IMPACT OF DAMS ON FISH IN THE RIVERS OF NEPAL

DECEMBER 2018

ASIAN DEVELOPMENT BANK

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In this publication, $ refers to United States dollars.

On the cover: Golden Mahseer (*Tor putitora*) in Babai River, Western Nepal (photo by Arun Rana).

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Foreword

After the successful political transition toward federalization and a stable elected government, Nepal is now aiming to expedite the pace of its economic growth to achieve prosperity. As a biodiversity hotspot, the country seeks rapid economic growth, but maintaining a balance between development activities and conservation has become a daunting challenge. Bestowed with a significant and diverse ecological system, an amazing conglomeration of biodiversity, and a huge potential of fresh water, the country is nurtured by a vast reservoir of untapped natural resources.

By virtue of being the second richest country in the world in water resources, export-oriented hydropower generation and food security through irrigated agriculture are two important catalysts that can steer Nepal toward prosperity. The country has initiated planning and construction of hydropower projects that aim to generate 5,000 megawatts of electricity within the next 5 years. Major irrigation systems with inter-basin water transfer are being implemented to improve commercial agriculture. The majority of these projects need dams or barrages across rivers for water diversion. Dams are important to harness water's potential to support economic growth but also pose environmental concerns, such as damage to aquatic habitats and blockage to the movement of endemic and migratory fish in river basins.

The water bodies of Nepal represent unique riverine ecosystems that are highly rich in fish fauna. All rivers of Nepal drain to the Ganges in India, hence they are interconnected. Many short- and long-distance migratory fish species travel along these river basins during their life cycle. Some of them are believed to spawn in the Bay of Bengal and travel all the way back to the Ganges and reach the rivers of Nepal to complete their reproductive cycle. However, their movement is becoming seriously affected by the increasing number of dams along their migratory routes. Dams block fish movement and create reservoirs in a free-flowing river, which deteriorate water quality, alter the existing ecosystem, and damage spawning grounds of native fish species. Early findings of this study suggest that the fish population in Nepalese river basins with dams are in sharp decline.

The impact on aquatic biodiversity generally goes unnoticed when sufficient legal provisions and a dedicated government agency to enforce them are lacking. Gaps in research on fish in river basins of the country and limitations to mapping their routes have made it difficult for decision-makers to locate dams at suitable places to avoid blockage of fish movement in interconnected river basins.

In this context, the Asian Development Bank (ADB) conducted a study to assess the impact of projects involving the construction of dams on aquatic biodiversity. The findings may not be authoritative due to limitations in the duration and depth of research. But the study concluded that projects involving the construction of dams affected fish populations and the diversity of species due to alterations in the ecosystem and blockage in life-cycle movements.

I thank Mr. Deepak Bahadur Singh, Senior Environment Officer, Nepal Resident Mission, ADB, and Dr. Deep Bahadur Swar, Consultant Fisheries Expert, ADB, and his team for initiating this study and recommending measures to conserve the aquatic biodiversity in the rivers of Nepal. I wish the recommendations in the study—including the use of an "Aquatic Biodiversity Screening Framework" and the concept of institutional arrangements and regional cooperation—will receive the due attention of policy makers, development partners, and project developers to collectively protect the unique and rich aquatic biodiversity of Nepal while pursuing their development endeavors.

Mukhtor Khamudkhanov
Country Director
Nepal Resident Mission

Abbreviations

ADB	–	Asian Development Bank
BANCA	–	Biodiversity and Nature Conservation Association
CBS	–	Central Bureau of Statistics
EIA	–	environmental impact assessment
EMP	–	environmental management plan
FAO	–	Food and Agriculture Organization of the United Nations
FRISP	–	Forest Resource Information System Project
ICIMOD	–	International Centre for Integrated Mountain Development
IUCN	–	International Union for Conservation of Nature
KGHP	–	Kali Gandaki A Hydropower Project
MMHEP	–	Middle Marshyangdi Hydropower Project
NABSC	–	National Aquatic Biodiversity Subcommittee
NRs	–	Nepalese rupees
SEA	–	strategic environmental assessment
UNEP	–	United Nations Environment Programme
US	–	United States
WCD	–	World Commission on Dams

Weights and Measures

ha	–	hectare
km	–	kilometer
km^2	–	square kilometer
kW	–	kilowatt
m	–	meter
mg/l	–	milligram per liter
mm	–	millimeter
m^3/s	–	cubic meter per second
MW	–	megawatt

Executive Summary

Multiple dams have been constructed in the rivers of Nepal for diverting water for power generation and irrigation. The rate of damming rivers is expected to increase rapidly in the future to generate more hydropower and construct major irrigation systems. The rivers flowing through the varied ecological realms of the country host many indigenous rare and endangered fish species and other aquatic organisms, creating unique river ecosystems. However, the aquatic fauna's migratory behavior, routes, and range of movement for feeding and reproduction are neither properly studied nor understood. In the absence of this information, it is difficult to identify locations for dams on the rivers without significantly obstructing the animals' migratory route. The past and ongoing damming of rivers have had huge environmental costs with serious and irreversible impacts, including the rapid decline in the population of many fish species.

The Asian Development Bank conducted a rapid study and assessed the potential impacts of damming of rivers in Nepal on fish biodiversity (hereinafter referred to as "the study"). It assessed the operation of selected hydropower and irrigation systems with dams to divert water. The systems included the Kali Gandaki, Marshyangdi, Middle Marshyangdi, Kulekhani, Khimti, and Trishuli hydropower projects, and the Babai irrigation project. The study also reviewed international good practices, particularly in South Asia, on mitigating the impacts on fish while constructing projects with dams on rivers. The study reviewed the result of mitigation and compensatory measures for the protection of fish that were adopted in past projects and the recommended measures that proved to be successful. A fish biodiversity screening checklist was prepared to screen future development projects for impacts on fish biodiversity and to design appropriate mitigation measures, depending on the significance of the impact. The study also aimed to prepare a basis for future research on fish biodiversity in the rivers of Nepal to better understand the impacts and formulate appropriate mitigation measures.

Fisheries in Nepal are significant sources of food, nutrition, and recreation; this is a traditional way of sustaining life and livelihood. Recreational angling is rapidly picking up, with the presence of highly sought-after game fish species like the *Tor putitora* (Golden Mahseer) and *Bagarius yarrelli* (Goonch). A healthy fish habitat is vital to maintaining balance in the ecosystem and food chain and generating economic and social benefits from fisheries. This requires a comprehensive approach for fisheries management, including conservation of existing fish habitats, restoration, and sustainable commercial use.

Fish habitats can be damaged in obvious and subtle ways and by big or small changes. For example, a fish habitat can be damaged by a large hydropower project or a poorly installed culvert that blocks the migratory route of endangered and vulnerable fish species. Among the most common threats to fish habitats are those associated with damming of rivers for water diversion, which usually produce dry river stretches downstream from the dam, destroying the riverine ecosystem. Population depletion of fish species is not solely caused by dams, and many abiotic and biotic factors play a role. Increase of silt and contaminants in the water, formation of a reservoir on a free-flowing river, removal of sand or gravel from river beds, and industrial and municipal waste discharge are some of the other causes of destruction of fish habitats.

The study recorded 223 dams at different phases of development at different locations in the rivers of Nepal. A comparative study of environmental impacts and effectiveness of mitigation measures in 13 dam projects was carried out. The results showed that all the dammed rivers are inhabited by *Tor putitora, Bagarius* sp., *Clupisoma garua*, and *Anguilla bengalensis*, as well as other fish that are important long-distance migratory species. Of these four species, *Tor putitora* and *Bagarius* sp. are listed under the International Union for Conservation of Nature (IUCN) Red List as "endangered" and "near threatened," respectively. Similarly, several short-distance species such as *Schizothorax richardsonii, Puntius chelynoides, Tor tor*, and *Neolissochilus hexagonolepis* were also recorded in most of the rivers. *Schizothorax richardsonii* is "vulnerable" per the IUCN Red List and *Neolissochilus hexagonolepis* is "near threatened."

The study preliminarily mapped the route of short- and long-distance migratory fish in rivers interlinked among river basins and found that the locations of dams were not selected with reference to the cumulative impact on the migratory routes of the fish.

The study also referred to regional experience with the impacts of dams on fish population and successful mitigation measures adopted in the Southeast Asia and South Asia regions. Based on lessons learned, the study proposes (i) various mitigation measures that projects can take to facilitate fish movement across dams, or (ii) compensatory measures to maintain fish populations. Some of these include providing a fish ladder, fish passage, natural fish bypass channel, catch and haul system, fish lock, fish lift, and breeding fish in hatcheries and annually releasing them upstream and downstream of the dam to maintain their populations.

The study recognized the need to update Nepal's existing Aquatic Animal Protection Policy and Act and make cumulative impact assessment a mandatory requirement during environmental impact assessment. It recommends reconsidering the government's waiver of environmental impact assessment requirements for hydropower projects with up to 50 megawatt capacity. Strategic environmental assessments should also be carried out for important national policies, plans, and programs, including hydropower and irrigation policies and master plans, in order to look at rivers in an integrated basinwide context with interlinked fish movement paths. This information will help select the appropriate location of dams with the least impact on biodiversity. The study also recommends establishing a National Aquatic Biodiversity Subcommittee under the framework of the National Biodiversity Conservation Committee to gain collective support of stakeholders, support the government in policy making, and conduct independent monitoring and enforcement of compliance in projects under construction and operation. An effective regional cooperation mechanism between Bangladesh, India, and Nepal needs to be established to collectively conserve the valuable and threatened aquatic fauna by ensuring the animals' transboundary movements for feeding and reproduction. A few tributaries in each major river basin could also be declared aquatic life protection areas (i.e., fisheries national park). A strong local-level mechanism—for monitoring and controlling illegal and destructive fishing and damaging of fish habitat or spawning grounds by mining or industrial discharges—could be established by the government by mobilizing communities, enhancing their awareness, and motivating them through compensatory incentives to protect aquatic life.

The study recommends a follow-up comprehensive study of aquatic biodiversity to establish a national database on ecosystem-based topics, including connectivity, hydrology, and geomorphology; and to develop measures to strike a balance between development projects and conservation. The outcome of the proposed study would serve as an important tool for decision makers when choosing the location and type of dam in future projects.

1 Introduction

A. The Study

1. This report presents the findings of a study conducted by the Asian Development Bank (ADB) on the impacts of dams on fish in the rivers of Nepal. The study assesses the impacts of dams on fish biodiversity and population after barricading natural water flow and diverting water for energy generation or irrigation.

2. There are 118 identified ecosystems in Nepal, including 112 forest ecosystems, 4 cultivation ecosystems, 1 water body ecosystem, and 1 glacier or rock ecosystem. These ecosystems range from the tall grasslands, marshlands, and tropical and subtropical broadleaf forests along the Terai and Siwalik Hills to the subtropical and tropical broadleaf and conifer forests in the Middle Mountains. Furthermore, there are mixed conifer forests in the High Mountains and alpine meadows above the tree line. Among the rangeland ecosystems, the tropical savannas and alpine meadows are exceptionally rich in biodiversity. Nepalese wetlands have high ecological value, as they provide habitat for many threatened and endemic species of flora and fauna, and serve as resting places for many migratory and globally threatened birds. The wetlands have high cultural and economic significance. Nepal also has a high degree of agroecological diversity.[1]

3. More than 6,000 rivers drain the country. The three major river basins of Nepal—Koshi, Gandaki, and Karnali—host about 230 species of freshwater fish and scores of zooplankton and phytoplankton, forming a rich and unique aquatic ecosystem. The river source (snow melt, spring, or rain-fed), topography (mountains, hills, and Terai plains), and associated change in climate (alpine tundra in mountains to warm and tropical climate in Terai) create great variation in river characteristics such as velocity, morphology, and temperature, which provide habitats for a variety of fish species unique to those particular ecosystems. The barrier effect of dams restricts seasonal fish migration to the upper reaches for spawning and feeding and returning back downstream. It is widely observed that the barrier effect is responsible for the sharp decline in the fish population in rivers with dams. The situation is of serious concern as there are proposals for every river in Nepal to develop hydropower plants in series through damming. However, in the absence of baseline information on the interlinked migratory route of fish in the rivers, the cumulative impact of unplanned damming on the vulnerable aquatic ecosystem goes unnoticed. A strategic environmental assessment of the hydropower and irrigation development policy and master plan in order to analyze the cumulative impact of damming of the rivers on the aquatic environment, including migratory fish species, has not been conducted.

4. Nepal has a technoeconomic potential of generating 42,000 megawatt (MW) of hydropower.[2] The current peak energy demand of the country is 1,300 MW, of which only 786 MW installed capacity is under operation, and

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[1] Government of Nepal, Ministry of Forests and Soil Conservation. 2014. *Nepal Fifth National Report to Convention on Biological Diversity*. Kathmandu.

[2] Government of Nepal, Ministry of Water Resources. 2001. *The Hydro Power Development Policy, 2001*. Kathmandu.

51 hydropower projects totaling 910.311 MW are under various stages of development.[3] Construction of hydropower plants for generating energy to meet domestic and export demands has been a top priority of the government and its development partners. Large-scale irrigation systems are also under construction, and many more are planned for future implementation to improve irrigated agriculture to enhance productivity, increase farmers' income, secure food sufficiency, and attract farmers toward commercial agriculture. The Irrigation Policy, 2013 of the Government of Nepal aimed to enhance irrigated agriculture in water-deficient areas by developing major-scale interbasin water transfer schemes or reservoir-type schemes. However, with the lack of credible baseline information on basinwide river ecology, dam locations for hydropower and irrigation systems are being selected ad hoc. Nevertheless, being a party to the Convention on Biological Diversity, Nepal has obligations to conserve and sustainably utilize the country's unique biodiversity for the benefit of present and future generations. Development partners of the Government of Nepal, including ADB, provide support in constructing bigger hydropower plants and irrigation infrastructure to utilize the water resources potential of the country. However, due to the lack of baseline information on aquatic biodiversity in different river basins, there is a serious constraint in the ability to adequately evaluate the impact of such dams on aquatic resources and develop mitigation and compensation measures. Hence, ADB initiated a rapid study to assess the retrospective impacts of dams on the fish population in the rivers of the country and identify possible measures to mitigate such impacts in future. Findings are expected to assist in developing a strategy for conservation and sustainable use of aquatic biodiversity while implementing development projects.

B. Aquatic Biodiversity

5. Aquatic biodiversity is defined as the variability among living organisms from all sources, including marine and freshwater ecosystems, and the ecological complexes of which they are part. This includes diversity within species, between species, and of ecosystems.

6. Biodiversity is often described in hierarchical terms such as ecosystem diversity, species diversity, and genetic diversity. Ecosystem diversity refers to the variety of habitats, the dynamic complexes of plant, animal, and microorganism communities; and their nonliving environment, which interact as a functional unit and change over time. Species diversity refers to the frequency and variety of species within a geographical area. Genetic diversity refers to the genetic differences between populations of a single species and between individuals within a single population.

C. Importance of Aquatic Biodiversity

7. Aquatic biodiversity is important for human beings in several ways:

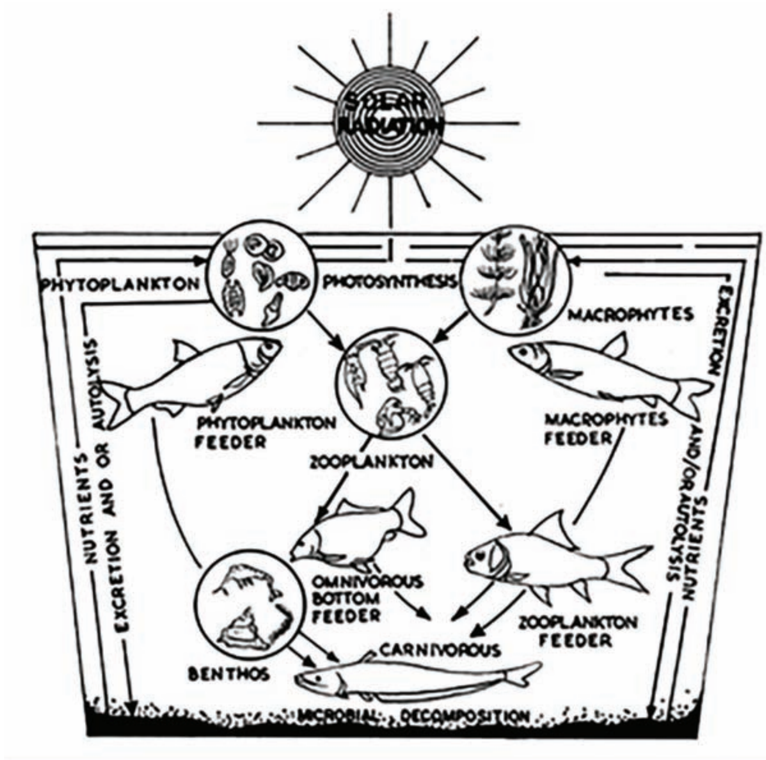
(i) Species have utilitarian (subsistence and commercial) value to humans. Diversity of aquatic flora and fauna is a crucial component in the livelihood of millions of people who depend on these organisms to meet their nutritional and economic needs.

(ii) Biodiversity represents the natural balance within the ecosystem. Detoxification and decomposition of waste by biological communities and generation or renewal of soil fertility, including nutrient cycles, are just a few examples of ecological services associated with aquatic biodiversity (Figure 1).

(iii) Species have intrinsic value. Human beings have an ethical responsibility to save them from extinction.

[3] Nepal Electricity Authority. 2017. *Nepal Electricity Authority Annual Report, 2017*. Nepal.

Figure 1: Food Chain Web in a Freshwater Ecosystem



Source: Texas Education Agency, Austin, Texas, United States. https://www.texasgateway.org/resource/food-chains-food-webs-and-energy-pyramids.

8. Aquatic fauna (particularly fish and crustaceans) play an important role in providing people with food and income. Fish are an important natural asset. Aquatic resources support subsistence fishing, and generate income through ecotourism, sport fishing and small-scale aquaculture. In Nepal, fish provide sport, food, and income for rural communities. There are reportedly 462,000 active fishers in Nepal.[4] The rich diversity of plants and animals in wetlands provides a wide range of goods and services as well as income-generating opportunities for local people, including ethnic groups.[5]

[4] Government of Nepal, Directorate of Fisheries Development. 2014. *Annual Progress Report, 2013–2014*. Kathmandu.

[5] International Centre for Integrated Mountain Development (ICIMOD). 2004. Biodiversity and Livelihoods in the Hindu Kush Himalayan Region. *ICIMOD Newsletter. No. 45*. Kathmandu.

D. The Study Methodology

9. The scope of the study is to address the impact of dams on fish species and identify measures to mitigate and/or compensate for adverse impacts in future projects. The analysis and findings of the study are primarily based on stocktaking of the current situation through the review of government policies, study of available literature, and analysis of secondary data available from different government and nongovernment agencies. Primary data were collected through consultation with national and international institutional and subject specialists, stakeholders, and communities, and through field observations. Data and information related to the project were also collected from the internet. Both quantitative and qualitative methods were used in data analysis. The main tasks involved in the process were the following (Annex 1):

- assessment of river basins in relation to integrated movement routes during the life cycle of different fish species;
- assessment of the trends of changes in fish populations and species in the rivers after construction of dams;
- review and analysis of the existing mechanism for management of aquatic biodiversity and identification of key achievements, gaps, constraints, issues, and challenges in various projects;
- review and assessment of study on aquatic biodiversity and compliance to the proposed mitigation measures in various water resources projects, and identification of gaps and lessons learned;
- proposal of various measures to protect the existing rich aquatic biodiversity in the rivers of Nepal while developing water resource projects; and
- proposal of an “aquatic biodiversity screening framework” to examine the impact of projects on aquatic life, make necessary assessments, and design appropriate mitigation measures.

2 Country Background

10. Nepal, with an area of 147,181 square kilometers (km^2), is a predominantly mountainous and landlocked country bordered by the People's Republic of China to the north and India to the south, east, and west. The country stretches from east to west with an average length of 885 kilometers (km) and breadth of 193 km. Administratively, it is divided into 7 provinces and 77 districts, situated in 3 physiographic regions: (i) southern Terai plain in 20 districts, covering 23% of the area; (ii) middle hills in 39 districts, covering 41.8% of the area, and (iii) northern mountains in 16 districts, covering 35.2% of the area of the country. In Nepal, 76% of the population is dependent on agriculture.

A. Geographic and Physiographic Details

11. Located along the southern slopes of the Central Himalayas, Nepal has five physiographic regions: Terai flatland in the south (below 500 meters [m]), Lower Hills (Chure or Siwalik, 500–1,000 m), Mid-Hills (1,000–3,000 m), High Mountains (3000–5,000 m), and High Himalayas (above 5,000 m) in the north. The lowest elevation is 60 m above mean sea level at Kechana Kalan in Jhapa district of eastern Terai, and the highest is the peak of Mount Everest at 8,848 m above mean sea level in the north. There is considerable heterogeneity within each physiographic region, particularly the valleys of the Siwaliks (Dun Valleys), tropical valleys and elevated plains of the Middle Mountains, subtropical valleys of the High Mountains, and the dry Trans-Himalayan area of the High Himalayan Region. The Terai includes the southern plain and foothills of the Siwaliks with hot tropical to subtropical climate. Mid-Hills have warm to cool temperate climate. High Mountains have cool temperate to subalpine climate. The High Himalayas have alpine to tundra-type climate.[6] Settlements are mostly in the tropical, subtropical, and temperate zones. People use the Trans-Himalayan and subalpine areas for grazing their livestock and collecting medicinal herbs.

12. The remarkable differences in climatic conditions are due to the rapid change of altitude within a short north–south average distance of 193 km. Nepal possesses eight ecological zones: (i) lower tropical, (ii) upper tropical, (iii) subtropical, (iv) temperate, (v) subalpine, (vi) alpine, (vii) Trans-Himalayan, and (viii) nival or arctic zone. The tropical and subtropical zones occupy 58%, temperate zone 12%, subalpine 9%, alpine 8%, Trans-Himalayan 8%, and nival 5% of the country's area (Figure 2).

13. The Trans-Himalayan zone lying north of the Himalayan range is a rain shadow area with arid and semi-arid valleys, low temperature stress with a mean annual temperature of 6.5°C, moisture-deficient annual precipitation of 157–339 m, and dry winds and high evaporation rate, causing the desertification process.[7] Settlements are located up to an altitude of 4,500 m. Natural vegetation such as Caragana-Lonicera, steppe spiny shrubs, and

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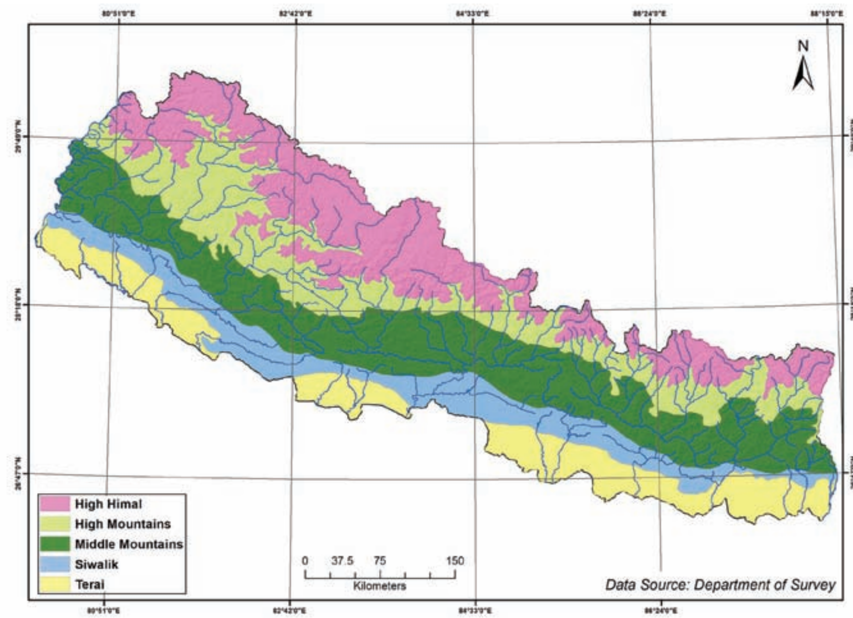
6 J.P.B. Lilleso et al. 2005. The Map of Potential Vegetation of Nepal. *Development and Environment*. Series No. 2. Denmark: University of Copenhagen. p. 76.

7 R. Nayaju and J.P.B. Lilleso. 2000. *Nation-wide Climatic Tables*. Database at HMG/Danida. Kathmandu.

Figure 2: Physiographic Zones of Nepal



Source: Government of Nepal, Ministry of Forests and Soil Conservation. 2014. *Nepal Biodiversity Strategy and Action Plan (2014-2020)*. Kathmandu.

scarce trees exists in the area. The scarcely available natural vegetation is heavily exploited for domestic use and grazing by mountain goats, accelerating the desertification process.

14. The climate is predominantly influenced by the altitudinal variations, monsoon, and westerly disturbances. It is characterized by four distinct seasons: pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November), and winter (December–February).[8] The country receives average annual rainfall of 1,600 millimeters (mm), which varies from 165 mm in the rain shadow areas in the north of the Himalayas (upper Mustang) to 5,500 mm in the Pokhara Valley. Almost 80% of the precipitation occurs during the months of June–September in the form of monsoon rain.[9]

15. River flow is governed by the monsoon season and dry season, which produce the highest and lowest flow conditions, respectively. River discharge is minimal during the dry season (November–April) with low suspended load and bed load. Suspended load and bed load are highest during the monsoon (June–September) when rainfall and snow melt in the mountains are high. The months of May and October are the typical transition months between these two seasons.

[8] Government of Nepal, Water and Energy Commission Secretariat. 2011. *Water Resources of Nepal in the Context of Climate Change*. Kathmandu.
[9] Practical Action. 2009. *Temporal and Spatial Variability of Climate Change over Nepal (1976–2005)*. Kathmandu.

B. Land Use and Water Coverage

16. The first detail mapping of Nepal's land resources and the second survey of forest resources[10] reveal the total land use of Nepal, which shows 382,700 hectares (ha)—2.6% of country area—being under water, mostly in the form of rivers and natural lakes (Table 1).[11]

Table 1: Changes in Nepal's Land Use between 1979 and 1994

Category	1978-79 (LRMP)		1994 (NFI)		% Change, 1979–1994	
	Area ('000 ha)	%	Area ('000 ha)	%	Total	Annual
Cultivated	269.40	20.13	3,090.80	21.00	4.09	0.30
Noncultivated	986.90	6.69	1,030.40	7.00	4.41	0.31
Forest	5,612.40	38.05	4,268.20	29.00	(23.95)	(1.60)
Shrub land	694.00	4.71	1,560.10	10.60	124.80	8.40
Grass land	1,755.90	11.91	1,766.20	12.00	0.59	0.00
Water	NA	NA	382.70	2.60	NA	NA
Other	2,729.80	18.51	2,619.80	17.80	(4.03)	(0.30)
Total	14,748.40	100.00	14,718.20	100.00		

( ) = negative, ha = hectare, LRMP = Land Reform and Mapping Project, NA = not available, NFI = National Forest Inventory.

Source: Central Bureau of Statistics of Nepal.

C. Demography and Socioeconomy

17. Nepal had a population of 28.4 million as of June 2016.[12] The population grew at an average annual rate of 1.35% during 2001–2011. Socioculturally, the nation is multilingual, multireligious, multiethnic, and multicultural, comprising 125 castes and ethnic groups.[13] The *Third Nepal Living Standards Survey, 2010–2011* indicated a substantial decline in poverty and an improvement in income equality. The Global Hunger Index for Nepal decreased from 20.3 in 2012 to 17.3 in 2013, and by 38.2% in the last 2 decades.[14] Remittances play a crucial role in these developments. In 2010, 55.8% of households received remittances, with an average of NRs80,436 per household (foonote 14). Despite this, economic growth has remained slow (less than 4% after 2007), which declined to 3% in 2015 from 5.1% in 2014. The Human Development Index (0.463) and Gender Inequality Index (0.485) of the country were below the South Asian average in 2012.[15]

18. Nepal's economy is very much dependent on the use of natural resources, including lands, forests, and water. Agriculture (including forestry and fishery) remains the country's principal economic activity, employing 80% of the population and providing 35% of the gross domestic product. At the national level, 28% of all household income comes from agriculture, 37% from nonfarm enterprises, and 17% from remittance (footnote 15). About 116,000 fisher families are involved in fishing activities in Nepal.[16]

[10] Kenting Earth Sciences Limited, Government of Nepal, and Government of Canada. 1986. Land Utilization Report. *Land Resources Mapping Project.* Kathmandu: Government of Nepal.

[11] Department of Forest Research and Survey/Forest Resource Information System Project (FRISP). 1999. *Forest Resources of Nepal (1987–1998). No. 74*. Government of Nepal: Department of Forest Research and Survey and Government of Finland: FRISP. Government of Nepal, Nepal.

[12] Central Bureau of Statics of Nepal (CBS). http://www/cbs.gov.np/

[13] CBS. 2012. Environment Statistics of Nepal, 2011. Kathmandu. http://cbs.gov.np/wp-content/uploads/2012/03/environment_book_final.pdf (accessed on 25 August 2013).

[14] CBS. 2011. *Third Nepal Living Standards Survey, 2010–2011. Statistical Report (in two volumes)*. Kathmandu.

[15] United Nations Development Programme. 2013. *Human Development Report 2011*. New York.

[16] Footnote 4.

3 Water Resources

A. Water Bodies of Nepal

19. The water bodies of Nepal include rivers and streams, lakes, reservoirs, ponds, and swamps. On the basis of resource availability, rivers cover 94% of the total water area.

20. Water is one of the principal natural resources supporting the country's economy. About 30% of Nepal's agriculture production is based on irrigation. In the fiscal year 2015–2016, about 95% of Nepal's electricity came from hydroelectricity. There is a prospect of generating 42,000 MW of hydropower, although the country has installed capacity of only 786 MW as of March 2017. Most of the power plants are run-of-river type. While the increased number of hydropower plants and irrigation systems help reduce energy deficits and ensure food security, the cascade of dams on the same rivers is causing severe adverse impacts on the aquatic biodiversity, affecting the livelihoods of local communities that depend on them.

B. River Systems

21. There are about 6,000 rivers and rivulets in Nepal, with a total drainage area of about 194,471 km^2, accounting for 75% of the land. The country is drained by four major Himalayan river systems—the Koshi, Gandaki, Karnali, and Mahakali. The Karnali River has the largest catchment area (29.3% of the country), followed by the Gandaki (21.7%), and the Koshi (19%). The catchment of Mahakali River, which flows along the western Nepal–India border covers 3.2% of Nepal's area. The rest of the country is drained by a few medium-sized perennial rivers that rise in the Middle Mountains and Mahabharat Range (Table 2 and Figure 3). Such rivers are Mechi, Kankai, Kamala, Bagmati, Rapti, and Babai, which are fed by precipitation and groundwater. Their discharge is commonly characterized by wide seasonal fluctuation. Many small rivers originate from Siwalik Hills and are characterized with little flow during dry season and flash floods during monsoon. Most of the rivers traverse from north to south and ultimately join the Ganges, contributing about 41% of its annual flow and about 71% of its dry season flow.[17] These rivers are rich in fish, water fowls, and other aquatic lives.

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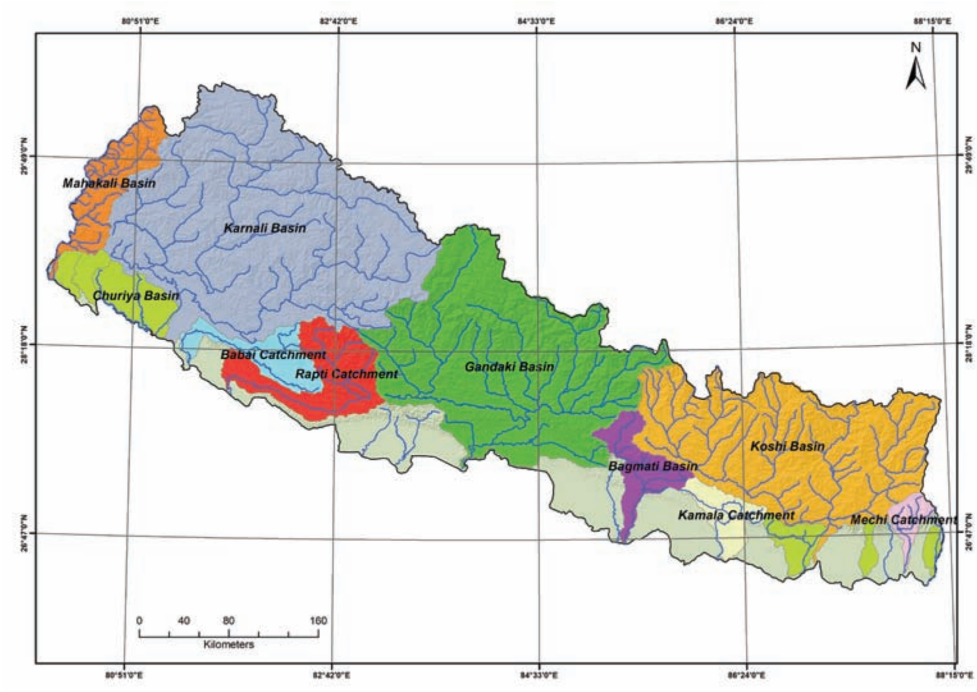
[17] B.M. Abbas. 1982. *The Ganges Water Dispute*. Dhaka, Bangladesh: The University Press Limited.

Figure 3: Main Rivers in Nepal and Their Catchments



Source: National Biodiversity Strategy and Action Plan, 2014–2020, Nepal. 2014.

Table 2: Main Rivers and Coverage by Their Catchments

Name	Catchment Area (%)	Major Tributaries and Key Characteristics
A. Large rivers		
Koshi	19.0	Koshi has seven tributaries—Indravati, Sunkoshi, Tamakoshi, Dudhkoshi, Likhu, Arun, and Tamor in eastern Nepal. Most of these rivers arise in the People's Republic of China.
Gandaki (Narayani)	21.7	Gandaki flows in central–western Nepal and has seven major tributaries—Daraudi, Seti, Madi, Kali Gandaki, Marshyangdi, Budhigandki, and Trishuli. East Rapti joins Gandaki in Chitwan Valley.
Karnali	29.3	Karnali drains western Nepal, with the Sano Bheri, Thulo Bheri, Tila, Mugu Karnali, Humla Karnali, Budhi Ganga, and West Seti rivers as its major tributaries.
Mahakali	3.2	Mahakali flows along the Nepal–India border on the west and joins the Karnali River in India. Chamelia River drains into the Mahakali River system.
B. Medium-sized rivers		
Kankai	0.9	Kankai is a rainfed perennial river of eastern Nepal, which originates in the Mahabharat range.
Bagmati	3.2	Drains the Kathmandu Valley between Koshi and Gandaki river systems.
West Rapti	4.2	West Rapti originates from the rugged highland of the western hills. Jhimruk and Mardi rivers join to form Rapti.
Babai	2.6	Babai River originates in and completely drains the Inner Terai (Dang Valley) of mid-western Nepal.
C. Siwalik streams	**15.9**	**Originates in the Siwalik and passes through the Terai to India.**

Source: Government of Nepal, Ministry of Forests and Soil Conservation. 2014. *Nepal Biodiversity Strategy and Action Plan 2014–2020*. Kathmandu.

C. Lakes

22. A number of small and medium-sized lakes are scattered throughout the country, ranging from the freezing nival zone to the subtropical Terai. It is estimated that the lakes cover around 0.6% of the water surface of the country.[18] Lakes located in the High Mountains are glacial in origin and are poorly inhabited with aquatic life. Among the high altitude lakes, fish fauna is reported only in Rara Lake. Other lakes such as Tilicho in Manang, Gosaikunda in Rasuwa, Shey Phoksundo in Dolpa are considered oligotrophic. In the midhill, the tectonic lakes of Pokhara Valley (Phewa, Begnas, Rupa, Deepang, and Khaste) are considered mesotrophic and provide habitats for several fish species. Many oxbow lakes are scattered in the Terai. These lakes (Badhaiya Tal, Banda Tal, Puraina Tal, Gaidahawa Tal, etc.) are eutrophic in nature and are inhabited with warmwater fish and several invertebrates (Annex 2).

[18] Government of Nepal, Directorate of Fisheries Development. 2012. *Annual Progress Report, 2011–2012*. Kathmandu.

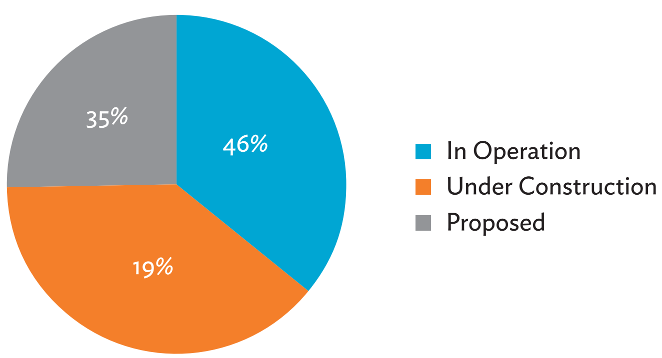
4 Dams in the Rivers of Nepal

23. In Nepal, a majority of the dams are constructed for hydropower generation, about a dozen are for irrigation, and a few are for water supply. The dams over river or lake outlets are scattered throughout the country. The location of main dams for different purposes at different stages of their construction and operation are presented in Annex 3, which illustrates a high concentration of dams in the Koshi, Bagmati, and Gandaki river basins; and a few in the Karnali River basin. Details of the location of dams in different river basins are shown in Annexes 4–7.

A. Hydropower Dams

24. Development of hydropower began in Nepal with the commissioning of Pharping Hydropower Station (500 kilowatt [kW]) in 1911. Soon, Sundarijal Hydropower Station (600 kW) and Khopasi Hydropower Station (2,400 kW) were commissioned under grant assistance from the former Soviet Union, followed by Trishuli Hydropower Station (21 MW) with the support of India in the 1960s. They were followed by Sunkoshi Hydropower Station (10 MW), built with grant assistance from the People's Republic of China in the early 1970s. The first hydropower project financed with multilateral loan assistance from the World Bank was Kulekhani-I Hydropower (60 MW), commissioned in 1981. Marshyangdi (69 MW) followed the Kulekhani-I project. With the formulation of the first hydropower development policy and enactment of law to put the policy in effect in 1992, the early 1990s was an epoch of hydropower development in Nepal. With a major policy shift to liberalize the economy during the early 1990s, private investment in power generation was encouraged. Bhote Koshi Hydropower Plant (36 MW) and Khimti Hydropower Plant (60 MW) were built under foreign investment, and a few small hydropower projects were commissioned with domestic private sector investment. Kali Gandaki A (144 MW) was the major addition to the power system of Nepal under ADB support in 2002. About a dozen public sector hydropower projects are in operation. Several hydropower plants are under construction and more than 200 are under planning. Out of 223 dams at different phases of development at different locations in the river basins of the country, 46% are in operation, 19% are under construction, and 35% are proposed according to the Department of Electricity Development and Nepal Electricity Authority. The present status of hydropower dams in various river systems is presented in Figure 4. The list of dam projects is presented in Annex 8.

Figure 4: Hydropower Projects in Nepal



Source: Department of Electricity Development and Nepal Electricity Authority.

B. Irrigation Dams

25. A list of large irrigation projects with dams in various rivers in the country is presented in Table 3.

Table 3: List of Irrigation Projects with Dam

Irrigation Project	River	District	Irrigated Land (ha)
Sharada	Mahakali	Kanchanpur	6,800
Rani Jamara (under construction)	Karnali	Kailali	40,000
Babai	Babai	Bardiya	13,600
Sikta (under construction)	Rapti	Banke	35,566
Ban Ganga	Ban Ganga	Kapilvastu	8,000
Gandak	Narayani	Bara, Parsa, Rauthat, Nawal Parasi	51,000
Eastern Rapti	Eastern Rapti	Chitwan	56,000
Bagmati Multipurpose	Bagmati	Bara, Rautahat, Sarlahi	50,200
Kamala	Kamala	Dhanusa	25,000
Chandra Nahar	Trijuga	Saptari	10,500
Koshi	Koshi	Saptari	22,000
Sunsari	Koshi	Sunsari, Morang	58,000
Kankai	Kankai	Jhapa	8,000

ha = hectares.

Source: Government of Nepal, Ministry of Irrigation, Department of Irrigation. 2017. Irrigation Handbook 2017. Kathmandu.

5 Aquatic Resources

A. Fish Faunal Diversity

26. The faunal diversity of Nepalese water bodies comprises 230 species of freshwater fish (Annex 9), 1,001 species of phytoplankton,[19] 121 species of zooplankton,[20] 192 species of mollusks,[21] and 117 species of amphibians.[22] Information on aquatic invertebrates of Nepal is limited due to lack of proper research.

B. Endemic Fish Species

27. Out of 230 native fish species, 16 species are endemic to Nepal.[23] Of these, three endemic species of Schizothorax are found in Rara Lake in Mugu, which is a protected area. The 13 other species are distributed in different rivers in the Mid-Hills and Terai (Table 4).

Table 4: Endemic Fish of Nepal

Fish Species	Common Name (English)	Common Name (Nepali)	Authority	Year	Water Body	IUCN Red List Status
Myersglanis blythii	Stone Catfish		Jayaram	1991	Pharping	Data deficient
Psilorhynchus pseudecheneis	Stone Carp	Tite Machha	Menon and Datta	1962	Dudh Koshi	Least concern
P. nepalensis			Conway and Mayden	2008	Rapti, Seti, Narayani	Not evaluated
Pseudeutropius murius batarensis	Indus Garua	Golmuhi	Shrestha	1981	Trishuli	Not evaluated
Schizothoraichthys macrophthalmus	Nepalese Snow Trout	Trout	Terashima	1984	Rara Lake	Least concern

continued on next page

19 V. Prasad. 2013. Biodiversity: Algae. In P.K. Jha, F.P. Neupane, M.L. Shrestha, and I.P. Khanal, eds. *Biological Diversity and Conservation*. Lalitpur: Nepal Academy of Science and Technology. pp. 97–103.

20 (i) R. Surana et al. 2005. Community Structure of Zooplanktonic Group of Chimdi Lake, Sunsari, Nepal. *Our Nature* (2005) 3:81–82.; (ii) D.B. Swar. 1979. Some Studies on the Freshwater Crustacean Zooplankton *(Natural Fish Food) from Nepal.* MSc Thesis. Ontario, Canada: University of Waterloo. p. 141.; (iii) R.B. Tiwari and P. Chhetry. 2009. Diversity of Zooplankton in Betna Wetlands, Belbari, Morang. *Our Nature* (2009) 7:236–237.

21 P.B. Budha. 2012. *Review of Freshwater and Terrestrial Molluscan Studies in Nepal: Existing Problems and Future Research Priorities*. Paper presented at the Entomological Review Workshop organized by Nepal Agriculture Research Council. Khumaltar. 4–6 March.

22 ICIMOD and Ministry of Environment, Science and Technology. 2007. *Nepal Biodiversity Resource Book: Protected Areas, Ramsar Sites, and World Heritage Sites*. ICIMOD and Ministry of Environment, Science and Technology, Kathmandu in cooperation with United Nations Environment Programme (UNEP) Regional Office for Asia and the Pacific, Bangkok, Thailand.

23 K.G. Rajbanshi. 2013. *Biodiversity and Distribution of Freshwater Fishes of Central Nepal Himalayan Region*. Kathmandu: Nepal Fisheries Society.

Table 4 *continued*

Fish Species	Common Name (English)	Common Name (Nepali)	Authority	Year	Water Body	IUCN Red List Status
S. nepalensis	Snow Trout	Tikhe Asala	Terashima	1984	Rara Lake	Critical endangered
S. raraensis	Rara Snow Trout	Asala	Terashima	1984	Rara Lake	Critical endangered
Batasio macronotus	Catfish		Ng and Edds	2005	Sapta Koshi	Least concern
Pseudecheneis crassicaudata			Ng and Edds	2005	Mewa Khola (River Tamor)	Data deficient
P. serracula			Ng and Edds	2005	Seti, Kali Gandaki, Narayani, Mahakali, and Karnali	Least concern
P. eddsi			Ng	2006	Mahesh Khola (Trishuli)	Data deficient
Erethistoides ascita			Ng and Edds	2005	Mechi, Kankai, Trijuga, Koshi	Data deficient
E. cavatura			Ng and Edds	2005	Dhungra, Rapti, Narayani	Data deficient
Balitora eddsi			Conway and Mayden	2010	Karnali	Data deficient
Neoanguilla nepalensis			Shrestha	2008	Narayani	Data deficient
Turcinoemacheilus himalaya			Conway, Edds, Shrestha, and Mayden	2011	Indravati, Kali Gandaki, Narayani	Not evaluated

IUCN = International Union for Conservation of Nature.
Source: K.G. Rajbanshi. 2013. *Biodiversity and Distribution of Freshwater Fishes of Central Nepal Himalayan Region*. Kathmandu: Nepal Fisheries Society.

28. Among the recorded 230 species of freshwater fish, 21 species are in the IUCN Red List. Of these, three are listed as critically endangered, one is endangered, four are vulnerable, and 13 are near threatened (Table 5).

Table 5: Nepalese Fish Species in the International Union for Conservation of Nature Red List

Scientific Name	Common Name	Nepali Name	IUCN Red List Status
Glyptothorax kashmirensis	Catfish		Critically endangered
Schizothoraichthys nepalensis	Snow Trout	Tikhe Asla	Critically endangered
Schizothoraichthys raraensis	Rara Snow Trout	Asla	Critically endangered
Tor putitora	Golden Mahseer	Sahar	Endangered
Physoschistura elongata	Dwarf Loach	Suiree	Vulnerable
Puntius chelynoides	Dark Mahseer	Halundae	Vulnerable
Schistura prashadi	Creek Loach	Gadela	Vulnerable
Schizothorax richardsonii	Snow Trout	Buchhe Asala	Vulnerable
Ailia coila	Gangetic Ailia	Patsi	Near threatened
Bagarius bagarius	Goonch	Gounch	Near threatened
Bagarius yarrelli	Goonch	Gounch	Near threatened
Balitora brucei	Gray's Stone Loach	Patthartata	Near threatened
Chitala chitala	Clown Knifefish/Humped Featherback	Chittal	Near threatened
Ctenops nobilis	Frail Gourami		Near threatened
Garra rupicula	Sucker	Buduna	Near threatened
Labeo pangusia	Pangusia Labeo	Thed	Near threatened
Neolissochilus hexagonolepis	Chocolate Mahseer/Copper Mahseer	Katle	Near threatened
Ompok bimaculatus	Butter Catfish	Nauni	Near threatened
Ompok pabda	Pabda Catfish		Near threatened
Tor tor	Red-finned Mahseer	Ratar/Sahar	Near threatened
Wallago attu	Whiskered Catfish	Buhari	Near threatened

IUCN = International Union for Conservation of Nature.

Source: International Union for Conservation of Nature.

29. Many rivers and lakes, such as Koshi, Narayani, Karnali, Mahakali, Babai, Rapti, Kamala, Mechi, and Bagmati rivers; and Koshi Tappu, Jagdishpur, and Bis Hazari lakes, are resting places with plenty of fish for food for migratory and globally threatened birds. For example, *Anthropoides virgo* (Demoiselle Crane) is a seasonal visitor to Nepal. Other birds that use Nepal as their wintering grounds are the cinereous vulture, common greenshank, common teal, Eurasian curlew, gadwall, great cormorant, greater spotted eagle, pallas gull, and ruddy shelduck.

6 Impact of Impoundment on Fish

30. Among the various threats to freshwater biodiversity, artificial obstruction plays an important role. In recent years, the construction of hydropower dams has occurred at an unprecedented rate that disrupts dynamic processes and the ecological integrity of natural systems.[24] The collapse of riverine fisheries is attributed more to hydrological alterations and changes brought about by dams than pollution and destructive fishing.[25] It is estimated that about 50% of all large rivers have been affected by dam construction.[26] Other studies have noted that cold water fish in Nepal are threatened due to barrier effects of the dams of hydropower projects, causing loss of habitat, deterioration of water quality, blockage of fish movement, physical injury, and predation.[27]

A. Overall Impact of Dam and Diversion Structures

31. The construction of a dam across a river alters the aquatic environment of that area, affecting the fish populations. The overall impact is presented in Table 6.

Table 6: Overall Impact of a Dam on Its Aquatic Environment

Direct Impact	Indirect Impact	Secondary Impact	Cumulative
Conversion of a lotic into a lentic pond ecosystem	Habitat destruction	• Eutrophication of reservoir • Effect of exotic and invasive fish species • Emission of methane from reservoir • Effect on food chain • Effect on fish health	Loss of movement path, blockage in inter-connected pathways of migratory fish in the rivers, extinction of fish species
Downstream riverine environment from dam will be converted into dry stretch	• Low flow • Habitat destruction • Destruction of spawning bed impacts on fish breeding • Obstruction of fish migration	• River aggradation • Increase in shore erosion • Change in water quality	
Fish migration will be obstructed	Impact on fish breeding	• Decrease in fish population	

Source: D.E. McAllister, J.F. Craig, N. Davidson, S. Delany, and M. Seddon. 2001. Biodiversity Impact of Large Dams, Background Paper No. 1, Prepared for IUCN/UNEP/WCD.

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24 M.P. McCartney et al. 2000. *Ecosystem Impacts of Large Dams. Report to IUCN, UNEP and World Commission on Dams* (WCD). Wallingford, UK: Center for Ecology and Hydrology. p. 81.

25 UNEP. 2002. *Environmental Impact Assessment Training Resource Manual, 2002*. Geneva.

26 C. Nilsson et al. 2005. Fragmentation and Flow Regulation of the World's Large River Systems. Science (2005) 308:405–408.

27 (i) S.R. Gubhaju. 2002. Impact of Damming on Aquatic Fauna in Nepalese Rivers. In T. Petr and D.B. Swar, eds. Cold Water Fisheries in the Trans-Himalayan Countries. *Fisheries Technical Paper*. No. 431. Rome: Food and Agriculture Organization of the United Nations (FAO). p. 376. (ii) B.R. Jha et al. 2006. Fish Species Composition, Number, and Abundance in Different Rivers and Seasons in Nepal and the Reevaluation of Their Threat Category for Effective Conservation and Management. *Ecology Environment and Conservation* 12 (1). pp. 25–36. (iii) B.R. Jha et al. 2007. Fish Base Study of the Impacts of Dams in Different Rivers of Nepal and Its Seasonal Variations. *Ultra-Science* 19 (1): 27–44.

B. Habitat Destruction

32. The construction of dams in rivers causes habitat destruction in both feeding and breeding grounds, which leads to biodiversity loss. Habitat alteration has led to stunted growth, diseases, parasite infestation, and increased mortality of the Golden and Copper Mahseer.[28]

33. Dams block the natural flow of water, reducing water discharge in the downstream. Flowing water is vital as it cleans interstitial spaces of pebbles, gravel, and boulders and prepares spawning substrate for fish. In the absence of water flow after diversion, the spawning ground is covered by sediment that limits fish recruitment. Migratory fish like *Tor putitora* and *Tor tor* (Mahseer), *Neolissochilus hexagonolepis* (Copper Mahseer), and *Schizothorax plagiostomus* and *S. richardsonii* (Snow Trout) are affected by the destruction of their spawning beds (footnote 28).

34. Dams with large storage reservoirs reduce or eliminate inundation of downstream floodplains. Inundation of the floodplain typically provides shallower, prey-rich habitats for fish.[29] The most common downstream effect of large dams is that variability in water discharge over the year is reduced such as high flows are decreased and low flow period is increased due to regulated flow. Reduction of flood peaks reduces the frequency, extent, duration, and area of floodplain inundation that impacts aquatic species.[30] Fish yields in floodplain river ecosystems are directly related to the height and duration of floods.[31] Quist and Guy suggested that increased growth of channel catfish in the Kansas River in the United States (US) resulted from floodplain inundation.[32] Brouder explained that a reduction or elimination of flooding through hydrologic alteration impacts recruitment of species.[33]

35. Dams trap sediment and reduce its load in the water released from power stations, increasing the erosive effect of the river flow in the downstream and thus resulting in the scouring of the river bed. The impact of dams in habitat destruction is mainly described in downstream areas. However, upstream habitat destruction is also noticeable where dams create huge reservoirs, converting a lotic habitat to a lentic habitat, which is unfavorable for endemic species. In most reservoirs, spawning beds of major migratory game fish are inundated and lost.

36. The worst impact of habitat destruction caused by dams is the complete desiccation of the entire stretch of river below the impoundment and the exposure of the river beds, as in the case of the Kulekhani Hydropower Project.

[28] T.K. Shrestha (n.d.). Conservation and Management of Fishes in the Large Himalayan Rivers of Nepal. Retrieved from http://www.ibcperu.org/doc/isis/2948.pdf.

[29] R.L. Welcomme. 1979. *Fisheries Ecology in Floodplain Rivers*. New York: Longman.

[30] Biodiversity and Nature Conservation Association (BANCA). 2009. *Report on Survey of Aquatic Ecological Conditions and Mitigation Measures of Hydropower Development of Ayeyarwaddy River Basin above Myitkyina*. Yangon, Myanmar. pp. 108–237.

[31] G. Marmulla, ed. 2001. Dams, Fish, and Fisheries. Opportunities, Challenges, and Conflict Resolution. *FAO Fisheries Technical Paper*. No. 419. Rome: FAO. p. 166.

[32] M.C. Quist and C.S. Guy. 1998. Population Characteristics of Channel Catfish from the Kansas River. *Journal of Freshwater Ecology* 13: 351–359.

[33] M.J. Brouder. 2001. Effects of Flooding on Recruitment of Round Tail Chub, *Gila robusta*, in a Southwestern River. *The Southwestern Naturalist* (2001) 46: 302–310.

C. Changes in Limnological Parameters

37. Fish are affected indirectly at different levels, depending on species, by modification of the velocity, temperature, and quality of the water. Development works such as river damming cause changes that affect the aquatic organisms, depending on the species. Damming of rivers converts the naturally flowing river to a calm pool upstream, inundating the river banks. The size of impoundment depends on the height of the dam and water volume of the river. Such reservoirs are (i) low in oxygen due to decomposition of debris brought by rivers, (ii) rich in nutrients coming from catchment areas, and (iii) high in temperature due to water stagnancy. These factors lead to eutrophication because of favorable conditions for blooming of phototrophic organisms that favor exotic species to flourish. Such a situation reduces or eliminates endemic species. Existing species like Snow Trout do not like lacustrine conditions and cannot survive well in reservoirs. Some economically important species of the family Cyprinidae such as *Schizothorax* sp. inhabit flowing water and prefer fast-flowing water over a gravel bottom for spawning. This helps fertilization and completion of the larval life cycle of the species. In stagnant water, the eggs sink to the bottom and larvae cannot swim to the surface for the completion of the larval life span. The larvae will die at the bottom and the population of these species are found to decline gradually after dam construction (footnote 30).

38. The water temperature in reservoirs rises and becomes thermally stratified, which depends on the water retention time, depth of reservoir, and lack of circulation between water layers. Thermal stratification of reservoirs during the warm season can result in deoxygenation of the hypolimnion. Cool and anoxic water discharged from the hypolimnion can severely reduce water quality downstream and negatively affect fish stocks and fisheries. Fish may be eliminated from the river downstream from the dam to the distance deoxygenation persists.[34] Moreover, the release of warm surface water from the epilimnion results in increased summer temperatures that reduce the survival of some aquatic organisms.[35] Reduced water flow will also increase the downstream water temperature.

39. Dams store sediments in the reservoir transported by streams, decreasing the amount of substrate available to freshwater species in the floodplain. This will reduce the fertility and productivity of downstream aquatic environments. Many fish species are adapted to natural turbidity. Turbid water helps conceal the fish and other biota from airborne predators like birds. When naturally turbid water becomes clear at the downstream of dams, the indigenous fish species may be at a disadvantage in terms of increased visibility in low turbid water.[36] In contrast, turbidity of a river may become too high downstream during sediment flushing from reservoirs. Such high turbidity deteriorates the water quality and aquatic ecosystem in downstream areas.[37] Suspended solids in excess of 100 parts per million chokes the fish gills, and above 25 milligrams per liter (mg/l) adversely affects the development of fish eggs and fish.[38] Shrestha reported negative impact on growth and development of *Tor* sp. and *Schizothorax* sp. in reservoirs such as Kulekhani, Marshyangdi, Trisuli, and Sunkoshi, which are loaded with heavy silt during monsoon.[39] Sediments trapped in the reservoir may be contaminated with pesticides and industrial

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34 G.M. Bernacsek. 2001. Environmental Issues, Capacity and Information Base for Management of Fisheries Affected by Dams. In G. Marmulla, ed. Dams, Fish and Fisheries: Opportunities, Challenges and Conflict Resolution. *FAO Fisheries Technical Paper*. No. 419. Rome: FAO. p. 166.

35 B.D. Horne et al. 2004. Simulating Effects of Hydrodam Alteration on Thermal Regime and Wild Steelhead Recruitment in a Stable-flow Lake Michigan Tributary. *River Research and Applications.* 20: 185–203.

36 D.E. McAllister et al. 2001. *Biodiversity Impacts of Large Dams.* Background Paper No. 1. Prepared for IUCN/UNEP/WCD.

37 Hydro Consult Private Limited. 2011. *Updated Report on Environmental Impact Assessment (EIA) of Nyadi Hydropower Project*. Kathmandu.

38 NJC Hydropower Limited (n.d.). Chapter 3 Fisheries Management Plan. Retrieved from http://apspcb.org.in/pdf/28_12_10/NJC%20HEP%20REPORT8.12.10/EMP%20Report%20Nymjangchhu%20HEP_6.12.10/Chapter-3_Fisheries_Conservation_Plan.pdf.

39 T.K. Shrestha. 1993. Chronology of Early Development and Life History of the Golden Mahseer in the Intergravel Environment of the Himalayan Streams of Nepal. In H.R. Singh, ed. *Advances in Limnology*. Delhi: Narendra Publishing House. pp. 253–276.

chemicals from catchment sources, and residues can enter the reservoir food chain leading to health hazards for consumers (footnote 34).

D. Obstacles in Fish Migration

40. Fish migrates from one environment to another during their life cycle. Such migration could be a few meters to hundreds of kilometers depending on the species. Fish migratory stages may be adult and/or juveniles of both large and smaller species.[40] Based on migration, fish are categorized into potamodromous (migrate within freshwater), diadromous (migrate between marine and freshwater), catamodromous (spend most of time in freshwater and migrate to sea to breed), and amphidromous (migrate between marine and freshwater for food but not for spawning).

41. Migratory fish require different environments for the main phases of their life cycle such as reproduction, production of juveniles, growth, and sexual maturation (footnote 30). Altered stream flow through floods and other stimuli such as change in water temperature and altered photoperiod provide clues for many freshwater fish species to migrate downstream or upstream for reproduction or habitat colonization (footnote 40).

42. Short and mid-distance migratory *Schizothorax* sp. and *Schizothoraichthys* sp. move upstream in response to high turbidity and higher water temperature, and downstream due to the scarcity of food during the rainy season.[41] Species like *Schizothorax* sp. and *Tor* sp. migrate upstream during summer and downstream during winter in response to water temperature (footnote 38).

43. Ever-increasing numbers of weirs, barrages, and dams incur harmful effects on river ecosystems. As a physical barrier, such structures prevent many fish species from reaching their traditional areas of spawning and feeding, leading to changes in composition of upstream and downstream species and even loss of the species. In Nepal, dam construction has adverse impacts on river fauna such as *Platanista gangetica* (Gangetic dolphins) and migratory fish species. Shrestha also mentioned that barrages like Kailashpuri, Girjapuri, and Koshi constructed in Nepal have blocked fish migration. Authors (footnotes 27[i] and 28) mentioned the movement of migratory fish such as *Tor tor, Schizothorax richardsonii, Anguilla bengalensis, Bagarius* spp.*, Clupisoma garua, Pseudeutropius* spp., and *N. hexagonolepis* is obstructed due to blockage created by dams of hydropower projects.[42] Jha and colleagues recognized that higher fish abundance was found downstream compared to upstream in Aandhi Khola; the conclusion was that dams blocked the upstream migration of fish (footnote 27[iii]). The construction of a dam on a river prevents bloodstock from reaching their spawning grounds during the breeding season, resulting in massive failure of recruitment and eventual extinction of the stock.[43]

44. The longitudinal pattern of species distribution and abundance was found to be consistent in the free-flow river, while inconsistent in the river with dams.[44] Maintenance of natural patterns of longitudinal and lateral connectivity is essential for the conservation of aquatic biodiversity in riverine systems.[45]

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[40] R. Kapitzke. 2010. Culvert Fishway Planning and Design Guidelines, Part B – Fish Migration and Fish Species Movement Behavior. James Cook University, School of Engineering and Physical Sciences.

[41] Footnotes 27(i) and 30.

[42] Footnote 28.

[43] M. Larinier. 2000. Dams, Ecosystem Functions, and Environmental Restoration, WCD Environmental Issues, Dams and Fish Migration, Final Draft, 30 June, Institut de Mecanique des Fluides, Toulouse, France. Prepared for Thematic Review II. 1., i–ii, pp. 1–25.

[44] M.B. Brain and A.D. Kinsolving. 1993. Fish Assemblage Recovery along a Riverine Disturbance Gradient. *Ecological Applications*. (3). pp. 531–544.

[45] S.E. Bunn and A.H. Arthington. (n.d.). Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity. *Environmental Management30): 492–507.*

E. Fish Injury and Predation

45. Fish injury and predation are problems linked to hydropower dams. Mortality resulting from fish passage through hydraulic turbines or over spillways during downstream migration is unavoidable. Bottom feeders such as *Schizothorax* sp. and *Tor* sp. may be pulled in the intake and killed by the hydropower turbines. Even riverine fish adapted to fast current may be lost. Entrapment of fish is a critical problem after damming and some provision should be made to protect the fish against entrapment. Installation of appropriate screen devices at the intake can divert the fish from entering water intakes.[46]

Raj Bam (*Anguilla bengalensis*) caught in the Koshi River in Eastern Nepal. The Koshi River is one of the major tributaries of the Ganges. The fish is found to travel to the Bay of Bengal for spawning in salty water. They along with their juveniles swim back to the freshwater rivers in Nepal to complete their reproductive cycle. (photo by Upen Limbu).

46. Fish are easily exploited in the drawdown zone due to low water flow and depth as a result of water diversion at the intakes. Fish movement slows down at the dam site for upstream and downstream migration, making them easier prey to certain predatory species and poachers (footnote 30). High oxygen concentration in the tailwaters, in the case of epilimnion release, also attracts fish and makes them easy to catch. A diagrammatic view of environmental impacts associated with a dam is presented in Annex 10.

[46] Footnote 30.

7 Policies and Regulatory Framework

47. The value of aquatic biodiversity was recognized in Nepal in 1961 with the adoption of the Aquatic Animal Protection Act, 1961. Since then, various aquatic biodiversity-related acts, policies, strategies, and regulations have been developed and implemented to facilitate sustainable economic growth with the participation of local communities. Aquatic biodiversity has also been featured in different water resource developments. The policies, strategies, and legislations related to aquatic biodiversity developed in Nepal are briefly described in Annex 11.

48. The existing policies, strategies, and legislations have the following major gaps with regard to management of aquatic biodiversity:

(i) **Policy and legislative gaps.** Despite becoming a party to the Convention on Biological Diversity, 1992 in 1994, Nepal is yet to enact laws for conservation of aquatic biodiversity and its sustainable use.

(ii) **Inadequate importance to aquatic biodiversity.** Many of the relevant policies relating to industry, roads, and local governance sectors have not assigned due priority to aquatic biodiversity. The government's decision to waive environmental impact assessment (EIA) requirements for hydropower projects with up to 50 MW capacity undermines the serious impact on aquatic biodiversity.

(iii) **Poor integration and harmonization of policies and laws.** The policies of different sectors are not connected and coordinated. For example, the Ministry of Agriculture and Livestock Development encourages commercial aquaculture in natural water bodies with the introduction of exotic cultivable fish species—this contradicts the main objectives of the National Biodiversity Strategy and Action Plan, 2014.

(iv) **Gap in implementation of policies.** Implementation and monitoring of the existing policies and strategies in biodiversity conservation must be improved.

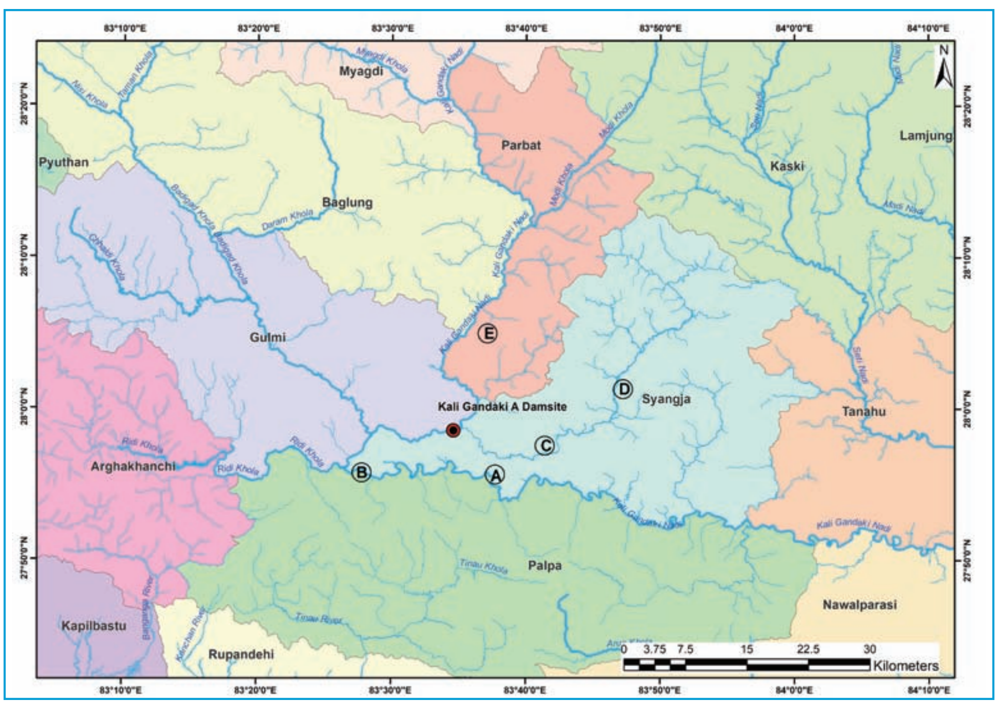
8 Case Studies of Selected Dams

A. Kali Gandaki A Hydropower Project

Introduction

49. The Kali Gandaki A Hydropower Project (KGHP) is a run-of-river type system located 500 m downstream of the confluence of the Kali Gandaki and Andhi Khola at Mirmi (Figure 5). The project has an installed capacity of 144 MW. The river flows west, turns south and east to form a 50 km loop, and reaches the powerhouse site at Beltari. A 44 m high and 110 m long concrete dam forms a 65 ha reservoir 5.3 km in length, with an average depth

Figure 5: Location of Kali Gandaki A Hydropower Project



AK = Andhi Khola, KGA = Kali Gandaki A.

Note: Fish sampling sites:
A - Downstream of KGA powerhouse; B - In between KGA dam and powerhouse; C - In between AK dam and KGA dam; D - Upstream of AK dam (Andhi Khola River); E - Upstream of KGA dam (Kali Gandaki River).

Source: Government of Nepal, Department of Survey.

of 12 m and operating level of 518–524 m. From the desilting basin at the headwork site, water low in sediment is diverted into a 5.9 km tunnel, which then enters the power plant equipped with a surge tank, pressure shaft, three power units, transformer, draft tube gate, and a tail race from where water is released back into the river.

Status of Aquatic Biodiversity

50. The Kali Gandaki River originates from the Tibetan Plateau in the People's Republic of China adjoining the northern border with Nepal. The river runs between the elevations of 5,500 m and 1,250 m, forming deep gorges. Four tributary streams join as the river loses elevation and enters the KGHP area. The river receives Andhi Khola at the upstream of the dam, and Bagarh and Ridi Kholas between the dam and the powerhouse. Trishuli River discharges into Kali Gandaki at the downstream of the powerhouse. The river is named Narayani before flowing into the Ganges in India and finally into the Bay of Bengal.

51. The Kali Gandaki River has a number of fish species adapted to the extreme gradient of the river and support subsistence, commercial, and sport fisheries. The annual catch from the river, before construction of the project and damming, was estimated between 80 tons and 150 tons . The main species were *Schizothorax* spp., *Tor* spp., carp, catfish, *Anguilla bengalensis* (eel), murrel, loach, and barbs. About 57 fish species were recorded in the Kali Gandaki River in 2004.[47] These fish have adapted to extreme flow and turbidity. Migration patterns include long-distance (to and from Terai or Bay of Bengal), medium-distance, and residents (moving from the main stream to immediate tributaries). Upstream migration starts at the beginning of the monsoon, which triggers spawning behavior, and downstream migration starts when water levels in the tributaries subside. The catadromous eel was abundant in the Kali Gandaki River in the past.

Kali Gandaki A Hydropower Project showing dam and desilting basin. The Kali Gandaki A Hydropower Project has a desanding reservoir at the downstream of the dam (photo by Samir J. Thapa).

[47] (i) Kali Gandaki A Associates, Morrison Knudsan Corp., United States, Nor Consultant International., Norway and IVO International Limited Finland. 1996. EIA. *Kali Gandaki A Hydro Electric Power Project Detail Design Report*. Vol. 1; (ii) footnote 23; (iii) J. Shrestha and R. Chaudhari. 2004. Fish Diversity in Kali Gandaki River before and after the Project Construction. In A.K. Rai and A.P. Nepal, eds. *Proceeding of Workshop on Hydropower Dams: Impact on Fish Biodiversity and Mitigation Approaches.* Godawari, Nepal: Nepal Agricultural Research Council, Fisheries Research Division. pp. 20–31.

***Anguilla bengalensis* (long-distance migratory fish Raj Bam) from Kali Gandaki.** The fish is believed to have spawned in the Bay of Bengal and traveled to freshwater rivers such as Kali Gandaki as its habitat (photo by D.B. Swar from Kali Gandaki A Hydropower Project).

***Bagarius yarrelli* (long-distance migratory fish) from Kali Gandaki.** The fish is one of the biggest freshwater catfish, although little is known about its biology and spawning behavior (photo by D.B. Swar).

Impacts of Dam as Predicted by Environmental Impact Assessment

52. The following adverse impacts of the dam was predicted in the EIA:

(i) barrier effect due to dam will block upstream migration of important migratory fish;
(ii) diversion of smaller fish and juveniles into the penstock and power plant will cause considerable loss of fish populations;
(iii) a fast-flowing downstream riverine environment will be converted into a dry stretch for about 8 months (October to May) in a year; and
(iv) water quality of the project area will deteriorate due to human activities.

Mitigation Measures

53. The following mitigation measures were recommended in the EIA report to protect fish population from the adverse effect of the dam:

(i) **Provide fish passage on the dam.** A fish outlet funnel is provided for fish passage from upstream to downstream of the dam.
(ii) **Establish a multispecies fish hatchery and release fish fingerlings upstream and downstream of the dam.** A fish hatchery was built for mass seed production of economically high-value indigenous riverine fish species. It is run by the Nepal Agricultural Research Council and the Nepal Electricity Authority. The hatchery has successfully bred some native fish species such as *Tor putitora* (Sahar), *Neolissochilus hexagonolepis* (Katle), *Schizothorax richardsonii* (Asla), and *Labeo dero* (Gardi). Preliminary observation on induced breeding of some native fish species like *Labeo pangusia* (Hande), *Labeo angra* (Thend), *Garra annandalei* (Lahare), *Garra gotyla* (Buduna), and *Botia lohachata* (Baghi) has shown encouraging

results.[48] Fish fingerlings produced from the hatchery and released in the Kali Gandaki River are presented in Annex 12.

The hatchery is not being operated at full capacity due to insufficient annual budget. The Nepal Electricity Authority initially allocated NRs8 million as the annual budget to run the hatchery, which has gradually decreased to a meager NRs1 million per annum. The decreased amount is insufficient to even feed the fish stock. At present, only one technician is deputed to operate the hatchery. Few unskilled laborers are hired by the hatchery on daily wages. Concerned agencies have not paid adequate attention to running the hatchery in full scale.

(iii) **Ensure fish migration both upstream and downstream through fish trapping and hauling activity with the involvement of local fishing community.** Fish trapping and hauling activities are infrequently carried out by the project.

(iv) **Restriction on fishing activities between the dam and the confluence of Rudrabeni.** Despite restrictions on destructive fishing and awareness campaigns, illegal use of electrofishing is still in practice.

(v) **Ensure 4 cubic meter per second (m^3/s) of water release in the river in the dry season.** Release of environment flow in the downstream is far less than the recommended volume.

(vi) **Restrict pollution of river.** There is no restriction on draining of household sewerage, disposal of solid waste, plastic bags, and bottles upstream of Mirmi.

(vii) **Arrangement of trash rack to control release of fish through penstock and power plant.** Trash racks are provided to restrict entry of fishes in the hydropower intake.

54. An upstream to downstream one-way funnel for fish passage is provided in the dam. Fish are attracted toward the funnel by using fish-attracting light.

Dam of Kali Gandaki A Hydropower Project. A fish outlet funnel is provided for fish passage from upstream to downstream of the dam (photo by D.B. Singh).

One-way fish outlet funnel in the dam of the Kali Gandaki A Hydropower Project. Fish are attracted toward the funnel by using fish-attracting light (photo by D.B. Singh).

[48] A.P. Baidya et al. 2008. *Domestication and Breeding Status of Native Fishes in Nepal.* Paper presented in Workshop on Indigenous Fish Stock and Livelihood. Lalitpur, Nepal: Fisheries Research Division. 5 June 2008.

55. A fisheries survey of the Kali Gandaki River in 2005 by Thomsen revealed that fish catch per day declined after construction of the KGHP and Andhi Khola dams. Population of migratory species like *Bagarius* sp., *Anguilla bengalensis*, *Labeo gardi*, and *Tor* sp. have also declined (Table 7). Illegal and destructive fishing, siltation, and damming of the interconnected rivers in Nepal and India could be a cause for the reduction in population of the long-distance migratory fish species, although a detailed study is required to validate this. Nevertheless, KGHP is using at least a few mitigation measures during operation of the system to protect the fish population.

Table 7: Average Maximum Weight of Migratory Fish Species Caught by Fishers before and after Construction of Dam of the Kali Gandaki A Hydropower Project (kg)

Fish Species	Before Damming					After Damming					Reduction in Weight (%)
	A+B	C	D	E	Average	A+B	C	D	E	All areas	
Bagarius sp. (Goonch)	32.5	23	NA	21	25.51	15.5	15	NA	20	16.84	33.98
Anguilla bengalensis (Eel)	4.5	6.1	NA	5	5.2	3.4	4	NA	0.62	2.67	48.59
Labeo gardi (Gardi)	1.2	2.1	NA	1	1.43	0.8	1.7	NA	1	1.17	18.6
Tor sp. (Sahar)	14.1	10.9	4.4	4.1	7.28	5.3	4.8	0.7	4.5	3.65	49.83

KGHP = Kali Gandaki A Hydropower Project, NA = species not caught during sampling.
Note: A, B, C, D, and E are fish sampling locations shown in Figure 5.
Source: Thomsen (Unpublished 2005).

56. The study selected the sampling location where fishers regularly catch fish. A total of five such areas were identified (Table 8).

Table 8: Fish Catch per Day per Fisher before and after Construction of the Kali Gandaki A Hydropower Project (kg)

Fish Catch per Day per Fishers	Before KGHP Dam	After KGHP Dam	Difference	Difference (%)
Area A (downstream of KGHP powerhouse)	6.60	1.30	5.30	80.30
Area B (between KGHP dam and powerhouse)	6.70	0.70	6.00	89.55
Area C (between AK dam and KGHP dam)	6.30	1.10	5.20	82.54
Area D (upstream of AK dam)	4.60	0.90	3.70	80.43
Area E (upstream of KGHP dam)	10.90	1.40	9.50	87.16
All areas	7.02	1.08	5.94	84.62

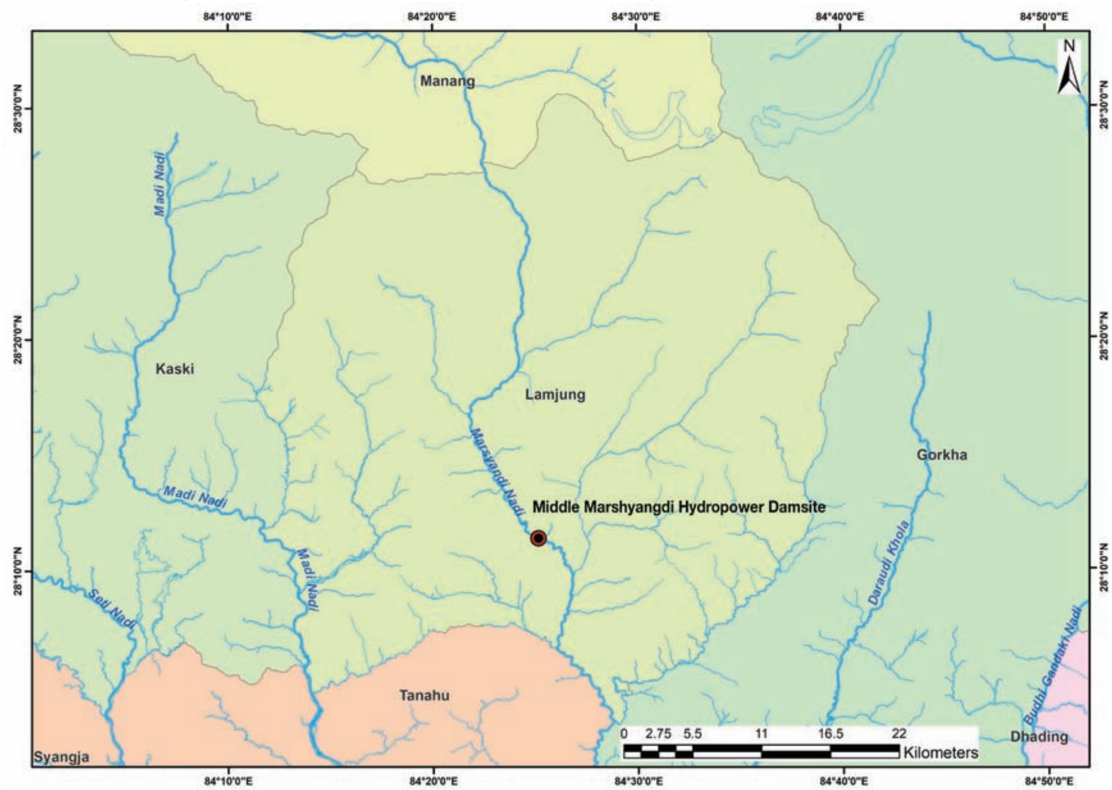
AK = Andhi Khola, KGHP = Kali Gandaki A Hydropower Project.
Source: Thomsen (Unpublished 2005)

B. Middle Marshyangdi Hydroelectric Project

Introduction

57. The Middle Marshyangdi Hydroelectric Project (MMHEP) is the second-largest hydroelectric project in Nepal. It is a run-of-river project with a reservoir for 5-hour daily peaking and an installed capacity of 72 MW. The key components of the project are a 74 m high concrete dam, reservoir area of 4.7 ha, underground desanding basin, 5.3 km long headrace, tunnel 5.2 m in diameter, a surge shaft, and a semi-underground powerhouse. The dam is located at Phalia Sangu, and water is diverted through a tunnel to Bhote Odar, Shiudibar to generate electricity (Figure 6).

Figure 6: Location of Middle Marshyangdi Hydroelectric Project



Source: Government of Nepal, Department of Survey.

58. The MMHEP dam has no provision of fish pass or fish ladder. The project hardly releases environment flow in the downstream of the dam up to the confluence of Dordi Khola, a spring-fed tributary of the Marshyangdi River. There are several small hydropower projects proposed in Dordi Khola, but the actual construction has not yet started. The length of the river stretch between the dam site and the powerhouse is about 5.7 km. Dordi Khola joins the Marshyangdi River 3 km downstream of the dam site. The EIA of MMHEP envisaged to protect Dordi Khola as a stream dedicated for fish habitat. However, the objective will remain unfulfilled with the planned construction of hydropower projects in the river.

59. The study team's fish sampling downstream of the powerhouse site revealed that there is plenty of Buchhe Asala fish in the river, but other species were not caught.

Middle Marshyangdi Hydroelectric Project (MMHEP) site. An aerial view of the MMHEP dam, which has no fish pass or fish ladder (photo by Bijaya.Ad).

Status of Aquatic Biodiversity

60. A baseline study of fish fauna indicated that the MMHEP provided habitat to at least 30 indigenous fish species. The section of the river between the dam and tailrace was good habitat for Snow Trout such as *Schizothorax richardsonii* and *Schizothorax plagiostomus*, although presence of large-scale Barbels (*Tor* spp. and *Neolissochilus hexagonolepis*) was rare. A study in 1997 indicated that out of 30 species, Snow Trout contributed more than 30% of the total catch by number.[49]

[49] D.B. Swar. 1997. *Aquatic Fauna and Flora of Middle Marshyangdi Hydroelectric Project.* EIA Report. Annex 4. Lahmeyer International/New ERA. pp. 20.

Potential Impact

61. The EIA of the project identified the following potential impacts:

- the 3 km river stretch between the dam and confluence with Dordi Khola will become almost dry for about 9 months a year;
- movement of fish along the river to the upper reach will be blocked by the dam; and
- natural fish habitat will be destroyed if sand and stone mining from the riverbed is continued.

Mitigation Measures Proposed

62. The mitigation measures proposed in the environmental management plan (EMP) in the EIA included the following:

- **Release of a minimum of 1 m^3/s water from dam as environment flow throughout the year**
  Compliance status: The release of water needs to be ascertained as a mandatory practice.
- **Construction of a multispecies fish hatchery**
  Compliance status: Fish hatchery was not established. About 50,000 *Labeo dero* (Gardi) fingerlings were released in the upstream of dam on a trial basis in 2012–2013 without any tags. There is no record of recapture.
- **Restriction on fishing and mining (sand and stone) in the project area**
  Compliance status: There is no restriction on fishing, although a signboard is erected with a "no fishing" sign in front of the powerhouse. Destructive fishing is in practice. Local fishers expressed their dissatisfaction about unabated illegal fishing (poisoning, electrofishing). Sand and stone mining is very common at different parts of the river, all contributing to a sharp decline in fish population in the river.

Result of Dam and Mitigation Measures

63. Intensive fishing with the help of cast net, rod, and hook (angling), and indigenous method (paso) in the project area was carried out at four stations (powerhouse, confluence of Dordi Khola, dam site, Khudi and Marshyangdi confluence) during March 2014. No migratory fish were caught. The absence of migratory species upstream from the powerhouse and dam site was confirmed through interviews with local fishers.

64. The results obtained from water quality analysis at different stations during the survey indicated that the water quality parameters were suitable for growth of fish and aquatic life. The dissolved oxygen content, which is an important parameter for examining the quality of water for fish survival, was in a very good range at 10–12 mg/l. Similarly, the pH of the water at all four sampling sites was 7.5–8 (Annex 14). Hydrogen ion concentration from 6.5 to 9 is considered most suitable for fish growth. Variation in water temperature has an important influence on all organisms, including fish. Feeding, breeding, respiration, and other physiological activities are influenced by temperature. About 9°C variation in water temperature was observed below and above the dam site. The higher water temperature below the dam (25°C) was due to a significant reduction in water discharge from the dam (Annex 13).

C. Marshyangdi and Upper Marshyangdi Hydropower Systems

65. Marshyangdi Hydropower was the first power plant built in the Marshyangdi River. The 69 MW hydropower plant was commissioned in 1989 with financial assistance of ADB, the International Development Association, German Development Cooperation through KfW, the Kuwait Fund for Arab Economic Development, and the Saudi Fund for Development. The run-of-river system has a dam at Simle and water is diverted to the powerhouse through a tunnel. The powerhouse is located at Abun Khaireni VDC, Tanahun. For almost 8.5 km downstream of the dam, the river requires release of environment flow during the 9-month low-flow period (September to May). Daraundi Khola, a tributary of Marshyangdi, joins the dry stretch of the river at Abun Khaireni, which is about 3 km upstream of tailrace. Fishers informed a distinct reduction in fish population in the river after construction of the hydropower system.

66. A third plant—Upper Marshyangdi A—in the series in the Marshyangdi River has a dam at the upstream of the Middle Marshyangdi Hydropower. This is also a run-of-river type system of 50 MW installed capacity commissioned in September 2016. The dam does not have the provision of fish passage. At the upstream of this project, a fourth hydropower project—Upper Marshyangdi Hydropower—with a dam is planned for implementation. Aside from the series of four dams in the Marshyangdi River, there are plans to construct several hydropower projects with dams in its tributaries like Daraundi and Dordi rivers. It is widely assumed that the dams will obstruct the passage of migratory fish in the entire upreach of the river basin, seriously impacting their population.

D. Babai Irrigation System

Introduction

67. The Babai River originates in the Dang Valley and runs from mid-western Nepal to India where it is known as the Rardar River. The watershed area of the river is 3,260 km^2. It is a warm water river in contrast to the majority of rivers in Nepal that are snow-fed with cold water. The Babai is an important river of the Karnali river basin.[50]

68. The Babai Irrigation System diverts water through a diversion barrage, which was constructed in 1993 for irrigating 13,600 ha of agricultural land in the Bardiya district. The dam has 13 gates, a fish ladder approximately 4 m wide, a 27 m wide main river channel, and an 18 m wide diversion channel.

[50] B.C. Shrestha. 1991. EIA. *Fisheries Baseline Report of Bheri–Babai Hydroelectric Project*. Report prepared for New Era/Nippon Koei/Japan International Cooperation Agency. Kathmandu, Nepal. p. 51.

Irrigation dam of Babai. The Babai Irrigation System diverts water for irrigation through a barrage (photo by D.B. Swar).

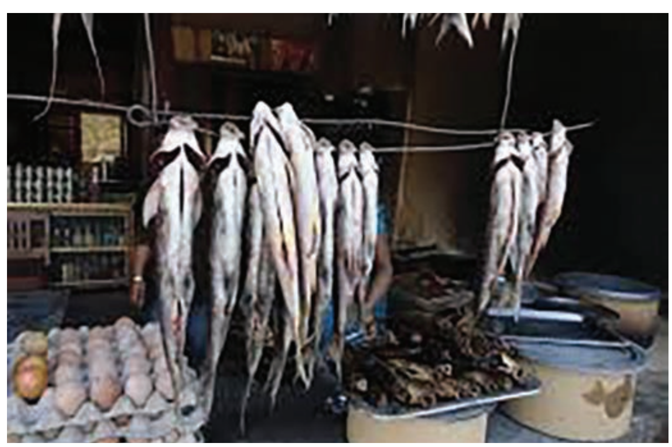
Fish ladder in the dam of the Babai Irrigation System. The dam has a fish ladder approximately 4 meters wide (photo by D.B. Swar).

Status of Aquatic Biodiversity

69. A total of 33 species of fish was recorded in the Babai River (footnote 50). Principal fish species of the Babai River are the following:

- Major carps: *Labeo dyocheilus, Labeo dero* (Carp); *Garra gotyla, Garra annandalei* (Sucker head); *Neolissochilus hexagonolepis* (Katle)
- Catfish: *Bagarius yarrelli* (Goonch)
- Eels: *Mastacembelus armatus* (Spiny eel), *Anguilla bengalensis* (Raj Bam)
- Murrells: *Channa punctate* (Snakehead)
- Mahseers: *Tor putitora* (Golden Mahseer), *Tor tor* (Sahar)
- Minnows: *Barilius barna, Barilius bendelesis, Barilius vagra*

Fish from the Babai Irrigation Project. A total of 33 species of fish was recorded in the Babai River (photo by D.B. Swar).



Fish of the Karnali River for sale in Chisapani. Copper Mahseer and catfish are among the major fishes found in Babai River, a tributary of Karnali (photo by D.B. Singh).

Potential Impacts Identified in Project Initial Environmental Examination

A 3 km river stretch will remain dry for about 9 months if environment flow is not released.

- Migration of fish past the dam will be completely restricted.
- Natural habitat is being destroyed due to sand and/or aggregate mining in the river.

Mitigation Measures

70. The mitigation measures adopted by the project were the following:

- **Water release.** Releasing 1 m^3/s water throughout the year from the dam as environment flow, which is maintained by the project.
- **Fish ladder constructed in the dam.** A fish ladder was constructed in the dam. The fish ladder was constructed at a slope of 10% to enable fish to comfortably pass in an equivalent "normal" flow situation.
- **Restriction on fishing and mining (sand and stone) in project area.** The Babai River is fast flowing with various types of characteristics such as pools, runs, rapids, and riffles of various sizes and shapes. The physical and chemical parameters of the water are favorable for a variety of fish. The confluence of Khote Khola and the Babai River in Kurule to the Babai bridge irrigation weir site is a good habitat for a variety of fish, including *Tor* sp. The river gradually becomes steep with rocks and pebbles of various sizes. A section of the river from Babai Bridge (at Chepang) to the irrigation weir site on the East–West Highway lies within Bardiya National Park area. The stretch is hence guarded and restricted for fishing by the park. This section, including small tributaries of the Babai River, especially Khote Khola, Mimire Khola, and Sano Kakatre Khola provide a good spawning habitat for many important fish like Golden Mahseer, Goonch, and Katle.

Goonch (*Bagarius yarrelli*) caught by Arun Rana in Babai River. The Babai River passing through Bardiya National Park is a good habitat for many gamefish species found in Nepal (photo by Christopher Tan).

A fully grown 18.9-kilogram Golden Mahseer (*Tor putitora*). This female ready for spawning was caught and safely released in the West Seti River in April 2015. It is categorized as endangered in the International Union for Conservation of Nature Red List (photo by Juha Rouhikoski).

Result of the Dam and Mitigation Measures

71. The fish population is found to be declining despite the implementation of several mitigation measures such as the construction of a fish ladder, release of downstream environment flow, and restriction on fishing and sand mining from the river within Bardiya National Park. Nevertheless, the fish survey conducted in the study found decreased fish species and population compared to past studies such as that by Mike Allen who monitored the Mahseer population in four pools above the dam during the last week of October to first week of November for 10 continuous years (1990–1999).[51] His findings concluded that the Mahseer population declined since the construction of the dam. Similar views were expressed by local fishers who have been traditionally fishing in the river. Cave observed the reduction in runs and number of Mahseer in the Babai River since the dam was constructed and that the fish pass does not function effectively for the migration of Mahseer.[52] Also, monitoring and enforcement is required to restrict fish catching by the locals by opening the sluice gate of the headworks.[53]

Lessons Learned

- The fish ladder was discharging back into the river through an opening located below the main river sluice. It was apparent that upwardly migrating fish would be lured into the backchannel rather than toward the opening of the fish ladder because of the greater water velocity over the dam.

- The first three steps of the fish ladder from the downstream were covered with silt. The lack of maintenance decreased the efficiency of the structure.

Water Quality

72. Results of the river water quality test carried out by the study at the dam site revealed that the water was suitable for growth of fish and aquatic life (Table 9). The dissolved oxygen was in excess of 5 mg/l, which is an important parameter for assessing the quality of water in relation to the survival of flora and fauna, although the idle range is 8–10 mg/l. Water pH was alkaline (7.75–8) and hydrogen ion concentration (pH) was 6.5–9, which are considered suitable conditions for fish growth. The water temperature was 27.5°C–29°C. Composite analysis of the physical and chemical properties of water at different sampling sites of the river indicated that water quality was suitable for fish survival.

Table 9: Water Quality of Babai River at Irrigation Dam Site

Parameters	D/S of Dam	U/S of Dam
Date of sampling	21 May 2014	21 May 2014
Air temperature (°C)	37.50	41.70
Water temperature (°C)	27.50	29.00
Dissolved oxygen (mg/liter)	8.00	10.00
Total hardness (mg/liter)	188.10	222.30
Alkalinity (mg/liter)	171.00	136.80
pH	7.75	8.00

D/S = downstream, mg/liter = milligram per liter, U/S = upstream.

Source: Field survey.

[51] H. Hall et al. 2001. *Babai Fish and Biodiversity Project Report*. Regent's Park, London: Zoological Society of London. pp. 56.

[52] J. Cave. 2000. Project—Bardia National Park, Nepal. Babai River Dam Irrigation Scheme. Unpublished report shared by Cave.

[53] Based on interviews with local fishers during the study.

E. Kulekhani Reservoir

Introduction

73. Kulekhani Reservoir was constructed in 1982 with a 114 m high dam on Kulekhani River. The reservoir is situated in the Mid-Hill of central Nepal and has a catchment area of 126 km^2.[54] At full capacity, the reservoir is about 7 km long, 380 m wide, and 105 m deep. The valley in which the reservoir is located has steep sides and variation in depth. The system consists of two power stations of Kulekhani No. 1 (KL-1) and No. 2 (KL-2), with a third KL-3 under construction. KL-1 is a reservoir type scheme having installed capacity of 60 MW, commissioned in 1982. KL-2 is a cascade scheme utilizing discharge from KL-1 with installed capacity of 32 MW and commissioned in 1986.

Kulekhani Reservoir with dam. Kulekhani Reservoir was constructed in 1981 with a 114-meter high dam on the Kulekhani River (photo by D.B. Singh).

Fish cage culture in the Kulekhani Reservoir. About 500 fish cages arranged like a big flower in the reservoir symbolize how families displaced after formation of the reservoir were mobilized by the project to benefit economically by adopting cage fish culture as an alternate occupation (photo by D.B. Singh).

Status of Aquatic Biodiversity

74. The first documented survey of the fish species in the Kulekhani River was conducted in 1980.[55] It was reported that *Garra lamta* (Gray), *Neolissochilus hexagonolepis* (McClelland), *Puntius chilinoides* (Ham), *Schizothorax richardsonii* (Gray), *Puntius ticto* (Ham), and *Puntius* sp. of the family Cyprinidae (Dark Mahsheer) were abundant in the river. The families Balitoridae and Channidae were also represented by *Nemacheilus* sp. and *Channa gachua* (Ham). The family Sisoridae was represented by *Glyptosternum* sp. and *Coraglanis* sp.

[54] D.B. Swar. 1994. A Study on the Ecology of Katle Neolissochilus hexagonolepis (McClelland), in a Nepalese Reservoir and River. PhD Thesis. Department of Zoology. The University of Manitoba. pp. 264.

[55] S.B. Shrestha et al. 1980. Pre-impoundment survey of the Kulekhani Reservoir Area. A report submitted to Fisheries Development Division, Department of Agriculture, Harihar Bhawan. Kathmandu.

Predicted Potential Impacts

75. Environmental assessment of the project reported the following potential impacts:

(i) Downstream of Kulekhani Reservoir will be completely dry for about 9 months of low flow period.
(ii) Migration of fish through the dam will be completely blocked.
(iii) There will be serious impact on hillstream fish like Snow Trout with a possibility of extinction.

Mitigation Measures Adopted by the Project

76. No particular mitigation measures were undertaken to protect the existing fish species. However, two exotic carps—*Aristichthys nobilis* (Bighead Carp) and *Hypophthalmichthys molitrix* (Silver Carp)—and the indigenous fish species *Tor putitora* (Mahseer) were introduced in the reservoir to increase commercial fish production. Almost 310 indigenous fisher families were grouped for practicing cage culture to raise fish for commercial purpose. About 500 fish cages arranged like a big flower in Kulekhani Reservoir symbolize how families displaced after formation of the reservoir were supported by the project to benefit economically by adopting cage fish culture as an alternate occupation.

Impact from Dam and Mitigation Measures

77. The type and population of fish in the river encountered a profound change after formation of the reservoir. Carp and Mahseer fingerlings were released in the river as a part of the project, causing a relative abundance of the two fish in the reservoir within a short time of its formation.[56] The impacts occurred included:

(i) drastic decline in the number of *Schizothorax richardsonii* (Snow Trout);
(ii) disappearance of *Puntius* sp., *G. lamta, Nemacheilus* sp., *C. gachua, Glyptosternum* sp., *P. ticto*, and *Coraglanis* sp., whereas the population of *S. richardsonii* sharply declined;
(iii) two indigenous species, *Neolissochilus hexagonolepis* and *Puntius chilinoides* remained dominant; and
(iv) three introduced species, *Hypopthalmichthys molitrix* (Silver Carp), *Aristichthys nobilis* (Bighead Carp), and *Tor tor* (Mahseer), which were not native to the Kulekhani River, appeared in the catches of 1986–1987 and considerably increased in the catches of 1987–1989.

F. Trishuli Hydropower Project

78. Trishuli Hydropower Station, located in Nuwakot district has an installed capacity of 21 MW and was commissioned in 1967 under financial support of the Government of India. The power plant was rehabilitated in 1995 and upgraded to 24 MW. The plant is a peaking run-of-river system. The weir is an overflow weir and the barrage has undersluice, which provides fish passage. The power plant supplies water to a Snow Trout breeding area and research center located at the downstream of the peaking reservoir.

[56] D.B. Swar. 1992. Effect of Impoundment on the Indigenous Fish Population in Indrasarovar Reservoir Nepal. In S.S. De Silva, ed. *Reservoir Fishing Management in Asia.* Ottawa: International Development Research Centre. pp. 111–118; footnote 54.

G. Khimti Hydropower Project

79. Khimti Hydropower Plant has more than 11 km waterways with a low diversion overflow weir, desanding chambers, a 7,620 m long headrace tunnel, penstock, and an underground powerhouse. Water after generation is discharged to Tamakoshi River by a 1,418 m free-flow tailrace tunnel. The project conducts awareness programs against destructive fishing. No particular measures are adopted for fish conservation.

80. Proposed mitigation measures for the impact of dams across rivers and their implementation status in Nepalese hydropower projects are presented in Table 10.

Table 10: Mitigation Measures in Various Hydropower and Irrigation Projects

Number	Name of Project	Mitigation Measures Proposed in EMP	Current Status	Remarks
1	Kali Gandaki A HP	1. Trapping and hauling 2. Fish hatchery 3. Minimal downstream flow (4 m^3/s) 4. Trash rack 5. Fish funnel for giving passage to fish for D/S movement	• Environment flow in place, although requires better monitoring and compliance. • Fish hatchery: five species are being bred and five others are in preliminary observation. • NEA has gradually curtailed budget to run the hatchery. Required budget needs to be allocated for operation of hatchery.	Reduction in populations/ diversity of mainly migratory fish
2	Middle Marshyangdi HP	1. Fish hatchery 2. Minimal flow (1 m^3/s) 3. Entrainment	• Compliance for releasing environmental flow needs to be improved. • Fish fingerlings hatched in Kali Gandaki A Hydropower Project are annually released in the reservoir and river.	Stocking of 50,000 fish fry produced at Kali Gandaki fish hatchery
3	Babai Irrigation Project	-	• Fish ladder in operation • Water release (1 m^3/s) for D/S environmental flow during dry season	Last three pools of fish ladder are silted. They require cleaning and proper maintenance.
4	Kulekhani I HP	-	Cage culture in the reservoir is promoted among fishers for commercial raising of fish.	Downstream is usually dry except during flooding period.
5	Tinau HP	-	No fish passage facility.	
6	Trishuli HP	-	Government research center provided water from conveyance system to raise Snow Trout.	

Number	Name of Project	Mitigation Measures Proposed in EMP	Current Status	Remarks
7	Sikta Irrigation Project (under construction)	EIA conducted	Fish ladder is provided.	Location of fish ladder could have been at a better place.
8	Phewa Hydro/Irrigation Project	-	Stocking of fish fry of *Aristichthys nobilis* (Bighead Carp) and *Hypophthalmichthys molitrix* (Silver Carp) annually.	
9	Tanahu HP	EIA and supplementary EIA completed. 1. Fish hatchery 2. Minimal environmental flow (2.4 m^3/s) 3. Trash rack 4. Fish habitat management program 5. Trapping and hauling		-
10	Khimti HP	1. Low weir does not require fish ladder 2. Stocking of important species		
11	West Seti HP (proposed, storage)	Planning stage		
12	Dudh Koshi HP (proposed, storage)	EIA study ongoing		
13	Upper Karnali HP (proposed)	Proposed		

D/S = downstream, EIA = environmental impact assessment, EMP = environmental management plan, HP = Hydropower Project, m^3/s = cubic meter per second, NEA = Nepal Electricity Authority.

Source: Field survey and observation during the study.

9 | Fish Species Recorded in the International Union for Conservation of Nature Red List

81. The study assessed fish faunal diversity in 13 hydropower and irrigation projects with dam to search for the presence of species listed in the IUCN Red List. Among the 13 projects, the KGHP hosts the greatest number of IUCN Red List species (eight) and Tinau has the lowest with three IUCN Red List species. Among the 21 IUCN Red List species, *Tor putitora* (endangered) and *Neolissochilus hexagonolepis* (near threatened) were recorded in all 13 project sites, showing their existence in most of the river systems in Nepal. *Tor tor* was recorded in 11 project sites. *Ailia coila, Balitora brucei*, and *Chitala chitala* were observed in only one project site. This shows their relative rarity in Nepalese river systems. The presence of species in the 13 dam sites is presented in Table 11.

82. Comparison of the 13 dams shows that all rivers are inhabited by *Tor putitora, Tor tor, Bagarius bagarius, Clupisoma gaura,* and *Anguilla bengalensis*. These species are recognized as long-distance migratory fish. Similarly, several short-distance species such as *Schizothorax richardsonii, Puntius chelynoides*, and *Neolissochilus hexagonolepis* were recorded in most of the rivers. Among these, *Schizothorax richardsonii* is vulnerable. Different studies and field observation have clearly indicated that fish population is adversely affected by the formation of dams. However, in the absence of credible baseline data, it is not possible to quantify the reduction rate and percentage. It should also be taken into consideration that population depletion is not solely caused by the dam. Other abiotic and biotic factors also play vital roles in population decline. The status of migratory fish due to dams in different rivers is presented in Table 12.

Table 11: Presence of International Union for Conservation of Nature Red List Fish Species in Rivers with Hydropower and Irrigation Projects (after Construction)

IUCN Red-listed Species	IUCN Category	Important Dam Projects												
		Kali Gandaki A HP	Middle Marshyangdi HP	Kulekhani – I HP	Babai Irrigation project HP	Tinau HP	Trishuli Hydro-power	Sikta irrigation project	Phewa Hydro/ Irrigation project	Tanahu HP	Khimti HP[b]	West Seti HP[b]	Upper Karnali HP[b]	No. of Dams
Glyptothorax kashmirensis	Critically endangered													
Schizothorax nepalensis	Critically endangered	Kali												
Schizothorax raraensis	Critically endangered													
Tor putitora	Endangered	+	+		+	+	+	+	+	+	+	+	+	11
Physoschistura elongate	Vulnerable													
Puntius chilinoides (Naziritor chelynoids)	Vulnerable	+	+	+							+	+	+	6
Schistura prashadi	Vulnerable													
Schizothorax richardsonii	Vulnerable	+	+	+			+		+	+	+		+	8
Ailia coila	Near threatened				+									1
Bagarius bagarius	Near threatened				+		+			+	+	+	+	6
Bagarius yarrelli	Near threatened	+												1
Balitora brucei	Near threatened	+												1
Chitala chitala	Near threatened							+						1
Ctenops nobilis	Near threatened													
Garra rupecula	Near threatened													
Labeo pangusia	Near threatened	+			+					+		+		4
Neolissochilus hexagonolepis	Near threatened	+	+	+	+	+	+		+	+	+	+	+	11
Ompok bimaculatus	Near threatened							+				+		2
Ompok pabda	Near threatened													
Tor tor	Near threatened		+	+ [a]	+	+	+	+	+	+	+		+	10
Wallago attu	Near threatened	+			+			+						3
		8	5	4	7	3	5	5	4	6	6	6	6	

HP = Hydropower Project, IUCN = International Union for Conservation of Nature.

Note: Total of 12 species are recorded from 13 different project locations

[a] Introduced species.

[b] Proposed.

Sources: J. Shrestha. 1999. Cold water fisheries of Nepal. FAO *Technical Paper No. 385*.; J. Shrestha and D.B. Swar. 1998. *EIA of Tamor Hydropower Project*. NEA.; J Shrestha. 1998. *Aquatic habitat and natural water fish and fisheries inn Nepal*. Kathmandu; and footnotes 27, 39, 47, 49, and 56.

Table 12: Migratory Fish Species Recorded from Different Dam Sites (in Operation)

Name of the Project	District	River	Fish Species: Short Distance	Fish Species: Long Distance	Total Number of Species Recorded	Impact
Kali Gandaki A HP	Syangja	Kali Gandaki	*Amphipnous cuchia, Chagunius chagunio, Labeo angra, Labeo dero, Labeo pangusia, N. hexagonolepis, Puntius chilinoides*	*Tor tor, Tor putitora, Bagarius yarrelli, Clupisoma gaura*	57	Reduction in catch per unit effort
Middle Marshyangdi HP	Lamjung	Marshyangdi	*Neolissochilus hexagonolepis, Schizothoraichthys progastus, Schizothorax richardsonii, Schizothorax plagiostomus*	Tor putitora, Clupisoma gaura, Anguilla bengalensis	30	Reduction of Tor sp.
Kulekhani I HP	Makawanpur	Kulekhani	*Puntius chilinoides, Neolissochilus hexagonolepis, Schizothorax richardsonii*	*Tor putitora, Tor tor*	20	Drastic decline of indigenous species such as *Schizothorax* sp., *Puntius* sp., *Garra lamta*, etc.
Babai Irrigation Project	Bardiya	Babai	*Labeo angra, Labeo dero, Labeo pangusia, Labeo boga*	*Tor tor, Tor putitora, Bagarius bagarius*	33	Reduction in fish population
Tinau HP	Rupandehi	Tinau	*Labeo dero, Neolissochilus hexagonolepis*	*Tor putitora, Tor tor*	17	Impact on fish diversity is seen mainly above the dam
Trishuli HP	Nuwakot	Trishuli	*Schizothorax plagiostomus, Schizothorax richardsonii, Schizothoraichthys progastus, Neolissochilus hexagonolepis, Labeo dero*	*Tor putitora, Tor tor, Bagarius bagarius, Anguilla bengalensis, Clupisoma gaura*	28	
Sikta Irrigation Project (under construction)	Banke	Rapti	*Labeo dero, Labeo pangusia, Labeo rohita*	*Anguilla bengalensis, Tor putitora, Tor tor*	35	

continued on next page

Table 12 continued

Name of the Project	District	River	Fish Species: Short Distance	Fish Species: Long Distance	Total Number of Species Recorded	Impact
Phewa Hydro/ irrigation Project	Kaski	Phewa lake	*Neolissochilus hexagonolepis, Labeo angra, Labeo rohita, Schizothorax richardsonii*	*Tor tor, Tor putitora, Anguilla bengalensis*	25	Reduction of indigenous species due to introduction of alien species like tilapia and catfish (such as Clarius garipinus, African catfish)
Tanahu HP	Tanahu	East Seti	*Neolissochilus hexagonolepis, Labeo pangusia*	*Bagarius bagarius, Tor putitora, Tor tor*	18	
Khimti HP	Dolakha/ Ramechhap	Khimti Khola	*Neolissochilus hexagonolepis, Schizothorax richardsonii, Schizothoraichthys progastus, Schizothorax plagiostomus, Labeo angra, Labeo dero*	*Anguilla bengalensis, Tor tor, Tor putitora, Clupisoma gaura, Bagarius bagarius*	45	
West Seti						
HP	Doti	Seti	*Schizothorax plagiostomus, Schizothoraichthys progastus, Neolissochilus hexagonolepis, Labeo pangusia*	*Tor putitora, Ompuk bimaculatus, Anguilla bengalensis*	13	
Upper Karnali HP	Surkhet, Dailekh, Achham	Karnali	*Xenentodon cancila, Schizothorax plagiostomus, S. richardsonii, S. progastus, Neolissochilus hexagonolepis, Barilius vagra, Puntius chelynoides*	*Anguilla bengalensis, Bagarius bagarius, Clupisoma gaura, Pseudeutropius antherinids, Tor tor, Tor putitora*	48	

Sources: Environmental Impact Assessment report of Middle Marshyangdi; S.R. Gubhaju. 2002. Impact of Damming on Aquatic Fauna in Nepalese Rivers. In T. Petr and D.B. Swar, eds. Cold Water Fisheries in the Trans-Himalayan Countries. *Food and Agriculture Organization* (FAO) *Fisheries Technical Paper*. No. 431. Rome: FAO. pp. 376; H. Hall, A. Courage, M. Allen, J. Cave, and P. Rai. 2001. *Babai Fish and Biodiversity Project Report*. Regent's Park, London: Zoological Society of London. pp. 56; B.R. Jha, H. Waidbacher, S. Sharma, M. Straif. 2006. Fish Species Composition, Number and Abundance in Different Rivers and Seasons in Nepal and the Reevaluation of Their Threat Category for Effective Conservation and Management. *Ecology Environment & Conservation*. 12(1). pp. 25–36; J. Shrestha and R. Chaudhari. 2004. Fish Diversity in Kali Gandaki River before and after the project construction. In A.K. Rai and A.P. Nepal, eds. *Proceeding of Workshop on Hydropower Dams: Impact on fish Biodiversity and Mitigation Approaches*. Nepal: Nepal Agricultural Research Council, Fisheries Research Division. pp. 20–31.

10 | Environmental Flow and Fish Passage

A. Maintenance of Environmental Flow

83. Minimum water discharge from dams as environmental flow is necessary to sustain aquatic flora and fauna in the dry stretch at the downstream of dam. The requirement of the minimum flow depends on the species inhabiting the river. Many hydropower projects in Nepal have committed to releasing minimum downstream discharge that varies from 0.5 to 15 cubic meters per second (m^3/s). The Hydro Power Development Policy of Nepal recommends to release a minimum of 10% river flow downstream of the dam as environmental flow (e-flow) at all times of the year, although this is a basic approach. E-flow should be determined by scientific studies depending on the type of fish, local ecosystem, and river gradient. While 10% is a useful starting point, calculations may show more needed, which should be done through an EIA. Hydropower plants generally tend to divert all available water for power generation, particularly during the lean season. Such practice is ongoing unabated in the absence of regular monitoring and enforcement by the government.

B. Fish Passage

84. Fish passages are an important means of addressing part of the detrimental effects of obstruction created by dams. It is not necessary that all fish passages are equally effective and utilized by all fish species.[57] Therefore, the suitability of a fish passage needs to be assessed for the fish species in the local context, particularly for critically endangered species. Design of the right type of fish passage requires sufficient knowledge of swimming behavior of the target fish species and their ability to negotiate the obstruction, which varies. Also, the passage structure should work throughout the year. There are hundreds of good examples of well-designed and effective fish passages. Gubhaju set the following criteria for an effective fish passage (footnote 27[i]):

(i) should meet the requirements of the species concerned;
(ii) could be pool type, rocky ramp type, or a vertical slot;
(iii) flow velocities must not exceed the swimming capacity of the concerned fish species;
(iv) should be used by all fish sizes—large and small; and
(v) should be provided with proper fencing, with total restriction on fishing from the passage area.

85. A fish passage needs to be tested for the known fish species' migratory behavior and monitored by fishery specialists. Efficiency of a fish passage should be regularly monitored and improved. A report by the Biodiversity and Nature Conservation Association mentioned that most of the existing fish passages in Nepal require modification to make them suitable for effective use by the native migratory fish species. As a result, valuable fish

[57] Studies have shown that concept of fish ladders, more appropriate for temperate species, does not apply in all cases. For example, in the Mekong River, fish ladders are not suitable since fish available are not jumping species, like the North American salmon.

stocks are being lost. Gubhaju noted that the design of fish passages at the Andhi Khola and Kankai Mai projects needs improvement (footnote 27[i]).

86. The efficiency of a fish passage is defined as the proportion of stock present in the river at the dam, which then enters and successfully moves through the fish passage in an acceptable period of time. Marking and telemetry are valuable techniques to assess the overall efficiency of fish passages and the cumulative effect of various dams along a migration path.

11 Fish Passages

A. Pool-Type Fish Passage or Fish Ladder

87. The pool-type fish passage is an old concept, wherein the height to be crossed by the fish is divided into several small drops, forming a series of pools. The passage of water from one pool to another is either by surface overflow, through one or more submerged orifices in the dividing wall separating two pools; or through one or more notches or slots. Often, hybrid pool passages with part of the flow through a notch, slot, or over the dividing wall in combination with submerged flow through an orifice are effective.[58] These are widely used mitigation measures, which offer resting areas for fish while passing from one pool to another. Pool length can vary from 0.50 m to more than 10 m, and water depth can vary from 0.50 m to more than 2 m. The discharge can vary from a few dozen liters per second to several m^3/s, and the slope can vary from more than 20% to less than 5%, frequently ranging from 10% to 12%.[59] The drop between pools varies from 0.10 m to more than 0.45 m according

Pool-type fish ladder. The pool-type fish passage is an old concept, wherein the height to be crossed by the fish is divided into several small drops and forms a series of pools (photo by the United States Army Corps of Engineers).

Typical example of fish ladder. If well-designed to different hydraulic criteria, a fish ladder provides passage for most fish species (photo by the Food and Agriculture Organization of the United Nations).

58 M. Larinier and G. Marmulla. 2004. Fish Passes: Types, Principles, and Geographical Distribution: An Overview. In R.L. Welcome and T. Petr, eds. Proceedings of the Second International Symposium on the Management of Large Rivers for Fisheries, Volume II. *Sustaining Livelihoods and Biodiversity in the New Millennium*. 11–14 February 2003. Phnom Penh.

59 (i) M. Larinier. 1998. Upstream and Downstream Fish Passage Experience in France. In M. Jungwirth, S. Schmutz, and S. Weiss, eds. *Fish Migration and Fish Bypasses*. Fishing News Books. Blackwell Science Ltd. Publisher; Bates. 1992; (ii) C.H. Clay. 1995. *Design of Fish Ways and other Fish Facilities*. 2nd edition. Boca Raton, Florida: CRC Press Publisher.

to the migratory species targeted (most frequently around 0.3 m). Experience shows that when pool-type fish passages are well-designed with respect to different hydraulic criteria, they allow passage for most fish species.[60] It is noted that the fish ladder is more suitable to jumping fish species, like the North American salmon, and does not apply to all types of fish. Hence, the relevance and value of the fish ladder for Nepalese fish species needs intensive study.

B. Denil Fish Passage

88. This type of pass is relatively selective depending on the fish species. It is suitable for salmon, sea-run trout, marine lamprey, and large rheophilic potamodromous species such as barbel.[61] There is no resting zone for fish in a Denil pass. The fish have to pass through the passage without stopping; hence, they have to make an exhaustive effort for a period, which may exceed the limit of their stamina. One or several resting pools could therefore be provided. Resting pools are recommended at 10–20 m intervals for adult salmon and at 6–8 m for smaller fish like brown trout or other adult potamodromous species (footnote 58).

Denil fish passage. This type of pass is relatively selective depending on the fish species because it has no resting zone (photo by the Food and Agriculture Organization of the United Nations).

89. Fish passes have been built at many dams and have been successful in allowing migrating stocks of various species to cross the dam. The correct choice of fish passage design is a critical factor (footnote 58). Early fish ladders built in Australia were of the pool-and-weir design used for salmonids in the Northern Hemisphere. These proved to be unsuccessful for the slow-swimming species present in Australian inland waters. In recent years, pool-and-weir ladders were replaced by vertical slot fish passes.[62] These are very successful and allow large numbers of migrating brood stock and juveniles access to upstream habitats.[63] A vertical-slot fish passage is similar to a pool-and-weir system, except that each "dam" has a narrow slot in it near the channel wall. This allows fish to swim upstream without leaping over an obstacle.

[60] F. Travade et al. 1998. Performance of Four Fish Pass Installations Recently Built in France. In M. Jungwirth, S. Schmitz, and S. Weiss , eds. *Fish Migration and Fish Bypasses*. Fishing News Books. Oxford, UK: Blackwell Science Ltd.

[61] Suitability of Danil fish passage for the fish found in Nepal needs to be studied before use.

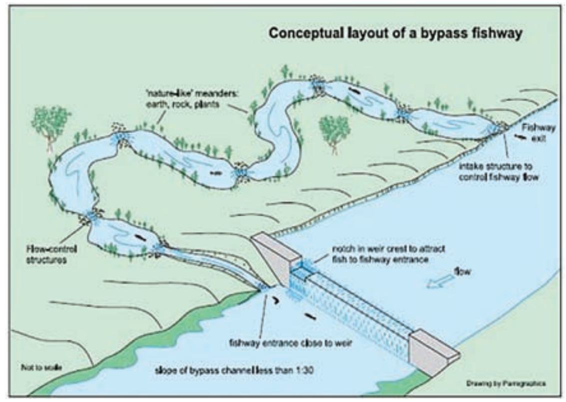
[62] J.H. Harris and M. Mallen-Coper. 1993. Fish-Passage Development in the Rehabilitation of Fisheries in Mainland South-eastern Australia. In I.G. Cowx, ed. *Rehabilitation of Inland Fisheries*. Oxford. Fishing News Books, Blackwell Science Ltd.

[63] M. Mallen–Cooper. 1997. Priority of Fish Ways in Semi-arid and Tropical Streams. In A. P. Berghuis, P. E. Long and I. G. Stuart, eds. *Second National Fishery Technical Workshop*. Rockhampton, Queensland, Australia: Fishery Group, Department of Primary Industries Publishers.

C. Bypass Channel

90. The nature-like bypass channel is a waterway designed for fish movement around a particular obstruction, creating the flowing water habitat lost due to blockage by a dam (Figure 7). These channels are characterized by low gradient. The energy is dissipated through a series of riffles or cascades positioned more or less regularly, similar to those in natural water courses.[64] Nature-like fish ways have proven effective for a wide range of fish species with varying swimming abilities. Gubhaju noted that more natural types of passes, for example rocky sumps or artificial rivers (bypass channels), can even enhance the beauty of the landscape.[65] Construction of a bypass channel, where applicable, along the entire dry stretch between an impoundment and power station can be a good solution to provide passage to all aquatic species, including fishes. The main disadvantage of such a channel is that it needs considerable space in the vicinity of the obstacle and cannot be adapted to significant variation in upstream level without special devices (gates, sluices). These control devices may cause hydraulic conditions that make fish passage difficult (footnote 58).

Figure 7: Conceptual Layout of a Bypass Fishway



Note: The channel provides natural passage to fish. However, they need protection against fishing.

Source: G. Thorncraft and J. H. Harris. 2000. *Fish Passage and Fishways in New South Wales: A Status Report*.

D. Fish Lock

91. A fish lock consists of a large holding chamber located at the downstream side of the dam linked to an upstream chamber at the fore bay level by a sloping or vertical shaft. Automated control gates are filled at the extremities of the upstream and downstream chamber (footnote 59[ii]). Fish are attracted into the downstream holding chambers, which is closed and filled along with the sloping shaft. Fish exit the upstream chamber through the opened gate. A downstream flow is established within the shaft through a bypass located in the downstream chamber to encourage fish to leave the lock.

E. Fish Lift

92. A fish lift can also be used to maintain longitudinal movement of migratory fish species. A mechanized lift provides passive migration of fish over dams to spawning areas. Fish swim into chambers at the base of the dam, guided by currents. The chambers are mechanically lifted up and over the dam, releasing fish in the upstream. The main advantages of a fish lift compared to other type of fish passages lie in its cost, which is practically independent of the height of the dam. Only little space is needed, and it has low sensitivity to variations in the upstream water level. The disadvantage lies in the higher operation and maintenance cost.

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64 R.J. Gebler. 1998. Examples of Near-natural Fish Passes in Germany: Drop Structure Conversions, Fish Ramps and Bypass Channels. In M. Jungwirth, S. Schmutz, and S. Weiss, eds. *Fish Migration and Fish Bypasses. Fishing News Books*. Blackwell Science Ltd. Publisher.

65 (i) DVWK (Deutscher Verband für Wasserwirtschaft und Kulturbau). 1996. Fischaufstiegsanlagen-Bemessung.Gestaltung, Funktionskontrolle. Merkblätter zur Wasserwirtschaft. Vol. 232: 110; (ii) footnote 58; (iii) footnote 27(i).

Ship lock concept for fish locks. Fish swim into the downstream holding chambers of fish locks, which is closed and filled along with the sloping shaft, and exit the upstream chamber through the opened gate (photos by Michael Spiller/Cmglee).

93. Lifts have been used to overcome high dams such as in the Susquehanna River and its tributaries in Pennsylvania, US (highest being 32 m). Another example is in the 30 feet dam in Connecticut River in Holyoke, Massachusetts (footnote 58). Fish are drawn into the lift system by an attraction water flow that the system gives off, which migrating fish instinctively seek out. Over 250,000 fish pass through the fishway each season before they are released to continue their journey upstream. In Nepal, fish lifts could be used in future hydropower and irrigation projects with high dams to assist fish in their upstream migration (footnote 27[i]).

12 Compensatory Measures

A. Fish Hatchery

94. Where the movement of migratory fish up and down the river is affected by a dam, fish hatcheries can be considered as an option. Fish hatcheries try to compensate for fish stocks affected by dams (footnote 30). A fish hatchery breeds and produces fingerlings for aquaculture activities as well as for economically important high-value native fish species to be stocked into the river for conservation. The fishers could be provided seed from the hatchery to grow fish in ponds or cages to marketable size, reducing the pressure on capture fisheries. Stocking the reservoir and tailwater will replenish the losses resulting from the disappearance of the natural spawning grounds and from secession of migrations (footnotes 30 and 36). Sturgeon populations in the Caspian Sea rely on hatcheries since a series of dams block natural spawning migrations. A similar case is the Three Gorges Hydropower Project in the People's Republic of China. A fish hatchery is also established near the KGHP in Nepal for artificial breeding and propagation of indigenous species in an effort to avoid extirpation of endangered and economically valuable fish species affected by the dam.

Fish hatchery of Kali Gandaki A Hydropower Project. Fish hatcheries try to compensate for fish stocks affected by dams (photo by D.B. Singh).

B. Catch and Haul Arrangement

95. Catch and haul is an alternative mitigation measure for maintaining fish populations in upstream reaches where the passage of fish is blocked by a dam. Trapping and transportation could be a more long-term measure in the case of dams where the construction of a pass would be difficult, or in the case of a series of dams where one dam is close to the next, thus creating a reach without valuable habitat for breeding. In this mechanism, a collection facility below the dam is developed to trap fish, which are later transported and released upstream to reach their feeding or breeding grounds. This method is labor intensive and stressful to fish, which may increase their mortality. Nevertheless, if handled properly, this is one of the effective measures for mitigating the barrier effect of dams and conserving important migratory fish species. Local fishers could be provided employment in catch and haul or operation of fish hatcheries.

C. Improvement of Spawning Ground (Incubation Channel)

96. Many fish species require clean flowing water with pebble, gravel, or stone beds for spawning or hiding from predators. Damming a river destroys such grounds either by complete desiccation or by scouring immediately downstream of the dams. Therefore, adequate attention must be given to the protection of the spawning and nursery grounds, including additional measures such as depositing gravel to maintain the spawning habitat. Placing shingle and large boulders on the bottom to create water pools could be considered (footnote 30). According to Shrestha, the provision of spawning and incubating channels would help maintain populations of *Tor* spp. (Mahseer), *Schizothorax* spp. (Snow Trout), *Labeo* spp. (Stone Carp), *Glyptothorax* spp., and *Glyptosternum blythii* (Torrent Catfish) (footnote 28).

D. Strengthen Monitoring and Enforcement by Mobilizing Local Community

97. Native fish are known to be disappearing at an alarming rate not only due to damming, but also due to over fishing, harmful and destructive fishing, destruction of habitats, and chemical and physical water pollution. Some unconventional and illegal fishing methods have emerged using explosives, electricity, and poison, which is destroying the aquatic life indiscriminately. Such fishing is carried out more for fun rather than for substance or commercial purposes. Since entire fish communities die due to destructive fishing, including the young juveniles, the fish population decreases significantly. Even birds consuming dead poisoned fish are found to be dying. Such practice could be controlled through generating awareness, strengthening monitoring, enforcement, and incentivizing community supporting in local level surveillance and controlling such practice. Local fishers communities or community based organizations could be engaged in such a program where they could be supported with some financial incentives in turn for protecting fish from harmful fishing methods. The incentive could be through various market based initiatives such as a protected stretch for game fishing, fishing tourism, and study and research spots. Local fishers could be provided employment to guard the river.

98. A summary of advantages and limitations of different mitigation measures is presented in Table 13.

Fish cannot be viewed like terrestrial wildlife. Hence, sport-fishing, or catch and release angling, where a fish is caught on a rod and line and released back into the water unharmed has emerged as a sustainable and popular recreational activity globally. Gamefish species are apex species, which indicate the overall health of the ecosystem, just like apex terrestrial species such as a tiger indicates the overall health of the ecosystem it lives in. Sport-fishing thus leads to conservation of aquatic ecosystems. The Golden Mahseer (*Tor putitora*) found in the waters of Nepal has been termed the "Tiger of the Water" by legendary conservationist Jim Corbett, and a leading fly-fishing magazine recently voted it the "most mystical fish to catch on a fly." Promoting sport-fishing in Nepal can thus ensure the conservation of life below water in the Himalayas. Simultaneously, the angling business can provide much-needed employment opportunities to local communities as angling guides, and through many other services anglers demand.

Game fishing in Mahakali River. Releasing the catch (photo by Arun Rana).

Table 13: Advantages and Limitations of Different Mitigation Measures

Measures	Advantages	Limitations	Remarks
Pool-type fish passage	• The height that has to be crossed by fish is divided into several small drops forming a series of pools. • It provides resting zone for fish and ensures adequate energy dissipation of water. • The entire water column is available. This accommodates a wider variety of species of both surface and bottom movers.	• It requires more water to operate. • Regular cleaning is required to avoid blockage of the passage.	• Should be located in the appropriate position • Suitable for small and medium-sized streams with dam height less than 10 meters
Denil fish passage	• It can be prefabricated, making it more economical to install. • This type of installation causes less site disturbance.	• There is no resting zone for fish; they must pass without stopping. • Only stronger species can swim up. Many species and weak swimmers cannot ascend the ladder and lose access to upstream habitat.	• It can be improved by creating larger pools to break water current and giving fish a resting place.
Natural-like bypass channel	• All aquatic species, including fish, can use this channel. • It enhances the beauty of the landscape. • It provides natural environment.	• The main disadvantage of such channel is that it needs considerable space in the vicinity of the obstacle. • It cannot be adapted to significant variation in upstream level without special devices (gates, sluices). These control devices may cause hydraulic conditions that make fish passage difficult.	• The fish entrance to the artificial river should be located as close to the obstruction as possible. • It is effective only in low slope.
Collection and transport facilities	• The technique is often used as a transitory measure before fish passage in dam is constructed or another measure for fish passage is implemented. • It is useful where the construction of a pass would be difficult or in the case of a series of dams where one dam is close to the next. • Local human resources can be used.	• Method is labor intensive • Stressful to fish, which increases their mortality • May encourage poaching	• Careful handling of fish is required to avoid fish injury. • Close observation is required.

Measures	Advantages	Limitations	Remarks
Fish lift	• Construction cost is practically independent of the height of the dam. • Little space needed to install • Low sensitivity to variations in the upstream water level	• The main disadvantage lies in the higher cost of operation and maintenance. • The efficiency of lifts for small individuals is generally low because sufficiently fine screens cannot be used for technical reasons.	• Effective for high dams • Expensive very small passage rate
Fish hatchery	• Indigenous and vulnerable species with declining populations can be bred and stocked for conservation • Provides seed to farmers for fish culture	• Practically not possible to produce all important species • High development and operation cost • Risk of introduction of parasites • Problems with genetics, including selection for adaptation to hatcheries, inbreeding, loss of alleles, founder effect, etc.	• Breeding techniques of indigenous species should be developed

Source: Summary of the details discussed in above sections.

13 | Aquatic Biodiversity Screening Framework (Fish)

99. Impact prediction refers to the analysis of the condition of an existing baseline as a result of potential impacts in future. The study suggests a "Fish Screening Framework" to predict the potential impact of a project on aquatic biodiversity. The impacts are assessed based on three categories: (i) magnitude and sensitivity, (ii) extent, and (iii) duration. The system of rating and ranking of the significance of impact depends upon the findings of due diligence of the waterbodies within a project area, including field study, consultation with local fishers, subject matter experts and study of existing literature.

A. Magnitude of Impact

100. The magnitude of impact is defined by the severity of each potential impact and indicates magnitude of impact before mitigation measures are applied and the estimated potential rate of recovery after mitigation measures are applied. The magnitude of impact is expressed in a scale of high, medium, or low. The numerical value for each indicator is assigned depending on the weightage of impact. Magnitude contributes a major percentage (40%) of the overall weightage distribution for impacts.

B. Extent of Impact

101. The extent of an impact is determined on the basis of spatial extent or the zone of influence. The extent of impact is categorized as site-specific, local, or regional. The site-specific, local, and regional impact influence project area, watershed area, and the region, respectively. Extent contributes 25% of the total score for assessing the impact.

C. Duration of Impact

102. Environmental impacts have a temporal dimension. An impact that generally lasts for only 3–5 years after project operation may be classified as short-term impacts. Impacts that continue for 5–10 years are considered as medium-term, and impacts that last beyond 10 years are considered as long-term. Duration contributes 35% to the total score for assessing impact. The proposed numerical values to rate and rank the impact are presented in Table 14.

Table 14: Proposed Score of Impact

Magnitude	Extent	Duration
Low – 10	Site specific – 10	Short term – 10
Medium – 20	Local – 30	Medium term – 30
High – 70	Regional – 60	Long term – 60

Source: Authors.

D. Rating and Ranking of Impact

103. The impact of a dam on each indicator should be evaluated against magnitude, extent, and duration by assigning a numerical score as shown in Annex 15. The total numerical values should be summed up in which the maximum value is 64 and the minimum value is 10. The level of impact according to the total score for a project is explained in Table 15.

Table 15: Proposed Level of Impact Based on the Total Score

Score	Level of Impact	Action
Total Score >45	High*scale impact	• In-depth ecosystem-based research and field investigation • Study food and reproductive cycle of fish species, particularly the vulnerable and endangered species • Conduct sensitivity analysis and recommend applicable mitigation measures
Total Score 25–45	Medium*scale impact	• Wider study of ecosystem, fish species, and movement pattern • Conduct sensitivity analysis and recommend appropriate mitigation measures
Total Score <25	Low*scale impact	• Apply typical mitigation measures

Source: Authors' proposed scoring.

104. Appropriate mitigation measures should be recommended according to the findings from the action. Some typical mitigation measures are suggested in Table 16.

Table 16: Typical Mitigation Measures for Different Levels of Impact

Impact Category	Typical Mitigation Measures to Be Considered
High	Following measures should be considered for high impact category projects: • Assess mitigation and compensatory measures such as establishing fish passageway/fish ladder and fish hatchery; arranging routine fish catch and haul program; and improving spawning ground • Test water quality once a month • Estimate sufficient environment flow to be mandatorily maintained at all times of the year • Plan continuous monitoring of fish population and take corrective measures as and when required • Restrict fishing in sensitive habitats • Set up special institutional unit to monitor and manage protection and conservation of fish species at project level • Maintain and monitor environment flow downstream of dam • Assist government to declare certain tributaries as aquatic biodiversity protected areas and do not allow any dam or diversion of water from the protected river • Support local administration to strictly restrict destructive fishing

continued on next page

Table 16 *continued*

Impact Category	Typical Mitigation Measures to Be Considered
Medium	Following measures should be considered for medium impact category projects: • Assess construction of fish hatchery • Release fish fingerlings on a routine basis • Catch and haul • Do not disturb spawning ground in the river • Monitor water quality at least once a year • Consult with local fishers on any visible effect on species and population of fish and document the information
Low	Following measures should be considered for low impact category projects: • Take measures preventing pollution of water bodies • Restrict fishing at sensitive areas • Restrict destructive fishing and provide monitoring by an enforcement office

Source: Authors' proposal.

14 Conclusion and Recommendations

A. Conclusion

105. The rivers of Nepal are a significant habitat of many resident and short- to long-distance migratory fish species. Some species live within short stretches of river, while others are believed to travel along the Ganges to the Bay of Bengal for spawning and swim back to the river basins in Nepal with their juveniles to complete their reproductive cycle. Dams create barriers that restrict such movement and, in many cases, threaten species' survival.

106 The IUCN Red List for fish fauna in Nepal includes 21 rare and endangered fish species. A brief study of fish at 13 hydropower and irrigation dam sites in the country conducted as part of this research indicated that some of these protected fish species are present in strong numbers. They include *Tor putitora* and *Tor tor* (recorded in the Red List as endangered) and *Neolissochilus hexagonolepis* (recorded as near threatened). These species were found at all 13 project sites, indicating their existence in most of the river systems of Nepal even after dam construction. However, the fish species *Ailia coila, Balitora brucei,* and *Chitala chitala* were found in only one project area, which indicates their relative rarity. This suggests broader research is needed on the availability of fish species and their life-cycle behavior in the rivers of Nepal.

107. Past studies and the findings presented here clearly indicate that the fish population is adversely affected by the blockage of their movement in river systems that arises from dams. Insufficient credible research and baseline information are available to quantify the significance of this impact, the rate of population decline, or life-cycle movement routes for food, spawning, rearing, and survival. Nevertheless, various studies have proven that the fish population is in alarming decline because of the cumulative impacts of restricted passage due to dam construction, the creation of dry stretches below dams, illegal and destructive fishing, habitat destruction, and water pollution from agriculture and industry. The situation has been worsened by the lack of sufficient legal provisions for the protection and governance of aquatic biodiversity, of a designated agency to manage them, and of a proper protection, monitoring, and enforcement mechanism.

108. This study of selected hydropower and irrigation dam projects attempted to predict the type and significance of their potential adverse impacts on the river ecosystem and fish survival. It also assessed the results of mitigation measures adopted to protect fish, such as the construction of fish ladders, and evaluated their effectiveness and efficiency. The findings suggest that environmental management plans for the protection of aquatic life were weakly implemented or ignored, and that fish ladders constructed in a few projects were poorly maintained and not functioning well. The study drew on good practices and successful examples in other countries to recommend ways of strengthening the protection of fish in project design and implementation.

109. The study noted that projects generally do not use any tool to gauge their potential impact on aquatic biodiversity. Hence, an "Aquatic Biodiversity Screening Framework" is proposed, to be applied during the project feasibility study stage as part of the environmental assessment. This recommends mitigation measures to protect aquatic life, particularly fish, according to the likely level of impact. The study also proposes the formation of a National Aquatic Biodiversity Subcommittee (NABSC) as a focal agency under the Ministry of Forests and Environment. The key responsibility of the subcommittee would be to formulate national policy and legal provisions for the protection of aquatic biodiversity, act as an oversight agency to encourage monitoring and enforcement by competent government agencies, and report on national aquatic biodiversity issues to the Ministry of Forests and Environment. The NABSC should promote close coordination on joint studies and conservation efforts to protect aquatic life in the interconnected river basins of Bangladesh, India, and Nepal.

B. Recommendations

110. This brief and rapid study, although not authoritative, recommends the following measures to protect aquatic biodiversity, particularly fish, while developing and implementing water resource development projects in the rivers of Nepal:

Policy and Legal Provisions

- Recognize the inland open natural water bodies as the primary source and abode of aquatic biodiversity, including indigenous fish stocks. Promote conservation of aquatic biodiversity to maintain indigenous fish populations and enhance the productive and regenerative capacity of water bodies.
- Update the National Wetland Policy, 2012.
- Update the old national policy, act, and regulation for the protection of aquatic animals based on national and regional experience and new technological developments in enforcing aquatic biodiversity conservation.
- Integrate environmental safeguards including the study and conservation of aquatic biodiversity requirements in the water resources policy, program, and master plans (such as irrigation and hydropower development).
- Make policy and legal provisions that encourage stronger community participation in the conservation of aquatic ecology and fisheries, and in turn receive financial benefits through the sustainable utilization of natural resources.
- Review government decisions taken during crisis situations, as these may not have been environment-friendly or supportive of the sustainable development agenda. One such decision is the waiver of EIA requirements for hydropower projects of up to 50 MW capacity during an energy crisis in Nepal). Implementing hydropower projects without sufficient environmental studies and management plans could have disastrous consequences for the aquatic ecosystem.
- Make it mandatory for all water resources projects to conduct a basin-wide cumulative impact assessment on aquatic biodiversity during environmental assessment. This shall decide the type, size and location of the dam; the measures to mitigate any barrier to fish movement; and possible tributaries that could serve as safe havens for fish.
- Consider linking the proposed "Aquatic Biodiversity Screening Framework" with the environmental protection regulations of the government and the rapid environmental assessment checklist of ADB as a screening tool, and make it mandatory during the environmental categorization of development projects.

Institutional Arrangements

- The lack of a dedicated government agency to plan, monitor, and enforce the control mechanism for the protection of aquatic biodiversity has enabled project developers to get away with non-compliance, damaging aquatic ecosystems and biodiversity. The study recommends the formation of a National Aquatic Biodiversity Subcommittee—under the framework of the National Biodiversity Conservation Committee—to support the government in updating the national policy, act, and regulations; integrating environmental perspectives in project design; and independently monitoring the compliance of projects, both during construction and operation.[66] NABSC would be the main institutional entity for the coordination and monitoring of aquatic biodiversity-related programs at the national and regional levels. The subcommittee shall be headed by the coordinator of the Wetland Thematic Subcommittee (as proposed by the Ministry of Forests and Soil Conservation was old name. Now the Ministry of Forests and Environment in 2014). The subcommittee shall be represented by the government, academia, independent experts, development partners, and international and nongovernmental organizations. The recommended composition of the nine-member NABSC is presented in Table 17.

Table 17: Proposed Composition of National Aquatic Biodiversity Subcommittee

Serial No.	Designation and Organization	Position in NABSC
1	Coordinator, Wetland Thematic Subcommittee, Ministry of Forest and Environment	Chairperson
2	Representative, Ministry of Home Affairs	Member
3	Representative, Department of Electricity Development	Member
4	Representative, Department of Water Resources and Irrigation	Member
5	Representative, Nepal Electricity Authority	Member
6	Representative, Ministry of Federal Affairs and General Administration	Member
7	Chief, Center for Aquaculture Promotion and Aquatic Life Conservation, Department of Livestock Services, Ministry of Agriculture and Livestock Development	Member Secretary
8	Two individual fish biodiversity experts	Member

NABSC = proposed National Aquatic Biodiversity Subcommittee.

Source: Government of Nepal, Ministry of Forest and Soil Conservation. 2014. *Nepal Biodiversity Strategy and Action Plan 2014-2020*. Kathmandu.

- The NABSC should map the migratory routes of fish in the interconnected river basins of Ganges in Bangladesh, India, and Nepal. An effective regional cooperation mechanism should be established to implement a joint conservation program for the rare and endangered aquatic fauna.

National Plan and Strategy

- Study, prepare the inventory, and develop an integrated conservation management plan for the safety of endemic fish in the rivers of Nepal.
- Conduct a strategic environmental assessment (SEA) of the national hydropower and irrigation policies and master plans. The SEA shall assess potential cumulative impacts of integrated water use; it shall identify potential locations for dam construction on rivers to avoid, minimize or compensate adverse environmental impacts on aquatic biodiversity, particularly on migratory fish species. The location of

[66] Government of Nepal, Ministry of Forests and Soil Conservation. 2014. *National Biodiversity Strategy and Action Plan*. Kathmandu.

dams shall be determined by an ecosystem-based approach by considering connectivity, hydrology, and geomorphology governed by precautionary principles. Dams shall be allowed only in rivers with complete baseline information on their aquatic ecosystem and with minimal irreversible impacts.

- The SEA shall identify key river stretches and their tributaries with high aquatic biodiversity value; a plan should be developed to maintain unhindered north–south biological connectivity between the tributaries of major river basins. Artificial barriers like dams and barrages shall be allowed only at designated locations to minimize the impacts of restrictions to the migratory movement of fish.
- The SEA shall declare important river stretches and tributaries as aquatic life conservation areas for sustaining the dwindling populations of fish, particularly the rare and endangered aquatic species. Damming, fishing, or any activity harmful to aquatic life shall be restricted in the designated aquatic life conservation areas.
- Develop and implement in situ and ex situ conservation plans for threatened and economically valuable fish species like *Tor* sp. (Mahseer). Mobilize watch groups to restrict illegal fishing and destructive mining in biologically important rivers.
- Enforce strict compliance with the provision in the hydropower master plan for the mandatory release of at least 10% water flow in rivers at all times; this maintains the natural environment that is crucial to the survival of aquatic animals, although the percentage also depends on the type of ecosystem and the local fish species.
- Assess the feasibility of stocking suitable native fish in the rivers for enhancement of fish production, and if possible initiate this process.
- Formulate a plan for regulating the introduction of fish and avoiding expansion of invasive alien species of aquatic fauna. Import and release of alien species like tilapia, rainbow trout, and brown trout shall be regulated and their proliferation controlled.
- Develop a pollution control strategy and action plan to enforce restrictions on the direct discharge of untreated urban wastewater, sewage, and industrial effluents in water bodies.
- Restrict the overdosage of harmful toxic chemicals in farms and agricultural runoff into rivers through regulation, monitoring, and interagency cooperation.
- Prepare a plan to educate local people, fishers, and children on the importance of protecting aquatic life.

Technology

- Research and prepare typical designs for the construction of fish passes—design of which requires a mulitdisciplinary approach—suitable in the context of Nepal. Policy makers, engineers, biologists, and construction managers must work together. Technologically improved and internationally tested practices and techniques for different fish passes across various types of dams and fish species are readily available as reference from countries like Australia, France, Germany, Japan, and the US. The People's Republic of China and India—and many others in Southeast Asia—could also have suitable and successful designs of fish pass.
- Existing tools could be used for the planning and design of individual dams, such as the Hydropower Sustainable Assessment Protocol which is promoted by the International Hydropower Association. Similarly, the Mekong River Commission has prepared a Rapid Basin-wide Hydropower Sustainability Assessment Tool, which could be a good reference while planning hydropower and irrigation system in Nepal.[67]

[67] Mekong River Commission Secretariat. 2010. The Basin-Wide Hydropower Sustainability Assessment Tool.

Governance

- Develop and implement an effective mechanism to control unplanned and destructive mining of gravel and sand from aquatic biodiversity-rich rivers and water bodies, which damage the fish habitat. Permission, monitoring, and enforcement from local bodies must be decisive in this regard.
- Strengthen monitoring for the strict implementation of regulations to control illegal and other destructive fishing activities in rivers. Mobilize the community (local fishers, ethnic communities, students, and community-based organizations) and form “fish guards” for guarding of rivers against destructive fishing. Regularly conduct public awareness program on the importance of protecting aquatic habitats.
- Local fishers, ethnic communities, and the communities displaced by construction of dams and reservoirs could be organized to act as active partners in the management and benefit-sharing of fisheries resources in the river.
- Promote “payment for ecosystem services" mechanism in selected watersheds to encourage local communities to protect aquatic biodiversity and receive recognition and financial benefits for their conservation efforts.

Mitigation Measures

- The EIA should investigate the significance of aquatic biodiversity in the given river basin, establish sound baseline data, assess the impacts of the project implementation, and recommend mitigation measures for protecting aquatic biodiversity. In this context, the proposed “Aquatic Biodiversity Screening Framework” could be applied (Annex 15).
- Entrapment of fish is a critical issue and provisions should be made to prevent it. Installation of appropriate screen and exclusion devices at the intake will divert the fish.[68]
- Water quality deteriorates with storage. Running water is necessary for maintaining downstream aquatic habitat. Artificial destratification is one of the effective measures to maintain the quality of water in a reservoir, which undergoes stratification. It requires a small amount of energy per unit volume to lift cooler bottom water to the surface of a stratified impoundment. This helps to mix water and to maintain uniform temperature and vertical distribution of dissolved oxygen (footnote 68).
- Trapping of fish downstream of a dam and transporting them to the reservoir or further upstream to maintain diversity is one of the effective methods to mitigate the barrier impact of a dam. While this could be a labor-intensive work, it could be offered as a source of job opportunities for fisher families (footnote 68).
- Some resident fish species such as the stone roller (*Garra gotyla*), stone loaches (*Nemacheilus beavani*), catfish (*Glyptothorax pectinopterus*), and murrel (*Corydoras punctatus*) utilize gravel bed areas for spawning. Spawning grounds could be established by depositing gravels, placing angular and large boulders to create pools for spawning and hiding from predators, and planting vegetation to increase shelter, shade, and drift food (footnote 68).
- Projects should establish a permanent environment monitoring unit, both during implementation and operation. This unit shall regularly examine the monthly limnological and biological data of the river and assess the population variation of fish species, and take timely corrective action to protect the aquatic biodiversity.

[68] Food and Agriculture Organization of the United Nations et al. 2002. *Fish Passes: Design, Dimensions and Monitoring.* Rome.

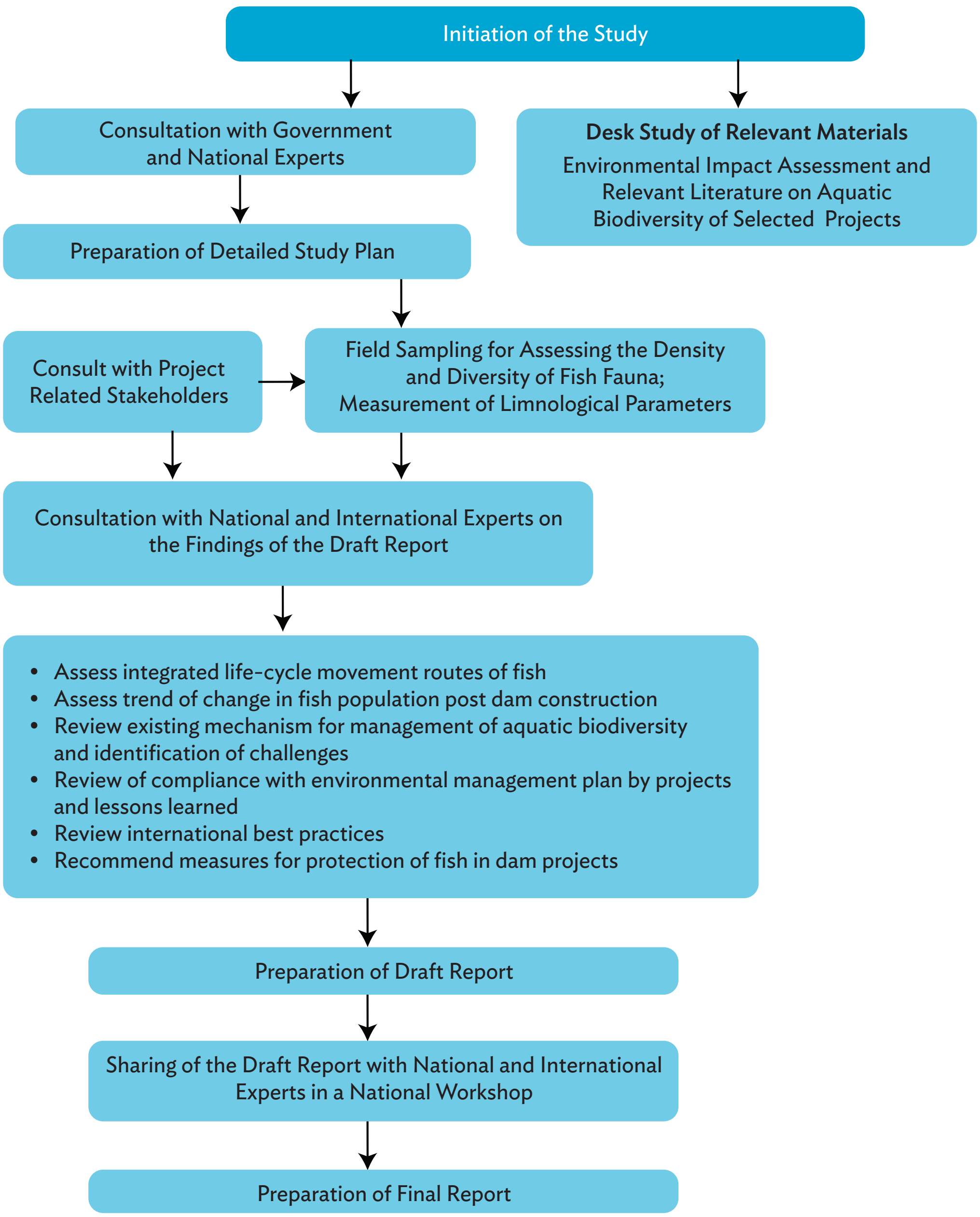
Research and Studies

- Conduct a national aquatic biodiversity study and prepare an inventory to establish a sound database of habitat, type of species, distribution, and linkages in a given river system in the varying ecological regimes between the Terai and the Himalayas.
- Form an environmental community of practice among government and development agencies, and meet regularly to share the work supporting environment protection, including aquatic biodiversity. This will avoid parallel efforts, share available baseline information, and provide an opportunity to synchronize efforts and resources among various agencies.
- Study and categorize the migratory fish species of Nepal (resident; short-, medium-, long-, and very long-distance) and their adaptation to changing environmental conditions (changes in feeding habits, breeding habits, growth, survival).
- Assess the efficiency of different fish passages for Nepal dams and formulate a guideline or manual describing the process of identifying and designing the right type of fish pass based on the type of river and fish species.
- Prepare detailed national and regional maps defining the migratory routes of various fish species along the rivers within and across international boundaries. This will support fish movement analysis and assessment of the impacts from the existing dams. Based on the findings, develop policy support for locating future dams, adopt corrective measures in the existing dams, develop alternative habitat conservation measures, and prepare technical guidelines for selecting the right type of mitigation measures.

ANNEX 1

Methodological Steps of the Study

The Study Procedure



ANNEX 2

List of Lakes in Nepal

District	Village Development Committee	Name of the Lake	Area
Ilam		Mai Pokhari	
Jhapa	Gaura Daha	Gaura Daha	6.5 ha
Jhapa	Kachana	Kachana Pokhari	
Taplejung	Taplejung	Suki Pokhari	
Taplejung	Taplejung	Panch Pokhari	
Taplejung	Taplejung	Lam Pokhari	
Taplejung	Taplejung	Teen Pokhari	
Sankhuwasabha		Nag Pokhari	
		Marg Pokhari	
		Banduke Pokhari	
		Jajala Pokhari	
		Sabha Pokhari	
		Bhut Pokhari	
		Rat Pokhari	
		Chirchiling Pokhari	
		Gupha Pokhari	
Sunsari			
Saptari	Sambhunath	Bhokhari Daha	8.0 ha
Rautahat	Gaur Municipality	Barahawa Tal	10.0 ha
Bara	Ratnapur	Halkhoria Daha	50.0 ha
Chitwan	Gitanagar	Bees Hazaar Tal	100.0 ha
	Sauraha	Nandan Tal	9.0 ha
	Kasarah	Devi Tal	11.1 ha
	Kasarah	Tamar	
	Kasarah	Lami Tal	
	Kasarah	Dhakre Tal	
	Kasarah	Kamal Tal	
	Kasarah	Munda Tal	
	Kasarah	Nanda–Bhauju Tal	
	Kasarah	Sapanabati Tal	

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Table *continued*

District	Village Development Committee	Name of the Lake	Area
	Kasarah	Simron Tal	
	Saradanagar	Rani Pokhari	
	Gunjanagar	Gobreni Ghol	
Kathmandu	Kirtipur Municipality	Tau Daha	
Lalitpur	Dhapakhel	Nag Daha	
Rasuwa		Gosai Kunda	
Manang		Tilicho Tal	Lake at highest elevation in the world. Located at altitude of 4,949 m in the Himalayas.
Gorkha		Dudh Tal	
Lamjung		Mai Tal	
Kaski	Pokhara Municipality	Phewa Tal	530.0 ha
	Pokhara Municipality	Kamal Pokhari	
	Lekhnath Municipality	Begnas Tal	
	Lekhnath Municipality	Rupa Tal	
	Lekhnath Municipality	Dipang Tal	
	Lekhnath Municipality	Khaste Tal	
	Lekhnath Municipality	Maidi Tal	
Mustang	Jhomsong	Dhumba Tal	9.0 ha
	Jhomsong	Pokal Tal	
	Upper Mustang	Damodar Kunda	Located at an altitude of 4,890 m
	Kunjo	Titi Tal	
	Kowang	Sekong Tal	
Palpa	Palpa municipality	Satyawati Tal	
Rupandehi	Gajedi	Matiyara Tal	7.0 ha
	Gajedi	Gajedi Tal	15.0 ha
	Gajedi	Lausa Tal	5.0 ha
	Khurda Bangar	Kharbalaha	5.0 ha
	Khurda Bangar	Amalahawa Tal	8.0 ha
	Dhamauli	Siktihawa Tal	22.0 ha
	Dhamauli	Padarhawa Tal	10.0 ha
	Bishunpura	Sagarahawa Tal	5.0 ha
	Suryapura	Gularia Tal	10.0 ha
	Suryapura	Gaindhawa Tal	50.0 ha
Kapilvastu	Bahadurganj	Lohraula Tal	5.5 ha
	Manpur	Sakhunia Tal	50.0 ha
	Buddhi	Buddhi Tal	50.0 ha

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Table *continued*

District	Village Development Committee	Name of the Lake	Area
	Agingara	Agingara Tal	25.0 ha
	Naglihawa	Lambu Sagar	10.0 ha
	Naglihawa	Naglihawa Tal	50. ha
	Naglihawa	Nigli Tal	
	Naglihawa	Purnihawa Tal	
	Naglihawa	Karmahawa Tal	
	Naglihawa	Mansarobar	
Surkhet		Bulbule Tal	
Banke	Khaskusma	Khasre Tal	7.0 ha
	Puraini	Kanti Pokhari	16.0 ha
Bardiya	Sorhawa	Badhaiya Tal	105.0 ha
	Dhodhari	Bhagairia	12.0 ha
	Tara Tar	Tara Tal	3.0 ha
Rukum		Syarpu Daha	
Jumla		Jogi Daha	
Dolpa		Phoksundo Tal	Deepest lake
Mugu		Rara Tal	
Achham (Bajura)		Khaptad Daha	
Kailali	Narayanpur	Ojhuwa Tal	9.0 ha
	Lalbhoji	Dudhwa Tal	5.0 ha
	Lalbhoji	Kasaiya Tal	8.0 ha
	Lalbhoji	Piparawa Tal	40.0 ha
	Khailad	Sonia Tal	40.0 ha
	Khailad	Ghor Tal	24.0 ha
	Khailad	Louka Bhouka Tal	30.0 ha
	Khailad	Rupia Tal	5.0 ha
	Chaumala	Badka Tal	6.0 ha
	Urma	Sahadev Tal	8.0 ha
	Urma	Mahadev Tal	50.0 ha
	Gadariya	Koilia Tal	5.0 ha
	Hasulia	Koilia Tal	30.0 ha
	Pawera	Sunhara Tal	5.0 ha
	Dhangadhi Municipality	Jugeda Tal	8.0 ha
	Lalbhoji	Larbarai Tal	6.0 ha
	Lalbhoji	Puraina Tal	60.0 ha
	Dhansinghpur	Gadbhijola Tal	300.0 ha
	Sadepani	Budi Nakhrodi Tal	6.0 ha
	Sadepani	Singrowa Tal	5.0 ha

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Table *continued*

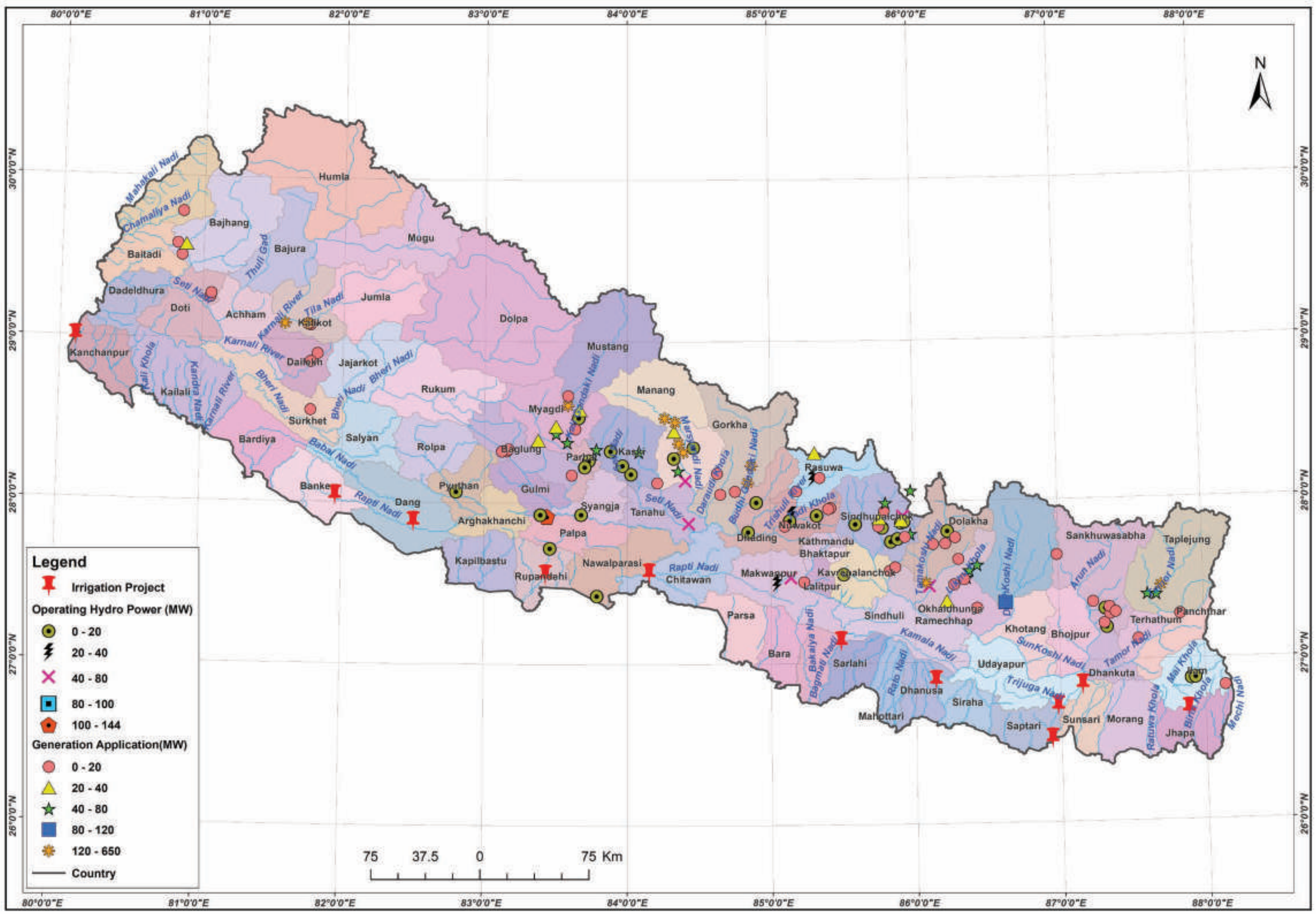
District	Village Development Committee	Name of the Lake	Area
	Sadepani	Nakhrodi Tal	70.0 ha
	Darakh	Bainshawa Tal	10.0 ha
	Darakh	Ojhuwa	6.0 ha
	Darakh	Chiraiyo Tal	8.0 ha
	Darakh	Ghodaghodi Tal	138.0 ha
Kanchanpur	Krishnapur	Titara Tal	10.0 ha
	Krishnapur	Padereni Tal	15.0 ha
	Krishnapur	Nun Khani Tal	6.0 ha
	Laxmipur	Banda Tal	45.0 ha
	Tribhuwan Basti	Sano Banda Tal	10.0 ha
	Tribhuwan Basti	Bichki Tal	4.0 ha
	Tribhuwan Basti	Aanp Tal	7.0 ha
	Kalika	Naini Tal	4.0 ha
	Shreepur	Tarbaria Tal	20.0 ha
	Parasan	Pipari Tal	24.0 ha
	Daiji	Bedkot Tal	5.0 ha
	Daiji	Peli Tal	5.0 ha
	Rauteli Bichawa	Gusta Tal	5.0 ha
	Rauteli Bichawa	Lalpani Tal	3.0 ha
	Shankarpur	Shova Tal	25.0 ha
	Shukla Phant Wildlife Reserve	Rani Tal	11.0 ha
	Shukla Phant Wildlife Reserve	Shikari Tal	3.0 ha
	Beldandi	Kaliktch Tal	10.0 ha
	Tarapur	Tara Tal	30.0 ha

ha = hectare, m = meter.

Source: Environment Statistics of Nepal, Central Bureau of Statistics 2013, Government of Nepal.

ANNEX 3

Location of Dams in Different Rivers in Nepal

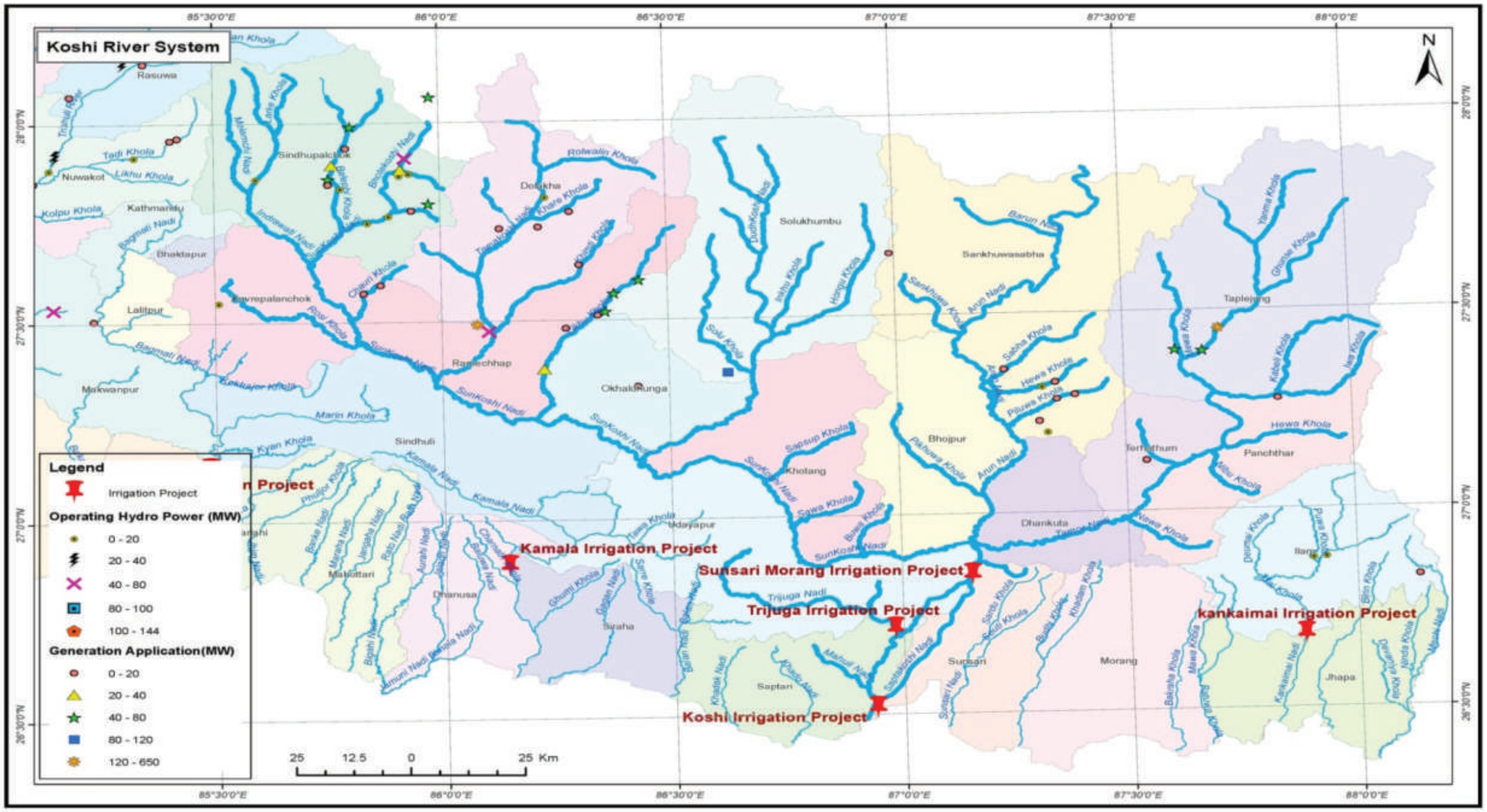


MW = megawatt.

Source: Department of Electricity Development, and Nepal Electricity Authority, Nepal.

ANNEX 4

Location of Dams in the Koshi River Watershed, Nepal

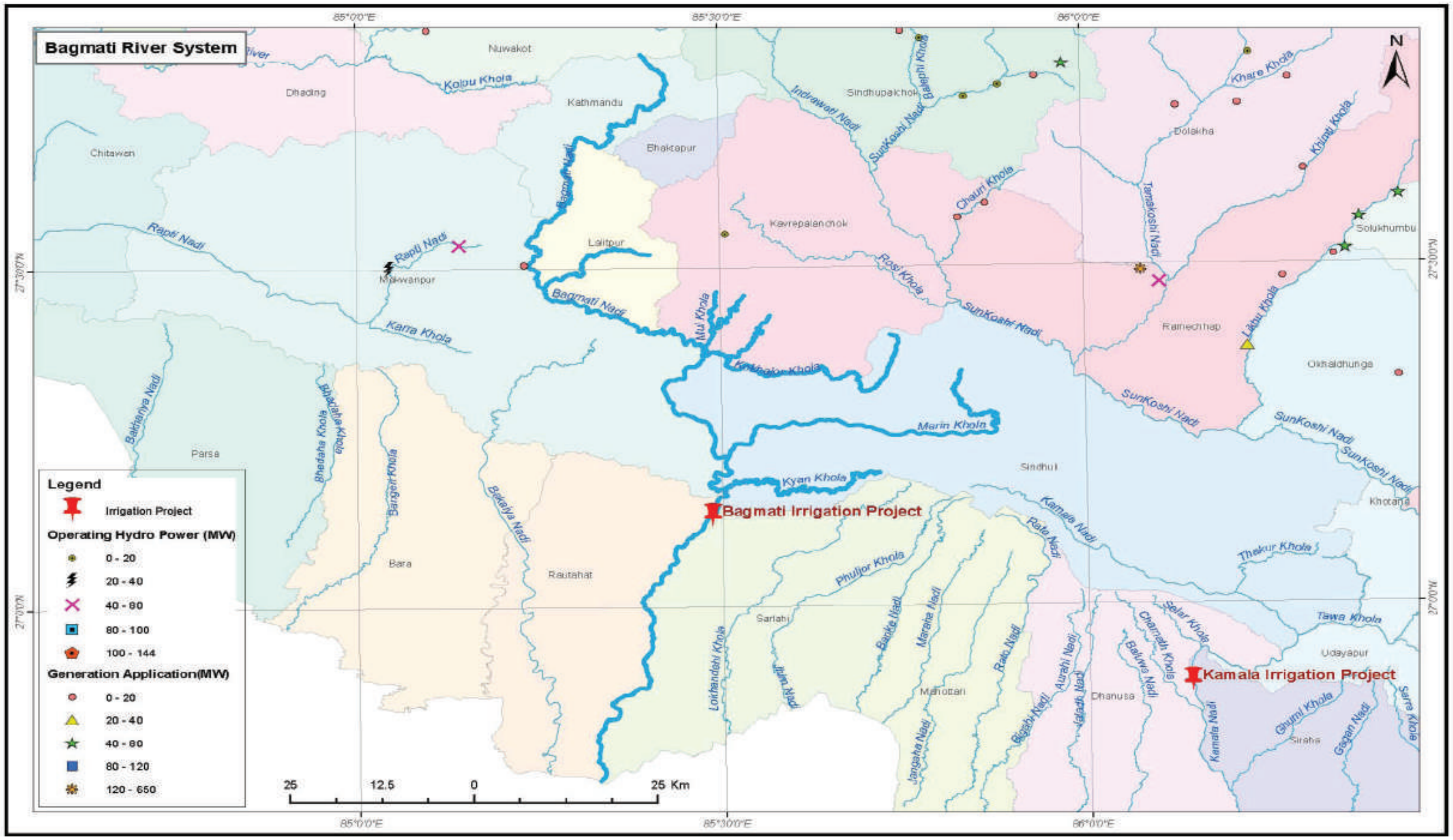


MW = megawatt.

Source: Department of Electricity Development, and Nepal Electricity Authority, Nepal.

ANNEX 5

Location of Dams in the Bagmati River Watershed, Nepal

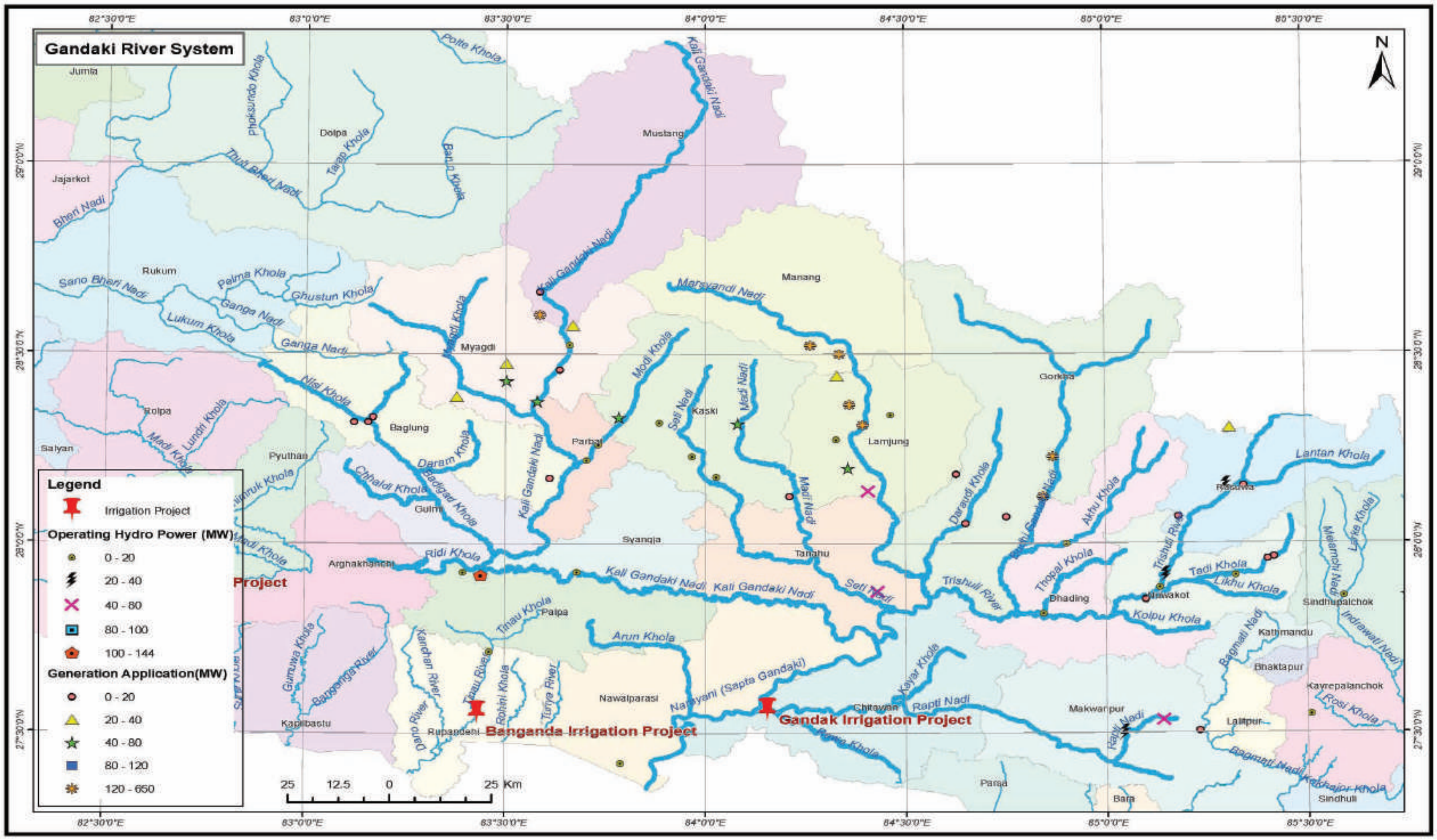


MW = megawatt.

Source: Department of Electricity Development, and Nepal Electricity Authority, Nepal.

ANNEX 6

Location of Dams in the Gandaki River Watershed, Nepal

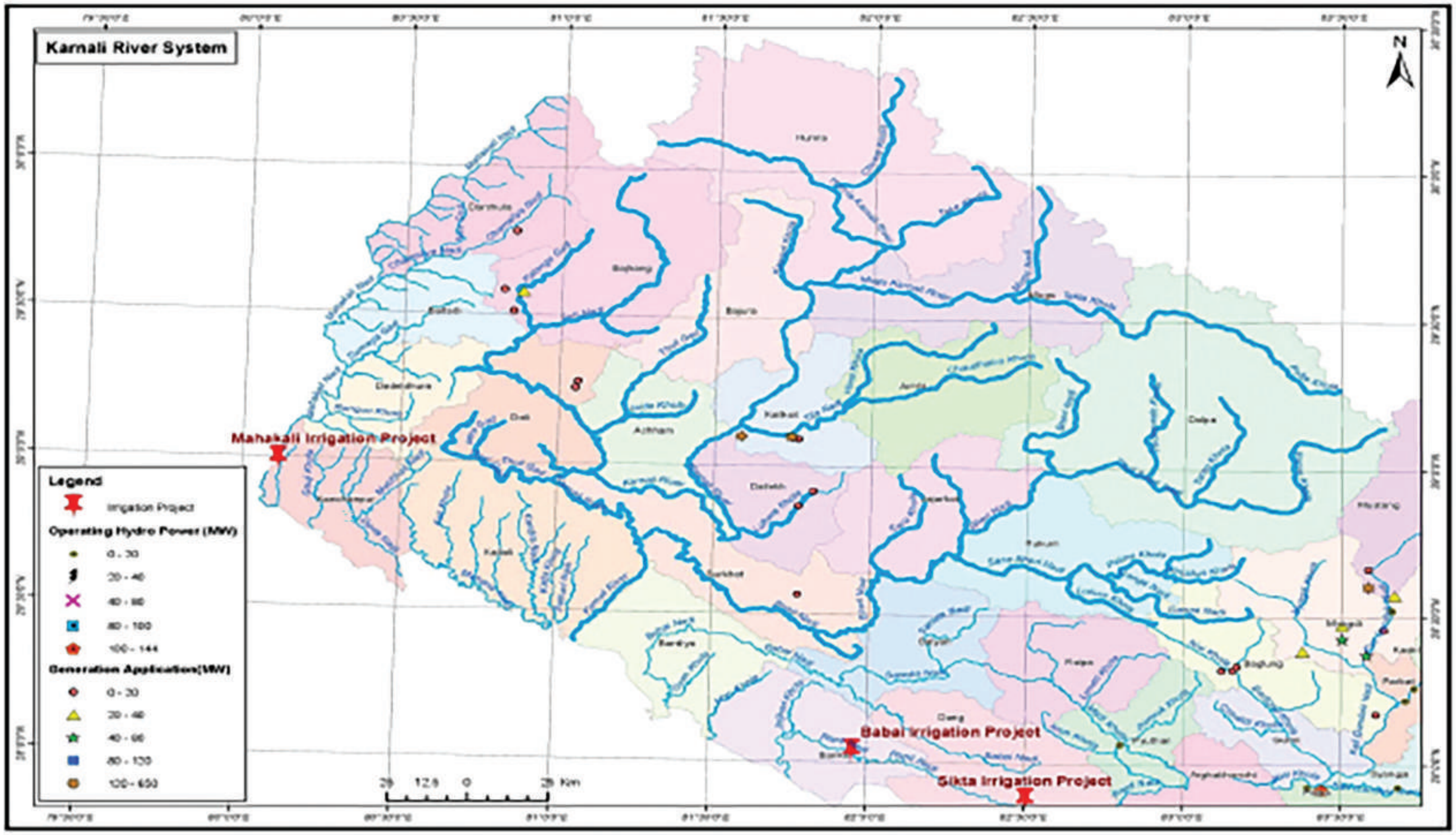


MW = megawatt.

Source: Department of Electricity Development, and Nepal Electricity Authority, Nepal.

ANNEX 7

Location of Dams in the Karnali River Watershed, Nepal



MW = megawatt.

Source: Department of Electricity Development, and Nepal Electricity Authority, Nepal.

ANNEX 8

List of Dam Projects in Different Rivers of Nepal and Their Status

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
1	Kali Gandaki A	Run-of-river	Kali Gandaki	Syangja	NEA	Operation	
2	Middle Marshyangdi	Run-of-river	Marshyangdi	Lamjung	NEA	Operation	
3	Marshyangdi	Run-of-river	Marshyangdi	Tanahun	NEA	Operation	
4	Trishuli	Run-of-river	Trishuli	Nuwakot	NEA	Operation	
5	Sunkoshi	Run-of-river	Sunkoshi	Sindhupalchok	NEA	Operation	
6	Gandak	Run-of-river	Narayani	Nawalparasi	NEA	Operation	
7	Kulekhani I	Storage	Kulekhani	Makawanpur	NEA	Operation	
8	Devighat	Run-of-river	Trishuli	Nuwakot	NEA	Operation	
9	Kulekhani II	Storage	Kulekhani	Makawanpur	NEA	Operation	
10	Puwa Khola	Run-of-river	Puwa Khola	Ilam	NEA	Operation	
11	Modi Khola	Run-of-river	Modi Khola	Parbat	NEA	Operation	
12	Sundarijal	Run-of-river	Bagmati	Kathmandu	NEA	Operation	
13	Panauti	Run-of-river	Roshi Khola	Kavre	NEA	Operation	
14	Phewa	Storage	Phewa lake	Kaski	NEA	Operation	
15	Seti (Pokhara)	Run-of-river	Seti	Kaski	NEA	Operation	
16	Tatopani	Run-of-river	Tatopani	Sindhupalchok	NEA	Operation	
17	Chatara	Run-of-river	Koshi	Sunsari	NEA	Operation	
18	Tinau	Run-of-river	Tinau	Rupandehi	NEA	Operation	
19	Pharping	Run-of-river	Pharping	Kathmandu	NEA	Operation	Not in normal operation
20	Jomsom	Run-of-river	Kali Gandaki	Jomsom	NEA	Operation	Leased to private sector
21	Baglung	Run-of-river	Kali Gandaki	Baglung	NEA	Operation	Not in normal operation
22	Khandbari	Run-of-river	Arun	Sankhuwasabha	NEA	Operation	Leased to private sector

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Annex 8 Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
23	Phidim	Run-of-river	Tamor	Pachthar	NEA	Operation	Leased to private sector
24	Surnaiyagad	Run-of-river	Surnaiyagad	Baitadi	NEA	Operation	
25	Doti	Run-of-river	Thuligad	Doti	NEA	Operation	Not in normal operation
26	Ramechhap	Run-of-river	Sunkoshi	Ramechhap	NEA	Operation	
27	Terhathum	Run-of-river	Khorunga	Terhathum	NEA	Operation	Leased to private sector
28	Gamgad	Run-of-river	Gamgad	Mugu	NEA	Operation	
29	Dhankuta	Run-of-river	Tamor Khola	Dhankuta	NEA	Operation	Not in normal operation
30	Jhupra (Surkhet)	Run-of-river	Jhupra	Surkhet	NEA	Operation	Not in normal operation
31	Gorkhe (Ilam)	Run-of-river	Gorkhe	Ilam	NEA	Operation	Not in normal operation
32	Jumla	Run-of-river	Tila	Jumla	NEA	Operation	Leased to private sector
33	Dhading	Run-of-river	Trisuli	Dhading	NEA	Operation	Not in normal operation
34	Syangja	Run-of-river	Adhikhola	Syangja	NEA	Operation	Not in normal operation
35	Helambu	Run-of-river	Indrawati	Sindhupalchok	NEA	Operation	
36	Darchula	Run-of-river	Mahakali	Darchula	NEA	Operation	Leased to private sector
37	Chame	Run-of-river	Marshyangdi	Manag	NEA	Operation	Leased to private sector
38	Taplejung	Run-of-river	Tamur	Taplejung	NEA	Operation	Leased to private sector
39	Manag	Run-of-river	Marshyangdi	Manag	NEA	Operation	Leased to private sector
40	Chaurjhari (Rukum)	Run-of-river	Veri	Rukum	NEA	Operation	Leased to private sector

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Annex 8 Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
41	Syaprudaha (Rukum)	Run-of-river	Syaprudaha	Rukum	NEA	Operation	Leased to private sector
42	Bhojpur	Run-of-river	Pikhuwa	Bhojpur	NEA	Operation	Leased to private sector
43	Bajura	Run-of-river	Budhiganga	Bajura	NEA	Operation	Leased to private sector
44	Bajhang	Run-of-river	Seti	Bajhang	NEA	Operation	Leased to private sector
45	Arughat (Gorkha)	Run-of-river	Arughat	Gorkha	NEA	Operation	
46	Okhaldhunga	Run-of-river	Dudh Koshi	Okhaldhunga	NEA	Operation	
47	Rupalgad (Dadeldhura)	Run-of-river	Rupalgad	Dadeldhura	NEA	Operation	
48	Achham	Run-of-river	Kailash Khola	Achham	NEA	Operation	
49	Dolpa	Run-of-river	Thuli Bheri	Dolpa	NEA	Operation	
50	Kalikot	Run-of-river	Tila	Kalikot	NEA	Operation	
51	Heldung (Humla)	Run-of-river	Heldung	Humla	NEA	Operation	
52	Khimti Khola	Run-of-river	Khimti	Dolkha/ Ramechhap	PVT LTD	Operation	
53	Bhotekoshi khola	Run-of-river	Bhotekoshi	Sindhuplchok	PVT	Operation	
54	Chilime	Run-of-river	Chilime	Rasuwa	PVT	Operation	
55	Indrawati-III	Run-of-river	Indrawati	Sindhupalchok	PVT	Operation	
56	Jhimruk Khola	Run-of-river	Jhimruk	Pyuthan	PVT	Operation	
57	Andhi Khola	Run-of-river	Andhi Khola	Syangza	PVT	Operation	
58	Syange Khola	Run-of-river	Syange	Lamjung	PVT	Operation	
59	Piluwa Khola	Run-of-river	Piluwa	Sankhuwasava	PVT	Operation	
60	Rairang Khola	Run-of-river	Rairang	Dhading	PVT	Operation	
61	Sunkoshi Khola	Run-of-river	Sunkoshi	Sindhupalchok	PVT	Operation	
62	Chaku Khola	Run-of-river	Chaku	Sindhupalchok	PVT	Operation	
63	Khudi Khola	Run-of-river	Khudi	Lamjung	PVT	Operation	
64	Baramchi Khola	Run-of-river	Baramachi	Sindhupalchok	PVT	Operation	
65	Thoppal Khola	Run-of-river	Thoppal	Dhading	PVT	Operation	
66	Sisne Khola	Run-of-river	Sisne	Palpa	PVT	Operation	
67	Sali Nadi	Run-of-river	Sali	Kathmandu	PVT	Operation	
68	Pheme Khola	Run-of-river	Pheme	Panchtar	PVT	Operation	
69	Pati Khola	Run-of-river	Pati	Parbat	PVT	Operation	
70	Seti-II	Run-of-river	Seti	Kaski	PVT	Operation	
71	Ridi Khola	Run-of-river	Ridi	Gulmi	PVT	Operation	

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Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
72	Upper Hadi Khola	Run-of-river	Hadi	Sindhupalchok	PVT	Operation	
73	Mardi Khola	Run-of-river	Mardi	Kaski	PVT	Operation	
74	Mai Khola	Run-of-river	Mai	Ilam	PVT	Operation	
75	Lower Piluwa	Run-of-river	Piluwa	Sankhuwasava	PVT	Operation	
76	Hewa Khola	Run-of-river	Hewa	Sankhuwasabha	PVT	Operation	
77	Siuri Khola	Run-of-river	Siuri	Lamjung	PVT	Operation	
78	Lower Modi I	Run-of-river	Modi	Prarbat	PVT	Operation	
79	Bijayapur-1	Run-of-river	Bijayapur	Kaski	PVT	Operation	
80	Sipring Khola	Run-of-river	Sipring	Dolakha	PVT	Operation	
81	Solar	Run-of-river	Solar	Kathmandu	PVT	Operation	
82	Tadi Khola (Thaprek)	Run-of-river	Tadi	Nuwakot	PVT	Operation	
83	Middle Chaku	Run-of-river	Chaku	Sindhupalchok	PVT	Operation	
84	Charnawati Khola	Run-of-river	Charnawati	Dolakha	PVT	Operation	
85	Lower Indrawati Khola	Run-of-river	Indrawati	Sindhupalchok	PVT	Under construction	
86	Ankhu Khola-1	Run-of-river	Arkhu	Dhading	PVT	Under construction	
87	Bhairab Khola	Run-of-river	Bhairab	Sindhupalchok	PVT	Under construction	
88	Lower Chaku Khola	Run-of-river	Chaku	Sindhupalchok	PVT	Under construction	
89	Jiri Khola	Run-of-river	Jiri	Dolkha	PVT	Under construction	
90	Pikhuwa Khola	Run-of-river	Pikhuwa	Bhojpur	PVT	Under construction	
91	Mai Khola	Run-of-river	Mai	Ilam	PVT	Under construction	
92	Upper Tamakoshi Hydropower Project	Run-of-river	Tamakoshi	Dolkha	PVT	Under construction	
93	Belkhu	Run-of-river	Belkhu	Dhading	PVT	Under construction	
94	Mailung Khola	Run-of-river	Mailung	Rasuwa	PVT	Under construction	
95	Jhyadi Khola	Run-of-river	Jhyadi	Sindhupalchok	PVT	Under construction	
96	Phawa Khola	Run-of-river	Phawa	Taplejung	PVT	Under construction	
97	Upper Mai Khola	Run-of-river	Mai	Ilam	PVT	Under construction	

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Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
98	Chake Khola	Run-of-river	Chake	Ramechhap	PVT	Under construction	
99	Upper Madi	Run-of-river	Madi	Kaski	PVT	Under construction	
100	Radhi Khola	Run-of-river	Radhi	Lamjung	PVT	Under construction	
101	Khani Khola-1	Run-of-river	Khani	Dolakha	PVT	Under construction	
102	Sanjen	Run-of-river	Sanjen	Rasuwa	PVT	Under construction	
103	Middle Bhotekhosi	Run-of-river	Bhotekoshi	Sindhupalchok	PVT	Under construction	
104	Rasuwa Gadi	Run-of-river	Gadi	Rasuwa	PVT	Under construction	
105	Badi Gad	Run-of-river	Badi Gad	Baglung	PVT	Under construction	
106	Sanjen	Run-of-river	Sanjen	Rasuwa	PVT	Under construction	
107	Gelun	Run-of-river	Gelun	Sindhupalchok	PVT	Under construction	
108	Hewa Khola A	Run-of-river	Hewa	Pachathar	PVT	Under construction	
109	Upper Marshyangdi A	Run-of-river	Marshyangdi	Lamjung	PVT	Under construction	
110	Upper Puwa Khola-1	Run-of-river	Puwa Khola	Ilam	PVT	Under construction	
111	Upgradation of Andhikhola	Run-of-river	Andhikhola	Syangja	PVT	Under construction	
112	Upgradation of Chuku	Run-of-river	Chuku	Sindhupalchok	PVT	Under construction	
113	Upper Tamakosi Hydropower Project	Run-of-river	Tamakoshi	Dolkha	NEA	Under construction	
114	Tanahu Hydropower Project	Run-of-river	Upper Seti	Tanahu	NEA	Under construction	
115	Chameliya HEP	Run-of-river	Chameliya	Darchula	NEA	Under construction	
116	Kulekhani III	Run-of-river	Kulekhani	Makawanpur	NEA	Under construction	
117	Upper Trisuli 3A HEP	Run-of-river	Trisuli	Nuwakot	NEA	Under construction	
118	Rahughat HEP	Run-of-river	Rahughat	Myagdi	NEA	Under construction	

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Annex 8 Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
119	Upper Trisuli 3B	Run-of-river	Trisuli	Nuwakot	NEA	Proposed	
120	Upper Arun HEP	Run-of-river	Arun	Dolpa	NEA	Proposed	
121	Upper Modi "A" HEP	Run-of-river	Modi	Kaski	NEA	Proposed	
122	Dudh Kosi Storage HEP	Run-of-river	Kosi	Solukhumbu	NEA	Proposed	
123	Tamor Storage HEP	Run-of-river	Tamor	Taplejung	NEA	Proposed	
124	Uttar Ganga Storage HEP	Run-of-river	Dhorpatan	Baglung	NEA	Proposed	
125	Madi-1 Khola	Run-of-river	Madi	Kaski	PVT	Proposed	
126	Narayani Shankar Biomass	Run-of-river	Belkhu	Rupandehi	PVT	Proposed	
127	Tinau Khola	Run-of-river	Tinau	Palpa	PVT	Proposed	
128	Charanawati	Run-of-river	Charanawati	Dolakha	PVT	Proposed	
129	Golmagad	Run-of-river	Golmagad	Doti	PVT	Proposed	
130	Dapcha– Roshi	Run-of-river	Roshi	Kavrepalanchok	PVT	Proposed	
131	Ladku Khola	Run-of-river	Ladku	Kavrepalanchok	PVT	Proposed	
132	Namarjung Madi	Run-of-river	Namarjung	Kaski	PVT	Proposed	
133	Lower Balephi	Run-of-river	Balephi	Sindhupalchok	PVT	Proposed	
134	Upper Hugdi Khola	Run-of-river	Hugdi	Gulmi	PVT	Proposed	
135	Seti Khola	Run-of-river	Seti	Chitwan	PVT	Proposed	
136	Madkyu Khola	Run-of-river	Madkya	Kaski	PVT	Proposed	
137	Lower Sunkoshi-III	Run-of-river	Sunkoshi	Sindhupalchok	PVT	Proposed	
138	Middle Gaddigad	Run-of-river	Gaddigad	Doti	PVT	Proposed	
139	Jumdi Khola	Run-of-river	Jumdi	Gulmi	PVT	Proposed	
140	Theule Khola	Run-of-river	Theule	Baglung	PVT	Proposed	
141	Tadi Khola	Run-of-river	Tadi	Nuwakot	PVT	Proposed	
142	Naugad Gad Khola	Run-of-river	Naugad	Baitadi	PVT	Proposed	
143	Dorkhu Khola	Run-of-river	Dorkhu	Nuwakot	PVT	Proposed	
144	Upper Mailun A	Run-of-river	Mailum	Rasuwa	PVT	Proposed	
145	Dhansi Khola	Run-of-river	Dhansi	Rolpa	PVT	Proposed	
146	Upper Chaku A	Run-of-river	Chaku	Sindhupalchok	PVT	Proposed	
147	Upper Charnawati	Run-of-river	Charnawati	Dolakha	PVT	Proposed	
148	Balefi	Run-of-river	Balefi	Sindhupalchok	PVT	Proposed	
149	Upper Khimti	Run-of-river	Khimti	Dolkha	PVT	Proposed	

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Annex 8 Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
150	Thapa Khola	Run-of-river	Thapa	Myagdi	PVT	Proposed	
151	Likhu-IV	Run-of-river	Likhu	Okhaldhunga, Ramechhap	PVT	Proposed	
152	Mistri Khola	Run-of-river	Mistri	Myagdi	PVT	Proposed	
153	Chhote Khola	Run-of-river	Chhote	Gorkha	PVT	Proposed	
154	Ingua Khola	Run-of-river	Ingua	Ilam	PVT	Proposed	
155	Daraudi Khola A	Run-of-river	Daraudi	Gorkha	PVT	Proposed	
156	Lower Modi	Run-of-river	Modi	Prarbat	PVT	Proposed	
157	Upper Mailung	Run-of-river	Mailung	Rasuwa	PVT	Proposed	
158	Tame Khola	Run-of-river	Tame	Dailekha	PVT	Proposed	
159	Dhunge–Jiri	Run-of-river	Dhunge–Jiri	Dolakha	PVT	Proposed	
160	Sardi Khola	Run-of-river	Sardi	Kaski	PVT	Proposed	
161	Saba Khola	Run-of-river	Saba	Sankhuwasabha	PVT	Proposed	
162	Upper Belkhu	Run-of-river	Belkhu	Dhading	PVT	Proposed	
163	Upper Tadi	Run-of-river	Tadi	Nuwakot	PVT	Proposed	
164	Daram Khola A	Run-of-river	Daram	Baglung	PVT	Proposed	
165	Upper Mai C	Run-of-river	Mai	Ilam	PVT	Proposed	
166	Chhandi	Run-of-river	Chhandi	Lamjung	PVT	Proposed	
167	Dordi Khola	Run-of-river	Dordi	Lamjung	PVT	Proposed	
168	Khan Khola (Dolakha)	Run-of-river	Khani	Dolakha	PVT	Proposed	
169	Kabeli B-1	Run-of-river	Kabeli	Taplejung, Panchthar	PVT	Proposed	
170	Selang Khola	Run-of-river	Selang	Sindhupalchok	PVT	Proposed	
171	Upper Piluwa Khola	Run-of-river	Piluwa	Sankhuwasabha	PVT	Proposed	
172	Tungun Thosne	Run-of-river	Tungun	Lalitpur	PVT	Proposed	
173	Khani Khola	Run-of-river	Khani	Lalitpur	PVT	Proposed	
174	Suspa Bukhari	Run-of-river	Suspa Bukhari	Dolakha	PVT	Proposed	
175	Middle Tadi	Run-of-river	Tadi	Nuwakot	PVT	Proposed	
176	Upper Jumdi	Run-of-river	Jumdi	Gulmi	PVT	Proposed	
177	Upper Dordi A	Run-of-river	Dordi	Lamjung	PVT	Proposed	
178	Tinekhu Khola	Run-of-river	Tinekhu	Dolakha	PVT	Proposed	
179	Salankhu Khola	Run-of-river	Salankhu	Nuwakot	PVT	Proposed	
180	Balefi A	Run-of-river	Balefi	Sindhupalchok	PVT	Proposed	
181	Jogmai	Run-of-river	Jogmai	Ilam	PVT	Proposed	
182	Miya Khola	Run-of-river	Miya	Khotang	PVT	Proposed	
183	Madhya Modi	Run-of-river	Modi	Parbat	PVT	Proposed	
184	Khorunga Khola	Run-of-river	Khorunga	Terhathum	PVT	Proposed	

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Annex 8 Table *continued*

No.	Name of Project	Project Type	Name of the River	Location (District)	Ownership	Status	Remarks
185	Upper Parajuli Khola	Run-of-river	Parajuli	Dailekha	PVT	Proposed	
186	Lohore Khola	Run-of-river	Lohare	Dailekha	PVT	Proposed	
187	Upper Solu	Run-of-river	Solu	Solukhumbu	PVT	Proposed	
188	Rawa Khola	Run-of-river	Rawa	Khotang	PVT	Proposed	
189	Bagmati Khola	Run-of-river	Bagmati	Makawanpur	PVT	Proposed	
190	Mai Cascade	Run-of-river	Mai Cascade	Ilam	PVT	Proposed	
191	Lower Khare	Run-of-river	Khare	Dolakha	PVT	Proposed	
192	Middle Midim	Run-of-river	Midim	Lamjung	PVT	Proposed	
193	Teliya Khola	Run-of-river	Teliya	Dhankuta	PVT	Proposed	
194	Midim Karapu	Run-of-river	Karapu	Lamjung	PVT	Proposed	
195	Rudi A	Run-of-river	Rudi	Lamjung, Kaski	PVT	Proposed	
196	Mai Sano Cascade	Run-of-river	Mai Sano Cascade	Ilam	PVT	Proposed	
197	Molung Khola	Run-of-river	Molung	Okhaldhunga	PVT	Proposed	
198	Phalankhu Khola	Run-of-river	Phalankhu	Rasuwa	PVT	Proposed	
199	Upper Khimti II	Run-of-river	Khimti	Ramechhap	PVT	Proposed	
200	Kapadigad	Run-of-river	Kapadigad	Doti	PVT	Proposed	
201	Junbesi Khola	Run-of-river	Junbesi	Solukhumbu	PVT	Proposed	
202	Ghalendi Khola	Run-of-river	Ghalendi	Myagdi	PVT	Proposed	
203	Dwari Khola	Run-of-river	Dwari	Dailekha	PVT	Proposed	
204	Lower Midim	Run-of-river	Lower Midim	Lamjung	PVT	Proposed	
205	Iwa Khola	Run-of-river	Iwa	Taplejung	PVT	Proposed	
206	Buku Khola	Run-of-river	Buku	Solukhumbu	PVT	Proposed	
207	Midim khola	Run-of-river	Midim	Lamjung	PVT	Proposed	
208	Tangchhahara	Run-of-river	Tangchhahara	Mustang	PVT	Proposed	
209	Upper Khadam	Run-of-river	Khadam	Morang	PVT	Proposed	
210	Midim Khola	Run-of-river	Midim	Lamjung	PVT	Proposed	

HEP = hydroelectric project, NEA = Nepal Electricity Authority, PVT = private, PVT LTD = private limited.

Source: Department of Electricity Development, Nepal Electricity Authority, 2013.

ANNEX 9

Checklist of Freshwater Fish in Nepal

No.	Family	Species
1	Notopteridae	*Notopterus notopterus* (Pallas)
2		*Chitala hitala* (Hamilton)
3	Anguillidae	*Anguilla bengalensis* (Gray)
4		*Neoanguilla nepalensis* (Shrestha)
5	Moringuidae	*Moringua raitaborua* (Hamilton)
6	Clupeidae	*Gudusia chapra* (Hamilton)
7		*G. variegate* (Day)
8	Engraulidae	*Setipinna phasa* (Hamilton)
9	Cyprinidae	*Securicula gora* (Hamilton)
10		*Salmonstoma acinaces* (Valenciennes)
11		*S. bacaila* (Hamilton)
12		*S. phulo* (Hamilton)
13		*Aspidoparia jaya* (Hamilton)
14		*A. morar* (Hamilton)
15		*Barilius barila* (Hamilton)
16		*B. barna* (Hamilton)
17		*B. bendelisis* (Hamilton)
18		*B. radiolatus* (Gunther)
19		*B. shacra* (Hamilton)
20		*B. tileo* (Hamilton)
21		*B. vagra* (Hamilton)
22		*B. modestus* (Day)
23		*B. bola* (Hamilton)
24		*B. guttatus* (Day)
25		*Chela cachius* (Hamilton)
26		*Chela laubuca* (Hamilton)
27		*Esomus danricus* (Hamilton)
28		*Danio aequipinna* (McClelland)
29		*D. dangila* (Hamilton)
30		*D. devario* (Hamilton)
31		*Brachydanio rerio* (Hamilton)
32		*Rasbora daniconius* (Hamilton)
33		*Bengana elanga* (Hamilton)
34		*Amblypharyngodon mola* (Hamilton)

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No.	Family	Species
35		*A. micropelis* (Bleeker)
36		*Tor putitora* (Hamilton)
37		*Tor tor* (Hamilton)
38		*Tor mosal* (Hamilton)
39		*Naziritor cheilynoides* (McClelland)
40		*Neolissochilus hexagonolepis* (McClelland)
41		*Osteobrama cotio* (Hamilton)
42		*O. neilli* (Day)
43		*Cyclocheilichthys apogon* (Valenceinnes)
44		*Chagunius chagunio* (Hamilton)
45		*Oreichthys cosuatis* (Hamilton)
46		*Puntius chola* (Hamilton)
47		*P. conchonius* (Hamilton)
48		*P. gelius* (Hamilton)
49		*P. guganio* (Hamilton)
50		*P. phutunio* (Hamilton)
51		*P. sophore* (Hamilton)
52		*P. ticto* (Hamilton)
53		*P. clavatus* (McClelland)
54		*P. sarana* (Hamilton)
55		*P. terio* (Hamilton)
56		*Semiplotus semiplotus* (McClelland)
57		*Cirrhinus mrigala* (Hamilton)
58		*C. reba* (Hamilton)
59		*Catla catla* (Hamilton)
60		*Labeo angra* (Hamilton)
61		*L. bata* (Hamilton)
62		*L. boga* (Hamilton)
63		*L. calbasu* (Hamilton)
64		*L. dero* (Hamilton)
65		*L. fimbriatus* (Bloch)
66		*L. gonius* (Hamilton)
67		*L. pangusia* (Hamilton)
68		*L. rohita* (Hamilton)
69		*L. caeruleus* (Day)
70		*L. dyocheilus* (McClelland)
71		*Schismatorhynchus* (Nukta) (Sykes)
72		*Schizothorax richardsonii* (Gray)
73		*S. sinuatus* (Heckel)
74		*Schizothoraichthys curvifrons* (Heckel)

No.	Family	Species
75		*S. ecocinus* (Heckel)
76		*S. niger* (Heckel)
77		*S. labiatus* (McClelland)
78		*S. progastus* (McClelland)
79		*Schizothoraicthys macrophthalmus* (Terashima)
80		*S. nepalensis* (Terashima)
81		*S. raraensis* (Terashima)
82		*Dipticus maculates* (Steindachner)
83		*Crossocheilus latius* (Hamilton)
84		*Garra annandalei* (Hora)
85		*G. gotyla* (Gray)
86		*Garra lamta* (Hamilton)
87		*G. lissorhynchus* (McClelland)
88		*G. mullya* (Sykes)
89		*G. nasuta* (McClelland)
90		*G. rupecula* (McClelland)
91	Psilorhynchidae	*Psilorhynchus balitora* (Hamilton)
92		*P. sucatio* (Hamilton)
93		*P. gracillis* (Rainboth)
94		*P. nepalensis* (Conway & Mayden)
95		*Psilorhynchoides homaloptera* (Hora & Mukherji)
96		*P. pseudecheneis* (Menon & Datta) .
97	Balitoridae	*Homaloptera bilineata* (Blyth)
98		*Balitora brucei* (Gray)
99		*B. eddsi* (Conway & Mayden)
100		*Acanthocobitis botia* (Hamilton)
101		*Nemacheilus corica* (Hamilton)
102		*Turcinomacheilus himalaya* (Conway, et.al)
103		*Schistura beavani* (Gunther)
104		*S. devdevi* (Hora)
105		*S. multifaciatus* (Day)
106		*S. rupecola rupecola* (McClelland)
107		*S. rupecola inglishi* (Hora)
108		*S. savona* (Hamilton)
109		*S. scaturigina* (McClelland)
110		*S. sikamaiensis* (Hora)
111		*S. prashadi* (Hora)
112		*S. harai* (Menon)
113		*S. himachalensis* (Menon)
114		*Aborichthys elangatus* (Hora)

No.	Family	Species
115	Cobitidae	*Botia almorhae* (Gray)
116		*B. dario* (Hamilton)
117		*B. histrionica* (Blyth)
118		*B. lohachata* (Chaudharuri)
119		*B. geto* (Hamilton)
120		*Neoeucirrhichthys maydelli Banarescu & Nalbant*
121		*Acantophthalmus pangio* (Hamilton)
122		*Semileptes gongota* (Hamilton)
123		*Lepidocephalus annadalei* (Chaudhuri)
124		*Lepidocephalus guntea* (Hamilton)
125		*L. menoni* (Pillai & Yazdani)
126	Bagaridae	*Rita rita* (Hamilton)
127		*Batasio batasio* (Hamilton)
128		*B. tengana* (Hamilton)
129		*B. macronotus* (Ng & Edds)
130		*Mystus bleekeri* (Day)
131		*M. cavasius* (Hamilton)
132		*M. gulio* (Hamilton)
133		*M. menoda* (Hamilton)
134		*M. tengara* (Hamilton)
135		*M. vittatus* (Bloch)
136		*Aorichthys aor* (Hamilton)
137		*A. seenghala* (Sykes)
138	Siluridae	*Ompok bimaculatus* (Bloch)
139		*O. pabda* (Hamilton)
140		*O. pabo* (Hamilton)
141		*Wallago attu* (Bloch & Schneider)
142	Schlbeidae	*Ailia coila* (Hamilton)
143		*Pseudeutropius atherinoides* (Bloch)
144		*P. murius batarensis* (Shrestha)
145		*Clupisoma garua* (Hamilton)
146		*Clupisoma montana* (Hora)
147		*Eutropiichthys murius* (Hamilton)
148		*E. vacha* (Hamilton)
149		*E. goongware* (Sykes)
150		*Silonia silondia* (Hamilton)
151	Pangasiida	*Pangasius pangasius* (Hamilton)
152	Amblycepidae	*Amblycepi mangois* (Hamilton)
153	Sisoridae	*Bagarius bagarius* (Hamilton)

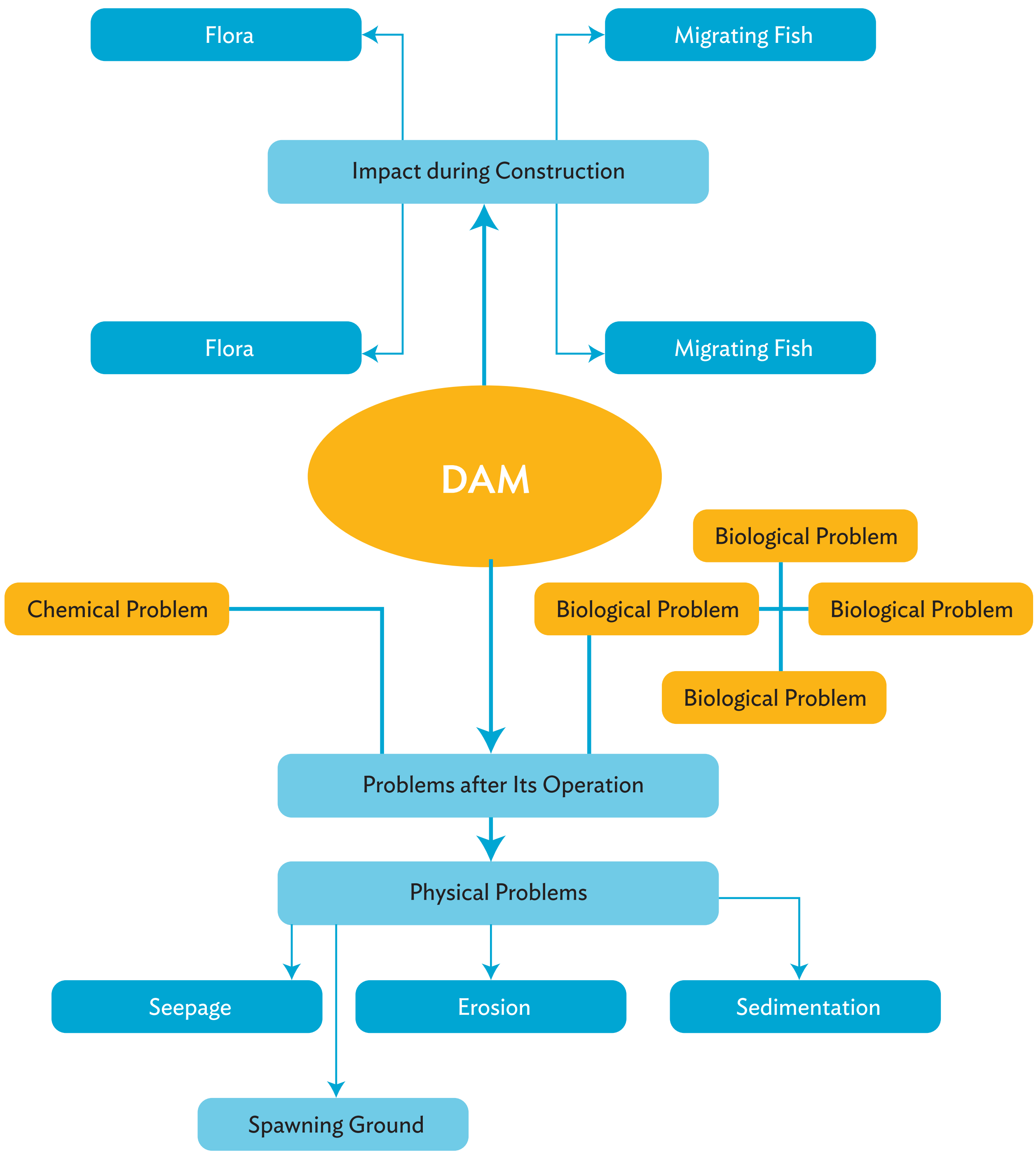
No.	Family	Species
154		*B. yerrellii* (Sykes)
155		*Gagata cenia* (Hamilton)
156		*G. gagata* (Hamilton)
157		*G. sexualis* (Tilak)
158		*Nangra nangra* (Hamilton)
159		*N. viridescens* (Hamilton)
160		*N. assamenisis* (Sen)
161		*Erethistes pussilus* (Muller & Troschel)
162		*Erethistoides montana* (Hora)
163		*E. ascita* (Ng & Edds)
164		*E. cavatura* (Ng & Edds)
165		*Hara hara* (Hamilton)
166		*H. jerdoni* (Day)
167		*Conta conta* (Hamilton)
168		*Glyptosternum maculatum* (Regan)
169		*G. reticulatum* (McClelland)
170		*Laguvia ribeiroi* (Hora)
171		*L. kapuri* (Tilak & Hussain)
172		*Glyptothorax annandalei* (Hora)
173		*G. cavia* (Hamilton)
174		*G. conirostris conirostae* (Steindacher)
175		*G. gracile* (Gunther)
176		*G. indicus* (Talwar & Jhingran)
177		*Glyptothorax kashmirensis* (Hora)
178		*G. pectinopterus* (McClelland)
179		*G. telchitta* (Hamilton)
180		*G. trilineatus* (Blyth)
181		*G. alaknandi* (Tilak)
182		*G. garhwali* (Tilak)
183		*G. botius* (Hamilton)
184		*Euchiloglanis hodgarti* (Hora)
185		*Coraglanis kishinouyei* (Kimura)
186		*Myersglanis blythii* (Day)
187		*Exostoma labiatu* (McClelland)
188		*Pseudechenesis sulcatus* (McClelland)
189		*P. crassicaudata* sp. nov. (Ng & Edds)
190		*P. serracula* (Ng & Edds)
191		*P. eddsi* (Ng)
192		*Sisor rhabdophorus* (Hamilton)
193		*Sisor rheophilus* (Ng)

No.	Family	Species
194	Claridae	*Clarius batrachus* (Linnaeus)
195	Heteropneustidae	*Heteropneustes fossillis* (Bloch)
196	Chacidae	*Chaca chaca* (Hamilton)
197	Olyridae	*Olyra longicaudata* (McClelland)
198	Mugilidae	*Sicamugil cascasia* (Hamilton)
199		*Rhinomugil corsula* (Hamilton)
200	Belonidae	*Xenentodon cancila* (Hamilton)
201	Hemiramphidae	*Hyporhamphus limbatus* (Valenciennes)
202	Aplocheilidae	*Aplocheilus panchax* (Hamilton)
203	Synbranchidae	*Monopterus cuchia* (Hamilton)
204	Mastacembelidae	*Macragnathus aral* (Bloch & Schneider)
205		*M. pancalus* (Hamilton)
206		*M. zebrinus* (Blyth)
207		*Mastacembelus armatus* (Lacepede)
208	Chandidae	*Chanda nama* (Hamilton)
209		*Parambassis baculis* (Hamilton)
210		*P. ranga* (Hamilton)
211		*P. lala* (Hamilton)
212	Sciaenidae	*Johnius coiter* (Hamilton)
213		*Daysciaena albida* (Cuvier)
214	Nandidae	*Badis badis* (Hamilton)
215		*Nandus nandus* (Hamilton)
216	Gobiidae	*Glossogobius giuris* (Hamilton)
217	Gobiodidae	*Brachyamblyopus burmanicus* (Hora)
218	Anabantidae	*Anabas testudineus* (Bloch)
219		*A. cobojius* (Hamilton)
220	Belontidae	*Ctenops nobilis* (McClelland)
221		*Colisa fasciatus* (Schneider)
222		*C. lalia* (Hamilton)
223		*C. sota* (Hamilton)
224	Channidae	*Channa barca* (Hamilton)
225		*C. marulius* (Hamilton)
226		*Channa orientalis* (Bloch & Schneider)
227		*C. punctatui* (Bloch)
228		*C. stewartii* (Playfair)
229		*C. Striata* (Bloch)
230	Tetradontidae	*Tetraodon cutcutia* (Hamilton)

Source: K.G. Rajbanshi. 2012. *Biodiversity and Distribution of Fresh Water Fishes of Central/Nepal Himalayan Region.* Kathmandu: Nepal Fisheries Society. p. 136.

ANNEX 10

Environmental Side Effects Associated with Dams



ANNEX 11

Aquatic Biodiversity Related Acts, Policies, Strategies, and Regulatory Framework in Nepal

Policy/Strategy/ Legislation	Aquatic Biodiversity Related Provision
Aquatic Animal Protection Act, 1960	• This is one of the oldest pieces of legislation, which indicates an early recognition of the values of wetlands and aquatic animals. • Introduced poisonous, noxious, or explosive materials; and/or electric current in a water resource with intent of catching or killing aquatic life is prohibited and punishable. • The act made it mandatory for authorities constructing a dam for electricity, drinking water, irrigation, or other purposes to construct a fish ladder or fish hatchery and nursery in the nearby area for breeding and rearing of fish to release in the river. • The act empowers the government to prohibit catching, killing, and harming certain kinds of aquatic animals through notification in the Nepal Gazette.
National Conservation Strategy, 1988	• It recognizes that increasing urbanization and an expanding industrial base are major contributors to air, noise, and water pollution, and that the quality of human life and health is adversely affected by this pollution. • It recommends formulating national policy and legislation on air, noise, and water pollution monitoring and control.
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.
Water Resources Act, 1992	• The act provides guidance for determining beneficial uses of water resources, preventing environmental and other hazardous effects, and keeping water resources free from pollution. • The act vests the ownership of water resources within Nepal to the Government of Nepal. • While making use of water resources, the act guides the proponents to maintain water quality within the prescribed standard. • The act restricts pollution of water resources and any discharge of waste into the water body exceeding the pollution tolerance limit.
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.
Water Resources Regulations, 1993	• The regulation 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.
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.

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Annex 11 Table *continued*

Policy/Strategy/ Legislation	Aquatic Biodiversity Related Provision
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.
Water Resource Strategy, 2002	• The strategy calls for the sustainable management of watersheds and aquatic ecosystems.
Nepal Biodiversity Strategy, 2002	• It provides a strategic planning framework for the conservation of biological diversity, maintenance of ecological processes and systems, and equitable sharing of the benefits accrued.
Sustainable Development Agenda for Nepal, 2003	• It identifies environmental conservation to be an integral component of poverty alleviation and sustainable economic growth. • It emphasizes the need for more effective management of forests, ecosystems, and biodiversity in order to achieve the goal of sustainable development.
National Agricultural Policy, 2004	• Its objectives include the conservation, promotion, and proper utilization of natural resources, environment, and biodiversity. • It encourages in situ conservation and provides a basis for the establishment of gene banks and participatory biodiversity parks.
Science and Technology Policy, 2005	• The policy espouses the sustainable use of natural resources through science and technology. • There is a need for education, research, training, and development in various sectors, including agriculture, forests, water resource, environment, and biotechnology.
Nepal Biodiversity Strategy Implementation Plan, 2006	• Its overall goal is to contribute to achieving the goal and objectives of the National Biodiversity Strategy, 2002 through its successful implementation for the conservation of biodiversity and maintenance of ecological process and systems.
Tourism Policy, 2009	• The objectives are to develop Nepal as a major tourism destination by conserving, promoting, and developing tangible and intangible natural, cultural, and biological heritages. • The policy emphasizes formulation and implementation of separate environmental protection and solid waste management guidelines for sustainable management and cleanliness to promote tourism.
Industrial Policy, 2011	• The policy emphasizes special measures to be taken to promote green industries and make established industries pollution-free with zero carbon emissions. • It provides a basis for the deduction of capital expenses from the technology and installation of pollution-control systems, which have less impact on the environment.

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Table *continued*

Policy/Strategy/ Legislation	Aquatic Biodiversity Related Provision
National Wetlands Policy, 2012	• The policy envisions 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; (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. • It provides working policies for the conservation, restoration, and effective management of wetland areas; wise use of wetlands; and promotion of good governance in the management of the wetlands. • It calls to establish a high-level National Wetlands Committee.
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.
Nepal National Biodiversity Strategy and Action Plan, 2014–2020	• The plan aims at the conservation of biodiversity for sound and resilient ecosystems and national propriety. • The specific strategies and actions are grouped into six biodiversity themes and 15 crosscutting subjects. • It aims to reduce the rate of loss and degradation of forest habitats, improve biological connectivity, and enhance knowledge and understanding about the conservation of species. • The strategies for wetland biodiversity focus on effective conservation and sustainable utilization of wetlands resources. It states the need to address the legislative gaps and administrative ambiguities.

EIA = environmental impact assessment.

Source: Nepal Law Commission.

ANNEX 12

Fingerlings Released in Kali Gandaki River

Species	Year 2002–2003	Year 2003–2004	Year 2004–2005	Year 2005–2006	Year 2006–2007	Year 2007–2008	Year 2008–2009	Year 2009–2010	Year 2010–2011	Year 2011–2012	Year 2012–2013	Total
Tor Putitora (Sahar)	20,000	40,500	80,000	122,900	160,000	110,000	260,000	92,000	25,500	-	-	910,900
Schizothorax richardsonii (Asla)	16,000	37,000	18,000	22,000	15,000	20,000	50,000	-	25,000	-	-	279,400
Neolissochilus hexagonolepis (Katle)	30,000	60,000	45,000	64,400	55,000	630,000	-	-	-	-	-	178,000
Labeo dero (Gardi)	40,000	300,000	470,000	155,900	510,000		390,000	392,000	30,000	404,000	305,000	3,596,900
Labeo rohita (Rohu)	-		50,000	47,000	-		-	-		-	-	97,000
Labeo pangusia (Hande)	-				15,000		110,000	371,000		84,000	230,000	810,000
Garra gotyla (Buduna)	-				5,000		-	-				5,000
Garra annandalei (Lahare)	-				5,000		-	-				5,000
Total	106,000	437,500	663,000	452,200	765,000	760,000	810,000	855,000	80,500	488,000	535,000	5,952,200

- = Data not available.

Note: This table shows the number of fish fingerlings released per species for each corresponding year.

Source: Dr. Arun Baidhya, Office, Incharge, Kali Gandaki Fish Hatchery, Beltari, Syangja.

ANNEX 13

Water Quality in Different Stations of Different River Systems

Water Quality in Different Stations of Different River Systems in Marshyangdi

Parameters	Middle Marshyangdi Powerhouse (After Tailrace)	Middle Marshyangdi Powerhouse (Before Tailrace)	Dordi and Marshyangdi Confluence	Dordi River	Below Dam (Marshyangdi)	Middle Marshyangdi Dam Site	Khudi and Marshyangdi Confluence	Khudi River
	Station 1		Station 2		Station 3		Station 4	
Date	26 March 2014	26 March 2014	27 March 2014	27 March 2014	26 March 2014	27 March 2014	27 March 2014	27 March 2014
Time	13:35	12:30	8:45	8:00	15:15	11:15	14:30	14:00
Air temperature (°C)	30.90	29.80	22.70	19.50	28.60	27.40	28.00	27.70
Water temperature (°C)	14.70	19.20	16.60	16.20	24.50	16.85	17.60	18.00
Dissolved oxygen (mg/l)	12.00	10.00	10.00	10.00	10.00	11.00	10.00	10.00
Total hardness (mg/l)	102.60	102.60	85.50	85.50	85.50	153.90	68.40	51.30
Alkalinity(mg/l)	68.40	85.50	34.20	51.30	68.40	51.30	51.30	34.20
pH	7.75	7.75	7.50	8.00	8.00	8.00	8.00	7.75

mg/l = milligram per liter.

Source:

Water Quality in Different Stations of Different River Systems: Babai, West Rapti, and Seti

Parameters	Babai Irrigation Dam Site		Sikta Irrigation Dam Site		Proposed Tanahu Hydropower Project	
	Below Dam	Above Dam	Below Dam	Above Dam	Dam site	Powerhouse site
Date	21 May 2014	21 May 2014	22 May 2014	22 May 2014	28 March 2014	28 March 2014
Time	11:30	14:30	10:15	0:00	11:10	13:45
Air temperature (°C)	37.50	41.70	36.90	33.80	34.60	35.00
Water temperature (°C)	27.50	29.00	27.90	28.90	23.60	24.50
Dissolved oxygen(mg/l)	8.00	10.00	9.00	9.00	9.50	10.00
Total hardness (mg/l)	188.10	222.30	256.50	273.60	213.75	153.90
Alkalinity(mg/l)	171.00	136.80	136.80	102.60	85.50	102.60
pH	7.75	8.00	8.00	8.00	7.75	8.00

mg/l = milligram per liter.

Source: ADB field observation.

Water Quality in Different Stations of Different River Systems: Kali Gandaki

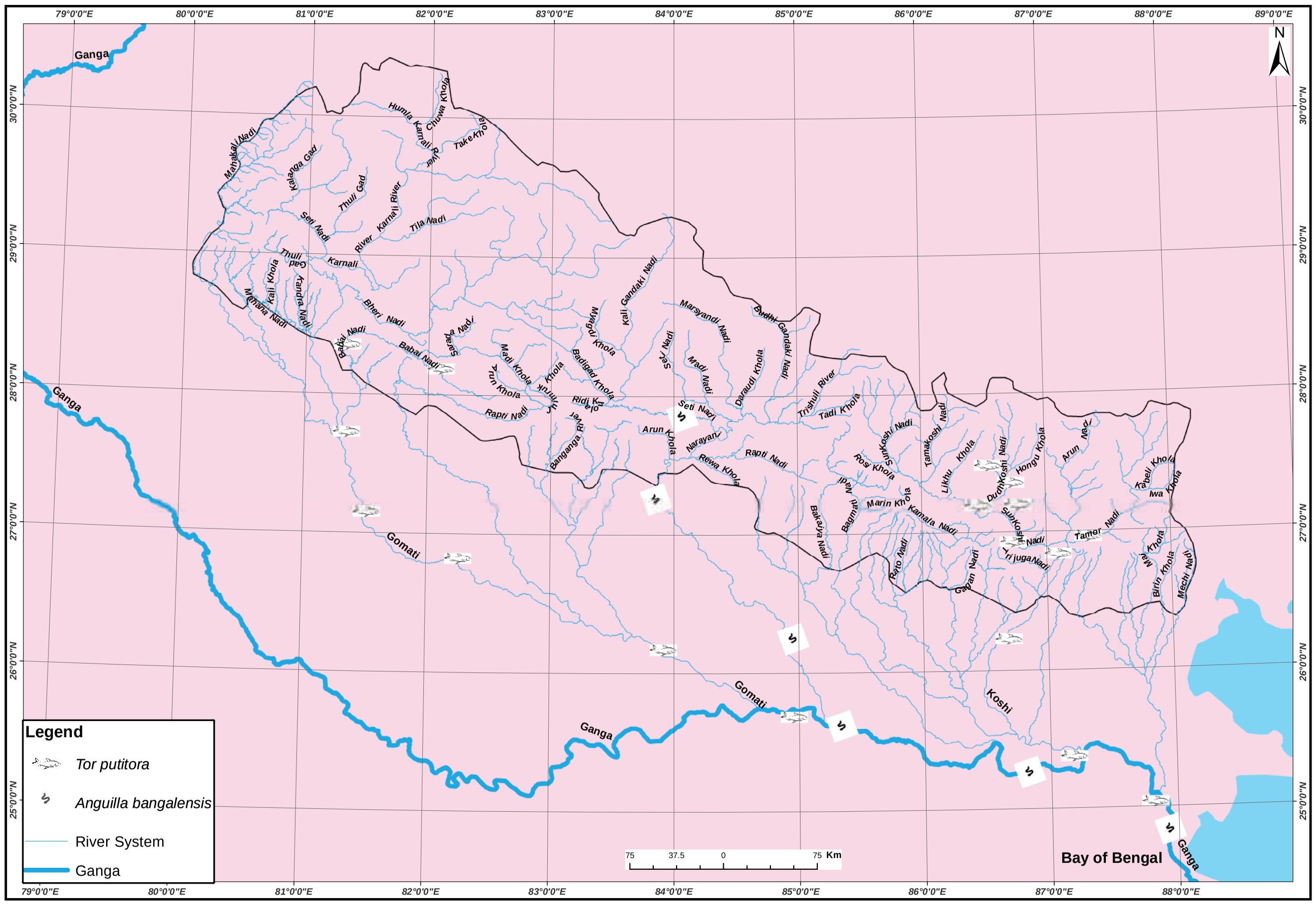
Parameters	Mirmi (Dam Site)			Beltari (Powerhouse Site)		
	June 2006	June 2009	June 2013	June 2006	June 2009	June 2013
Water Temperature (°C)	21.00	18.00	30.00	22.00	22.00	23.00
pH	8.60	7.80	7.05	8.30	7.90	7.75
Conductivity (mhos/cm)	268.00	328.00	NA	344.00	334.00	NA
Alkalinity (mg/l)	148.00	148.00	100.00	142.00	160.00	105.00
Dissolved oxygen (mg/l)	8.10	7.01	9.00	8.00	7.71	9.00
Carbon dioxide (mg/l)	8.70	13.00	NA	8.50	14.00	NA
Total hardness (mg/l)	138.00	152.00	99.00	132.00	160.00	110.00
Nitrite (mg/l)	0.010	0.003	0.099	0.010	0.002	0.050
Nitrate (mg/l)	0.150	0.043	NA	0.900	0.033	NA
Ammonia (mg/l)	0.010	0.005	0.010	0.030	0.005	0.005

mg/l = milligram per liter, mhos/cm = mhos per centimeter, NA = not available.

Source: ADB field observation and Kali Gandaki Fish Hatchery office.

ANNEX 14

Migration Route of Long-Distance Migratory Fish (*Tor putitora and Anguilla bengalensis*)



Source: Department of Survey, Nepal.

ANNEX 15

Framework for Screening Environmental Impact on Fish by Project Implementation

Indicators	Method	Potential Nature of Impact due to Dam Construction												Rationale
		Magnitude of Impact on Local and Migratory Fish (40%)				Extent (25%)			Duration of Impact (35%)				Total Score in the Scale of 100%	
		Low (10)	Medium (20)	High (70)	Total Score (40%)	Site-specific (10)	Regional (60)	Total Score (25%)	Low (10)	Medium (20)	High (70)	Total Score (35%)		
The waterbody is important for subsistence fishery	Consultation with local fishers				0			0				0		
The waterbody is important for commercial fishery	Consultation with local fishers				0			0				0		
Population of common fish species	Fish sampling Consultation with local fishers				0 0			0 0				0 0		
Population of threatened or endangered fish species listed under IUCN Red List	Fish sampling Consultation with local fishers				0 0			0 0				0 0		

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Annex 15 Table *continued*

Indicators	Method	Potential Nature of Impact due to Dam Construction												Rationale
		Magnitude of Impact on Local and Migratory Fish (40%)				Extent (25%)			Duration of Impact (35%)				Total Score in the Scale of 100%	
		Low (10)	Medium (20)	High (70)	Total Score (40%)	Site-specific (10)	Regional (60)	Total Score (25%)	Low (10)	Medium (20)	High (70)	Total Score (35%)		
Evidence of the presence of short- to medium-distance migratory fish species	• Fish sampling				0			0				0	0	
	• Consultation with local fishers				0			0				0	0	
	• Secondary information							0				0	0	
Evidence of the presence of long- distance migratory fish species traveling from India or Bangladesh	• Fish sampling				0			0				0	0	
	• Consultation with local fishers				0			0				0	0	
	• Secondary information				0			0				0	0	
Potential impact on migratory fish species due to barrier effect of dam	• Consultation with local fishers				0			0				0	0	
Population of endemic species	• Fish sampling				0			0				0	0	
	• Consultation with local fishers				0									
Number of fishers families fully dependent on fishing in the river around the proposed dam location	• Total Score				0			0				0	0	

IUCN = International Union for Conservation of Nature.

Source: Proposed by the study.

Impact of Dams on Fish in the Rivers of Nepal

This study was conducted by the Asian Development Bank to assess the impact of projects involving the construction of dams on aquatic biodiversity in Nepal. The findings may not be authoritative, but conclusions suggest that fish populations and the diversity of species are affected due to alterations in the ecosystem and blockage in life cycle movements.

About the Asian Development Bank

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