECIES

7.2.1.2.1 DOLPHIN

Gangetic River Dolphin (*Platanista gangetica gangetica*) is a legally protected mammal in Nepal, and the country's only cetacean (the aquatic order of mammals comprising whales, dolphins and porpoises). It has been recorded in lowland stretches of the Karnali, Koshi, and Narayani rivers. However, it was not recorded in the Narayani River in last census of 2016, and the Advisory Group suggested that the Narayani now be considered an historical habitat. (Figure 40).

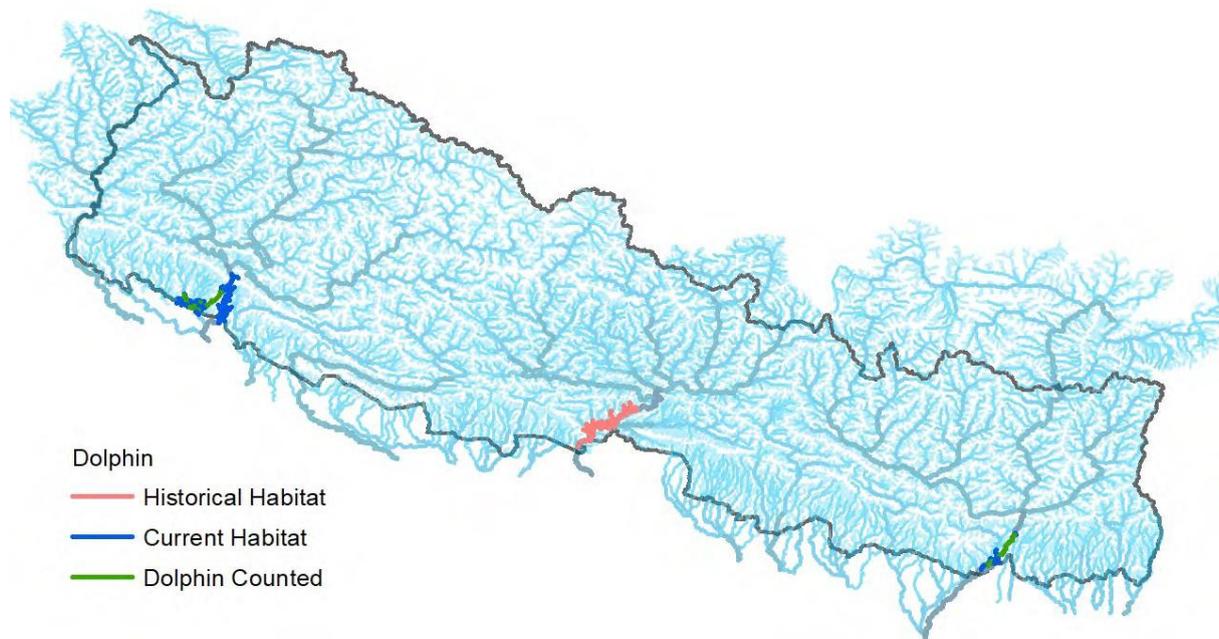


Figure 40: Dolphin habitats in Nepalese rivers.

7.2.1.2.2 GHARIAL

According to the last census in 2016, 198 gharials have been recorded in the Babai, Narayani, and East Rapti rivers. Recently in 2019, a gharial has also been spotted in West Rapti River by WWF Nepal (Figure 41).

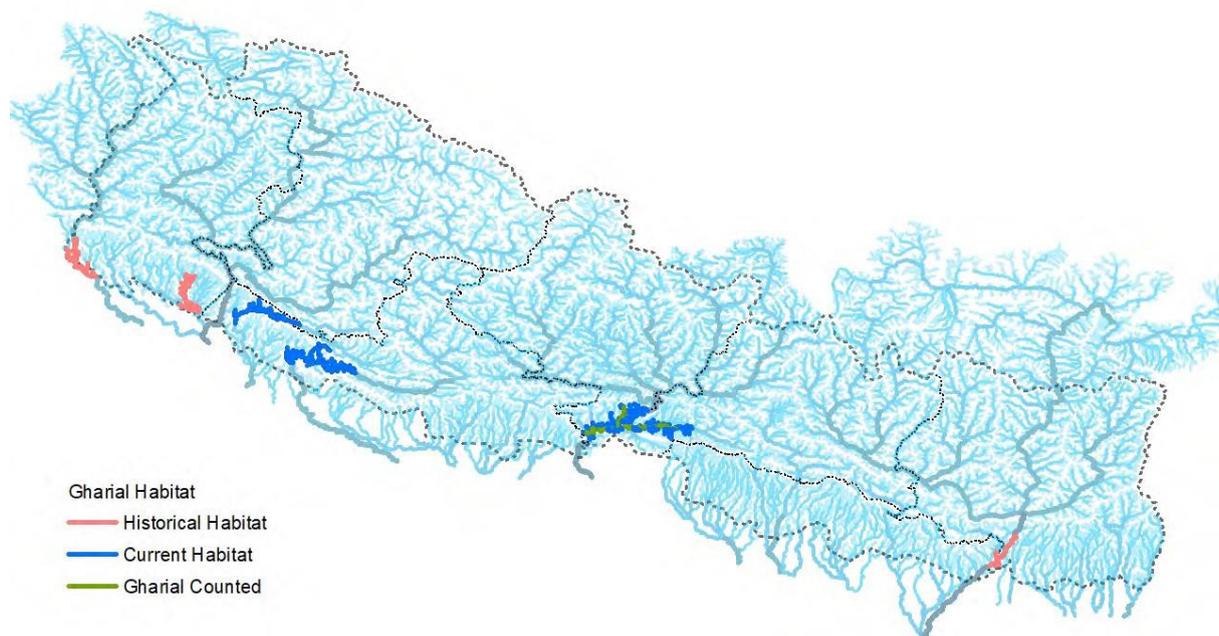


Figure 41: Gharial habitats in Nepalese rivers.

7.2.1.2.3 MAHSEER

Four species of mahseer were included as flagships in this assessment (Table 13). Where they occurred or have been recorded, there were often three to four species of mahseers (Figure 42). Golden Mahseer is found in fast-moving water, pools, of the Himalayan foothills, especially in rivers like Kaligandaki, Trishuli, Sunkoshi, Narayani, and Karnali rivers (Prakritinepal, 2018). Copper Mahseer is recorded from Gandaki, Trishuli, Koshi, Karnali, Mahakali river basins from Nepal (Shrestha 2003 cited by Arunachalam, 2010). Deep Bodied Mahseer is the most widely distributed among the four mahseers.

Table 13: List of Mahseer Species found in Nepal.

SN	SCIENTIFIC NAME	COMMON NAME	NEPALI NAME	IUCN STATUS
1	<i>Neolissochilus hexagonolepis</i>	Copper Mahseer	Katle	NT
2	<i>Tor chelynoides</i>	Dark Mahseer	Halude	VU
3	<i>Tor putitora</i>	Golden Mahseer	Sahar/Mahseer	EN
4	<i>Tor tor</i>	Deep Bodied Mahseer	Sahar/Mahseer	DD

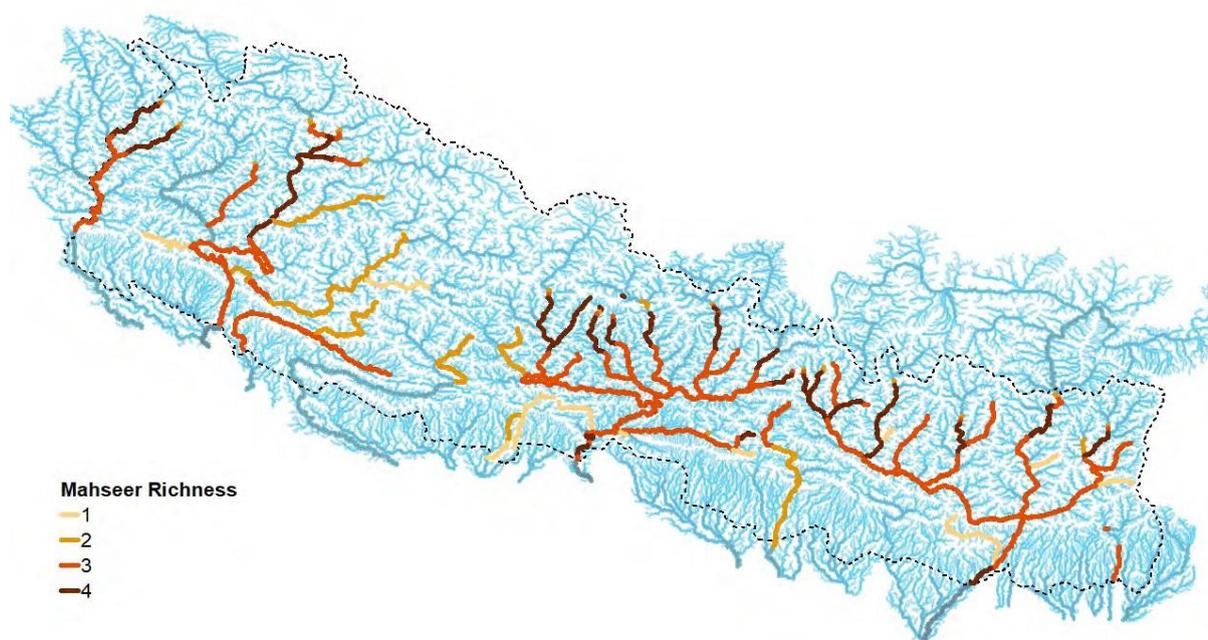


Figure 42: Mahseer richness in Nepalese rivers.

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 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 43).

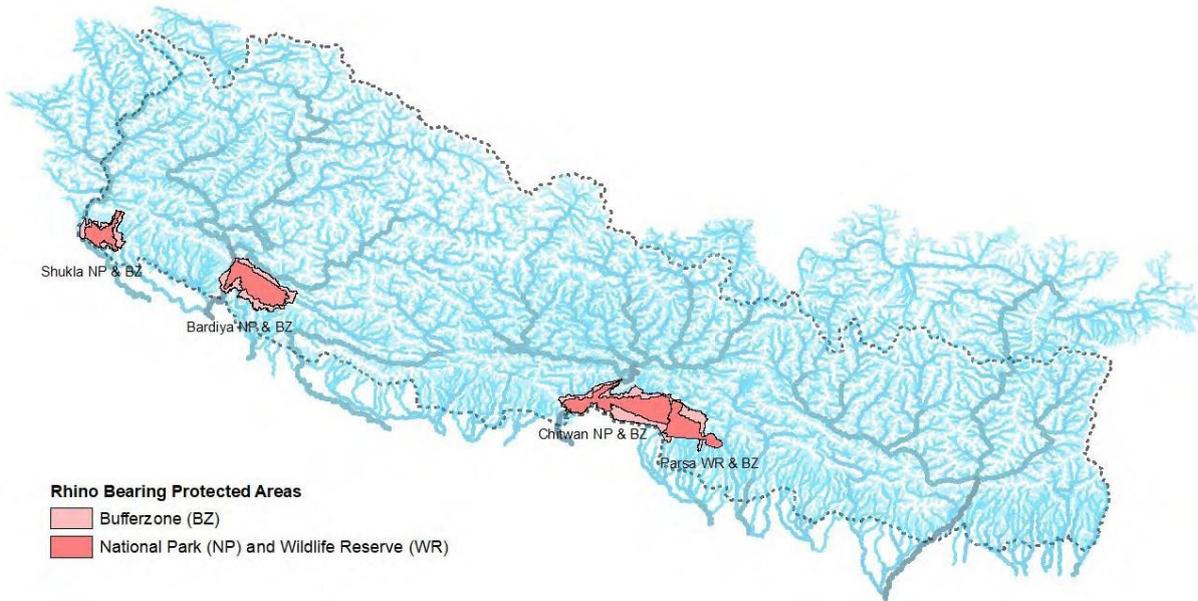


Figure 43: Protected areas that host rhinoceros in Nepal.

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 44).

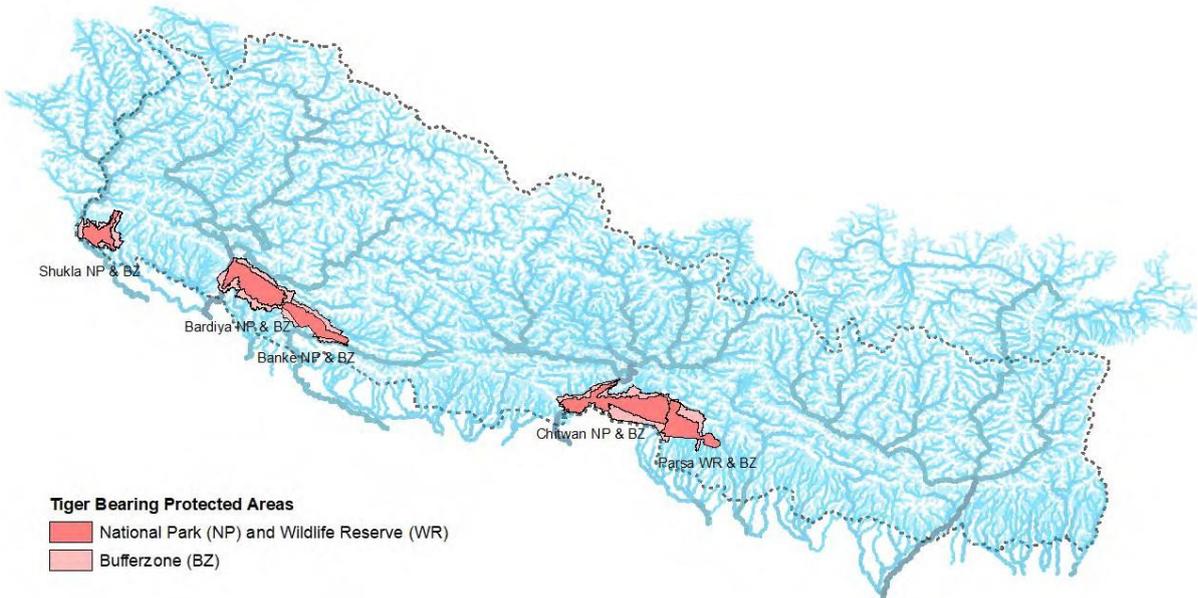


Figure 44: Protected areas that host tigers in Nepal.

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 14). 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 spraints and spoor 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).

Very few river reaches are considered current habitat in the country (Figure 45). 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 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 were formerly inhabited by otter. Similarly, West Seti and East Rapti rivers are confirmed as 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 14: Otter species documented in Nepal.

SN	SCIENTIFIC NAME	ENGLISH NAME	IUCN RED DATA LIST	CITES APPENDIX	NPWC ACT	AQUATIC LIFE PROTECTION ACT
1	<i>Lutrogale perscapillata</i>	Semi-coated Otter	VU	II	Not listed	Listed
2	<i>Lutra lutra</i>	Eurasian Otter	NT	I	Not listed	Listed
3	<i>Aonyx cinerea</i>	Oriental small-clawed Otter	VU	II	Not listed	Not listed

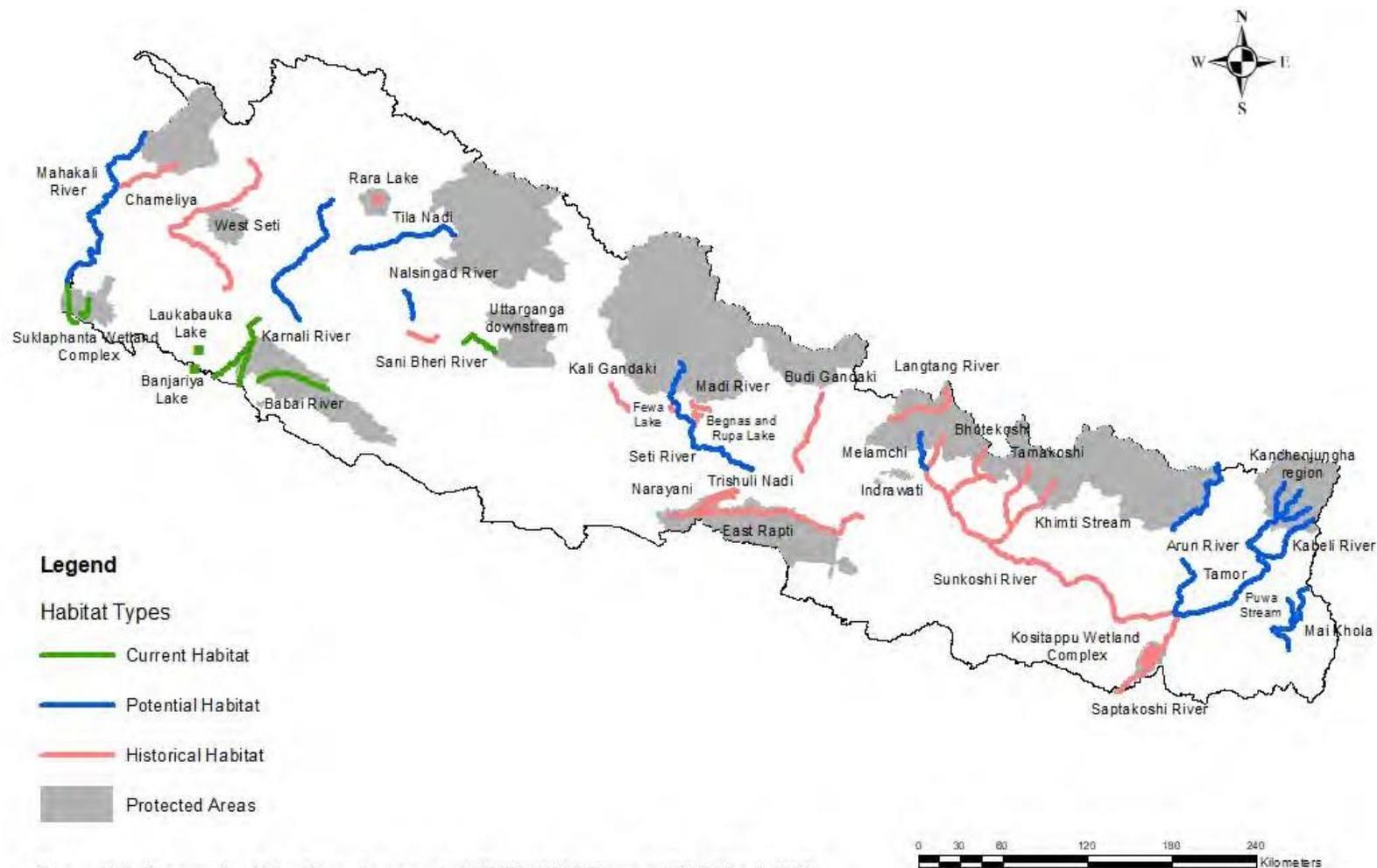


Figure 45: Current, historic, and potential habitat distribution for otters in Nepal. Only the Smooth-coated Otter (*Lutrogale perspicillata*) has been sighted in Nepal in recent years (green). Other otter species inhabited historic sites (red) or may inhabit potential habitats in the future (blue).

7.2.1.3.4 WETLAND BIRDS

In Nepal, there are many river reaches that are home to several species of wetland birds that are considered important for their life history including the Koshi River, Narayani River along Chitwan National Park, Rapti River in Dang, and Karnali River in Bardiya NP (Figure 46).

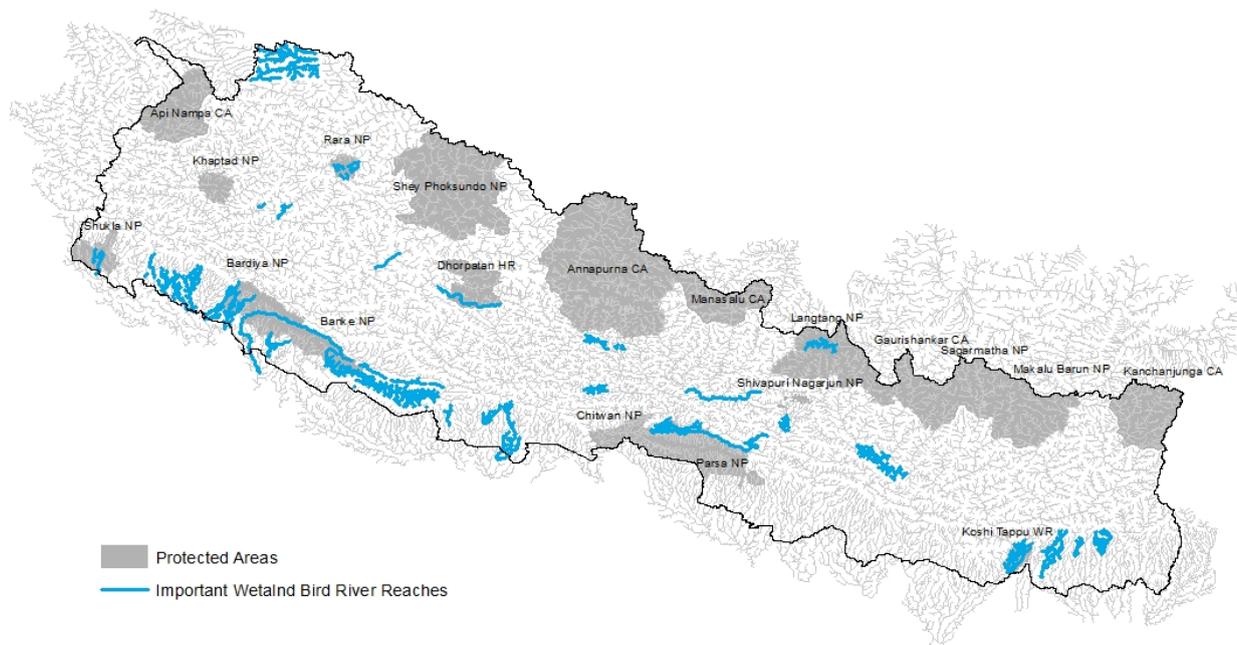


Figure 46: Important river reaches for wetland birds in Nepal.

7.2.1.3.5 CRITICAL CORRIDORS

Critical corridors connect protected areas and facilitate movement and dispersal of wildlife, especially megafauna (Figure 47). 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 as it has been identified as a priority for ecological connectivity between the Churia, Nepal and India's Katarniaghat Wildlife Sanctuary. Frequent use of this corridor by elephant, rhino, and tiger has been reported.

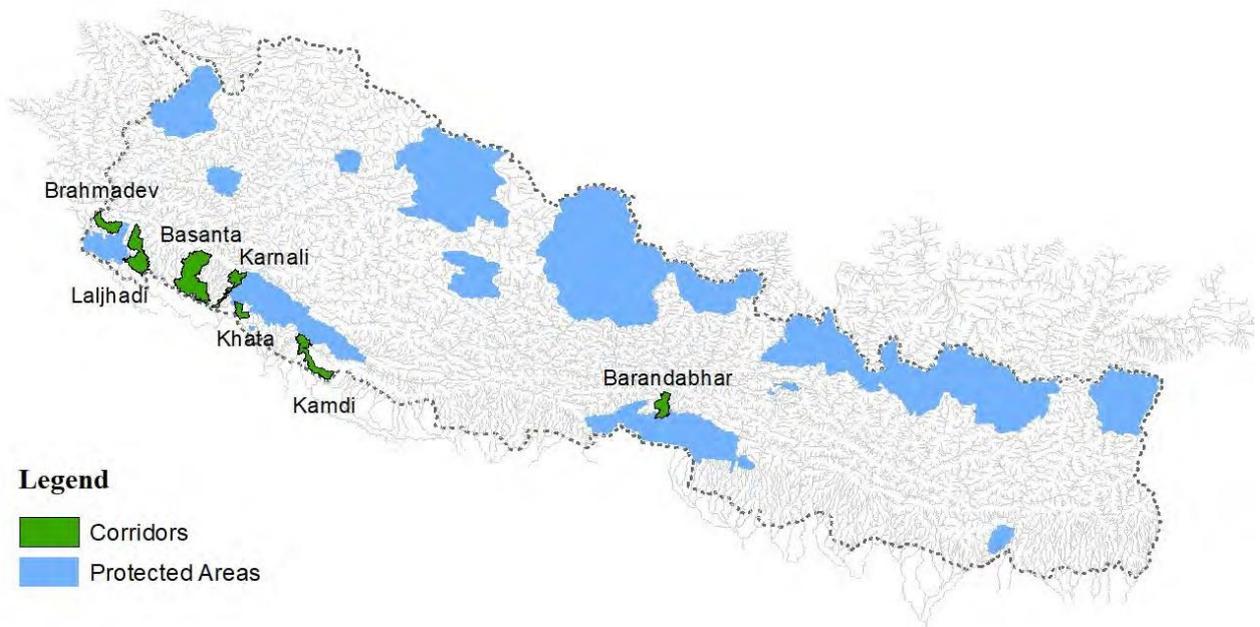


Figure 47: Critical corridors in Nepal.

7.2.2 RECREATIONAL VALUES

Generally speaking, Himalayan rivers in the north of Nepal have greater recreational values than those originating in the Mahabharat or Chure Ranges in the south. 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 48, which includes the values ‘angling’, ‘rafting’, trekking’ and ‘protected areas’.

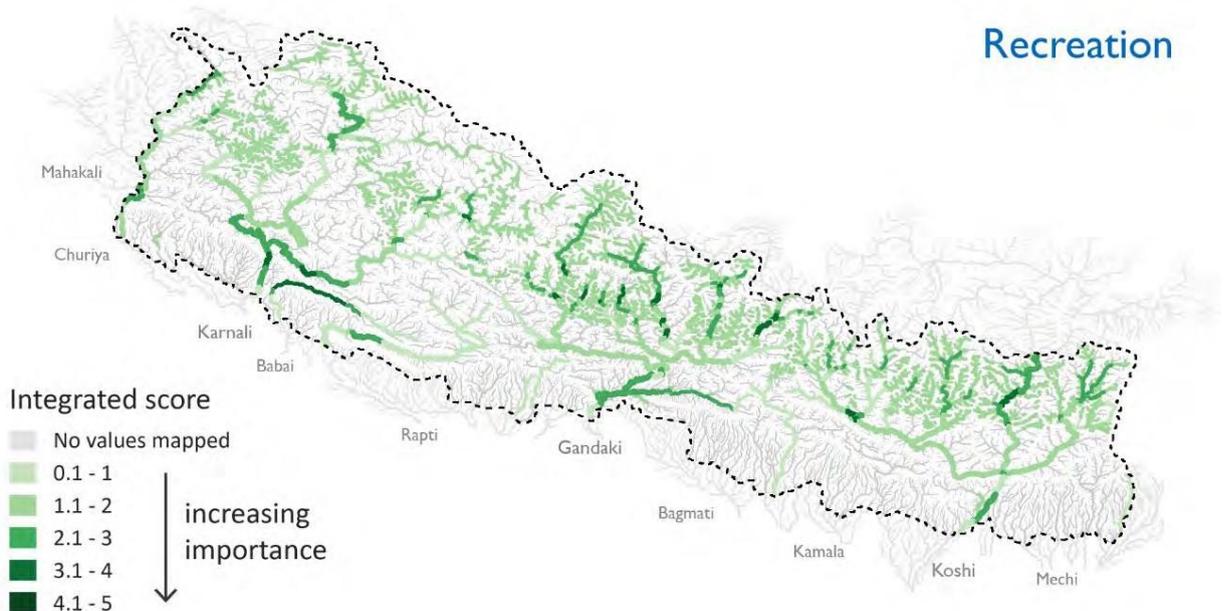


Figure 48: Recreational values in Nepal are composed of an overlay of the freshwater values ‘angling’, ‘rafting’, trekking’ and ‘protected areas.’

7.2.2.1 ANGLING

Prime angling locations for key species which are most sought after by anglers in Nepal, are, in order of preference, lowland warmwater rivers, by mid-hills cool-water rivers, and upland cold-water rivers. 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, Goonch, Warm water species and Asala and their combined presence (Figure 49). Warm water species includes bullseye snakehead (*Channa marulius*), giant river-catfish (*Sperata seenghala*), long-whiskered catfish (*Sperata aor*), catla (*Catla catla*), *Cirrhinus mrigala*, knifefish (*Chitala chitala*), orangefin labeo (*Labeo calbasu*), rohu (*Labeo rohita*) among others.

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

Locations further upstream but still on the mainstem have fewer species for angling. Due to decreasing water temperature, warmwater species such become rare to encounter, indicated in river stretches with 'good' angling value, or medium angling value, if only Mahseer, Goonch and Asala are found, but no other warmwater species.

Further upstream and in tributaries of the main arteries, even fewer angling species are found and these rivers are rated as "poor", due to missing Mahseer and Goonch species, but some recreational value can be derived from fishing Asala or other species.

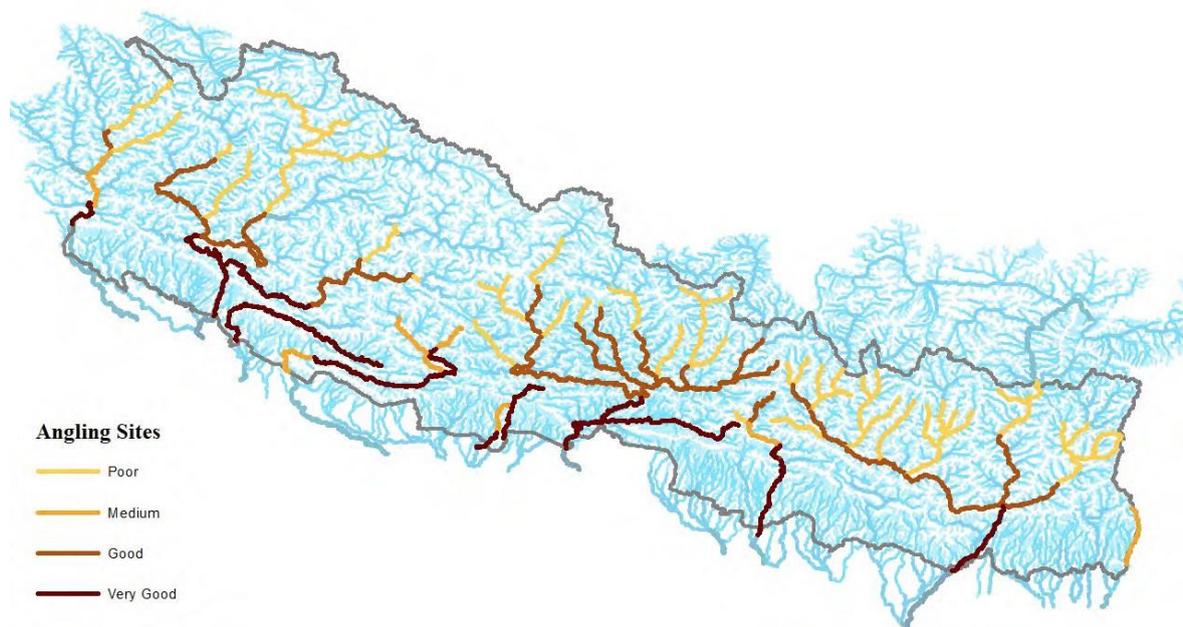


Figure 49: Rating of rivers for Angling value based on number of angling species.

7.2.2.2 RAFTING & KAYAKING

There are 33 rivers in Nepal that are important for rafting and kayaking (Figure 50). 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. Only a small section in the Bagmati river is found to be suitable for rafting.

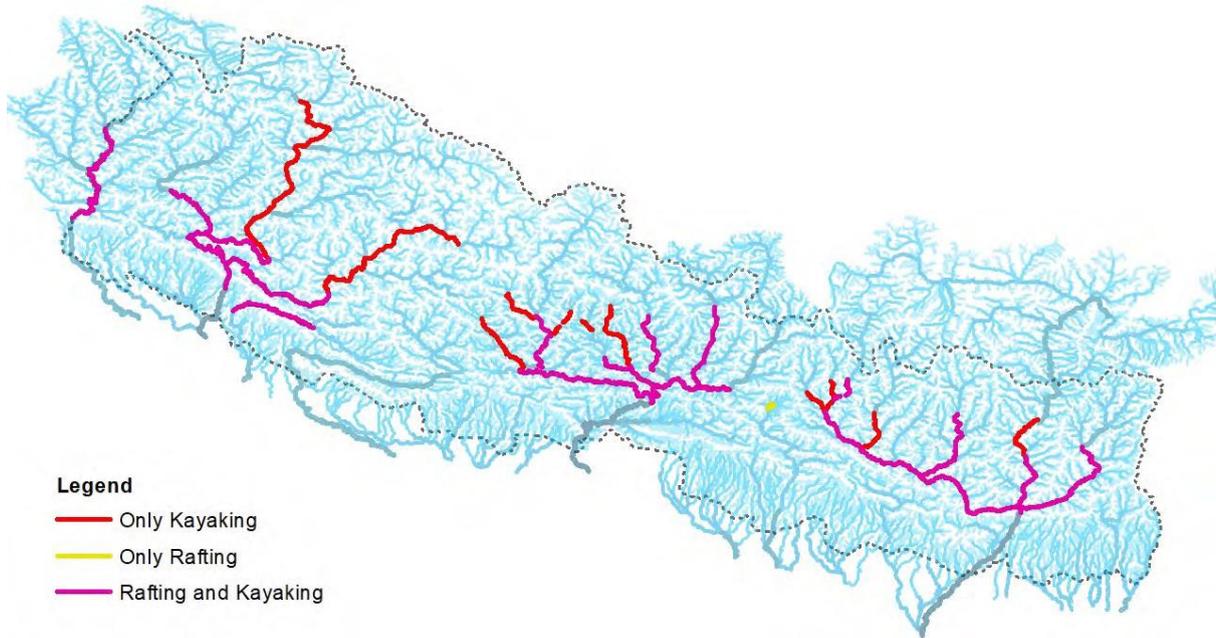


Figure 50: Rivers that are important for kayaking and rafting in Nepal.

7.2.2.3 TREKKING

Many upland river reaches of the Himalayas and Midlands have been identified as important river reaches for trekking (

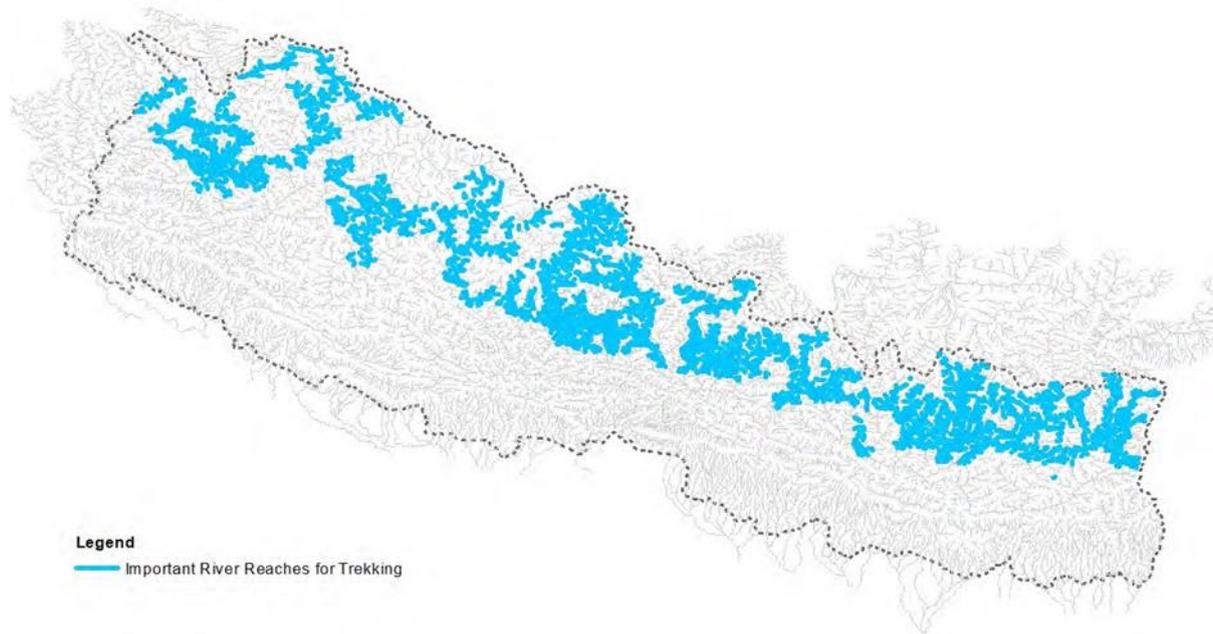


Figure 51). These regions include Everest, Annapurna, Langtang and Kanchenjunga. These regions include Everest, Annapurna, Langtang and Kanchenjunga.

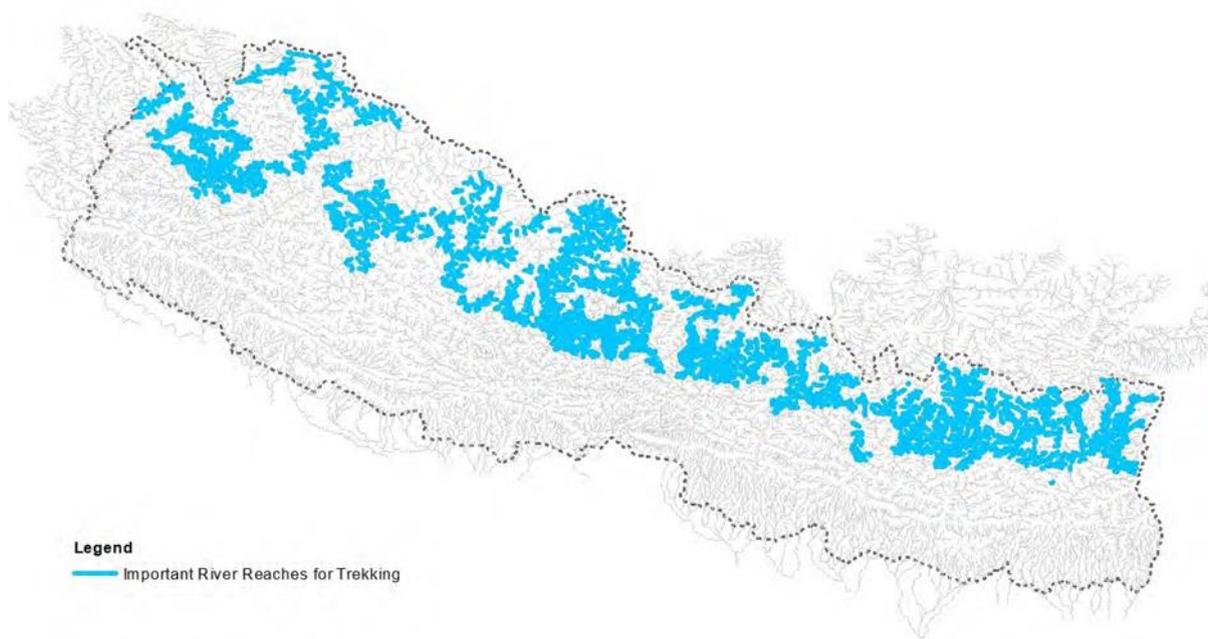


Figure 51: River reaches that are important for trekking.

7.2.2.4 PROTECTED AREAS

There are 20 protected areas in Nepal including 12 National Parks and one Wildlife Reserve, which also have buffer zones, 6 Conservation Areas, and one Hunting Reserve and 10 Ramsar Sites conserving a vast assemblage of wild fauna, flora, and other important natural resources of the country (Figure 52). 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.

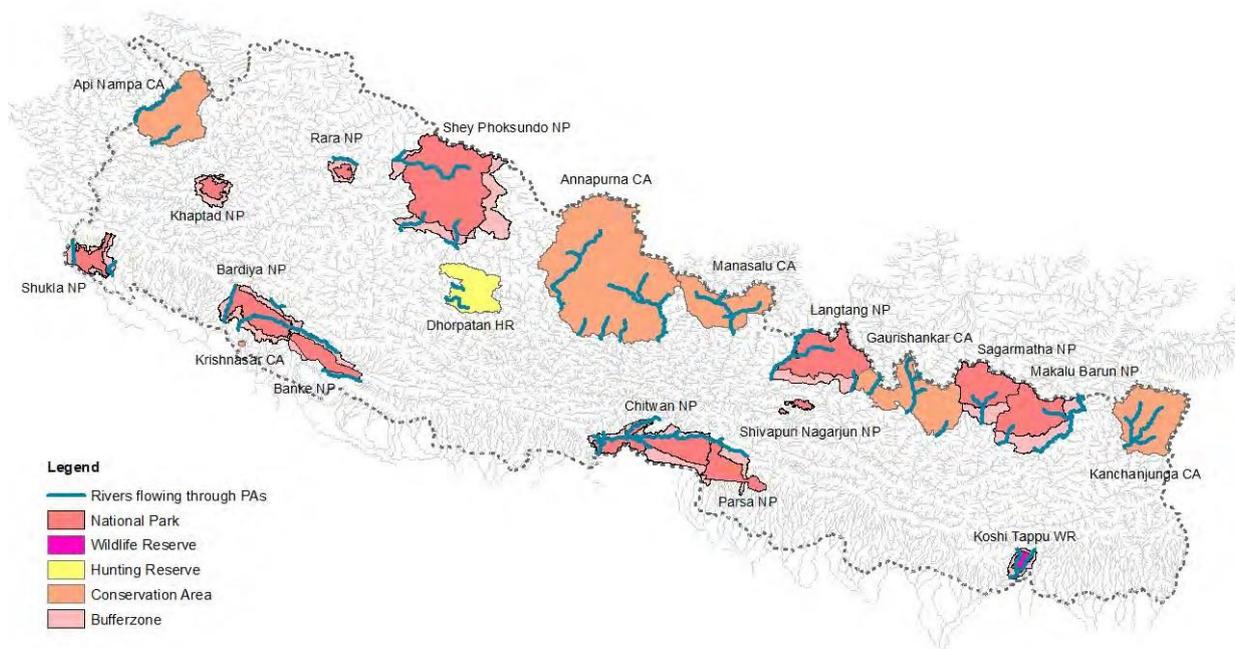


Figure 52: Protected areas in Nepal.

7.2.3 LIVELIHOOD VALUES

Livelihood values combine two other values: food and commercial value of fisheries and water provision value.

In terms of livelihoods, small rivers or stream are highlighted equally or more than large rivers (Figure 53). Rivers ranked with high livelihood values include Madi Khola, Banganga, Sarada, Panar, Jhimruk Khola, Mai Khola, Ratamata Khola, Trijuga, and Kamala rivers.

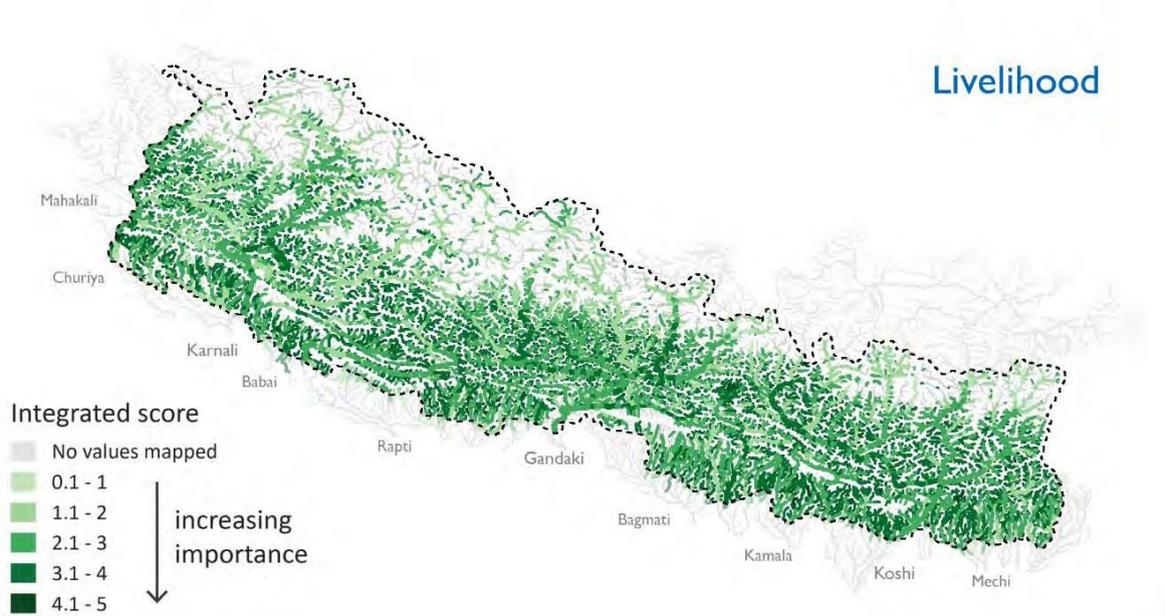


Figure 53: Livelihood values overlay map.

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 of different communities including the Newar community. Coldwater fish are considered tastier than other fishes. *Schizothorax*, *Schizothoracichthys*, *Clupisoma*, *Barilius*, *Tor* and *Neolissocheilus* are considered exceptionally good quality food. *Schizothorax* sps. (Asala) and *Raimas bola* (Jalkapoor) are considered to be highly delicious fish. Up to 220 fish species are used as a source of food in Nepal. Most of the fishes are eaten and consumed fresh.

Small fishes provide food, nutrition and supplemental income to many 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 fishing communities, small fishes have occupied an important position as a popular food item and source of protein. They are eaten whole; with head, viscera and bones and are particularly rich in bioavailable calcium, vitamin A, iron and zinc (Thilsted, 1997).

Out of the 256 fish species (240 indigenous species and 16 exotic species) found in Nepal, 166 species are small indigenous species (SIS). The lowland Terai area harbors a large number of SIS, and ethnic communities living there are dependent fully or partially on capturing SIS that are living at the fringe of rivers using traditional fishing gears. Among SIS, mola carplet (*Amblypharyngodon mola*), Indian carplet (*Amblypharyngodon microlepis*), large razorbelly minnow (*Salmostoma bacaila*), Gangetic leaf-fish (*Nandus nandus*), climbing perch (*Anabas testudineus*), flying barb (*Esomus danrica*), olive barb (*Puntius sarana*), two-spot barb (*Puntius ticto*), swamp barb (*Puntius chola*), pool barb (*Puntius sophore*), tank goby (*Glossogobius giuris*), and *Danio devario* are cultivable and are in high demand, and can be introduced as a candidate species in freshwater aquaculture. Bullseye snakehead (*Channa marulius*), striped snakehead (*Channa striatus*), green snakehead (*Channa punctatus*), dwarf snakehead (*Channa gachua*), and *Channa stewartii* are being cultured at minimum scale, mostly from wild seed collection.

One hundred and sixty six species have been identified as having food (i.e., for domestic consumption in the home by those who caught the fish) or commercial value (i.e., sold in market) in Nepal including fish having SIS value. Among others, the Lower Karnali, Narayani, East Rapti, Kaligandaki and Sunkoshi rivers are highlighted as they have 106 – 129 fishes having high commercial or food value.

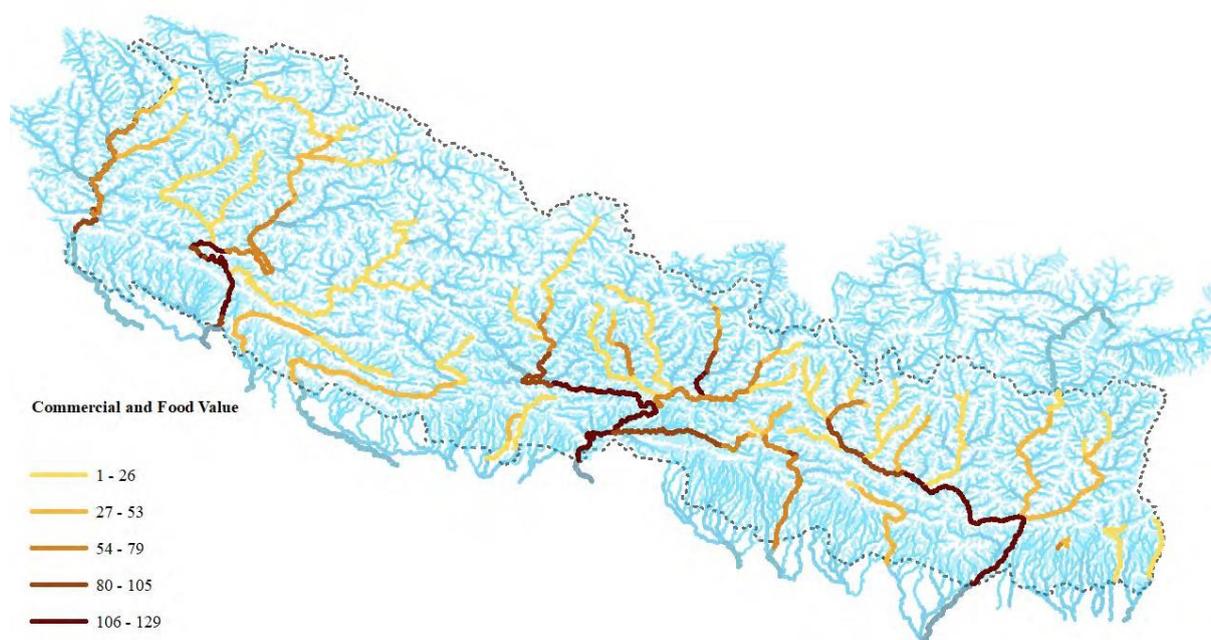


Figure 54: Number of fish species providing food or commercial value.

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 55). Our methodology was based on the relationship between capacity and demand of the 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 the Karnali, Gandaki, and Koshi provide large amounts of water, even during the dry season, to relatively small local populations, rendering these rivers as relatively low value. On the other end of the spectrum, we can see smaller rivers that provide a relatively small amount of river flow to a large number of people, for example in the Kathmandu Valley, or near other larger cities, thus providing high value in terms of water provision. Many small and medium sized rivers of the Terai region also show increased values for water provision, due to their relatively low flow and high local demand.

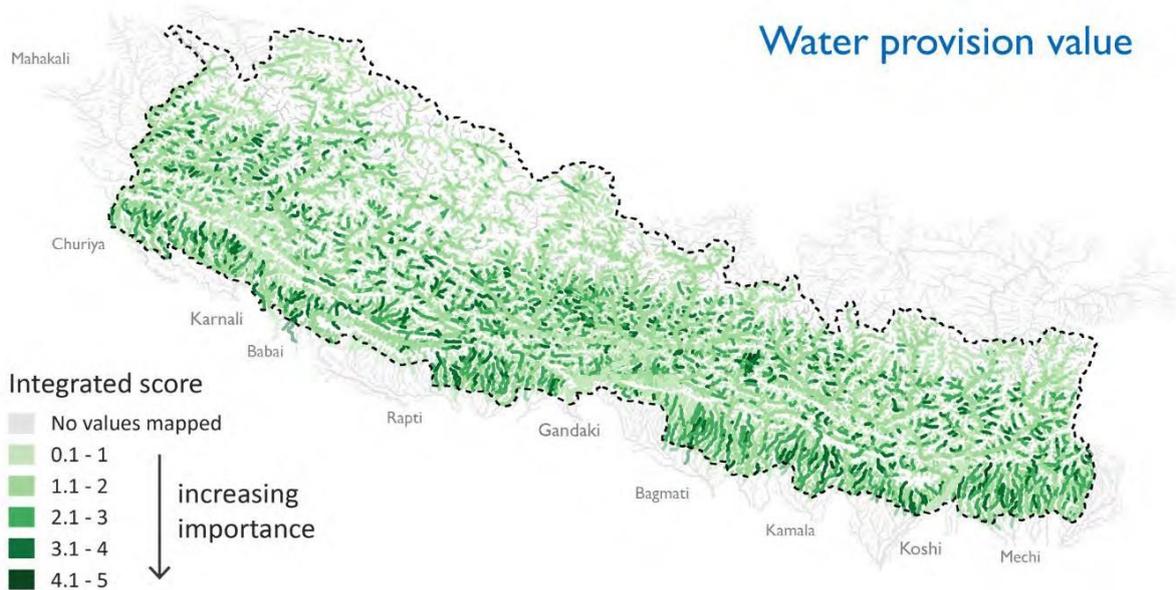


Figure 55: Water provision values.

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. The value mapped was “religious landmarks in proximity to rivers” (Figure 56). These include the Bakaiya, Kamala, Panar, Madi Khola, Banganga, Ratmata Khola, and Tila rivers.

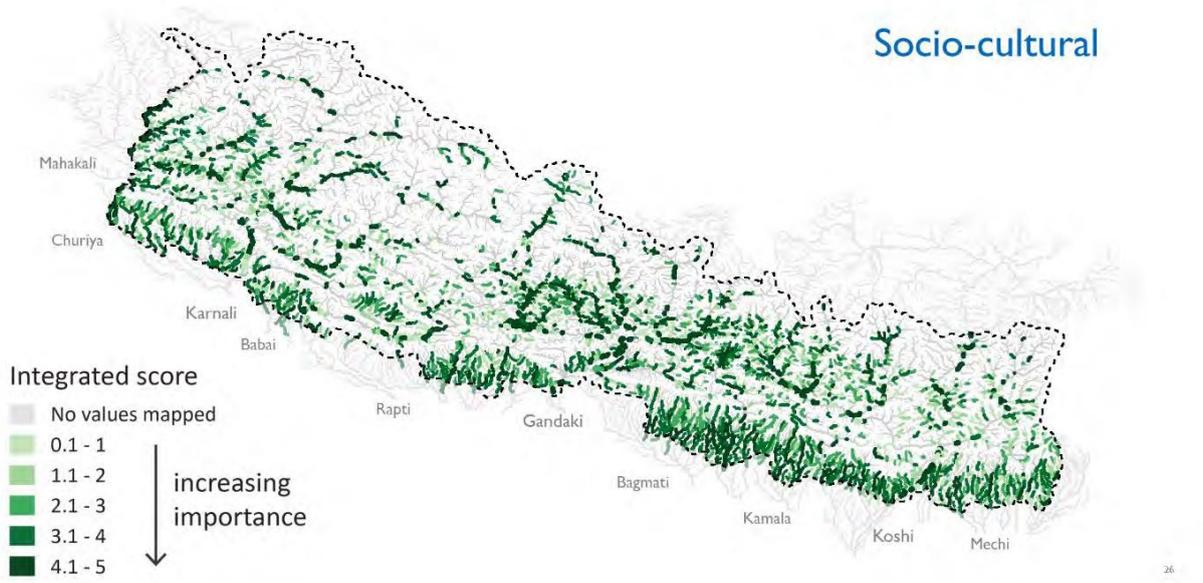


Figure 56: Socio-cultural values mapping based on religious sites in proximity to rivers.

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 Figure 14. The overall results for integrated HCV values are shown in Figure 57.

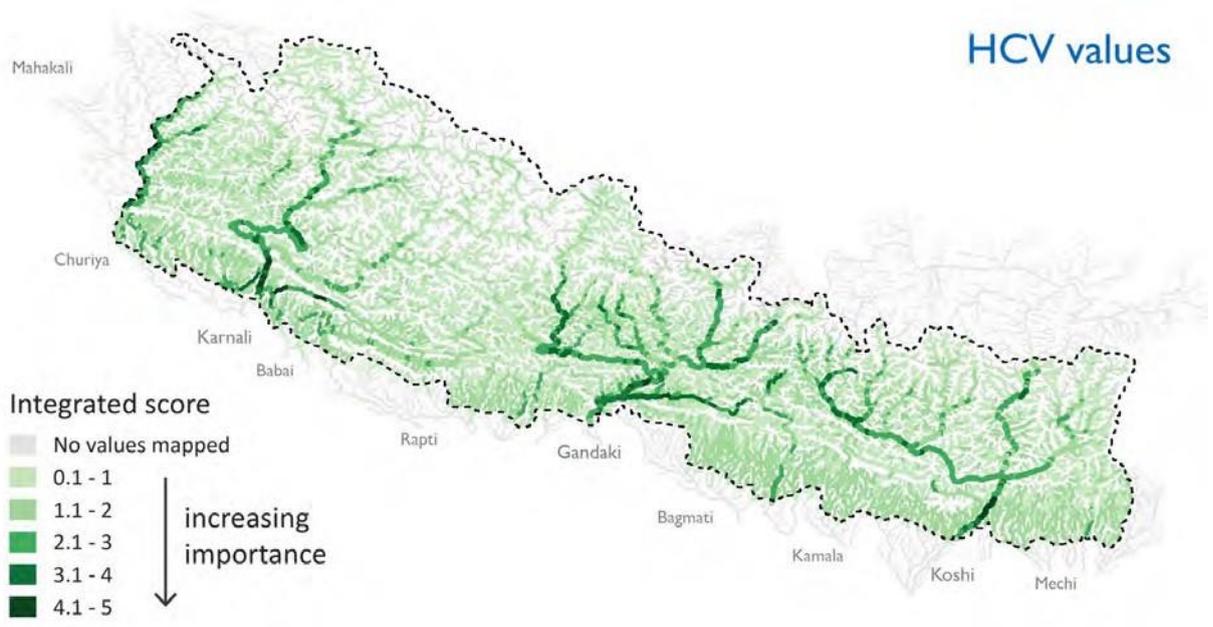


Figure 57: HCV integrated values.

The map reflects the weighted combination of all twenty freshwater value layers. A typical shortcoming of weighted averages is that the importance of the individual components is somewhat masked 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 58.

We can see that mainstem rivers are mainly dominated by biodiversity values, however some stretches,

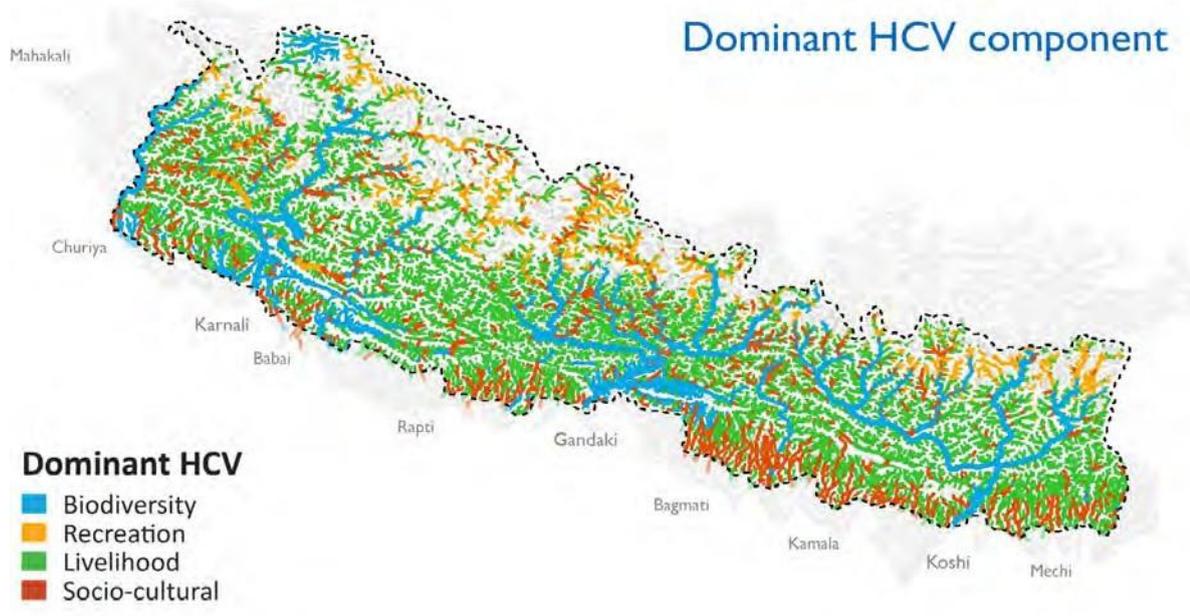


Figure 58: Dominant HCV component.

such as on the Bheri 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 Mid Hills 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 Himalayan region are driven by recreational values, specifically trekking and protected area tourism along larger rivers in protected areas.

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 59, we see that the resulting patterns generally align with the results in Figure 57, 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 scaled the resulting values from 0 to 5.

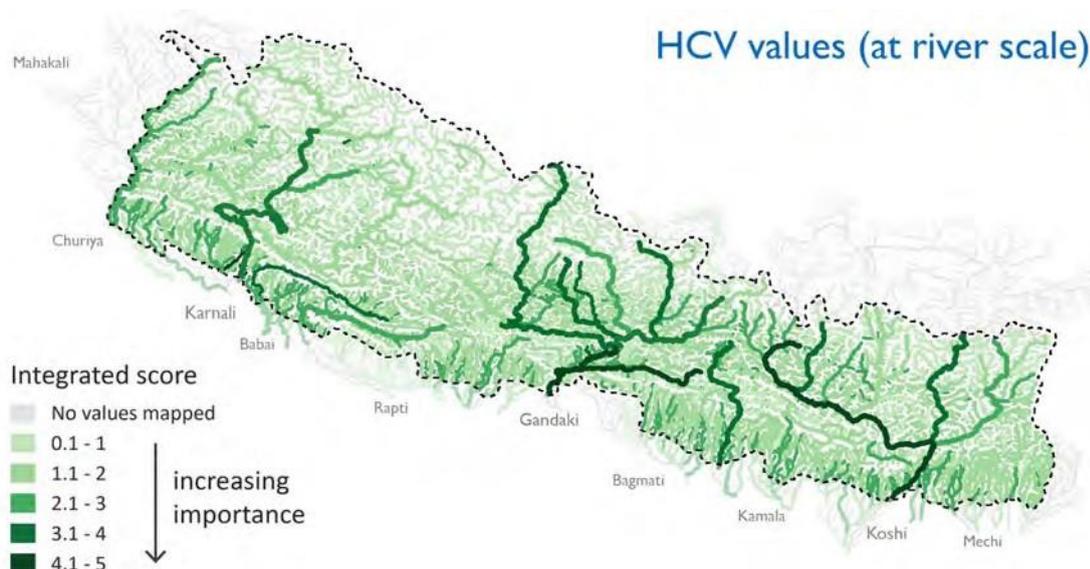


Figure 59: Integrated HCV value at the river scale.

A ranked list of rivers is shown in Table 15. It provides the river identifier for establishing a linkage to the GIS database, the river name, as well as its total length in kilometers. Note that a portion of the mainstem Karnali river – the Humla Karnali river, starting in the North-west close to the Chinese border and ending at the confluence with the Mugu 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 58) 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 Narayani (4.8), Saptakoshi (4.7), Sunkoshi (4.1), Trishuli (3.8), Karnali (3.7), Babai (3.6), and Seti (3.4) 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 15: Overview of ranked rivers. The red to blue colors represent Low and High values, respectively, for each of the four main categories. Similarly, and in accordance with the color scheme used in the HCV maps, the intensity of the green color shade represents low to high HCV values, with rivers sorted from high to low HCVR value.

RIVER ID	RIVER NAME	LENGTH (KM)	BIODIVERSITY	RECREATION	LIVELIHOOD	SOCIO-CULTURAL	HCVR VALUE
2085978	East Rapti Nadi	138	61.1	10.9	17.6	10.4	5
2085860	Narayani (Sapta Gandaki)	108	66.6	11.4	15.6	6.4	4.8
2085807	Saptakoshi Nadi	77	58.6	9.3	17.4	14.8	4.7
2085791	Sunkoshi Nadi	263	56.3	13.2	22.2	8.3	4.1
2085921	Karnali Nadi	334	56.3	13.6	21.5	8.5	3.9
2085762	Trishuli Nadi	156	45.6	14.1	21.7	18.5	3.8
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
2085801	Seti Nadi	132	49	13.6	18.5	18.9	3.4
2085882	Madi Nadi	75	40	18.7	21.7	19.6	3.4
2086047	Arun Nadi	158	46.3	21.5	21.3	10.9	3.3
2085930	Kali Gandaki Nadi	365	42.7	17.1	22.7	17.4	3.2
2085784	Tamakoshi Nadi	86	46.9	12.8	17.3	22.9	3.2
2086016	Budi Gandaki Nadi	126	48.7	17.3	23.3	10.7	3.1
2085881	Mahakali Nadi	262	51.4	13.9	21.4	13.4	3
2086008	Chameliya Nadi	83	47.7	11.5	22.9	17.9	2.7
2085781	Tamur Nadi	175	49	18.3	25.4	7.4	2.6
2085771	Tila Nadi	64	37.4	2.5	26	34.2	2.6
2085875	Marsyangdi Nadi	156	28.1	26.4	19	26.5	2.4
2085825	West Rapti Nadi	182	37.8	13	31	18.2	2.2
2085927	Kandra Nadi	61	50.8	0	28.5	20.7	2.2
2085980	Dudhkoshi Nadi	140	33	24.9	24.6	17.5	2
2086017	Budhi Ganga Nadi	90	41	10.5	26.1	22.4	2
2085891	Likhu Khola	80	46.4	16.9	28	8.7	2
2085866	Mugu Karnali Nadi	75	50.2	11	29.9	8.9	2
2085764	Trijuga Nadi	64	37.4	1.3	42.9	18.5	2
2086024	Bheri Nadi	311	31.1	27.3	22.7	19	1.9
2085868	Mohana Nadi	85	32.9	0	33.9	33.2	1.9
2085953	Humla Karnali Nadi	139	40.3	21.5	26	12.1	1.7
2085806	Sarada Nadi	95	37.3	0	37.7	25	1.7

RIVER ID	RIVER NAME	LENGTH (KM)	BIODIVERSITY	RECREATION	LIVELIHOOD	SOCIO-CULTURAL	HCVR VALUE
2085945	Jhimruk Khola	84	35.6	12.6	45.9	5.9	1.7
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
2085929	Kamala Nadi	127	21.5	0	43.5	35	1.6
2086029	Banganga River	86	6.3	0	45.8	47.9	1.6
2085847	Panar	67	0	0	55.3	44.7	1.5
2085758	West Seti Nadi	210	24.2	25.8	27.8	22.2	1.4
2085974	Ganga Nadi	63	33.4	17.6	42.4	6.6	1.4
2086033	Bakaiya Nadi	92	0	0	39	61	1.3
2085877	Mai Khola	77	25.9	0	50.5	23.6	1.2
2086056	Thuli Bheri Nadi	62	0	40.3	39.3	20.4	1.1
2040810	Madi Khola	96	0	10.4	56.7	32.9	1
2085966	Ghunse Khola	61	11	53.8	24.1	11.1	1
2085876	Marin Khola	64	0	0	64.8	35.2	0.9
2085988	Daraudi Khola	61	0	29.9	57.9	12.3	0.8
2086028	Barun Khola	65	0	43.8	30.5	25.7	0.7

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 6.3.7 in more detail.

The map in Figure 60 shows the distribution and extent of the HCVR types throughout Nepal and Table 16 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 I and can be described as both free-flowing and with potentially high water quality (Table 16). The Karnali river basin stands out as the basin with the highest number of HCVR type I rivers, followed by the Gandaki, Koshi and Mahakali, and the West Rapti river basins, which all show more HCVR type I rivers than other types. Smaller basins, such as the Bagmati, Babai, Kanakai, and Mechi river basins, show only 40%, 34%, 23%, and 4% respectively 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 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 I require protection, whereas the other types require management or restoration measures (see section 6.3.7).

HCVR typology

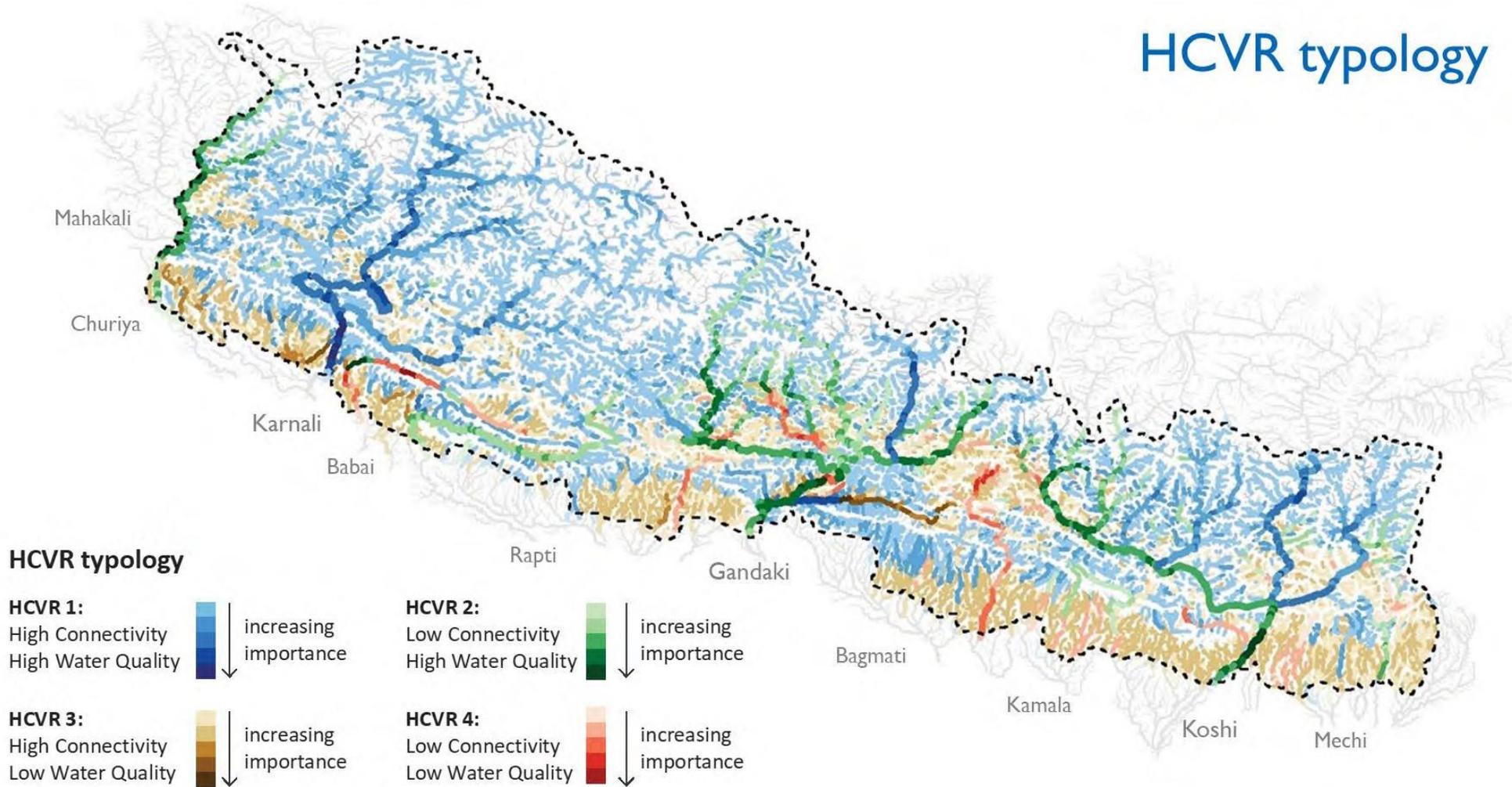


Figure 60: High Conservation River Typology. The increasing color saturation within each of the HCVR types indicate increasing HCV value scores.

Table 16: Overview statistics of the HCVR analysis. The table shows a) percentage of river kilometers and b) total 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. Twenty-nine river types occur within Nepal including large, glacier- and snow-influenced Himalayan rivers to small, rain- influenced Terai rivers (*Figure 61*).

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 ≥ 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.

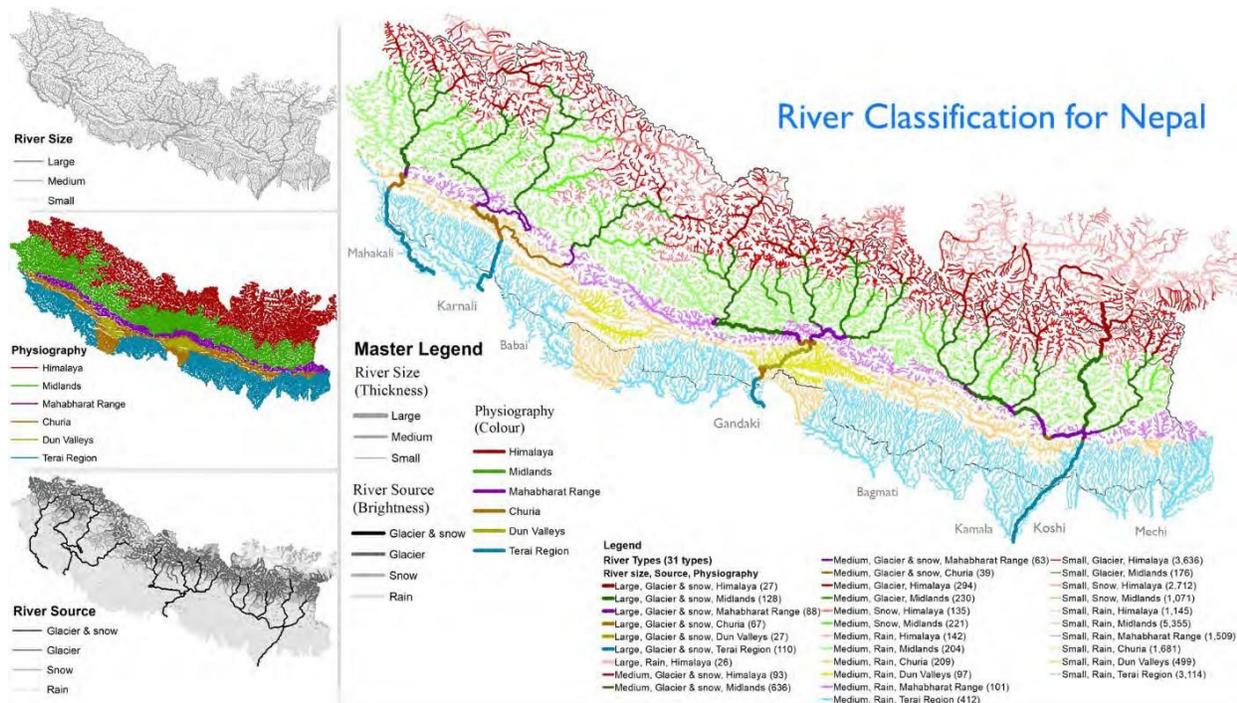


Figure 6 I: Final River Classification for Nepal. The left side shows the three different components that were combined to create the final river types classes (right). List of identified river classes (bottom).

Table 17: Representation of River Types in HCV Value Categories. Number of river reaches mapped to each river type and HCV value category. The colors provide a visual clue to distinguish small (red) to large (green) numbers.

SN	NUMBER OF RIVER REACHES	HCV VALUE CATEGORIES (HCV VALUE RANGE)					TOTAL	
		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

SN	NUMBER OF RIVER REACHES RIVER TYPES	HCV VALUE CATEGORIES (HCV VALUE RANGE)						TOTAL
		NO VALUE MAPPED (0)	VERY LOW (<1)	LOW (1-2)	MEDIUM (2-3)	HIGH (3-4)	VERY HIGH (4-5)	
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 the SDGs, goal 6 is focused on water “to ensure availability and sustainable management of water and sanitation for all” and SDG 6.6 is 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 river connectivity, 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. The Nepalese government is preparing legal instruments to use the power provided in the Constitution.

8.1 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 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. Below please find several recommendations for possible policy applications:

- 1) 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 provides 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.** 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. In addition, this work can support the

preparation of the National Integrated River Basin Strategy and Action Plan, and associated River Conservation Bills and Aquatic Biodiversity Conservation Bills.

- 2) Identification of HCVR is an important tool to 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 understanding of where opportunities for mitigation of development impacts could be located. Avoidance, minimization, restoration and offsetting (protecting a river of similar socio-cultural-ecological value to the one that is being degraded) are options to mitigate the potential negative impacts of hydropower on river biodiversity and other values. **The results provide a quantitative assessment of rivers to avoid and rivers to protect or restore.** For example, the high values of the main channel of the Karnali and its tributaries make it inadvisable to develop the large-scale projects proposed for this basin. If these projects are developed, the impacts on the river ecosystem and its conservation values would be significant. The Karnali is one of the last long 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*). Other basins that stand out as ones with high numbers of HCVR type I rivers, are the Gandaki, Koshi and Mahakali, and the West Rapti river basins.
- 3) This assessment can especially contribute to 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). WECS is an apex body of Government of Nepal whose mandate is to formulate plans and policies related to water and energy resources sector.

8.2 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 for 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.

9. REFERENCES

- Acharya, K. P., Khadka, B. K., Jnawali, S. R., Malla, S., Bhattarai, S., Wikramanayake, E., & Köhl, M., 2017. Conservation and Population Recovery of Gharials (*Gavialis gangeticus*) in Nepal. *Herpetologica*. <https://doi.org/10.1655/HERPETOLOGICA-D-16-00048.1>
- ADB, 2018. Impact of Dams on Fish in the Rivers of Nepal. Asian Development Bank (ADB). Bennett, K., Weinhold, M., Reeves, G., Eldred, P., Sharma, S., 2016. Natural Resource Baseline Assessment. USAID/Nepal and USDA Forest Service International Programs.
- Boavida, I., 2015. Barbel habitat alterations due to hydropeaking. *Journal of Hydro-Environment Research* 9, 237–247. <https://doi.org/10.1016/j.jher.2014.07.009>
- Brussock, P.P., Brown, A.V., Dixon, J.C., 1985. CHANNEL FORM AND STREAM ECOSYSTEM MODELS I. *JAWRA Journal of the American Water Resources Association* 21, 859– 866.
- Conway, K. W and R. L. Mayden. 2008. Description of two new species of *Psilorhynchus* (Ostariophysi: Psilorhynchidae) and redescription of *P. balitora*. *Ichthyological Exploration of Freshwaters*, 19(3): 215-232.
- Conway, K. W and R. L. Mayden. 2010. *Balitora eddisi* a new species of hill-stream loach (Ostariophysi: Balitoridae) from Nepal *Journal of fish biology*. B: 1466-1473.
- Conway, K.W., D. R. Edds, J. Shrestha and R. L. Mayden. 2011. A new species of Gravel dwelling Loach, *Turcinoemacheilus Himalaya* (Ostariophysi, Nemacheilidae) from the Nepalese Himalayan Foothills, *Journal of Fish Biology*.
- Dahal, R.K., Hasegawa, S., 2008. Representative rainfall thresholds for landslides in the Nepal Himalaya. *Geomorphology* 100, 429–443.
- Department of National Parks and Wildlife Conservation and Bird Conservation Nepal (2018). *Birds of Nepal: An Official Checklist*, Kathmandu, Nepal.
- Dhakal, M., Thapa, M., Jnawali, S., Subedi, N., Pradhan, N., Malla, S., Lamichhane, B., Pokheral, C., Thapa, G., Oglethorpe, J., Subba, S., Bajracharya, P., Yadav, H., 2014. Status of Tigers and Prey in Nepal. <https://doi.org/10.13140/2.1.3290.2407>
- Dimmick, W. W. and Edds, D.R. 2002. Evolutionary genetics of the endemic Schizorathicine (Cypriniformes: Cyprinidae) fishes of Lake Rara, Nepal. *Biochemical Systematics Ecology*. 30 (10): 919-929.
- DNPWC and DFSC, 2018. National Tiger Survey, 2018. Government of Nepal. Kathmandu, Nepal.
- DNPWC, 2015. National Rhino Count, 2015. Government of Nepal. Kathmandu, Nepal.
- DNPWC, 2018. Crocodile Survey, 2016. Government of Nepal. Kathmandu, Nepal.

- DNPWC, 2018. Gharial Conservation Action Plan for Nepal (2018-2022). Government of Nepal, Kathmandu, Nepal.
- DoED. Existing Hydro Power Plants. 2020. Government of Nepal, Kathmandu, Nepal. <https://www.doed.gov.np/>.
- Döll, P., Kaspar, F., Lehner, B., 2003. A global hydrological model for deriving water availability indicators: model tuning and validation. *J. Hydrol.* 270, 105–134. [https://doi.org/Pii S0022-1694\(02\)00283-4](https://doi.org/Pii S0022-1694(02)00283-4) Doi 10.1016/S0022-1694(02)00283-4
- EDC. 2016. Inventory of Rivers of Nepal, Energy Development Council, Kathmandu, Nepal.
- Esch, T., Taubenböck, H., Roth, A., Heldens, W., Felber, A., Schmidt, M., Mueller, A.A., Thiel, M., Dech, S.W., 2012. TanDEM-X mission-new perspectives for the inventory and monitoring of global settlement patterns. *JARS* 6, 061702. <https://doi.org/10.1117/1.JRS.6.061702>
- FAO, 2003. Review of World Water Resources by Country. FAO.
- Felts, R. A., Fajts, F. and Akteruzzaman, M. 1996. Small Indigenous Fish Species culture in Bangladesh (Technical brief), IFADEP Sub Project 2, Development of Inland Fisheries, p. 41.
- Frissell, C.A., Liss, W.J., Warren, C.E., Hurley, M.D., 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. *Environmental management* 10, 199–214.
- GoN, 1992. Water Resources Act 2049. Kathmandu, Nepal.
- GoN, 1998. Drinking Water Regulation 2055. Kathmandu, Nepal.
- GON, 2014. Nepal National Biodiversity Strategy and Action Plan 2014-2020. Ministry of Forests and Soil Conservation (MoFSC), Government of Nepal.
- GoN, 2015. The Constitution of Nepal 2015. Nepal Gazette.
- GoN, Survey Department, 2001. Topographic Mapping of Nepal (1992-2001). Kathmandu, Nepal.
- GoN., 2015. Nature Conservation National Strategic Framework for Sustainable Development (2015-2030). Kathmandu, Nepal.
- Great Himalaya Trail. Great Himalayan Trail Map. 2018.
- Grill, G., Lehner, B., Thieme, M., Geenen, B., Tickner, D., Antonelli, F., Babu, S., Borrelli, P., Cheng, L., Crochetiere, H., Ehalt Macedo, H., Filgueiras, R., Goichot, M., Higgins, J., Hogan, Z., Lip, B., McClain, M., Meng, J., Mulligan, M., Nilsson, C., Olden, J.D., Opperman, J., Petry, P., Reidy Liermann, C., Saenz, L., Salinas-Rodríguez, S., Schelle, P., Schmitt, R.J.P., Snider, J., Tan, F., Tockner, K., Valdujo, P.H., van Soesbergen, A., Zarfl, C., 2019. Mapping the world's free-flowing rivers. *Nature* 569, 215. <https://doi.org/10/c5k8>
- Grimmett, R., Inskipp, C. and Inskipp, T., 2000. Birds of Nepal. Christopher Helm, London.
- Gubhaju, S.R. 2011. Impact of Damming on the Environment of flow and persistence of native fishes.

- Proceedings of the consultative workshop on Fish Conservation in Nepal. NARC, pp. 13-34
- Gubhaju, S.R., 2002. Impact of damming on the aquatic fauna in Nepalese rivers. FAO fisheries technical paper, (431), pp.129-145.
- HMGN. 2001. Hydropower Development Policy. His Majesty's Government of Nepal, Ministry of Water Resources, Kathmandu, Nepal.
- HMGN, 2003. National Wetland Policy. His Majesty's Government of Nepal, Environment Protection Council, Kathmandu, Nepal.
- HMGN. 1961. Aquatic Animal Protection Act 1961. His Majesty's Government of Nepal, Law Books. Management Committee, Kathmandu, Nepal.
- HMGN. 1982. Soil and Watershed Conservation Act. His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.
- HMGN. 1988. National Conservation Strategy: Building on Success. His Majesty's Government of Nepal, Ministry of Forests and Soil Conservation, Kathmandu, Nepal.
- HMGN. 1992. Electricity Act 1992. His Majesty's. Government of Nepal, Kathmandu, Nepal.
- HMGN. 1993. Nepal Environmental Policy and Action Plan. His Majesty's Government of Nepal, Environment Protection Council, Kathmandu, Nepal.
- HMGN. 1997. Protection of Environment Act 2053. His Majesty's Government of Nepal, Environment Protection Council, Kathmandu, Nepal.
- HMGN/ADB/FINNIDA, 1988. Master Plan for Forestry Sector Nepal (main report). His Majesty's Government of Nepal, Ministry of Forest and Soil Conservation.
- HMGN/MFSC. 2002. Nepal's Biodiversity Strategy. His Majesty's Government of Nepal, Ministry of Forest and Soil Conservation.
- Hossain, M.A., Afsana, K. and Shah, A.K.M A. 1999. Nutritional value of some small indigenous fish species (SIS) of Bangladesh. Bangladesh Journal of Fish. Resources, 3(1):77-85.
- ICIMOD, 2010a. Land cover of Nepal 2010.
- ICIMOD, 2010b. Glaciers of Nepal 2010.
- IUCN, 2015a. IUCN Threatened Species: Lutra Lutra.
- IUCN, 2015b. IUCN Threatened Species: Lutrogale perspillata.
- IUCN Nepal, 2017. Status, Distribution and Conservation Threats of Ganges River Dolphin in Nepal. International Union for Conservation of Nature and Natural Resources (IUCN), Kuponhole, Lalitpur.
- Knowles, P. and Allardice, D., 1992. White Water Nepal: A Rivers Guidebook for Rafting and Kayaking.

Rivers Publishing UK.

Knowles, P., Clarkson-King, D., 2011. *White Water Nepal: Third Edition*.

Knowles, P., Watt, A., Allardice, D., 1999. *White Water Nepal: A Rivers Guidebook for Kayakers and Rafters*. Rivers Publishing UK.

Lehner, B., Grill, G., 2013. Global river hydrography and network routing: baseline data and new approaches to study the world's large river systems. *Hydrol. Proces.* 27, 2171– 2186. <https://doi.org/10.1002/hyp.9740>

Lehner, B., Liermann, C.R., Revenga, C., Vorosmarty, C., Fekete, B., Crouzet, P., Doll, P., Endejan, M., Frenken, K., Magome, J., Nilsson, C., Robertson, J.C., Rodel, R., Sindorf, N., Wisser, D., 2011. High-resolution mapping of the world's reservoirs and dams for sustainable river-flow management. *Front. Ecol. Environ.* 9, 494–502. <https://doi.org/10.1890/100125>

Lehner, B., Verdin, K., Jarvis, A., 2008. New global hydrography derived from spaceborne elevation data. *EOS, Trans. Am. Geophys. Union* 89, 93. <https://doi.org/10.1029/2008eo100001>

Menon, A. G. K. 1999. Check List – Fresh Water Fishes of India. Record of Zoological Survey, India, Occasional Paper No. 175, pp. 1-366.

Messenger, M.L., Lehner, B., Grill, G., Nedeva, I., Schmitt, O., 2016. Estimating the volume and age of water stored in global lakes using a geo-statistical approach. *Nat Commun* 7, 13603. <https://doi.org/10.1038/ncomms13603>

Mishra, B.K., Regmi, R.K., Masago, Y., Fukushi, K., Kumar, P. and Saraswat, C., 2017. Assessment of Bagmati river pollution in Kathmandu Valley: Scenario-based modeling and analysis for sustainable urban development. *Sustainability of Water Quality and Ecology*, 9, pp.67-77.

MOFE, 2018. Nepal's Sixth National Report on Convention on Biological Diversity. Government of Nepal, Kathmandu, Nepal.

MoFE, 2018. NEPAL'S SIXTH NATIONAL REPORT TO THE CONVENTION ON BIOLOGICAL DIVERSITY. Ministry of Forests and Environment (MoFE), Government of Nepal, Singha Durbar, Kathmandu, Nepal.

MOFSC, 2003. Nepal Biodiversity Strategy. Government of Nepal, Kathmandu, Nepal.

MOFSC, 2012. National Wetland Policy. Government of Nepal, Kathmandu, Nepal.

MOFSC, 2014. Nepal National Biodiversity Strategy and Action Plan 2014-2020. Government of Nepal, Kathmandu, Nepal.

MOFSC, 2018. National Report on the Implementation of the Ramsar Convention on Wetlands. In National Reports to be Submitted to the 13th Meeting of the Conference of the Parties. Dubai, United Arab Emirates. Kathmandu, Nepal.

Moir, K., Thieme, M., Opperman, J.J., 2016. *Securing A Future that Flows: Case Studies of Protection Mechanisms for Rivers*. World Wildlife Fund and The Nature Conservancy, Washington, DC.

- Montgomery, D.R., Buffington, J.M., 1997. Channel-reach morphology in mountain drainage basins. *Geological Society of America Bulletin* 109, 596–611.
- Muhammad, S., Thapa, A., 2020. An improved Terra-Aqua MODIS snow cover and Randolph Glacier Inventory 6.0 combined product (MOYDGL06*) for high-mountain Asia between 2002 and 2018. *Earth System Science Data* 12, 345–356. <https://doi.org/10.5194/essd-12-345-2020>
- Mulligan, M., van Soesbergen, A., Sáenz, L., 2020. GOODD, a global dataset of more than 38,000 georeferenced dams. *Scientific Data* 7, 31. <https://doi.org/10.1038/s41597-020-0362-5>
- Ng, H. H. 2006. The identity of *Pseudecheneis sulcata* (McClelland, 1842), with description of two new species of rheophilic catfish (Teleostei: Sisoridae) from Nepal and China. *Zootaxa*, 1254: 45-68.
- Ng, H. H. and D. R. Edds .2004 *Batasio macronotus*, a new species of bagrid catfish from Nepal (Teleostei: Bagridae). *Ichthyological Exploration of Freshwaters*, 16(4): 295-300.
- Ng, H. H. and D. R. Edds. 2005. Two new species of *Erethistoides* (Teleostei: Erethistidae) from Nepal. *Ichthyological Exploration of Freshwaters*, 16(3): 239-248.
- Opperman, J., S. Orr, H. Baleta, M. Dailey, D. Garrick, M. Goichot, A. McCoy, A. Morgan, L. Turley and A. Vermeulen, 2018. *Valuing Rivers: How the Diverse Benefits of Healthy Rivers Underpin Economies*. WWF.
- OSM, 2020. OpenStreetMap data. Retrieved from <https://www.openstreetmap.org/>.
- Ouellet Dallaire, C., Lehner, B., Sayre, R., Thieme, M., 2019. A multidisciplinary framework to derive global river reach classifications at high spatial resolution. *Environmental Research Letters* 14(2): 024003. [doi: 10.1088/1748-9326/aad8e9](https://doi.org/10.1088/1748-9326/aad8e9)
- Poudyal, L., Yadav, B., Ranabhat, R., Maharjan, S., Malla, S., Lamichhane, B., Subba, S., Koirala, S., Shrestha, S., Gurung, A., Paudel, U., Bhatt, T., Giri, S., 2018. STATUS OF TIGERS AND PREY IN NEPAL 2018.
- Rajbanshi, K. G. 2012. Biodiversity and Distribution of freshwater Fishes of Central Nepal / Nepal Himalayan region. Nepal Fisheries Society / Nepal academy of Science and Technology, Kumaltar.
- Rayamajhi, A, and Arunachalam, M. 2017a. A new Species of *Garra* (Cyprinide: Cypriniformes) from Western Nepal. *International Journal of Fisheries and Aquatic Studies*, 5(5):402- 407.
- Rayamajhi, A, and Arunachalam, M. 2017b. A New Record of the *Pseudolaguvia nubile* (Siluriformes: Erethistidae) from Baandhkhola (stream) in Central Nepal. *International Journal of Applied Science and Biotechnology*, 5(4):434-441.
- Rayamajhi, A, and Arunachalam, M. and Usharamalakshmi, A. 2016. *Pseudolaguvia nepalensis*, a new catfish (Teleostei: Siluriformes: Erethistidae) from Central Nepal. *International Journal of Pure and Applied Zoology*, 4(1):446-56.
- Regmi, R.K. and Mishra, B.K., 2016. *Current Water Quality Status of Rivers in the Kathmandu Valley*.

- Rosgen, D.L., 1994. A classification of natural rivers. *Catena* 22, 169–199.
- Schneider, A., Friedl, M.A., Potere, D., 2009. A new map of global urban extent from MODIS satellite data. *Environ. Res. Lett.* 4, 044003. <https://doi.org/Artn 044003> 10.1088/1748- 9326/4/4/044003
- Sharma, C.M. & J. Shrestha. 2001. Fish Diversity and Fishery Resources of The Tinau River, Western Nepal. Proceedings of an International Conference on Environment and Agriculture: Biodiversity, Agriculture and Pollution in South Asia, Ecological Society (ECOS), Kathmandu, Nepal: 78-83
- Sharma, C.M. & Jha, B.R 2012. Spatial and Temporal distribution of Fish assemblages in Indrawati Sub Basin (A report). WWF Kathmandu, Nepal
- Shrestha, J. 1995. Enumeration of the Fishes of Nepal. Bio-diversity Profile Project, Technical Publications No. 10, Euroconsult, Arnhem of the Netherlands, Department of National Parks and Wildlife Conservation, HMG of Nepal, Kathmandu, Nepal, 150.
- Shrestha, J. 2011. Threats status of indigenous fish species of Nepal. Proceedings of the consultative workshop on Fish Conservation in Nepal. NARC, pp. 13-34.
- Shrestha, Mandira, Deep Narayan Shah, Bandana Pradhan, and Ram Devi Tachamo. “Water Quality Mapping of the Bagmati River Basin, Kathmandu Valley, ASSESS-HKH: Proceedings of the Scientific Conference ‘Rivers in the Hindu Kush-Himalaya - Ecology & Environmental Assessment,’” no. January (2008): 202.
- Shrestha, T. K. 2019. Ichthyology of Nepal: A Study of Fishes of the Himalayan Waters. B.J. Shrestha Publisher, Kathmandu, Nepal.
- Shrestha, T.K. 1990. Rare Fishes of the Himalayan water of Nepal. *Journal of Fish Biology*, 37:213- 216.
- Shrestha, T.K., 2008. Ichthyology of Nepal. Himalayan Ecosphere, Kathmandu, Nepal.
- Strahler, A.N., 1964. Part II. Quantitative geomorphology of drainage basins and channel networks. *Handbook of Applied Hydrology*. McGraw-Hill, New York 4–39.
- Terashima, A. 1984. Three New Species of the Cyprinid Genus *Schizothorax* from Lake Rara, North-Western, Nepal. *Japanese Journal of Ichthyology*, 31(2): 122-135.
- Thieme, M., 2019. High Conservation Value Rivers: Definitions & Cases. WWF US, Washington, D.C.
- Thilsted, S. H., Roos, N. and Hossain, N. 1997. The role of small indigenous fish species in food and nutrition security in Bangladesh. *NAGA, The ICLARM Quarterly*, July-December 1997, pp. 13-15.
- Thorp, J.H., Flotemersch, J.E., Delong, M.D., Casper, A.F., Thoms, M.C., Ballantyne, F., Williams, B.S., O’Neill, B.J., Haase, C.S., 2010. Linking ecosystem services, rehabilitation, and river hydrogeomorphology. *BioScience* 60, 67–74.
- Tractebel, 2020. Nepal River Basin Masterplan.

- USAID Paani Program and WWF- Nepal, 2020. Data for fish species, otters, wetland birds, commercial and food value of fisheries, water provision, and water quality. Kathmandu, Nepal.
- Vogl, A.L., R.J.P Schmitt, R.D. Simpson, B.P. Bryant, S. Wolny, and U. Narain. “Valuing Green Infrastructure: Volume I: Case Study of Kali Gandaki Watershed, Nepal.” Washington, DC.: The World Bank, 2019.
- WECS, 1993. Water Resource Regulation 2050. Government of Nepal, Kathmandu, Nepal.
- WECS, 2002. Water Resources Strategy. Government of Nepal, Kathmandu, Nepal.
- WECS, 2005. National Water Plan. Government of Nepal, Kathmandu, Nepal.
- WECS, 2011. Water Resources of Nepal in the context of climate change.
- WWF, 2005. An Overview of Glaciers, Glacier Retreat and its Subsequent Impacts in Nepal, India and China. WWF Nepal Program.
- Zhao, Y., Ding, A., 2016. A decision classifier to classify rivers for river management based on their structure in China: an example from the Yongding river. *Water Science and Technology* 74, 1539–1552.

10. ANNEXES

10. I 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)

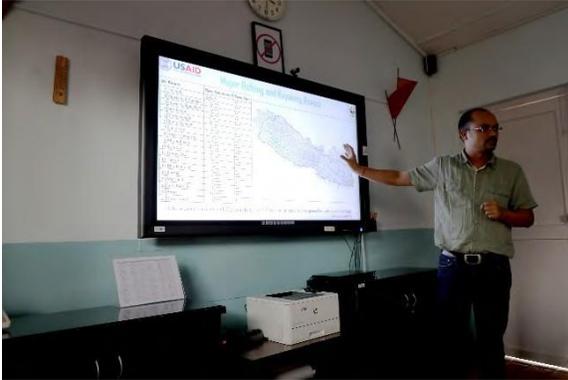


Photos from workshops in Kathmandu, Surkhet, and held virtually

10.1.2 ADVISORY GROUP MEETINGS

NUMBER	DATE	VENUE	NO. OF PARTICIPANTS
1 st	27 th Sept 2019	WWF Nepal	19
2 nd	6 th Nov 2019	WWF Nepal	19
3 rd	6 th Dec 2019	Paani Office	15
4 th	11 th Feb 2020	Paani Office and Zoom	20
5 th	27 th May 2020	Zoom	31
6 th	7 th Oct 2020	Zoom	38





Photos from Advisory Group meetings held throughout the project.

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 (<i>Platanista gangetica</i>)
Justification	Gangetic River Dolphin is the only recorded cetacean species in Nepal and is a legally protected species. The River Dolphin is freshwater indicator species because it plays an important role in the food chain. Though it is regarded as an endangered flagship species, its habitat is highly degraded and destroyed by human interference thereby shrinking its distribution range and reducing 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 lower water levels, 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	Gharial (<i>Gavialis gangeticus</i>)
Justification	<p>Gharial is a critically endangered species and considered as habitat specialists 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.</p> <p>According to the last census, 198 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.</p>
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 (<i>Tor spp.</i>)
Justification	<p>Mahseer are called tigers of the river, mahseer was included in the flagship category given that they are emblematic species that are popular with anglers. 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 and it is an important food fish harvested for 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.</p>
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	Greater one-horned rhinoceros (<i>Rhinoceros unicornis</i>)
Justification	<p>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.</p>
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 (<i>Panthera tigris</i>)
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 (<i>Lutrogale perspicillata</i> (extant), <i>Lutra lutra</i> and <i>Aonyx cinerea</i> (historical, possible occurrence)
Justification	Representing one of the top predators in the food chain of freshwater ecosystems, otters are often regarded as indicator species for intact healthy wildlife habitat. Poaching, hydropower and infrastructure development are considered as 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. 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	<p>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.</p> <p>Within the Karnali basin, the Seti, Upper Seti, and Bheri rivers are popular tributaries for kayaking and rafting. Hydropower development could threaten the success of these recreation opportunities. Downstream flow alteration from dams could also impact rafting by changing the white- water rapids and the overall experience on the river.</p>
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	<p>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 people love to bird watch and gorge walks and other recreational activities in these sites.</p>
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	<p>Maintaining the natural flow regime of rivers within protected areas is critical to ensure that the natural ecosystem function continues.</p> <p>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.</p>
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	<p>for much of the rural and fisher communities. Although riverine fisheries have various opportunities for development of fisheries and aquaculture, they are generally unrecognized and undervalued. The majority of fish species provide a source of food and many are of commercial value. 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 farmed fishes, the capture fisheries benefit directly by increasing income and improving nutritional status.</p> <p>Some riverine fishes are considered more delicious than cultured species and thus are in high demand with good market price. The species that have high livelihoods value must be protected from threats.</p>
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 was included under the livelihood category to represent importance of Nepalese rivers in terms of drinking water, indigenous irrigation, other household uses and the waste disposal services that they provide. Proportion of water available in rivers relative to population nearby has been mapped.
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 near 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, including allowing species movements upstream, downstream, and laterally, transport of sediments, support to tourism activities, and maintenance of the healthy functioning of 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 for drinking or other household uses. 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

VALUE CATEGORY	FRESHWATER STATUS
VALUE 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
Category	Ecosystem representation

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 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 given as: 1) Drinking water and

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

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.

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, 2015

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.

10.4 USAID PAANI PROGRAM/WWF STUDIES

System-scale Planning to Support Sustainable Energy Systems and Conservation of Freshwater Resources for People and Nature.

USAID Paani Program, WWF/Nepal, and WWF/US. 2020. *Energy Options Assessment (EOA)*.

USAID Paani Program, WWF/Nepal, and WWF/US. 2020. *High Conservation Value River (HCVR) Assessment – Methodology and Results*.

USAID Paani Program, WWF/Nepal, and WWF/US. 2020. *Sediment Transport in the Rivers of Nepal*.

USAID Paani Program, WWF/Nepal, and WWF/US. 2020. *System-scale Planning to Support Sustainable Energy Systems and Conservation of Freshwater Resources for People and Nature – Executive Summary*.

USAID Paani Program, WWF/Nepal, and WWF/US. 2020. *System-scale Planning to Support Sustainable Energy Systems and Conservation of Freshwater Resources for People and Nature – Policy Briefs*.

USAID Paani Program, WWF/Nepal, and WWF/US. 2020. *System Scale Planning (SSP) Methodology*.