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MANAGEMENT OF AQUATIC INVASIVE PLANT AND ANIMAL SPECIES IN NEPAL

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Cover photo: Members of Bhagraiya Lake Management Committee removing water hyacinth from Bhagraiya Lake in Lower Karnali Watershed.

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CONTENTS

TABLES VI

FIGURE VII

ABBREVIATIONS VIII

1. EXECUTIVE SUMMARY 1

2. INTRODUCTION 4

3. OBJECTIVES 5

4. METHODOLOGY 6

5. ANALYSIS, RESULTS AND DISCUSSIONS 8

5.1 WETLANDS (RIVERS AND LAKES) OF NEPAL 8

5.1.2 WETLANDS OF LOWER MAHAKALI, LOWER KARNALI AND MIDDLE RAPTI WATERSHEDS 9

5.2 FRESHWATER AQUATIC BIODIVERSITY 9

5.3 AQUATIC INVASION 16

5.4 STATUS OF INVASIVE IN PAANI WATERSHEDS AND NEPAL 17

5.5 DISTRIBUTION OF EXOTIC SPECIES 23

5.6 DISPERSAL AND POTENTIAL FOR ESTABLISHMENT 27

5.6.1INVASIVE PLANTS 29

5.6.2 INVASIVE FISH 29

5.7 POTENTIAL IMPACT IN NATIVE ECOSYSTEM 36

5.7.1 EXOTIC AQUATIC INVASIVE PLANTS SPECIES (EAIPS) 38

5.7.2 AQUATIC INVASIVE FISH 40

5.8 COMMUNITY KNOWLEDGE AND PERCEPTION 43

5.9 COMMUNITY EFFORTS TO MANAGE INVASIVE SPECIES 43

5.10 DICHOTOMY OF ALIEN SPECIES 46

5.11 CLIMATE CHANGE AND NON-NATIVE FISH 47

5.12 QUARANTINE AND BIOSECURITY PROVISIONS 49

5.13 ACTS AND REGULATIONS ON INVASIVE 49

5.13.1 FOREST ACT 2019 50

5.13.2 PLANT PROTECTION ACT 2007 50

5.13.3 ANIMAL HEALTH AND ANIMAL SERVICE ACT 1999 50

5.13.4 LOCAL GOVERNMENT OPERATION ACT 2017 51

5.13.5 AGROBIODIVERSITY POLICY 2013 51

5.13.6 NATIONAL WETLANDS POLICY 2012 51

5.13.7 NATIONAL BIODIVERSITY STRATEGY AND ACTION PLAN 2014 51

5.14 INSTITUTIONS AND ARRANGEMENTS 52

5.14.1 RESEARCH 53

5.14.2 CAPACITY BUILDING AND EXTENSION 53

5.15 GAPS IN INVASIVE MANAGEMENT 54

5.15.1 KNOWLEDGE GAP 54

5.15.2 GAPS IN POLICY AND REGULATIONS GAPS 55

6. RECOMMENDATIONS 55
7. CONCLUSION 56
REFERENCES 57

TABLES

Table 1: Estimated water surface area (ha) in Nepal (Wagle et al., 2011) 4
Table 2: Aquatic invasive alien plant species (AIAPS) of Nepal (Source: Shrestha, 2016; Wagle et al. 17
Table 3: Exotic fish species of Nepal (Source: Shrestha, 2013; Gurung, 2005; Rai et al., 2003; Sharma, 2008) 19
Table 4: Exotic fish species and the characteristics of invasiveness 20
Table 5: Distribution of exotic aquatic plant species 23
Table 6: Distribution and major habitats of exotic fish species in Nepal 26
Table 7: Exotic Aquatic Invasive Plant Species (EAIPS) in surveyed LM, LK and MR watersheds, their nature of spread, mode of impact, and potential threats (Source: Paani Scoping Study, 2019) 38

FIGURE

Figure 1: Framework employed for impact assessment of aquatic invasive in Lower Mahakali, Lower Karnali, and Middle Rapti Watersheds 7
Figure 2: Fish breeding and nursing grounds in Lower Mahakali Watershed 11
Figure 3: Fish breeding and nursing grounds in Lower Karnali Watershed 13
Figure 4: Fish breeding and nursing grounds in Middle Rapti Watershed 15
Figure 5: Year wise introduction of number of exotic aquatic species in Nepal 18
Figure 6: Schematic representation of the phases between the introduction of an organism to a locality through human action, and its establishment and proliferation in natural (undisturbed) environments. [Adapted from Richardson et al., 2000] 28
Figure 7: Distribution of aquaculture facilities raising exotic species in Bhimdutta Municipality, Kanchanpur, and Lower Mahakali Watershed 33
Figure 8: Distribution of aquaculture facilities raising exotic species in Kailali and Bardiya, Karnali River Corridor, Lower Karnali Watershed 34
Figure 9: Distribution of aquaculture facilities raising exotic species in Lamahi and Gadhawa Municipality, Dang, Rapti River Corridor, Middle Rapti Watershed 35
Figure 10: Overall effects of invasive species on the abundance (a) and diversity (b) of five different functional groups of aquatic ecosystems and four environmental characteristics (c). In parentheses, the number of effect sizes are considered in each case. Error bars represent 95% confidence intervals and are only displayed when the number of effect sizes analyzed was ≥5. A significant effect of invasion is found when error bars do not overlap zero (adapted from Gallardo et al., 2016) 37
Figure 11: Annual trends of fish catch from Phewa Lake, Pokhara, Nepal (Adapted from Akbal, 2014) ... 42
Figure 12: Invasive management governance pathway of Rupa Lake Restoration & Fish cooperative (RLRFC), Rupa Lake, Kaski 45
Figure 13: Mean surface water temperature of the three lakes (Phewa, Begnas and Rupa) of mid hill Pokhara Valley, Nepal for a period of 1994 to 2006. 48

ABBREVIATIONS

ADB	Asian Development Bank
AFU	Agriculture and Forestry University
BCTS	Bhramhan, Chhatri, Thakuri, Sanyasi
BLMC	Bhagaraiya Lake Management Committee
CAACG	Community Aquatic Animal Conservation Group
CAQO	Central Animal Quarantine Office
CBD	Convention on Biological Diversity
CBO	Community Based Organization
CFPCC	Central Fisheries Promotion and Conservation Center
DoA	Department of Agriculture
DoLS	Department of Livestock Services
DoWNP	Department of Wildlife & National Park
EAIPS	Exotic Aquatic Invasive Plant Species
e-DNA	Environmental De-oxy Ribonucleic Acid
FGD	Focus Group Discussion
FRS	Fisheries Research Station
FVA	Fish Vulnerability Assessment
HPFC	Harpan-Phewa Fish Cooperative
IAS	Invasive Alien Species
INGO	International Non-Government Organization
IPPC	International Plant Protection Convention
IUCN	International Union for Conservation of Nature and Natural Resources

KII	Key Informant's Interview
KU	Kathmandu University
LK	Lower Karnali Watershed
LM	Lower Mahakali Watershed
MoALD	Ministry of Agriculture and Livestock Development
MoFE	Ministry of Forest and Environment
MoLMAC	Ministry of Land Management, Agriculture and Cooperative
MR	Middle Rapti Watershed
NARC	Nepal Agricultural Research Council
NBSAP	National Biodiversity Strategy and Action Plan
NEFEJ	Nepal Forum of Environment Journalists
NGO	Non-Government Organization
NIS	Non-Indigenous Species
PMC	Pokhara Metropolitan City
PSS	Paani Scoping Study
RLRFFC	Rupa Lake Restoration and Fish Farming Cooperative
SAARC	South Asia Association of Regional Cooperation
SNP	Shuklaphanta National Park
TU	Tribhuvan University
WECS	Water Energy Commission Secretariat

1. EXECUTIVE SUMMARY

Floral and faunal species, either terrestrial or aquatic, which grow and flourish away from their natural habitats and which influence native species or habitats, are considered invasive species for that ecosystem. According to the National Wildlife Federation (NWF,2019) an invasive species can be any kind of living organism that is not native to an ecosystem and causes harm to the environment, the economy, and/or human health. The International Union for Conservation of Nature and Natural Resources (IUCN, 2019) states that invasive species are a species introduced by humans – either intentionally or accidentally – that establishes itself outside of its natural past or present distribution, and whose introduction and/or spread threaten biological diversity.

USAID, through the USAID Paani Program (Paani), has been supporting the Nepal Government to enhance conservation of freshwater biodiversity through interventions that reduce threats to biodiversity and enhance community resilience. Paani focuses on strengthening the livelihoods of fish dependent communities by reducing poaching, overfishing, invasive species, and destructive and illegal fishing practices. The threat of invasive species to native biodiversity is a well-known issue around the world. In the case of water systems, invasive aquatic animals and plants pose a threat. With invasive fish, fishers are affected when these species decrease in important fish stock. Hence, it is important to have a full understanding of the scope and magnitude of the problems that invasive species prevent – to other aquatic life and to the livelihoods that depend on a diverse and healthy river system. With this full understanding, we can better devise effective management strategies to control the invasion and spread of invasive species.

Nepal is fortunate to have abundant and diverse water resources that are crucial in supporting the country's unique biological attributes, growing population and economy. There are three major river basins in Nepal with more than 6,000 freshwater streams that support 230 native fish species, including 16 endemic species. Freshwater biodiversity resources in Nepal provide a wide range of essential goods and services for the sustenance of human and ecological communities. Thus, it is critical to address current threats to the integrity of aquatic systems before they arise. The purpose of this study is

- to review and document the status of aquatic invasive management in Nepal, including current rules, policies and international arrangements;
- to identify potential gaps or areas needing more attention; and
- to suggest action steps for addressing invasive management issue in a more comprehensive manner.

This assessment report is based on Paani's consultations with numerous stakeholders at town hall meetings and two workshops devoted to this topic. Attendees included members of the general public (especially from fishing communities), government officials from relevant agencies, and members of the Nepal Forum of Environment Journalists (NEFEJ). The findings of Paani's scoping studies conducted in the Lower Mahakali (LM), the Lower Karnali (LK) and the Middle Rapti (MR) watersheds have also been incorporated into this report to provide necessary data for defining the scope and magnitude of the

problem. Additionally, Paani researchers conducted an extensive literature review, the details of which also inform the analysis.

The report provides information about the extent of aquatic invasive species throughout the country and more specifically in lower sections of the Mahakali, Karnali and Rapti watersheds. In Nepal, at least six exotic aquatic invasive plant species (EAIPS) have naturalized (i.e., established self-replacing populations), but at lower levels in the western part of the country, as compared to the central and eastern regions. Of the six EAIPS documented, water hyacinth, water lettuce and bush morning glory are abundant in lakes and marshy areas of all three watersheds.

Sixteen invasive fish species have been documented in Nepal, most of them introduced for aquaculture and naturalized through the technological advancement of hatchery propagation, especially in the Tarai and mid-hill regions of the country. The African catfish (*Clatias gariepinus*) and red-bellied piranha (*Pygocentrus nattereri*) were introduced by the private sector for fish farming, and these all have potential to self-reproduce in natural environment. The practice of fish farming these species – as well as pangas (*Pongasinodon hypophthalmus*) and red-bellied piranha (*P. nattereri*) – is becoming more popular in our study watersheds. However, if fish farming facilities are not properly regulated, the escape of these fish could disrupt riverine ecosystems. Furthermore, the status of their establishment in natural water (i.e., naturalization) is yet not known due to a lack of research on the topic.

A literature review of invasive species in Nepal finds that most perceived impacts of EAIPS are largely based on anecdotal evidence. EAIPS reported in Nepal can have numerous harmful effects. They can:

- reduce access to water for recreation;
- interfere with various engineering structures, block drains and cause flooding;
- prevent photosynthesis in the water below the surface;
- impact native animals and plants by altering aquatic ecosystems, especially with regard to available food and breeding grounds;
- smother and degrade fish spawning sites;
- reduce the aesthetic value of water bodies; and
- favor the spread of certain diseases spread by mosquitoes and snails.

Although careful impact analyses of invasive fish species have not yet been conducted in Nepal, some reports clearly indicate that invasive species currently play a destructive role in the natural ecosystem and human economy. This has been documented especially in the lakes of Pokhara Valley and the Kulekhani hydropower reservoir in central Nepal.

Most fishing communities in our study areas are aware of the presence of exotic fish, but they do not recognize these species as invasive because they grow quickly and promise high yields for good profits. On the other hand, the communities reported good knowledge on invasive plants and are aware of their characteristics of proliferation (reproductive capacity), distribution (scale), and competitive advantage against other plants. Implementation of a large-scale awareness and education program by the government could help change community perceptions on the risk of aquatic invasive species and improve the implementation of preventive measures to reduce future introductions.

Some local communities and their organizations are involved in the control and management of EAIPS, for example, in the lakes of Pokhara Valley and for Bhagaraiya Lake in Lower Karnali watershed. Institutional arrangements and centralized resource mobilization, as in the case of Rupa Lake in Pokhara, shows that network governance is more effective to control aquatic invasive problems. Most areas where invasive issues are present will require several factors to stop the spread, including better adherence to theoretical prescriptions, a more informed and more involved public, and stronger regulatory efforts by respective governments. A combination of these factors would likely have beneficial consequences in a sustainable manner.

Our extensive review of existing environmental regulatory policies found that they do not discuss nor prioritize the threat of invasive species to aquatic biodiversity and wild aquatic habitats. Policy and plans related to fisheries and aquaculture need to give special attention to address issues of aquatic invasive management in the future. Furthermore, institutional arrangements with clear mandates could shore up the current lack of knowledge, policy and implementation strategy for addressing invasive issues. With regard to the fishery sector, there is an urgent need for technical assistance to the Ministry of Forests and Environment (MoFE) and the Ministry of Agriculture and Livestock Development (MoALD) to flesh out a sector-specific plan of action for invasive management.

The lack of policy and official management strategies to confront invasive species in Nepal also points to the lack of solid evidence on the scope and magnitude of the problem. Access to scientific information is critical for ensuring an effective response to biological invasions. Research is needed to build a firm legal frame work, provide strict implementation of Convention on Biological Diversity (CBD) guidelines, and create a strong community knowledge about the principles of responsible aquaculture, including a healthy understanding of the threat of invasive species.

2. INTRODUCTION

Floral and faunal species, either terrestrial or aquatic, which grow and flourish away from their natural habitats and which influence native species or habitats, are considered invasive species for that ecosystem. According to the National Wildlife Federation (2019), an invasive species can be any kind of living organism, not native to an ecosystem that causes modifications to the environment, the economy, and/or human health. IUCN states that invasive species are a species introduced by humans – either intentionally or accidentally – that establishes itself outside of its natural past or present distribution, and whose introduction and/or spread threaten biological diversity.

Biological invasions by non-indigenous species (NIS) are widely recognized as a significant component of anthropogenic global environmental change and often result in a significant loss in economic value, biological diversity, and function of invaded ecosystems (Humle, 2003, Gibson et al., 2013). The Global Invasive Species Program (GISP) states that invasive species have the potential to affect ecosystems by changing the density, diversity and distribution patterns of the native species. Some invasive alien species can indirectly and directly affect the human health of a region by damaging the livelihoods of the surrounding economy (Bam et al., 2013; Sandilyan, 2016).

Wetlands support unique aquatic and terrestrial species of plants and animals, most of which are endemic to that habitat or region. Due to their biodiverse richness, wetlands are considered "biological supermarkets" (Lu, 2002). In addition, wetlands also provide unique values continuously to society (e.g., economic, aesthetic) (Heimlich *et al.,* 1998).

Nepal has diverse topography and different climatic zones, which support diverse wetland habitats. Wetlands in Nepal cover 2.06 million hectares (Table 1), including areas under paddy cultivation (Wagle et al., 2011). From a biodiversity point of view, Nepali wetlands support a variety of species and harbor unique taxonomic groups.

Table 1: Estimated water surface area (ha) in Nepal (Wagle et al., 2011)

Resource details	Estimated area (ha)	Potential area (ha)
Natural water	401,500	
Rivers	395,000	
Lakes	5,000	
Reservoirs	1,500	78,000
Village ponds	10,700	14,000
Seasonal water		
Marginal swamps	11,100	
Irrigated rice fields	1,227,353	
Irrigation canal length	12,640	
Total	2,064,793	92,000

With its wide elevation gradient and heterogeneous geomorphology, organisms from anywhere in the world may find suitable habitat and climatic conditions in Nepal. There are at least 219 exotic species of

flowering plants (Tiwari et al., 2005, Siwakoti, 2012, Sukhorukov, 2014) and 64 species of animals (Budha, 2014) that have naturalized (i.e., alien species with self-sustaining population) in Nepal. In comparison to alien plant species of Nepal, exotic fauna are poorly investigated and relatively neglected. Budha (2013) produced the first preliminary documentation on invasive exotic fauna in Nepal and provided first-hand information about 27 exotic species, including one species of crustacean, seven species of insects, nine species of mollusks, nine species of fish, and one species of bird. However, many more species need to be explored to produce the complete list.

The introduction of invasive exotic flora and fauna is considered to be a major cause for species endangerment and extinction in aquatic ecosystems, including inland wetlands (Claudi and Leach, 1999; Sala et al., 2000). Aquatic invasive species pose major ecological and economic threats to rivers, lakes and waterways worldwide through displacement of native species, altering hydrological cycles, affecting nutrient cycles, altering food web dynamics, introducing new diseases and parasites, hybridizing with native species, and causing large economic loss and cultural costs (Pimentel et al., 2000; Lockwood et al., 2007).

Nepal's several aquatic resources are exposed to exotic flora and fauna. Water hyacinth, water lettuce and other exotic aquatic plants in wetlands accelerate eutrophication, ecosystem degradation, fish migration and reproduction, and other water-related services (Bista et al., 2007). Historically, Nepal has introduced exotic carp and catfish to boost commercial aquaculture, but some of these species have been naturalized or are in the process of naturalization and are contributing to the economic development of rural communities. Exotic species management become complicated in situations where such species provide some economic benefits but also threaten the survival of endemic species. For example, the African Catfish (*Clarias geriepinus*) is very popular for commercial breeding (and profitable), but it also threatens the survival of multiple endemic species around the world (TET, 2015). In Nepal, knowledge about these trade-offs is currently lacking.

Paani has been working with the Nepal Government to enhance conservation of freshwater biodiversity through interventions that reduce threats to biodiversity and by enhancing community resilience. Paani focuses on strengthening livelihoods for fish-dependent communities by reducing poaching, overfishing, invasive species, and destructive and illegal fishing practices. Hence, it is important that all the factors that can affect fish stock are well understood along with the introduction source, magnitude of impact, and mode of dissemination of invasive species. This information will enable more effective management of invasive species in the Paani target watersheds.

3. OBJECTIVES

The overall goal of this study is to assess and analyse the impacts of invasive species on aquatic biodiversity and socio-economic aspects of human communities with a specific focus on the lakes and rivers in the lower reaches of the Mahakali, Karnali and Rapti river basins.

The specific objectives are to:

- Review and analyze the potential impacts of invasive species on freshwater biodiversity;
- Identify and assess the value of invasive species specific to livelihood support;

- Review climate change impacts on the spread of aquatic invasive;
- Review existing policies and institutions that address aquatic invasive species;
- Assess and analyze gaps in knowledge, policy and institutions to address invasive problems;
- Identify issues and challenges in the selected watersheds in relation to aquatic invasives; and
- Improve local capacity for advocating for freshwater biodiversity conservation and inform policy reform.

4. METHODOLOGY

This assessment report is based on Paani's consultations with numerous stakeholders at town hall meetings and two workshops devoted to this topic. Attendees included members of the general public (especially from fishing communities), government officials from relevant agencies, and members of the Nepal Forum of Environment Journalists (NEFEJ). Four special groups were invited to the workshop as well:

- Rupa Lake Restoration and Fish Farming Cooperative Pvt. Ltd. (RLRFFC);
- Harpan-Phewa Fish Cooperative Pvt. Ltd. (HPFC);
- Seed Foundation;
- Fisheries Research Station.

These groups shared the evolutionary history of invasive species and the mechanisms and measures applied to manage them. Following the workshop, participants completed a transect walk to observe and interact with fishery officials and fisher cooperatives in Phewa and Rupa lakes to learn more about the persistence of exotic/invasive species and management problems.

Paani also conducted scoping studies in the Lower Mahakali (LM), the Lower Karnali (LK) and the Middle Rapti (MR) watersheds for defining the scope and magnitude of the problem. In these studies, minutes from local town hall meetings were included to document the observations of communities regarding invasive species, such as the invasion of water hyacinth in Bhagaraiya Tal in Bardiya.

While many relevant observations were shared, many stakeholders admitted not having a broad and clear understanding about the potential impacts of invasives on aquatic biodiversity, and, hence, their ideas about invasives and their threat can often be over- or under-estimated. This situation calls for a necessary validation of such data through field observations. The watershed profiles and health reports of the LM, LK and MR watersheds also highlight some invasive species negatively impacting fisheries, but the level to which these species are a threat to biodiversity were not assessed.

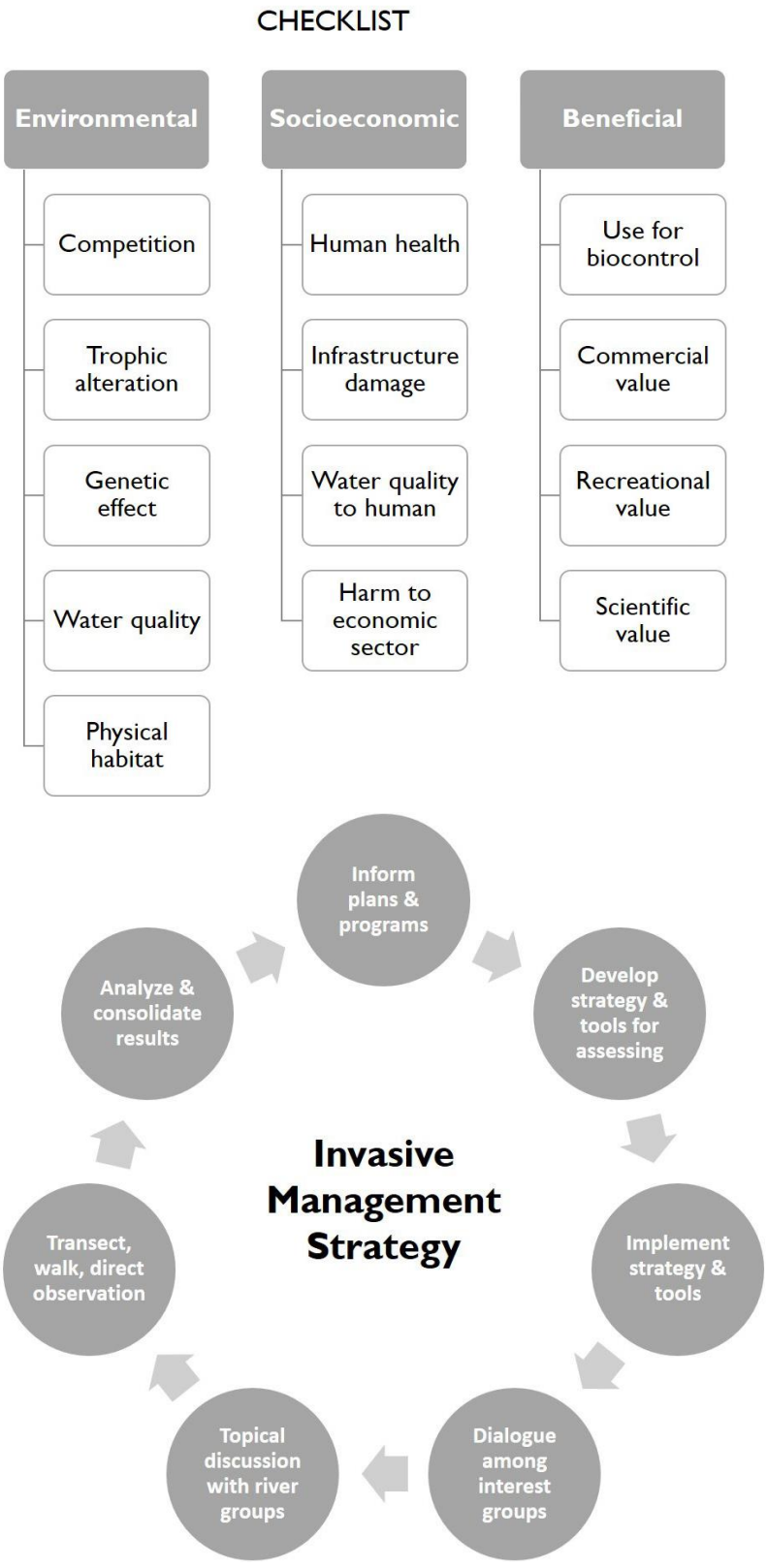


Figure 1: Framework employed for impact assessment of aquatic invasive in Lower Mahakali, Lower Karnali, and Middle Rapti Watersheds

Two consultation meetings with stakeholders were organized to understand:

1. The extent of knowledge and information available;
2. Status of relevant of legal instruments related to invasive species;
3. Which institutions would play what role for invasive species management;
4. How would new measures and policy be implemented; and
5. What are the next steps needed, short and long term?

Where data and information are deficient on this topic, literature reviews were used to provide supplementary information to understand the potential impact of aquatic inavasives. Figure 1 illustrates a full schematic of the study design and methodology.

5. ANALYSIS, RESULTS AND DISCUSSIONS

5.1 WETLANDS (RIVERS AND LAKES) OF NEPAL

Wetlands are defined as the lands transitional between terrestrial and aquatic ecosystems, where the water table is usually at or near the surface or the land covered by shallow water (Mitch and Gosselink, 1986). Wetlands are considered to be one of the most threatened of all major natural ecosystems and are claimed to deserve high priority for conservation and sustainable use. Wetlands of Nepal range from the torpid ponds of the subtropical Tarai to the glacial lakes of the High Himalayas, which indicates the diverse wildlife species supported by them. Wetlands of Nepal constitute an important ecosystem that harbors a large number of endemic wildlife. Wetlands are considered "biological supermarkets" because they support a large and complex food web, are rich in biodiversity, provide unique habitat for a large number of wildlife, and are loaded with immeasurable genetic wealth (Lu, 2002; Sandilyan et al., 2009). Apparently wetlands have also been shown to enhance a variety of ecological, biological and hydrological functions, which provide economic, aesthetic, recreational, educational and other values to society continuously, such as ecosystem services (Mistch and Gosselink, 1986, Heimlich *et al.,* 1998; Sandilyan *et al.,* 2009).

Nepal has a unique geographical diversity and different climatic zones, which support diverse wetland habitats throughout the country. Wetlands in Nepal cover 2.06 million hectares, including areas under paddy cultivation (Wagle et al*.,* 2011). Wetland ecosystems of Nepal fall into two broad categories: (i) natural wetlands, comprising of lakes and ponds, riverine floodplains, swamps and marshes, and (ii) man-made wetlands, including water reservoirs, ponds and deep-water paddy fields. Irrigated paddy fields cover the largest area followed by rivers. Rivers are the most extensive and visible wetlands in Nepal. The country has approximately 6,000 rivers and rivulets, including permanent and seasonal rivers, streams and creeks (WECS, 2002). The major river systems of Nepal include the Mahakali, Karnali, Gandaki, and Koshi. Large sections of the Mahakali and Mechi rivers form the Nepal-India border in the Far West and the East, respectively. Nearly half (45%) of the wetlands are in High Himal (GoN/MoFSC, 2014) due to the large number of glaciers and glacial lakes in the Himalayan region. Among the major river basins, Karnali hosts the highest number (36%) of wetlands, followed by Koshi (Bhandari, 2009).

5.1.2 WETLANDS OF LOWER MAHAKALI, LOWER KARNALI AND MIDDLE RAPTI WATERSHEDS

Lower Mahakali watershed is located in the Tarai and south of the Siwalik Range, and includes the Bhimdutta and Mahakali municipalities of Kanchanpur district. Wetlands of the watershed consist of 16 perennial streams that join in the lower section of Mahakali River and three natural lakes with an area of 26.7 ha (USAID/Paani a, 2017; MoFSC, 2017). Beside natural water, a recent compilation of fish farming activity reported that 198 ha manmade ponds and 95 ha natural ponds are being used for aquaculture, mostly with exotic carp and catfish (CFPCC, 2019).

The Lower Karnali watershed is located in the Tarai, south of the Siwalik range and the Chisapani Bridge along the Karnali River. The watershed forms the southern outlet for the Karnali River. It consists of three floodplains, the Karnali, Orahi and Kaurahi rivers (18188 ha), and three natural lakes covering an area of 40 ha (USAID/Paani, 2018). A recent compilation of fish farming activity reported that 408 ha of manmade ponds and 153 ha of natural ponds are being used for aquaculture (CFPCC, 2019).

The Middle Rapti watershed (453 km^2) is located within Dang district and about 8% of the area is watershed comprised of rivers, lakes and ponds. The main channel of the Rapti River runs north to south through the middle of the watershed and links with 47 streams and tributaries. According to CFPCC (2019), 244 ha of manmade ponds have been constructed in the watershed for aquaculture. The wetlands of these watersheds are prone to the spread of aquatic invasive species due to favorable climatic conditions and because the geomorphology is suitable for aquaculture, raising the possibility of exotic species being introduced into the wetlands for cultivation.

5.2 FRESHWATER AQUATIC BIODIVERSITY

Nepal's freshwater system harbors unique species of flora and fauna. Freshwater systems have very great ecological significance, as they harbor many threatened and endemic species of flora and fauna and serve as resting places for many migratory and globally-threatened birds. The country's freshwater sustains 230 species of indigenous fish, including 16 species that are endemic to Nepal (Rajbanshi, 2013). Among the Nepali wetlands, rivers are the richest in biodiversity. The river system is identified as one of the last frontiers of freshwater diversity, which in Nepal supports 21 species of fish that are listed on IUCN's threatened category of species (MoEST, 2014). The wetlands also host an estimated 117 species of amphibians (Bhuju et al., 2007). Fifty aquatic species of mollusks have been reported from Nepal, and of those, 25 species are consumed by ethnic communities (Subba, 2012, Wagle et al., 2017). Lakes and rivers of Nepal also host eight species of freshwater shrimp belonging to the genus *Macrobrachium* (Shrestha *et al.* 2001). Plant checklists for Nepal record 6,076 species of flowering plants and 534 ferns, of which twenty-five percent are found in wetlands with about 26 endemic wetlands species (Tiwari et al., 2019; GoN/MoEST 2014). The Tarai wetlands is home to 318 species of plants (DOF, 2017).

The Lower Mahakali watershed hosts 40 native fish species, including five species on the IUCN threatened species list, four migratory species, and one endemic species (Paani FVA, 2019; Rajbanshi, 2013). A recent study indicates that the Lower Mahakali watershed supports endemic fish species such as catfish (*Pseudoecheineis serracula)* (Rajabanshi, 2013). Five species of fish on the IUCN Red List and four migratory species dwell in the Mahakali River (Paani FVA, 1019). The lower reaches of the Mahakali

River and its tributaries are well-known migration routes and serve as breeding and spawning grounds for migratory and endemic species (Figure 2).

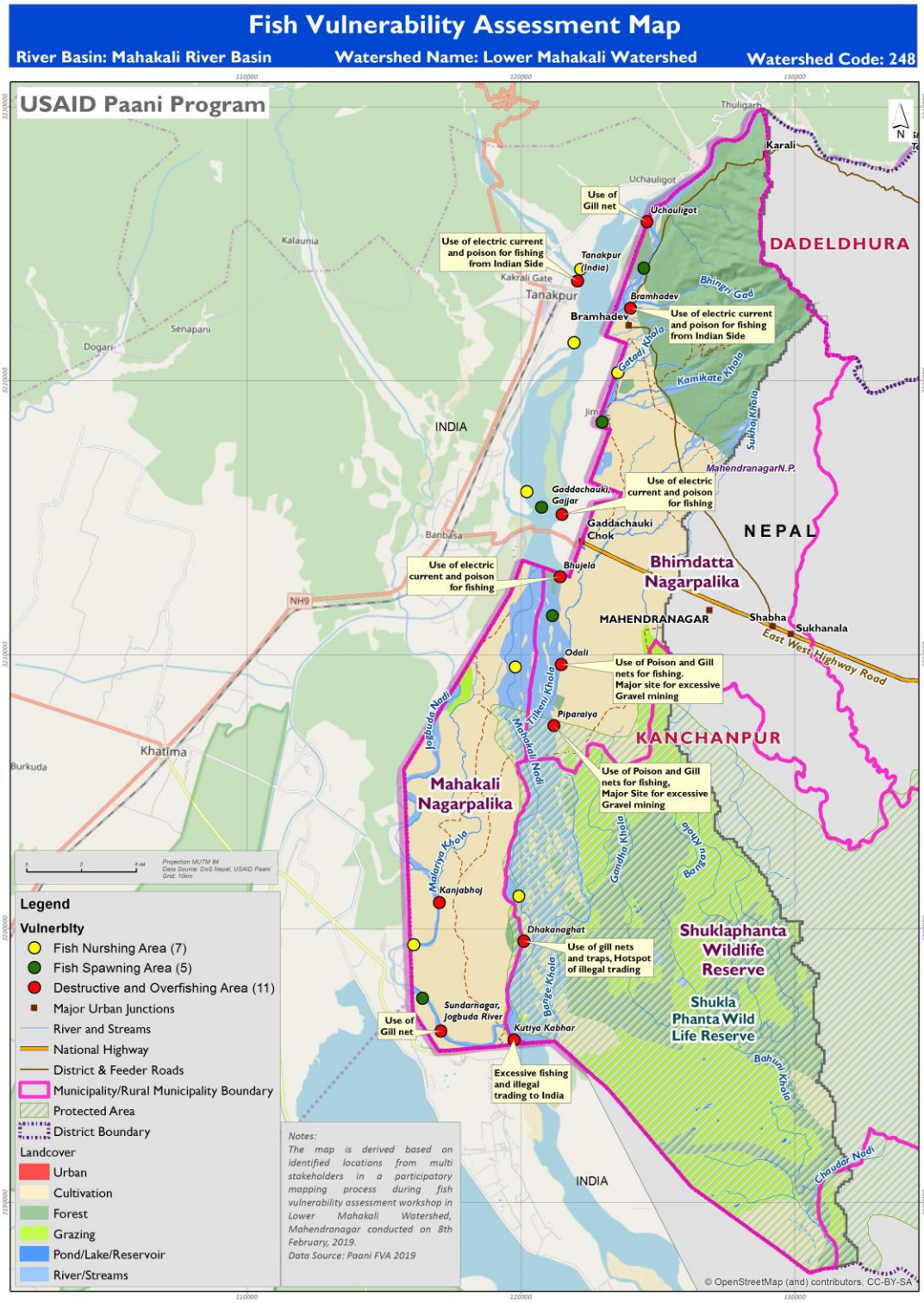


Figure 2: Fish breeding and nursing grounds in Lower Mahakali Watershed

A Fish Vulnerability Assessment (FVA) has identified three keystone fish species, such as mahseer (*Tor putitora*), clonch (*Labeo angra*) and asala (*Schizothorax richardsonii*) based on their availability, preference, economic and ecological values (Paani FVA, 2019). Historically, Gharials were distributed across all the major river systems of Nepal (Koshi, Gandaki, Karnali and Mahakali) (Maskey 1989). The disappearance of gharial from the Mahakali River can be attributed to the construction of barrages, excessive use of gill nets, and habitat loss.

Lower Karnali watershed hosts 123 fish species out of the 153 species identified in the Karnali River system (Paani FVA, 2019; Smith et al., 1996). Six species of fish appear on the IUCN Red List, and five migratory species dwell in the lower reaches of the Karnali River (Paani FVA, 1019). Among the fish species, golden mahseer (*Tor putitora*), gardi (*Labeo dero*), and kalanch (*Labeo angra*) are ecologically and economically important. The Gangetic river dolphin (*Platanista gangetica*), a globally threatened mammal, is found in the Lower Karnali watershed, as well as two species of crocodiles – the marsh Mugger (*Crocodylus palustris)* and the freshwater gharial (*Gavialis gangeticus).* The lower reaches of the Karnali River and its tributaries are well known migration routes, and serve as breeding and spawning grounds for migratory and endemic species (Figure 3).

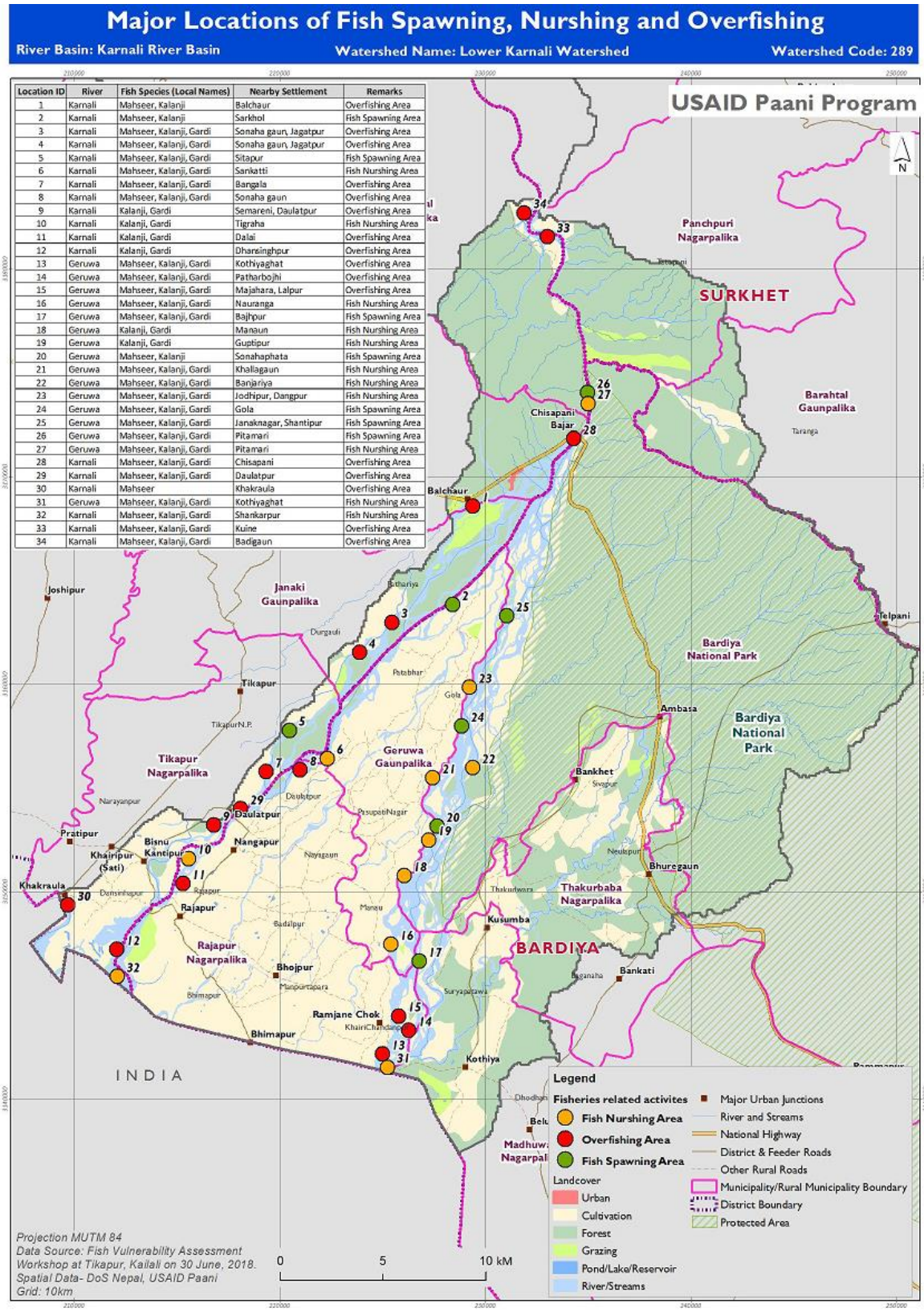


Figure 3: Fish breeding and nursing grounds in Lower Karnali Watershed

The Rapti River and its tributaries host 57 species of fish out of the reported 70 species in the entire basin (Paani FVA, 1019). Among the fish species dwelling in the Rapti's freshwater systems, six species are on included on the IUCN Red List threat category and five migratory species. A fish vulnerability assessment (FVA) identified three keystone species in the watershed: baikha (*Pongasius pongasius*), kalmuda (*Labeo dero*) and rawa (*Cirrhinus rewa*). The most important migratory species are mahseer (*Tor putitora*), rajbam (*Anguilla bengalensis*), goonch (*Bagarius bagarius, B. Yarreli*). The FVA also revealed no endemic species. Two catfish species (sauraa and undaar) have been reported extinct from the Rapti River Basin within the last ten years. These species prefer shallow water with vegetative substrate as habitat, and the loss of substrate and the use of pesticides in nearby agricultural fields have been blamed for their extinction. The Middle Rapti watershed also hosts the Crowned River Turtle (*Herdella thurjii*) and ghariyal (*Gavialis gangeticus*). The existence of these large aquatic vertebrates indicates that the aquatic environment of Middle Rapti supports a higher trophic level for the co-existence of diverse aquatic animals in different levels of ecosystems and habitats. The lower reaches of the Rapti River and its tributaries are well known migration routes and serve as breeding and spawning grounds for migratory and flagship species (Figure 4).

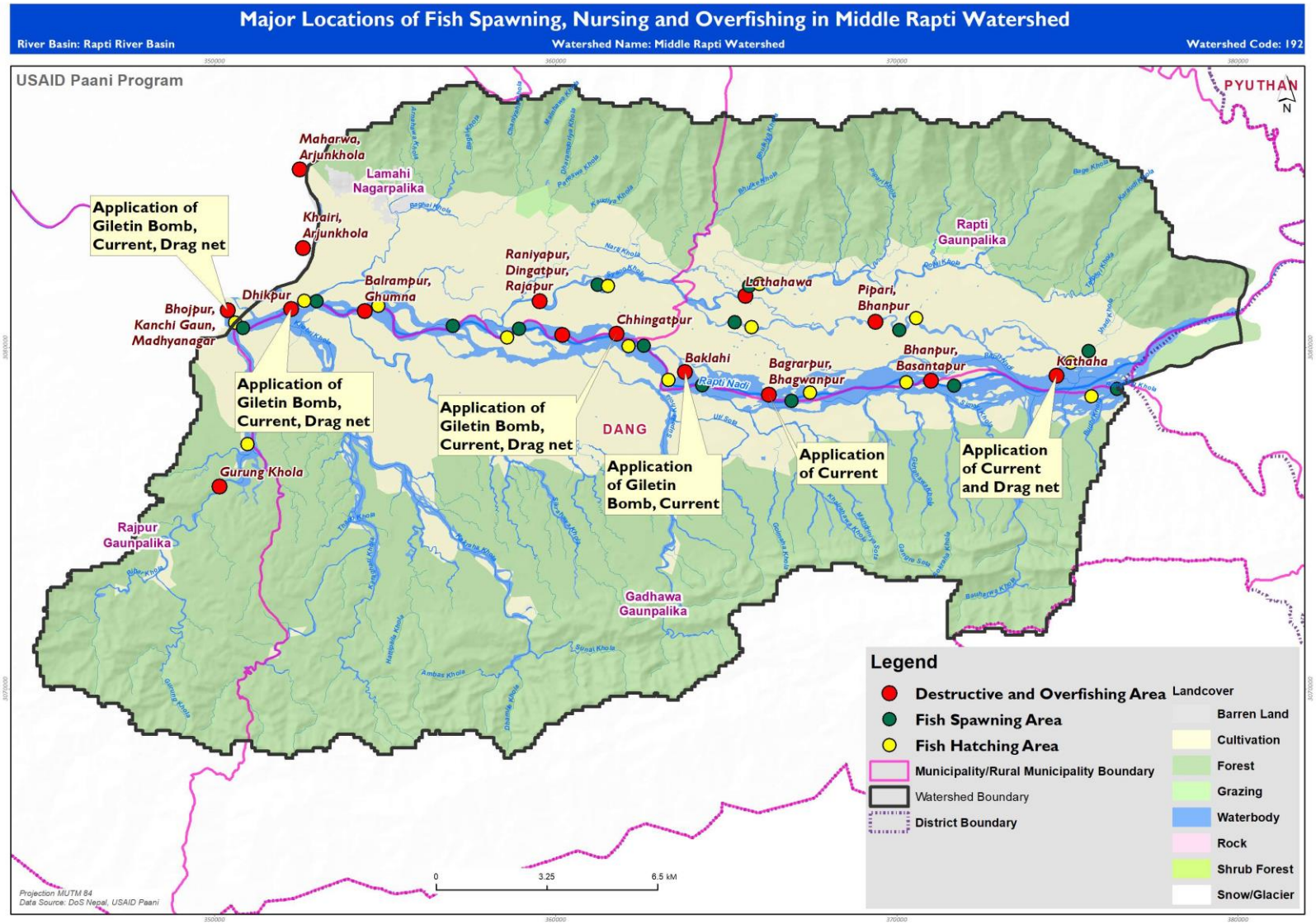


Figure 4: Fish breeding and nursing grounds in Middle Rapti Watershed

Pond aquaculture, mostly with exotic carp and catfish, is all three watersheds. Exotic carp include the common carp (*Cyprinus carpio*), silver carp (*Hypophthalmicthys molitrix*), grass carp (*Ctenopharyngodon idella*) and bighead carp (*Aristicthys nobilis*). There is also a growing trends of rearing of invasive catfish such as the African catfish (magur, *Clarias gariepinus*), red belly piranha (rupchanda, *Pygocentrus nattereri*), and Nile tilapia (*Oreochromis niloticus*) in the watersheds because of their high productivity and profitability. Of the 241 exotic ornamental fish species imported into Nepal (CFPCC, 2019), about 6-8% ornamental species from India are found in these watersheds. Intentional and unintentional release of these exotic fish species in natural water systems of these watersheds may pose threats to native biodiversity, which is discussed in the sections below.

5.3 AQUATIC INVASION

Several studies reveal that invasive species have emerged as a threat to endemic and threatened species in several vital ecosystems of Nepal, including biological hotspots (MoFSC, 2014; Budha, 2014; Shrestha et al., 2017). In freshwater systems, aquatic plants, ornamental and commercially important fish, and some species of shellfish have been identified as the worst invasives (e.g., Budha, 2014; Shrestha et al., 2017). Worldwide aquatic invasive species pose major ecological and economic threats to rivers, lakes and waterways for displacing of native species, altering hydrologic cycles, affecting nutrient cycles, altering food web dynamics, and introducing diseases and parasites and hybridization with native species (Bartley et al., 2006; Poulos et al., 2012). With these impacts on ecosystems and biodiversity, the invaders pose a serious threat to regional economies and livelihoods of rural communities (Pimentel et al., 2000) and exact high cultural costs (Lockwood et al., 2007).

Box 1: Recommended terminology in plant and animal invasion ecology (modified from Kunwar, 2003)

Native species	Plant or animal species or subspecies, occurring within their natural range (past or present) and dispersal potential (i.e. within the range they occupy naturally or could occupy without direct or indirect introduction by humans)
Alien species	Plant or animal taxa in a given area whose presence there is due to intentional or acci introduction as a result of human activity (exotic, non-native, non-indigenous plants o animal)
Casual alien species	Alien plants or animal that may grow and even reproduce occasionally in an area, but which do not form self-replacing populations and which rely on repeated introduction for their persistence
Naturalized species	Alien plants or animals that reproduce consistently and sustain populations over many life cycles without direct intervention by humans. They often recruit offspring freely, usually close to adult, and do not necessarily invade natural or human-made ecosystems
Invasive species	Naturalized plants or animal that produce reproductive offspring, often in very

5.4 STATUS OF INVASIVE IN PAANI WATERSHEDS AND NEPAL

In Nepal, at least 179 alien plant species have naturalized (i.e., established their self-replacing population) and among them, six wetland-dependent species, mostly native to the tropical Americas, have been reported to have negative impacts on aquatic ecosystems (Shrestha et al., 2017) (Table 2). The number of EAIPS is lower in western Nepal than in the central and eastern regions. The historical record of EAIPS in Nepal suggests that bush morning glory was introduced 160 years ago, while five other species, including water hyacinth, were introduced within the past 25-70 years (Figure 5).

Table 2: Aquatic invasive alien plant species (AIAPS) of Nepal (Source: Shrestha, 2016; Wagle et al.

S.N.	Scientific name	Common name	Country of origin	Year of introduction	Purpose of introduction
1	*Eichhornia crassipes*	Water hyacinth	South America	1966	Ornamental
2	*Ipomoea carnea*	Bush morning glory	Mexico & South America	1966	Not known
3	*Alternanthera philoxeroides*	Alligator weed	South America	1994	Ornamental
4	*Myriophyllum aquaticum*	Parrot's feather	South America	-	Ornamental
5	*Leersia hexandra*	Southern Cut Grass	-	1820	Ornamental
6	*Pistia stratiotes*	Water lettuce	South America	1952	Ornamental

Photo 1: Exotic aquatic invasive plant species (EAIPS) in Nepal (Photo credit: Paani, 2018)

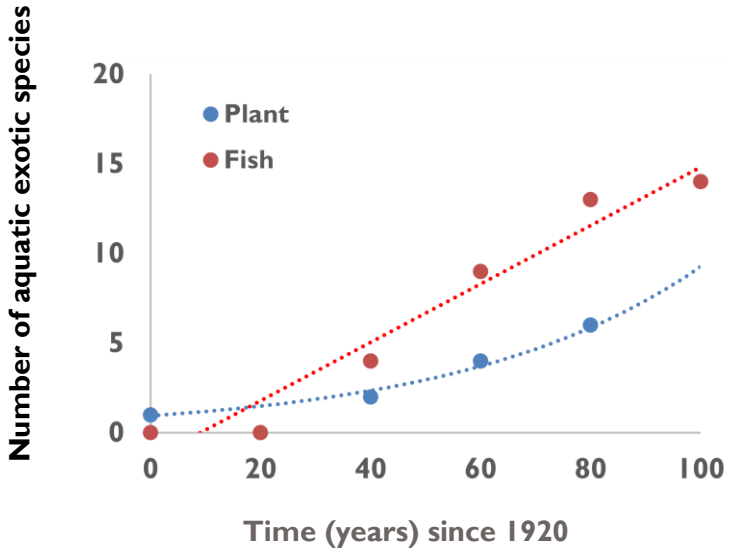


Figure 5: Introduction of number of exotic aquatic species in Nepal since 1920

There are 16 exotic fish species in Nepal, most of which were introduced for aquaculture (Table 3) (Shrestha, 2013; Sharma 2008). The aquarium industry in Nepal is emerging and entirely depends on exotic species. According to the CFPCC (2019), aquarists have introduced 241 species of ornamental fish species with limited cases of species establishment. Exotic fish were introduced for aquaculture as far back as 55 years ago, and most of them are naturalized through the technological advancement of hatchery propagation, leading to wider distribution across Tarai and midhill regions of the country (Table 4).

Table 3: Exotic fish species of Nepal (Source: Shrestha, 2013; Gurung, 2005; Rai et al., 2003; Sharma, 2008)

S.N.	Scientific name	Common name	Country of origin	Year of introduction	Purpose of introduction
1	*Gambusia affinis*	Mosquito Fish	Unknown	1964 (unofficial)	Unknown
2	*Ctenopharyngodon idella*	Grass Carp	China	1965/66	Aquaculture
3	*Hypophthalmichthys molitrix*	Silver Carp	China	1967/68	Aquaculture
4	*Salmo trutta*	Brown Trout	Europe	1969	Ranching in river
5	*Aristichthys nobilis*	Bighead Carp	China	1971	Aquaculture
6	*Onychorynchus mykiss*	Rainbow Trout	Japan	1971, 1988	Aquaculture
7	*Onychorynchus rhodurus*	The Biwa Trout	Japan	1975	Ranching in river
8	*Cyprinus carpio*	Common carp	Hungary	1979	Aquaculture
9	*Oreochromis mossambicus*	Mozambique Tilapia	Unknown	1985 (unofficial)	Unknown
10	*Oreochromis niloticus*	Nile Tilapia	Thailand	1985	Aquaculture
11	*Clarias gariepinus*	African Catfish	India	1996-97 (unofficial)	Aquaculture
12	*Pongasinodon hypophthalmus*	Pangas	India, Thailand	2004, 2016	Aquaculture
13	*Cyclocheilichthys apogon*	Beardless Barb	Indonesia	Unknown (unofficial)	
14	*Puntius gonionotus*	Silver Barb	Bangladesh	Unknown	Aquaculture
15	*Carassius carassius*	Crucian Carp	Japan	Unknown	Aquaculture

S.N.	Scientific name	Common name	Country of origin	Year of introduction	Purpose of introduction
16	*Pygocentrus nattereri*	Red belly piranha	India	2008	Aquaculture

Table 4: Exotic fish species and the characteristics of invasiveness[1]

Mosquito Fish (*Gambusia affinis*)

Viviparous, reproduces in natural environment, larvivorous, feeds on zooplankton, small insects and insect larvae (mosquito) and detritus material, naturalized species,

Photo credit: https://en.wikipedia.org/wiki/Mosquitofish

Grass carp (*Ctenopharyngodon idella*)

Reproduces in controlled environment (hatchery), macrophytophagous, exotic species.

Photo credit: FRD, Pokhara

Silver carp (*Hypophthalmichthys molitrix***)**

Reproduces in controlled environment (hatchery), planktivorous, exotic species.

Photo credit: FRD, Pokhara

Bighead carp (*Aristichthys nobilis***)**

Reproduces in controlled environment (hatchery), planktivorous, exotic species.

Photo credit: FRD, Pokhara

[1] The two alien species, brown trout (*Salmo trutta*) and the Biwa trout (*Onychorynchus rhodurus*), are extinct from the freshwater of Nepal.

Common carp (*Cyprinus carpio*)

Reproduces in natural environment with vegetative substrate, omnivorous, exotic invasive species.

Photo credit: FRD, Pokhara

African catfish (*Clarias gariepinus*)

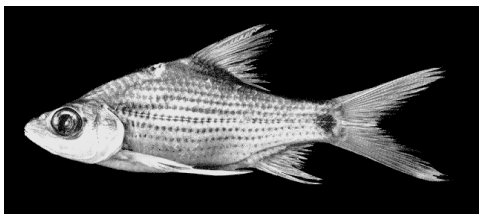
Reproduces in natural environment, carnivorous, invasive exotic species

Photo credit: Paani, Suresh Wagle

Pangas (*Pongasinodon hypophthalmus*)

Reproduces in controlled environments (hatchery), omnivorous, exotic species.

Photo credit: Suresh Wagle



Beardless barb (*Cyclocheilichthys apogon*)

Reproduces in natural environment, feeds on small plankton and crustaceans, invasive exotic species

Photo credit: https://www.fishbase.se

Silver barb (*Puntius gonionotus*)

Reproduces in natural environments, feeds on small plankton and crustaceans, invasive exotic species

Photo credit: https://www.fishbase.se

Crucian carp (*Carassius carassius*)

Reproduces in natural environment with vegetative substrate, omnivorous, exotic invasive species.

Photo credit: https://www.fishbase.se

Red belly piranha *(Pygocentrus nattereri)*

Reproduces in natural environment with vegetative substrate, carnivorous, exotic invasive species

Photo credit: https://www.fishbase.se

Suckermouth armoured catfish (*Pterygoplichthys* sp)

Prefers warm water, reproduces in natural environment, algae feeder, exotic invasive species.

Photo credit: Paani, Suresh Wagle

Rainbow trout (*Onychorynchus mykiss*)

Coldwater species reproduces in controlled environment (hatchery), omnivorous, exotic species.

Photo credit: Paani, Suresh Wagle

A scoping study conducted by Paani observed that the presence of EAIPS – mainly water hyacinth, water lettuce and bush morning glory – are present in the lakes and marshy areas of the LM, LK and MR watersheds (Paani, 2019b). Stakeholders during focus group discussions said EAIPS date back 15 years, except bush morning glory, which has been in country for more than 50 years in LK and MR (Paani, 2019c). The introduction of exotic aquatic fish species in LK and MR has a short history, dating back to the Asian Development Bank (ADB) supported Aquaculture Development Project (1982-1989), which

introduced exotic carp to boost aquaculture in the western Tarai (DoFD__). Catfish, including African catfish and freshwater piranha, have only recently been introduced in the LK and MR watersheds.

5.5 DISTRIBUTION OF EXOTIC SPECIES

Shrestha (2016) reports there is a high concentration of EAIPS in the southern half of the country (which includes Tarai, Siwalik and Mid Hills running east-west). EAIPS are distributed in lakes, swamps, drainage areas, and shallow streams of the Tarai, Siwalik and hill regions of the country – including the wetlands in LM, LK and MR watersheds. Most EAIPS are distributed between 75-1,500 masl, except Parrot's feather (*Myriophyllum aquaticum*), which is found only in the hill region (Table 5).

Table 5: Distribution of exotic aquatic plant species

Exotic species	Elevation range (masl)	Physiographic regions	Major Habitats
Water hyacinth	75-1,500	T, S, H	Lake, Swamp, drainage canal, shallow flowing stream
Bush morning glory	75-1,350	T, S, H	Swamp, Ditch, moist land-water interface
Alligator weed	80-1,350	T, S, H	Swamp, Ditch, moist land-water interface
Parrot's feather	700-1,350	H	Freshwater streams, ponds, lakes, rivers, and canals that have a high nutrient content
Southern Cut Grass	100-600	T, S, H	marshes, swamps, ponds, irrigation ditches, flooded rice fields
Water lettuce	75-1,350	T, S, H	Shallow lake, marshes, swamps, ponds, irrigation ditches,

A field assessment in the lower reaches of the Mahakali, Karnali and Rapti River Basins revealed that invasive species are emerging as a threat to a number of natural water bodies. Multiple cases of bio-invasions have been noted by fishing communities in the rivers and wetlands of these watersheds. They say that exotic species are competing with native fish species for food and space.

Water hyacinth (*Eichhornia crassipes*) is dominant in Bhagraiya Lake (LK) and water lettuce (*Pistia stratiotes*) in Bhadahaiya (LK) and Chamborala (MR) lakes. Water hyacinth has formed floating islands or extensive mats that cover more than 75% of the open water in Bhagaraiya Lake. Giant Reed grass (*Arundo donax*) has been documented in Raani Lake (LM) and hydrilla (*Hydrilla verticillata*) in Chamborala

Lake (MR). Giant reed grass is a perennial, clump-forming grass that has invaded riparian areas in Rani Tal in Shuklaphanta National Park (LM). Bushes of morning glory are abundant in the lakes mentioned here. Water lettuce abundantly grows along with lotus flower and has covered about 30% of 60 ha of the large Bhadahaiya Lake.

Photo 2: Mats of water hyacinth in Bhagraiya Lake, Lower Karnali watershed (Photo credit: Paani)

Photo 3: Spread of giant reed grass in Rani Taal (Lake), Shuklaphanta National Park, Lower Mahakali watershed (Photo credit: Paani)

Paani also investigated the status of alien invasive species in the lakes of the Pokhara Valley. Of the 41 reported in the lakes of Pokhara Valley, only 13 species are invasive. Among the invasive species, the most dominant is water hyacinth, which covers about 20% surface area of Phewa Lake. Five other EAIPS are also present Phewa and Rupa lakes (Table 5) and they negatively affect open water fishing, cage aquaculture, water navigation, and riparian infrastructure.

Photo 4: Water hyacinth (Eichhornia crassipes) in Phewa Lake, Pokhara (Photo credit: Agni Nepal, Fishery Research Station Pokhara)

Exotic carp fish species include common carp, silver carp, bighead carp and grass carp distributed in natural and man-made ponds across the Tarai and midhill regions of the country (75 to 1,600 masl) in all three watersheds including LM, LK and RM (Table 6). Aquaculture of these fish is promoted by the government to meet the demand for fresh fish through various seed production and distribution networks. Recently, the government has given priority for cultivation of pangas and nile tilapia (mono-sex) to enhance productivity. Tilapia is highly prolific and its mono-sex production technology (masculization) has not been well adapted by many seed production centers; hence, its multiplication has been rampant through excessive recruitment and escape in Tarai region. Furthermore, people are attracted to fast-growing and highly-productive fish like tilapia. Recent evidence shows that in lakes in Pokhara, tilapia eat the eggs and offspring of native fish species like mahseer (*Tor putitora*), fageta (*Barilius* spp) and katle (*Neolissochilus hexagonolepis*), causing their populations to decline. Howver, fish farmers in Pokhara still favor tilapia (Kantipur Daily, 2019).

African catfish and red-bellied piranha were introduced by the private sector for farming. These groups take fish from Indian farms and, without proper clearance, bring them into Nepal for cultivation. All these fish have the potential to self-reproduce in natural environment. African catfish have a distribution range between 75-1,600 masl in Nepal and dominate live fish markets in major urban areas, including markets in the LM, LK and RM watersheds. Distribution of red-bellied piranha is limited to the Tarai region. Suckermouth armored-catfish (*Pterygoplichthys* sp), likely escaped from aquariums, are now established in many aquaculture farms in the eastern part of the Tarai.

Table 6: Distribution and major habitats of exotic fish species in Nepal

S.N.	Common name	Elevation range (masl)	Major habitats
1.	Mosquito Fish	75-700	Lake, Swamp, Rice fields, Ditches, Irrigation canal
2.	Grass Carp	75-1,600	Lake, Reservoir, Pond
3.	Silver Carp	75-1,300	Lake, Reservoir, Pond
4.	Bighead Carp	75-1,300	Lake, Reservoir, Pond
5.	Rainbow Trout	650-2,000	Flow through raceway, streams
6.	Common carp	75-1,600	Lake, Reservoir, Pond
7.	Mozambique Tilapia	75-300	Swamp, Rice field, Ditches, Pond, Irrigation canal
8.	Nile Tilapia	75-500	Lakes, Reservoir, ditches, pond, Swamp
9.	African Catfish	75-1,600	Lakes, Reservoir, Pond, Swamp
10.	Pangas	90-1,000	Pond
11.	Beardless Barb	-	-
12.	Silver Barb	80-300	Ditches, Pond, Swamp
13.	Gold Fish	75-1,500	Ditch, Pond, Aquarium
14.	Crucian Carp	80-300	Pond, Rice field
15.	Bata Labeo	80-250	Pond, Lake, Ditches
16.	Suckermouth armoured catfish	80-300	Pond, ditches

Most alien fish species introduced in Nepal with the objective of fish productivity enhancement are raised in manmade ponds. There are several cases of escape of these species into natural waterways. Focus groups in Lower Mahakali reported that invasive African catfish often found in the Mahakali River were introduced when aquaculture facilities were flooded and fished washed outside the boundaries. Owner of pangas farms say that their fish often escape from the ponds during inundation.

5.6 DISPERSAL AND POTENTIAL FOR ESTABLISHMENT

Studies confirm that intensity of the invasion in a wetland correlates with the pattern of human settlement around the lakes and other traditional aquatic systems (SBSTTA, 2003). Globally, huge populations settled near large inland aquatic systems, making them extremely vulnerable to invasion. Introduction of exotic species exclusively depends on human activities while the subsequent dispersal of naturalized species occurs by natural processes and human activities. Richardson et al. (2000) have described the pathways for an alien species to become invasive (Figure 6).

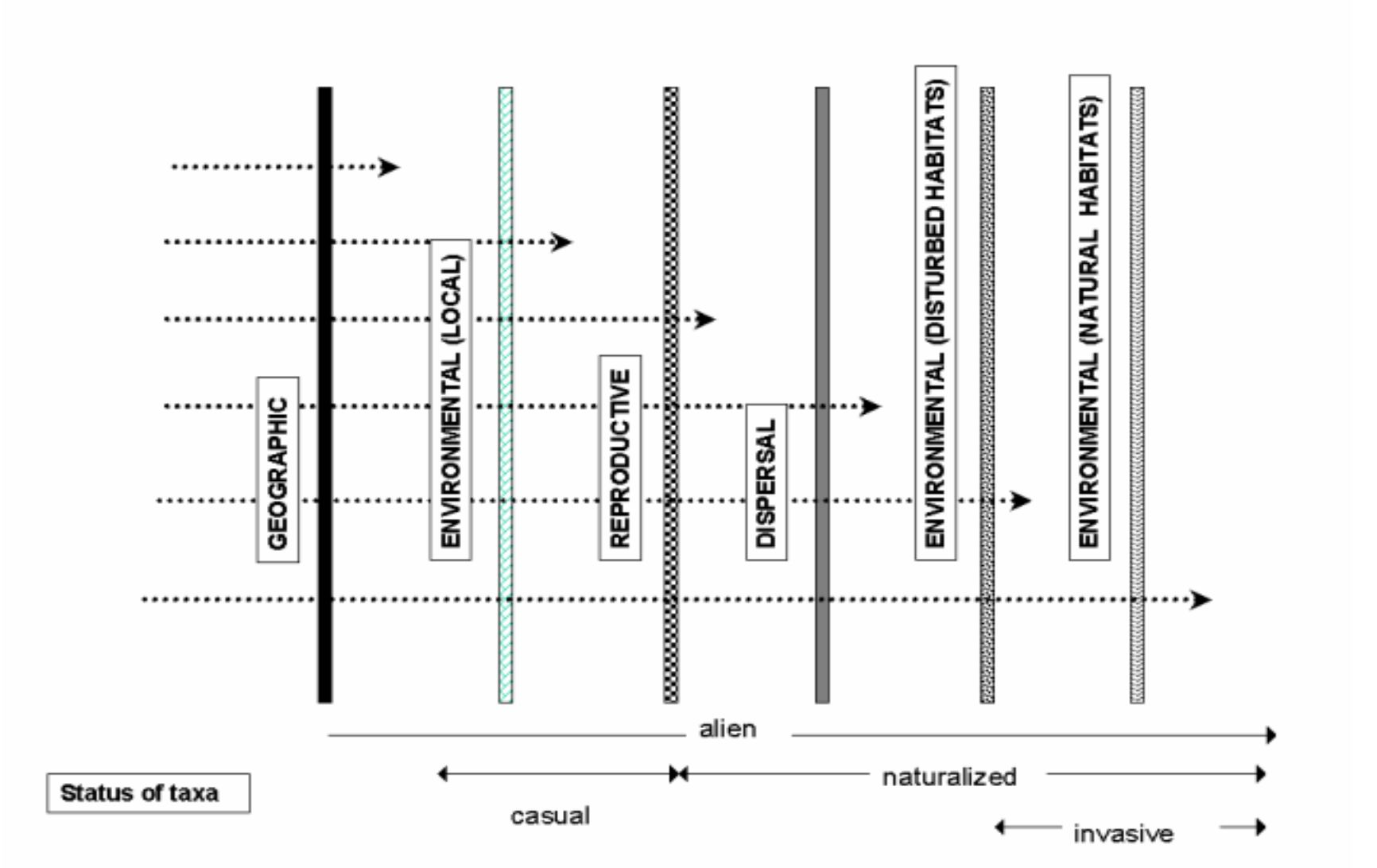


Figure 6: Schematic representation of the phases between the introduction of an organism to a locality through human action, and its establishment and proliferation in natural (undisturbed) environments. [Adapted from Richardson et al., 2000]

5.6.1INVASIVE PLANTS

Wetland aquatic plants are mostly dispersed by water, but species like water hyacinth and water lettuce are also transported to new locations for their ornamental value. Water hyacinth is predominantly spread by floating rosettes that break away from the growing mat. In addition, stem-bases may grow new leaves after frost damage or herbicide treatments. While seedlings are not a common source of new plants, re-infestation from seed is possible. Focus groups in Lower Karnali reported that water hyacinth is the most problematic invasive plant species in Bhagraiya and Badhahaiya lakes, which was not true 15 years earlier. Its current dominance may be ascribed to its invasive nature and its preference for highly eutrophic and stagnant water.

In Asia, including Nepal, water lettuce has a wide distribution and is considered invasive (CABI, 2016). Water lettuce grows in slow-moving rivers and reservoirs, irrigation channels, ponds, lakes, canals and ditches (Adebayo et al., 2011; Hussner, 2014). Water lettuce can survive drying and can re-infest ephemeral waters subject to seasonal drying because of seed survival and germination. Water lettuce is a clonal plant that forms small colonies with daughter plants attached to the mother plant through stolons. Dispersal is enhanced through detachment of daughter plants which form new colonies (OEPP/EPPO, 2017). The Paani scoping study observed such dispersal of water lettuce from Badhahaiya Lake in Lower Karnali to its drainage stream and nearby fish ponds by means of detachment of daughter plants during a flood period.

Bush morning glory (*Ipomoea carnea*) is a wetland species common in the Tarai region. Although the exact date of its introduction is not known, it has been believed to have been intentionally introduced some 60 years ago in Nepal as an ornamental and hedge (living fence) plant. The species has escaped cultivation to become naturalized and it is invasive mostly in disturbed sites, riparian areas and wetlands. Morning glory is a perennial and fast-growing species, able to spread from stem fragments and by seed (Henderson, 2015; PROSEA, 2017). Stem fragments can set root within a few days, while decumbent branches root in the soil and grow upwards, becoming new ramets (Al-Sodany, 2016). It is considered invasive in Nepal because of its rapid reproductive and proliferation, and for its rampant distribution in riparian areas and marshy land.

5.6.2 INVASIVE FISH

Several fish species have been introduced into Nepal for aquaculture and other purposes. Over time, a few of the species managed to escape into the wild and became invasive.

Paani interactions with fish growers, seed venders and Community Aquatic Animal Conservation Groups (CAACG) members during the scoping study revealed that although carp farming is dominant in aquaculture farms, the farming of feedlot-based productive animals such as African catfish, tilapia, pangas and rupchanda is strongly emergent in the LM, LK and MR watersheds. All these fish species are exotic and considered invasive if farming facilities are not properly regulated to prevent their escape to natural waters.

Nile tilapia and Mozambican tilapia introduced in Nepal have widely dispersed in several wetlands of the country. Nile tilapia was accidentally introduced with seeds of carp fish species in Pokhara Valley 15 years ago and now is well-established. The escape of juveniles and adults of this species from unregulated aquaculture farms to the natural drainage system is common. Key informant interviews in the MR watershed during the Paani scoping study found several incidences of Nile tilapia escape into natural canals that join Rapti River (Table 7). Considering the potential invasion of tilapia in natural water, the Central Fisheries Promotion and Conservation Center (CFPCC), a government line agency, has promoted the establishment of tilapia hatcheries in the private sector to produce only male mono-sex seeds for aquaculture. Lack of regulation and inadequate monitoring mechanisms for these hatcheries, however, would further enhance the spread of tilapia.

Table 7: Escape of exotic fish from aquaculture farms and recaptured from natural water in LM, LK and MR watersheds (Source: Paani Scoping Study, 2019)

Escape location	Species	Estimated number	Recipient natural water	Impact perceived by community
Ponds, Bhimdatta-16, Kanchanpur	African catfish, Pangas	NA	Mahakali River	Few African fish caught from the adjoining canal to Mahakali River
Aqua farm, Suda and Daiji, Kanchanpur	Common carp, Grass carp	NA	Raani Taal, Shuklaphant National Park	Observed carps by SNP people
Ponds, Tikapur, Kailali	African catfish	NA	Sati Taal Karnali (Karnali Ox Bow Lake), Tikapur, Kailali	African catfish are regularly caught from the lake.
Catfish Ponds, Geruwa-5, Bardiya	African catfish	NA	Budhi Kulo, Geruwa River	Topical discussion responded that people were lured to catch African catfish in natural water during rainy days. Informed that African catfish from 7-9 kg have been caught from the Geruwa River.
Catfish ponds, Khairahani, Madhuban-2, Bardiya	African catfish	NA	Bhagraiya Lake, Madhuban, Bardiya	Estimated that African catfish make up 25% of total catch from the lake.

Escape location	Species	Estimated number	Recipient natural water	Impact perceived by community
Pangas Farm, Geruwa Integrated Fish Farm, Madhuban, Bardiya	Pangas	50000 fingerling	Rice field, natural canal and Geruwa River	Pangas recaptured from rice fields, natural canals and the Geruwa River even after a year of escape.
Pangas Farm, Lamahi-3, Dang	Pangas, Tilapia, Rupchanda	Responded occasional release during draining of the ponds	Natural canal which joins Rapti River	Community responded that Tilapia is frequently harvested from the canal and wetlands.

African catfish (*Clarias gariepinus*) was unofficially introduced into Nepal from India and Bangladesh with an aquaculture species tag. Initially, this species was introduced in the eastern Tarai region in 1995 and later spread across the Tarai and warm water midhill region of the country. The low operational costs and high profits derived from African catfish led to farming intensification of the species in different eco-regions of the country. Farmers prefer the monoculture of African catfish due its high growth rate and commercial benefits (Baruah *et al.,* 1999). In general, farmers used to stock very high densities of African catfish in their ponds. This resulted in periodical large-scale escape of the species to the neighboring wild habitats. African catfish is known for its behavior to slowly crawl on the land with the aid of their strong pectoral fins and enter into adjacent wetlands during the monsoon (Burgess, 1989). Focus groups and key informant interviews in the LK and MR watersheds found that African catfish escaped from aquaculture farms to natural drainage systems in Nepal. African catfish dispersal also occurs when Buddhists release live catfish to praise Buddha. Because the African catfish can survive for longer periods with less oxygen, they frequently survive to enter other waterways.

Recently, some fish farmers-initiated farming of Rupchanda (freshwater red belly piranha) in the Tarai region and the MR watershed. Piranha was illegally introduced in Nepal for aquaculture in 2009-10. Rupchada have high fecundity (3000 - 20000 eggs) and exhibit parental care which might make them aggressive to other fish species. This species also escapes from unregulated aquaculture farms including seed production centers. Its naturalization and establishment in natural water is not known.

Aquaculture of four types of carp (silver carp, grass carp, bighead carp and common carp) is widespread in Nepal with a relatively well-established network of seed production and supply. These species are also used to restock fish in lakes and reservoirs. Carp accounts for approximately 70% of national aquaculture production in Nepal (CFPCC, 2019). These fish escaped in natural water from fish hatcheries and aquacultures farm during flood inundations over the years. Focus groups and key informant interviews found they are common escapees due to their widespread culture and poorly constructed fish ponds in the LM, LK and MR watersheds (Table 7). Although carp are prevalent in all

three study watersheds, the status of their establishment in natural water is yet not known due to the lack of studies.

A large number of fish farms in these watersheds grow mostly exotic fish species recommended by the government, except African catfish and rupchanda. Because of the high economic return from aquaculture, fish farming is growing at a rapid pace (Figures 7, 8 & 9). Interviews revealed that conventional aquaculture is being gradually replaced by intensive aquaculture, which demands more productive fish to stock at high density, and with non-conventional feed and disease treatment measures. Most aquaculture farms visited during our study exhibited poor configuration of ponds and dikes and were prone to flood.

Interviewees said accidental release of these species had occurred in the past and they suspect more escape during future floods. Of the fish grown in aquafarms, tilapia, pangas and African catfish upon escape may have strongest the effect on native fish in rivers and streams. Moreover,) e-DNA assessment of the Karnali River water (CMDN, 2019) and fish diversity study of the middle Karnali (RHF, 2019) reported the presence of exotic African catfish, silver carp, goldfish (*Carassius auratus*), and common carp.

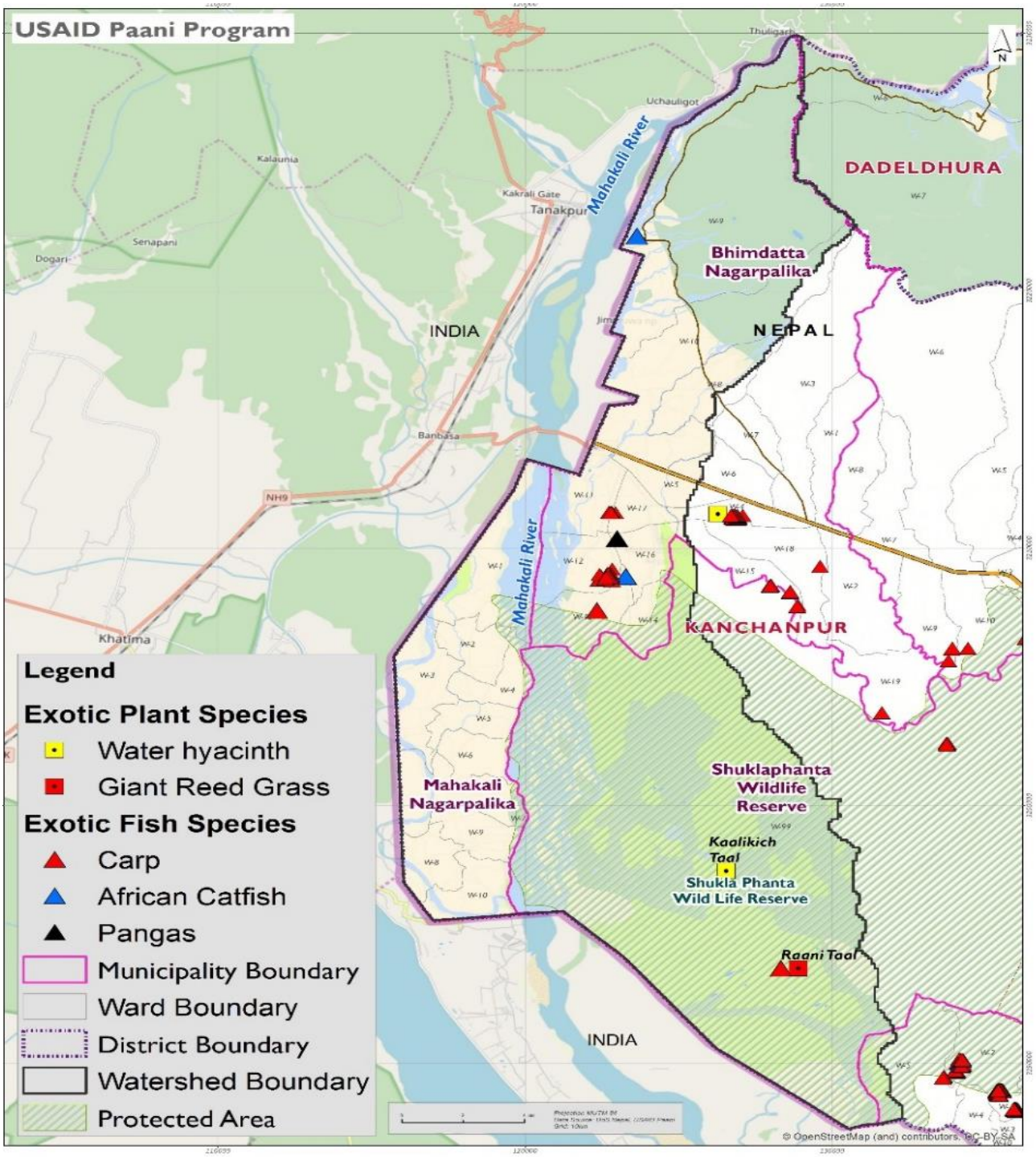


Figure 7: Distribution of aquaculture facilities raising exotic species in Bhimdutta Municipality, Kanchanpur, Lower Mahakali Watershed

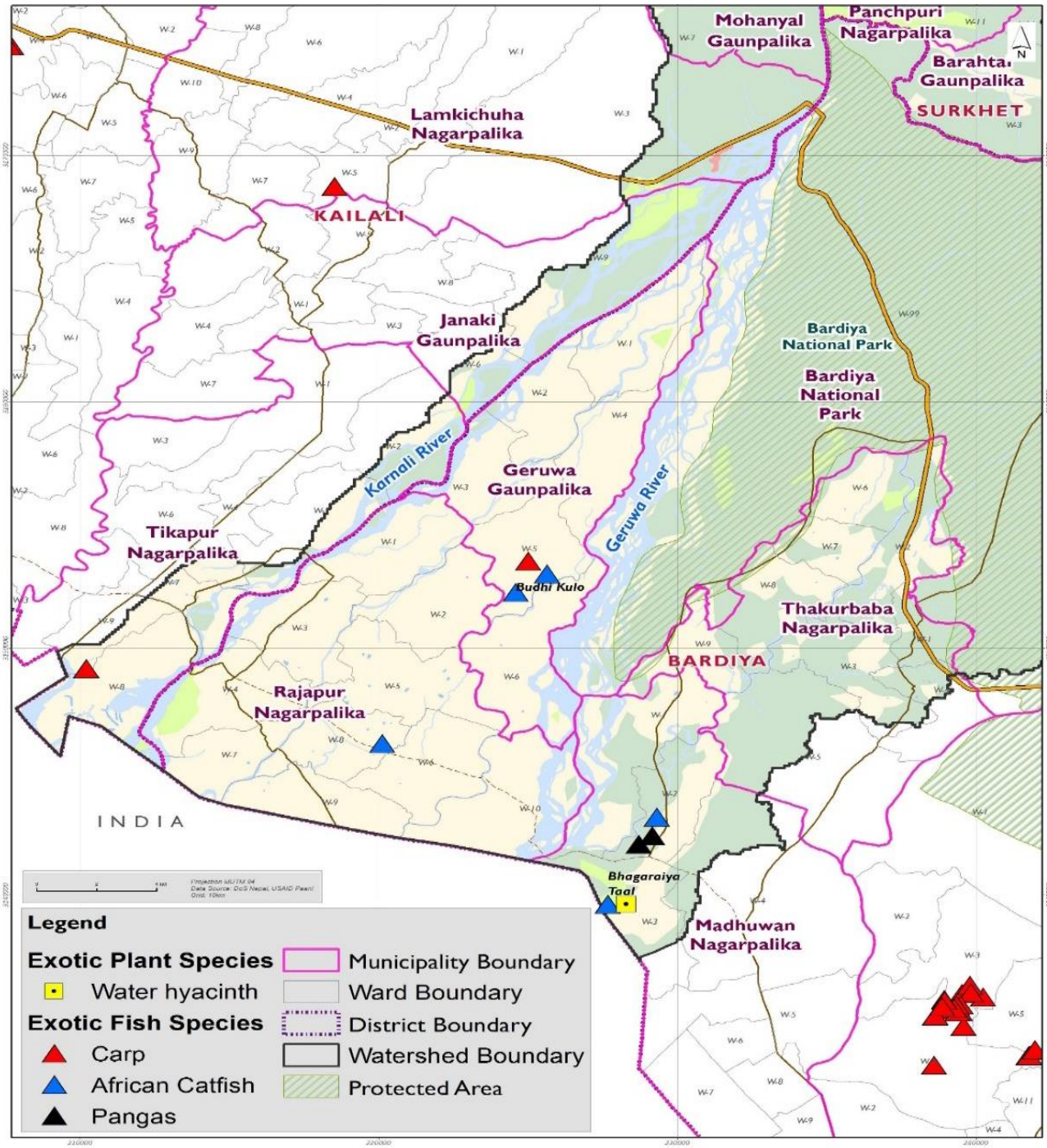


Figure 8: Distribution of aquaculture facilities raising exotic species in Kailali and Bardiya, Karnali River Corridor, Lower Karnali Watershed

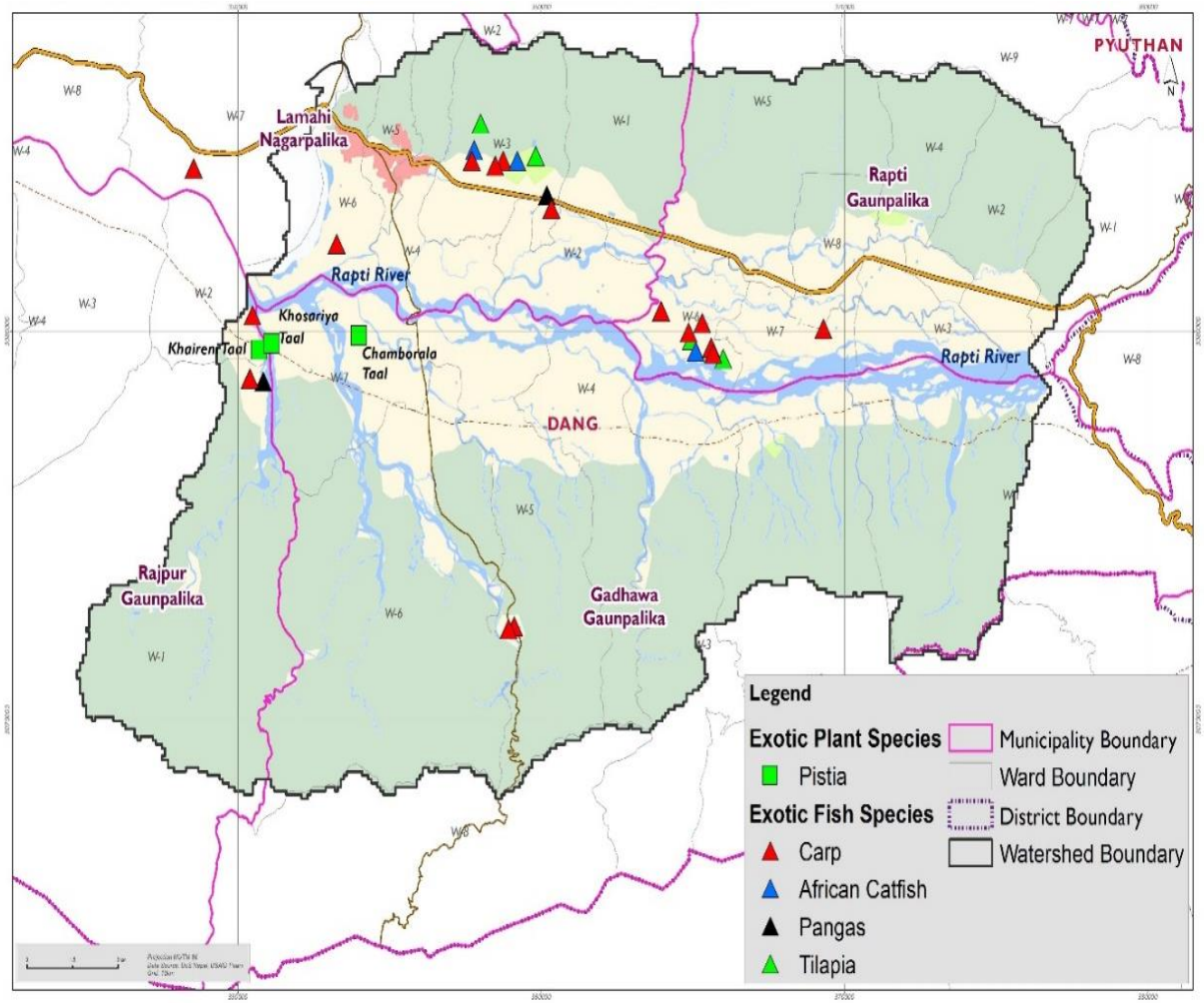


Figure 9: Distribution of aquaculture facilities raising exotic species in Lamahi and Gadhawa Municipality, Dang, Rapti River Corridor, Middle Rapti Watershed

Intensive aquaculture requires draining highly eutrophic (degraded) water to maintain water quality. Farmers growing pangas in these watersheds say they partially drain the ponds to prevent deterioration of water quality due to high protein feed for the fish. High nutrient content water discharged from the pond into natural waters may have severe impacts on native fish and water quality at the point of contact. However, no regulatory framework exists to monitor and control this practice.

5.7 POTENTIAL IMPACT IN NATIVE ECOSYSTEM

Every exotic species that becomes established alters the composition of native biological communities in some way. The ecological impact of the loss of biodiversity due to exotic aquatic species depends to a large extent on the link between native species (McNeely et al., 2001). The introduction of invasive species, which often constitute new functional components in the recipient community, generates ecological impacts that can propagate along the food web triggering trophic cascades (Moyle & Light, 1996; Strayer, 2010). Impacts can be caused by direct biotic interaction with the resident community (e.g. competition, predation) and by indirect changes in habitat conditions (e.g., turbidity, habitat structure) (Crooks, 2002). Gallardo et al. (2016) have illustrated these interactions and changes caused by invasives based on meta-analysis of literature searches and 733 cases that assessed the impact of aquatic invasive species on several aquatic functional groups and water physicochemical variables (Figure 10)

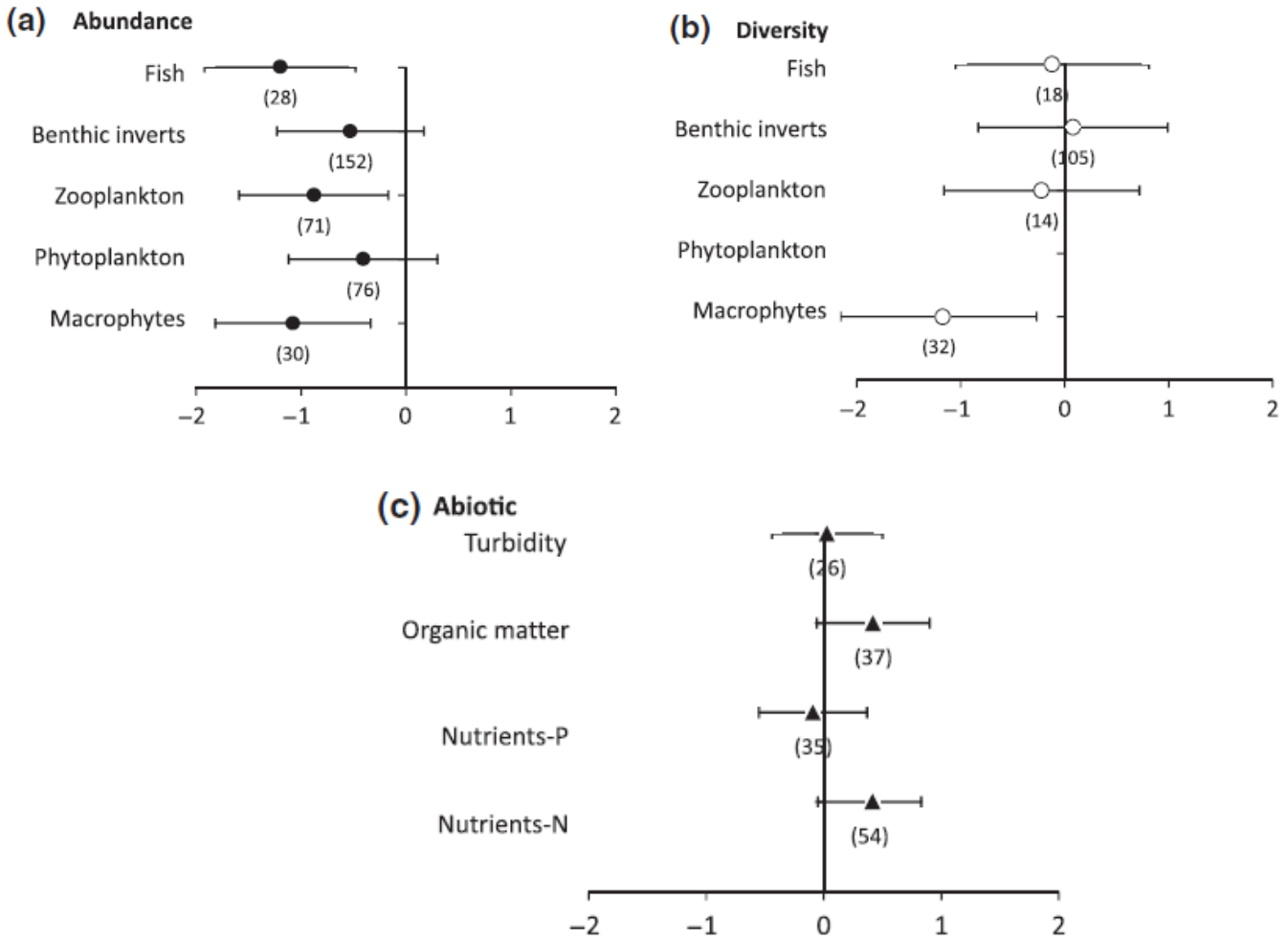


Figure 10: Overall effects of invasive species on the abundance (a) and diversity (b) of five different functional groups of aquatic ecosystems and four environmental characteristics (c). In parentheses, the number of effect sizes are considered in each case. Error bars represent 95% confidence intervals and are only displayed when the number of effect sizes analyzed was ≥5. A significant effect of invasion is found when error bars do not overlap zero (adapted from Gallardo et al., 2016)

5.7.1 EXOTIC AQUATIC INVASIVE PLANTS SPECIES (EAIPS)

Of the 25 EIAPS found in Nepal, four species are found in wetlands, and water hyacinth is the most problematic among them. EAIPS in Nepal can cause similar problems to those caused by excessive growth of other floating plants. They can reduce access to the water for recreation, interfere with various engineering structures and cause flooding, favor the spread of disease, reduce the aesthetic value of water bodies, prevent photosynthesis in the water below the mat, and impact native animals and plants more generally by significantly altering aquatic ecosystems.

In the Bhagaraiya wetlands in the LK watershed, water hyacinth and water lettuce smother wetland biodiversity but also negatively affect the livelihood of wetland-dependent local communities. For example, in Phewa Lake near Pokhara, boating and fishing are important economic activities and both have been increasingly diminished by the spread of water hyacinth. A 2004 report in the Nepali Times states that hyacinth is causing the lakes in the Pokhara Valley to shrink much faster than they would through sedimentation. In 1993, Phewa Lake was 523 ha and today it is only 452 ha. Potential impact of EAIPS found in wetlands of the LM, LK and MR watersheds is presented in Table 8.

Table 7: Exotic Aquatic Invasive Plant Species (EAIPS) in surveyed LM, LK and MR watersheds, their nature of spread, mode of impact, and potential threats (Source: Paani Scoping Study, 2019)

Exotic species	Local Name	Nature of spread	Mode of impact	Potential threat
Eichomia crassipes	Water Hyacinth, Jal Kumbhi (Nepali)	Spreads through wind propulsion of floating plants (or plant fragments), through water currents and on the feathers and feet of the numerous species of local and migratory water birds.	Covers entire surfaces of wetland, impacting water flow, blocking sunlight to native submerged plants, and starving the water of oxygen	Reduces primary production, hypoxia, habitat destruction, biodiversity loss Eichomia crassipes
Pistia stratiotes	Pistia, Kumbhika (Nepali)	Fragments, or whole plants, can be spread via boats or fishing equipment from an infested area to a clean body of water.	Covers entire surfaces of wetland, impacting water flow, blocking sunlight to native submerged plants	Reduces primary production, hypoxia, habitat destruction, biodiversity loss

Exotic species	Local Name	Nature of spread	Mode of impact	Potential threat
Ipomoea camea	Bush morning glory, Besharam or Behaya (Nepali)	Spreads vegetatively from stem fragments and by seed	Nutrient uptake from riparian area, light inhibition through shading	Competes and eliminates other marsh species with similar habitat requirements
Arundo donax	Giant Reed Grass, Thulo Narkat (Nepali)	Seeds spread by wind and water, spread from site to site is wetland plant transfer.		Competes and eliminates other marsh species with similar habitat requirements

Water hyacinth and water lettuce can reduce water flow in drainage and irrigation systems and flood control canals, and their mats block water flow and reduce hydropower production (Dray and Center, 2002). Jones (2009) reports that water hyacinth slows water flow by 40 to 95% in irrigation channels in several parts of India. The Paani team observed that water hyacinth has blocked irrigation channels and obstructs the flow of water to the Phewa hydroelectricity plant in Pokhara. Large mats of water hyacinth and water lettuce can increase water loss by evapotranspiration (Rao, 1988). Studies are needed to understand the full potential impact of EAIPS on water loss in Phewa, Bhagraiya and Badhahaiya lakes.

Although specific studies are lacking on the impact of EAIPS on the biological and physical conditions of lakes and rivers in Nepal, global references could be used to predict such impacts on Nepal's aquatic wild habitats. Dense monospecific growth of any aquatic plant species can deliver impacts on native plant communities and other aquatic organisms such as macro- and micro-invertebrates, fish and waterfowl. Water hyacinth and pistia species can completely transform and alter trophic dynamics, resulting in long-term changes. Dense mats of these EAIPS block sunlight, reducing primary production, and decrease water turbidity (Neuenschwander et al., 2009). Furthermore, the water shaded by water hyacinth and water lettuce shows decreased levels of oxygen and increased levels of nitrate, ammonium and phosphorus (Neuenschwander et al., 2009). As a result of this altered habitat, submerged vegetation decreased under dense mats along the River Erft in Western Germany (Hussner, 2014).
Cilliers et al. (1996) reported that water lettuce threatens indigenous flora and fauna in South Africa. Increased mortality rates of fish and macro-invertebrates have been reported in the USA as a result of the presence of water hyacinth and water lettuce (Dray and Center, 2002). In addition, the presence of these EAIPS can increase the rates of siltation, which can act to smother and degrade fish spawning sites (Dray and Center, 2002).

The Paani team (2019b) found that Raani Taal in Shuklaphanta National Park (SNP) in the LM watershed is severely invaded by giant reed grass (*Arundo donax*). Its invasion in riparian areas alters the native vegetative structure, and its rapid growth following floods or wildfire leads to competitive displacement

of native riparian vegetation. This dominance reduces arthropod diversity and abundance and also leads to decline in avian diversity and abundance. Shallowness of lake due to rapid sedimentation from upstream rivers probably has contributed to the spread of reed grass here. According to the SNP warden, invasion of giant reed grass has degraded the habitats for 26 native fish species in the lake.

5.7.2 AQUATIC INVASIVE FISH

Although impact analyses of invasive fish species have not yet been carefully studied in Nepal, some reports indicate that invasive species play a destructive role in natural ecosystems and human economies. Wagle et al. (2007) reported that some indigenous fish have declined in population and diversity due to over-exploitation coupled with habitat destruction, siltation and unintentional introduction of exotic fish species in the lakes of Pokhara Valley. Swar and Gurung (1988) report a 42 percent reduction of the native fish in Begnas Lake, Pokhara after the introduction of bighead carp. More than seven species have vanished from Indrasarobar reservoir (Swar, 1992), and only two native fish species – *Neolissocheilus hexagonolepis* and *Nazirator chelynoides* – are left (Saud and Shrestha, 2007). The potential impacts of exotic fish species introduced in Nepal are listed in Table 9.

Table 9: Aquatic exotic fish species in surveyed watersheds, their nature of spread, mode of impact and potential threats

Exotic species	Local Name	Nature of spread	Mode of impact	Potential threat
Fish				
Clarias gariepinus	African catfish, magur	Escape from aquaculture facility, survive in harsh environment, breed in shallow water at relatively high temperatures	Highly carnivorous, predate small size fish	Decline in diversity and abundance of native species
Pygocentrus nattereri	Red belly fish, rupchanda	Escape from aquaculture facility, survive in harsh environments	Highly carnivorous, predate small size fish	Decline in diversity and abundance of native species
Oreochromis niloticus	Tilapia, Nile tilapia	Escape from aquaculture facility, survive in harsh environments, highly prolific	Feed and space competition with native fish	Tilapia dominate the species assemblage
Cyprinus carpio	Common carp	Escape from aquaculture facility	Bottom feeder	Loss of macroinvertebrates
Ctenopharyngodon idella	Grass carp	Escape from aquaculture facility	Macrophytophagous	Inhibit the growth of underwater and riparian vegetation
Aristichthys nobilis	Bighead carp	Escape from aquaculture facility	Not known	Not known
Hypophthalmus molitrix	Silver carp	Escape from aquaculture facility	Phytoplankton feeder	Decline in organisms, feeds on primary production, imbalance in trophic order
Pangasius hypophthalmus	Pangas, baikha	Escape from aquaculture facility	Omnivore	Not known

Nile tilapia (*O. niloticus*) is an omnivorous species and ingests zooplankton, phytoplankton, or debris present in rivers. As a consequence, the release of tilapia into non-native aquatic ecosystems may result in competition for food and space, thereby damaging native species. The wide environmental tolerance and high reproductive rate of tilapia facilitates its use for aquaculture but also renders the species highly invasive. Nile tilapia's introduction was accidental in the lakes of Pokhara Valley, and it has appeared in catches since 2003 (Nepal, 2008). Since then, its catch has increased to 40-60% in Phewa and Begnas lakes while native fish species in catch have declined by 32.8% over the same time period (Figure 11) (Husen, 2014). Nile tilapia may compete for food and space with native fish species as well as feeding on larvae of native fish species. Nile tilapia are also found to modify nutrient regimes by increasing nitrogen and phosphorus availability in a reservoir via excretion, promoting algae growth, and contributing to eutrophication (Figueredo and Giani, 2005).

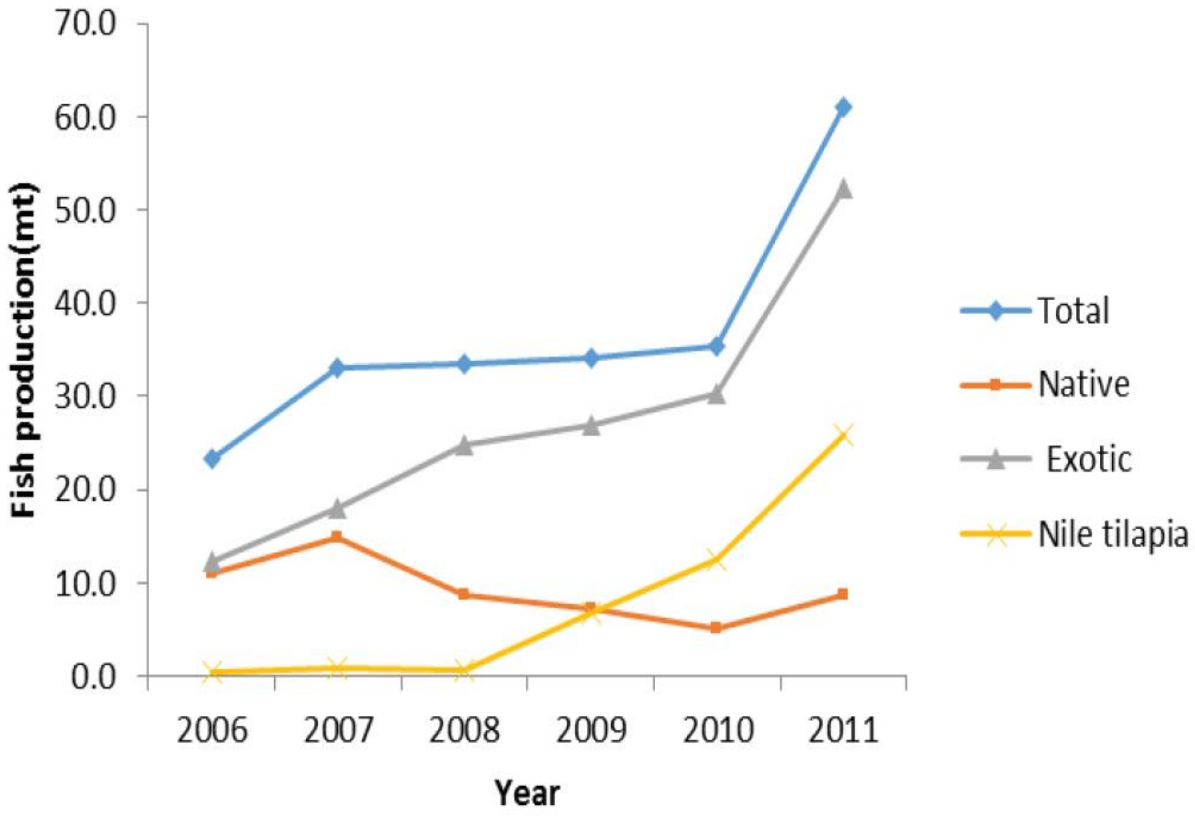


Figure 11: Annual trends of fish catch from Phewa Lake, Pokhara, Nepal (Adapted from Akbal, 2014)

Among the introduced invasive species of fish, African catfish is the most voracious eater. It has all the qualities of an aggressive and successful invasive species: high fecundity, flexible phenotype, rapid growth, wide habitat preferences, tolerance to extreme water conditions, and the ability to subsist on a wide variety of prey (Bruton, 1979). Focus groups during the Paani study revealed that African catfish have escaped into streams and rivers of LK and MR watersheds from aquaculture ponds and some catches have occurred from the Geruwa River in Bardiya. Without formal study on catch composition, however, the impact of African catfish on native fish populations is uncertain.

5.8 COMMUNITY KNOWLEDGE AND PERCEPTION

The Paani scoping study in the LM, LK and MR watersheds revealed that communities are aware of introduced (exotic) fish species and native fish species, and understand their general behavior, biology and ecology. They provided our team with a list of fish species dwelling in natural water and those farmed in ponds and regulated wetlands. Fish species with characteristics of high tolerance to harsh environmental conditions, fast growth, availability of seeds, and quick economic return are considered aquaculture species irrespective of their origin.

The Paani team found that fishing communities and fish farmers are knowledgeable about the feeding habits, habitat requirements and the sources of introduction for catfish species, but they do not recognize those as invasive species because they grow fast, can survive in poorly-managed conditions, have high yields. Some key informants were aware of the trophic order in the food chain for most of the fish in their area. Collectively, they have well recognized fish feeding habits and that catfish is carnivorous and feeds on other fish. Despite this knowledge, they still cultivate catfish for economic gain and have incomplete understanding about the danger of invasive species in freshwater systems. In fact, the local people in Bardiya reported having caught the catfish in the river stretches, which means those fish have already entered the river system. On the other hand, the communities displayed significant knowledge on invasive plants. They deemed water hyacinth, water lettuce and giant reed grass as invasive plant due to their characteristics of proliferation (reproductive capacity), distribution (scale) and competition. These findings reflect similar findings of Shrestha et al. (2019) on community perceptions of exotic invasive plant species in the Chitwan-Annapurna Landscape (CHAL).

Better understanding of stakeholders' knowledge, perceptions and practices can help in predicting future introductions and spread of aquatic invasive and thereby catalyze policy and management strategies to counteract the invasion (Cole et al., 2016). Government institutions should implement a large-scale awareness and education programs to help to change community perceptions about the risk of aquatic invasive species and improve the implementation of preventive measures to reduce future introductions. Cole et al. (2016) also stated that awareness campaigns alone may not be sufficient to prevent future introductions; therefore, other complementary policy and management options and approaches have to be considered to improve effectiveness in the future.

5.9 COMMUNITY EFFORTS TO MANAGE INVASIVE SPECIES

Invasion and spread of water hyacinth is a major problem in Phewa Lake, negatively affecting open water fisheries, cage aquaculture, water navigation, riparian infrastructure and livelihood of fisher and navigation dependent communities. Fisher and lake resource users' communities have taken the initiative

to manage aquatic invasive in lakes of Pokhara Valley. In Phewa Lake, the Pokhara Metropolitan City (PMC) has managed invasive aquatic plants. Traditional fisher groups, such as the Pode and Jalari, are given employment by PMC to remove water hyacinth. The Jalari community has organized into the Harpan-Phewa Fish Cooperative (HPFC), which charges a fee on fish caught by its shareholder members. The collected amount is spent to remove aquatic invasive plants. However, HPFC informed the Paani team that manual removal of water hyacinth is not effective because of the limited funds available and the rapid regeneration of the weed due to high siltation upstream, which provides nursery ground for its reproduction.

HPFC members cultivate planktivorous fish in Phewa Lake. They stock grass carp in cages to feed on hydrilla, the second most dominant plant in Phewa Lake. As an incentive, the reduction of hydrilla had a positive impact on production and improved the economic return from cage fish farming. However, in recent years, hydrilla levels have diminished to the point where cage fishing is less productive than in years past. Although efforts are being made to control water hyacinth spread in the Phewa Lake, history shows that it is difficult to fully control its population. Action against hyacinth spread is affected by a lack of collaboration among organizations.

The Rupa Lake Restoration and Fish Farming Cooperative (RLRFFC) removes submerged weeds through biological means and floating weed manually by paid labor. The cooperative stocks macrophytophagous fish (grass carp, *Ctenopharyngodon idella*) and omnivorous fish (common carp, *Cyprinus carpio*) every year to control the growth of hydrilla and water chestnut. Manual weeding is preferred for water hyacinth. The cost of weeding is covered through the income generated from culture-based fisheries in Rupa Lake. The cooperative has been spending 100,000-250 000 Nepali rupees depending on the spread of the plants.

In close cooperation with local government institutions like NARC and the Fisheries Research Center, the RLRFFC have create guidelines for benefit sharing, responsibility for conservation, and catchment management support for upstream communities. The cooperative follows a democratic process and has a governing body to develop plans and a budget, including for capacity building of the local community and support to community forestry and school children. It also has different management units to look after general administration for fish hatchery and culture-based fisheries, aquatic weed management, conservation practices, and marketing and publicity (Figure 12).The cooperative has allocated parts of the lake area for conservation of wild rice (Navo) and Narkat (Bamboo species), for spawning habitat for native fish and white lotus, and for protecting the Siberian Crane and other migratory birds.

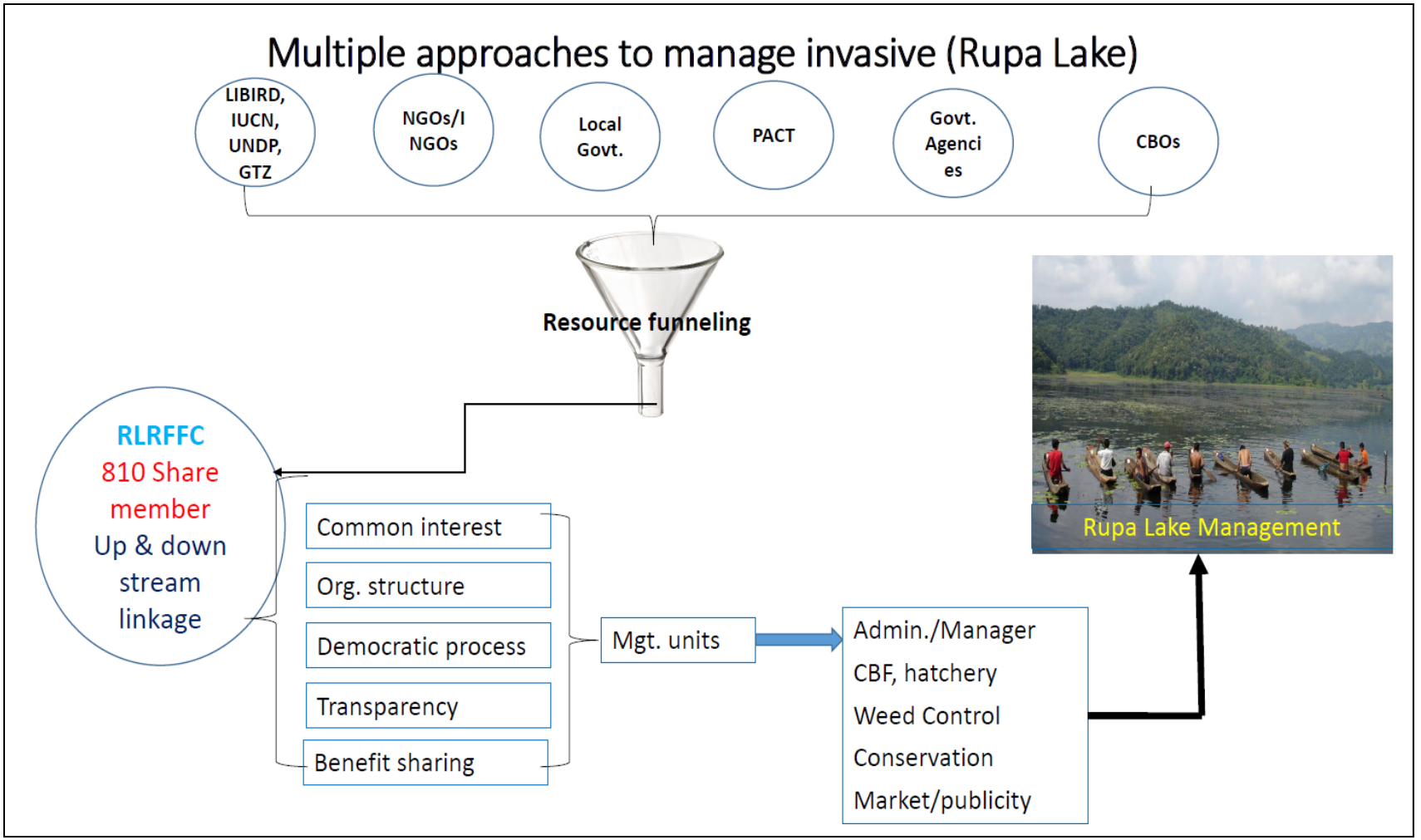


Figure 12: Invasive management governance pathway of Rupa Lake Restoration & Fish cooperative (RLRFC), Rupa Lake, Kaski

Institutional arrangements and centralized resource mobilization by RLRFFC clearly show that network governance is more effective to control aquatic invasive problems. Invasive water hyacinth and water chestnut features antecedent conditions that favor a centralized network as the best governance approach, as demonstrated by our observations at Rupa Lake. This centralized policy network, with a clearly defined core of actors with expertise, authority, and resources, produces effective cooperation. The RLRFFC institutional and governance framework has implications for invasive species management more generally, as well as other conservation issues featuring dynamic spatial ecological processes.

Recently, Paani supported the procurement of a water mower along with operation and maintenance capacity to the Bhagaraiya Lake Management Committee (BLMC) for removing water hyacinth and other floating weeds. Field studies conducted by Paani have shown conflicting interests among different stakeholder on the use of lake resources and benefit sharing. The study report clearly mentions that different ethno-political interests and conflicting views among members of different socio-economic backgrounds could delay development and implementation of the Bhagaraiya Lake management plan.

Despite some success (e.g., Rupa Lake) and potential failure (e.g., Phewa Lake and the wetlands in the LK watershed), in the absence of adequate regulatory problem-solving frameworks from all levels of government, addressing invasive species will require three factors:

1. better adherence to theoretical prescriptions for sustainable resource management – in particular, more meaningful collaboration that moves beyond an advisory capacity to a more decisive one and involves a broader array of stakeholders;
2. a better informed and more involved public; and
3. expanded regulatory efforts by respective local and provincial governments.

The combination of these factors would have the likely beneficial consequences of overcoming dysfunctions in the institutions of public and private governance for the management of invasive in sustainable way.

5.10 DICHOTOMY OF ALIEN SPECIES

The introduction of exotic fish species for aquaculture can accidentally expose the exotic fish to native aquatic systems, which will proliferate, establish their presence, and become a competitor for food and space with native fish of ecosystem. Of the eight worst species listed by Cambray (2003), two of them are common in Nepal. Sultana and Hashim (2015) reports that eight common fish including Prussian carp (*Carassius auratus*), common carp (*Cyprinus carpio*), rainbow trout (*Oncorhynchus mykiss*), mossabic tilapia (*Oreochromis mossambicus*), guppy (*Poecilia reticulate*), Atlantic salmon (*Salmo salar*), brown trout (*Salmo trutta*) and brook trout (*Salvelinus fontinalis*) are invasive alien fish in all continents except Antarctica. By contrast, in some instances, exotic fish have also shown positive impact on the aquaculture production and effective management.

Through focus group discussions and transect walks, the Paani team learned that aquaculture is one of the fastest-growing industries in the LM, LK and WR watersheds. The rapid expansion of aquaculture largely relies on the introduction and use of non-native species. This forms a paradox: some species significantly contribute to the fast expansion of aquaculture, while the negative effects associated with

unregulated introduction and irresponsible use of non-native species are increasing in all three watersheds. The aquaculture is dominated by exotic carp, catfish, and tilapia because of their high biomass productivity. Interviews with aquaculturists found that exotic species have provided socio-economic benefits for a large number of people (including the poor and vulnerable) in these watersheds.

The inland aquatic ecosystems of Nepal remain biodiversity hot spots with high levels of endemism. However, high demand for freshwater fish is prompting farmers to import freshwater fish from neighboring countries (e.g. India, Bangladesh) for cultivation and consumption. Several freshwater fish introduced in the country have become established populations. This assessment and another on e-DNA (CMDN, 2019) indicate there is evidence of intentional and unintentional release of exotic invasive fish species in natural water bodies, including the main stems of Karnali and Rapti rivers.

5.11 CLIMATE CHANGE AND NON-NATIVE FISH

Climate change and invasive species are two complex phenomena that threaten biodiversity and livelihoods. The success of an introduced alien species into a new system vastly depends on climate change events, which may influence their food, reproduction, survival and expansion. Climate change can facilitate invasive exotic species through changes in species' hierarchies and provide invasive pathways through climate-induced stress (Masters and Norgrove, 2010).

Climate change enhances the habitat disturbance, which facilitates establishment of invasive species (Chown et al., 2015). An increase in water temperature has been recorded in lakes of Pokhara Valley over the past decade (Figure 13). Establishment and expansion of tropical invasive water hyacinth and tilapia in Phewa, Begnas and Rupa lakes of the Pokhara Valley may have some association with elevated water temperature (Wagle et al., 2011).

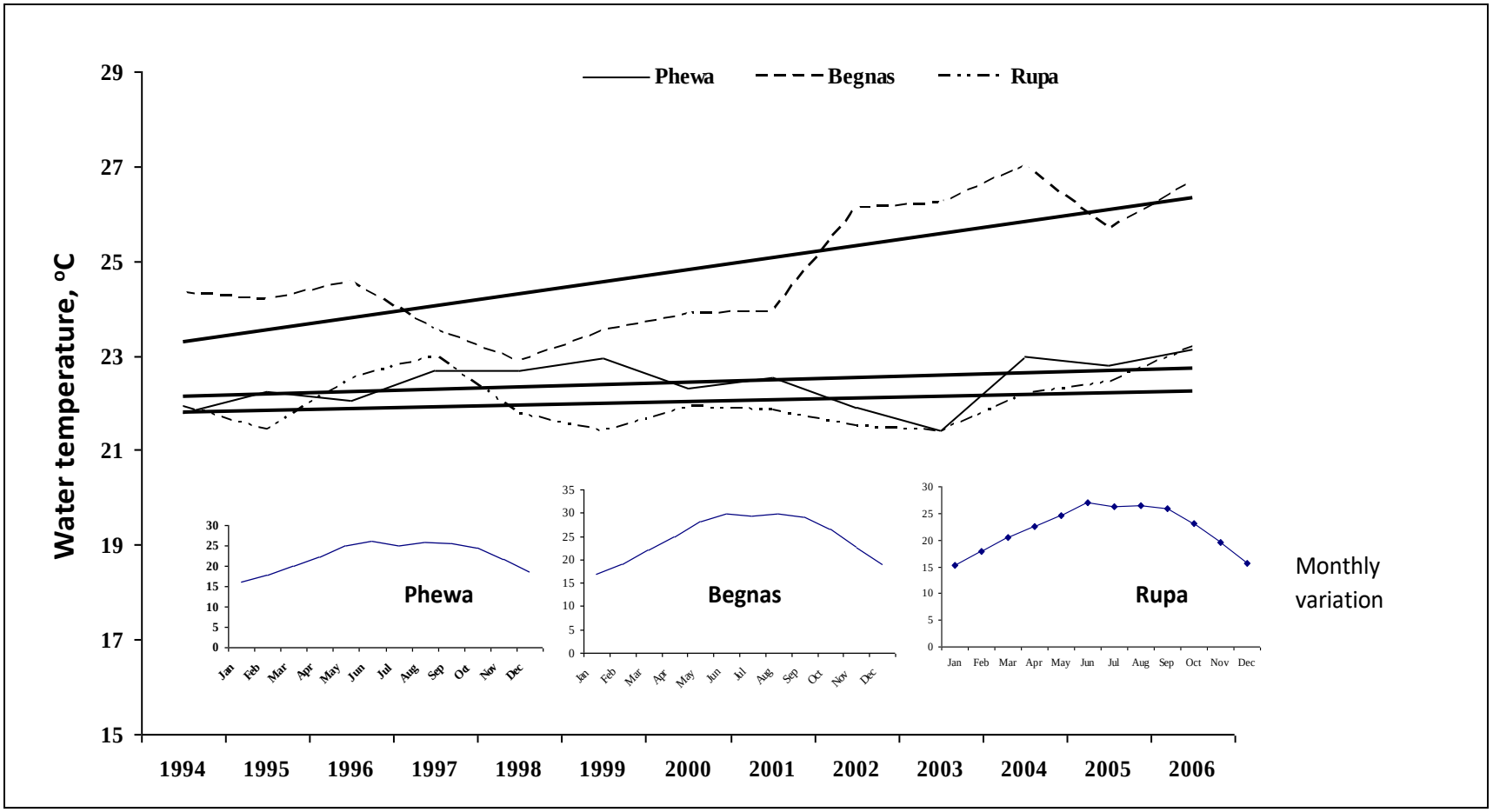


Figure 13: Mean surface water temperature of the three lakes (Phewa, Begnas and Rupa) of mid hill Pokhara Valley, Nepal for a period of 1994 to 2006.

In freshwater ecosystems, one of the most significant impacts of global warming would be a reduction in suitable habitat. Warming temperatures can facilitate the establishment and spread of introduced species (Barrange and Perry, 2009). As in recent days, invasions of aquatic plant, water hyacinth and African catfish in hilly regions of Nepal might be interpreted as visible impacts of global warming. Similarly, accidentally introduced glass fish (*Chanda* sp), a warm water species, was established in Kulekhani reservoir after the reservoir become warmer due to water stagnation and rising temperatures (Wagle, 2016).

Extreme weather has the potential to impact aquaculture activities. Potential impacts could range from physical destruction of aquaculture facilities to loss of stock and spread of disease. Aquaculture in Nepal, more specifically pond fish and cage fish culture, is dominated by exotic species to a significant extent (Wagle et al., 2007). Although escape from aquaculture installations is almost unavoidable under normal circumstances, and remains a persistent problem, the possibilities of large numbers of cultured stock entering natural waterways, because of the destructive effects of extreme climatic events, are far greater. Such large-scale unintentional releases have a greater probability of causing environmental disturbances and the potential for impacting native biodiversity becomes considerably higher.

In general, impacts of climate change events on inland freshwater systems of Nepal have not been widely studied. Given that human activity and temperatures are expected to increase in the future, aquatic fauna of the country will respond biologically, and this needs to be studied to establish relations between climate change and exotic fish fauna in inland ecosystems.

5.12 QUARANTINE AND BIOSECURITY PROVISIONS

Quarantine can be defined as the holding or rearing of animals under conditions that prevent their escape or the escape of organisms and potential disease agents associated with them, into the natural environment.

Over 84 million seeds of three exotic species (African catfish, pangas, rupchanda) were imported from India in 2019 for stocking in aquaculture ponds without any quarantine inspection (Ranjan, 2019). Although the government has not officially banned these seeds, there is a Fish Seed Standard policy (2004) that delegates power to the Central Animal Quarantine Office (CAQO), which has authority to prohibit import or introduction of several exotic species for commercial exploitation. However, no effective regulations or procedures for quarantine and inspection exist. Apart from regulations, lack of qualified quarantine personnel have also hindered better regulation of imported fish seeds of invasive fish species.

5.13 ACTS AND REGULATIONS ON INVASIVE

Nepal is a party to the Convention on Biological Diversity 1992 (CBD) and the International Plant Protection Convention (IPPC). The CBD requires each contracting Party to, as far as possible and as appropriate, prevent the introduction of, control or eradicate those exotic species which threaten ecosystems, habitats or species [article 8(h)]. The IPPC allows adopting legislative, technical and administrative procedures and standards to identify pests that threaten plant health, assess their risks and prevent their introduction and spread.

5.13.1 FOREST ACT 2019

Although the Forest Policy 2014 stipulates that multilateral participatory mechanisms will be established and mobilized to control invasive species, the Forest Act enacted in 2019 is completely silent about native and exotic invasive species. It does, however, require the Government of Nepal to conserve and manage the wetlands that are inside the national forest. Since most of the wetlands that are in Tarai and midhills suffer invasive species, it is obvious that the responsibility to conserve and manage wetlands entail prevention and control of invasive plant and aquatic species, including escape and release of exotic fish species in the wetlands. As per the Forest Act, 'forest area' includes ponds, lakes, wetlands, rivers, rivulets, and riverine lands (riverbank) that are inside the forest. Thus, it is inferred that the GoN is responsible only for prevention and control of invasive species inside the wetlands that are inside the forest area that are included on the Ramsar List. It will not be responsible for other lakes and ponds.

5.13.2 PLANT PROTECTION ACT 2007

The Plant Protection Act 2007 requires the person or body wishing to import plants, plant products, biological control agents, beneficial organisms or means of growing plants to obtain an entry permit [section 7 (1)]. The entry permit must be obtained prior to importing into Nepal any plants, plant products, biological control agents, beneficial organisms or means of growing plants at the entry point for import (section 11). It obliges the National Plant Protection Organization to carry out pest risk analysis and determine the risk level of regulated pests [section 17 (1)]. Further it empowers the Organization to make recommendations to the Ministry to declare such areas as quarantine pest-affected areas [section 19 (1)]. The legal provisions are useful to prevent and control import of invasive or exotic plant species that have the potential to be invasive, but the major challenge is the implementation of the Act.

5.13.3 ANIMAL HEALTH AND ANIMAL SERVICE ACT 1999

The Act obliges the GoN to establish temporary or permanent quarantine check posts in any area of Nepal by publishing a notification in Nepal Gazette (section 3). Section 3 obliges the government to establish quarantine check posts in different areas of the country, but it also gives discretionary power by not specifying that how many check posts be established at entry or exit points of Nepal.

Imported animals, animal products and animal production equipment must be kept in quarantine for certain period (section 6 (1)). The importer must import such things through a quarantine check post (section 9). The quarantine officer may prohibit the entry of animal, animal products or animal production inputs in different circumstances, such as if the imported animal, animal products or animal production inputs are brought from an outbreak area of contagious diseases. A quarantine officer holds the authority to permit the importer to take prohibited animals, animal products or animal production inputs back to the country of their origin (section 12(1). However, this Act does not mention invasive species.

5.13.4 LOCAL GOVERNMENT OPERATION ACT 2017

As per the Local Government Operation Act 2017, the functions, duties and rights of the rural municipality and municipality include:

- Formulation of local policies, laws, standards and plans related to environmental protection and biodiversity, and their implementation, monitoring and regulation;
- Mitigation of environmental risk at local level;
- Protection of agriculture environment and biodiversity conservation and promotion;
- Controlling invasive species; and
- Protection and promotion of native species.

The Local Governance Operation Act is perhaps the only federal legislation that mentions about invasive species.

5.13.5 AGROBIODIVERSITY POLICY 2013

The Agrobiodiversity Policy 2013 requires permission to import infected or genetically-modified food and agriculture-related plant and organisms for research and study. The policy provides government the authority to control or prohibit, as necessary, genetically-modified organisms and their products that could be risky for biodiversity, environment and human health.

5.13.6 NATIONAL WETLANDS POLICY 2012

The National Wetland Policy 2012 states that invasive species and other dangerous organisms, which displace or destroy native animal and plant species or expand faster, will be effectively controlled. Working policy 5.2.16 stipulates that productivity of wetland areas will be enhanced by habitat improvement by maintaining water level, control of invasive species, and wise use of wetland resources.

5.13.7 NATIONAL BIODIVERSITY STRATEGY AND ACTION PLAN 2014

The National Biodiversity Strategy and Action Plan (NBSAP 2014) includes the following priority actions for prevention and control of invasive species:

- Formulation and implementation of a plan for regulating introduction and expansion of invasive alien species of aquatic fauna, by 2018;
- Development and implementation of program to raise awareness of local people on invasive species, their impacts and control measures;
- Development, testing and application of appropriate biological control agents;
- Enhancing quarantine and detecting capacity of custom and quarantine offices; and
- By 2020, detail survey of the coverage and research on modes of propagation, ecological and economic damage and loss, control measures, and possible uses of at least five most problematic invasive species completed. However, the implementation of the priority actions relating to invasive species is very poor.

The NBSAP identifies national institutions (MoALD, MoFE) to formulate and implement plans for regulating the introduction and expansion of invasive species. The Local Government Operations Act

and the National Wetlands Policy, Forest Policy, and the NBSAP specifically provide for prevention and control of introduction and expansion of invasive species.

Although legislation related to water, the environment and conservation appears relevant to invasive species control, it is policy specifically for fisheries and aquaculture that require special attention. National level consultation meetings organized by Paani in 2018 and 2019 have identified six policy-related issues of aquatic invasive management:

- The specific inclusion of invasive issues in fisheries planning is necessary, preferably through risk evaluation and risk criteria;
- There is a need for greater attention to the application of the precautionary approaches due to the multifaceted impacts of aquatic invasion;
- There is need for a fisheries habitat conservation policy;
- Greater attention should be paid to the use of ecosystem indicators that may relate to the impact of invasive species;
- The need for regulation for responsible aquaculture that prevents the introduction and spread of invasive species, and minimizes the escape of invasive aquatic animals into native habitats; and
- Develop co-management and capacity building for fisher institutions to monitor and combat invasive encroachment.

The Business Allocation Regulations 2018 of GoN provide a mandate to MoALD to develop policy, laws, and standards relating to food quarantine, animal and plant-based quarantine, and their implementation and regulation. Similarly, the Regulations provide a mandate to MoFE for genetic resources, rare and endangered species and exotic species; and formulation of policy, law, and standards relating to the conservation of natural rivers, lakes and ponds, wetlands and watershed areas and their regulation. However, the Regulations do not provide a discrete mandate on prevention and control of introduction and expansion of invasive species. Nevertheless, the mandate was given to both the ministries to develop appropriate law in native and alien invasive species. It is therefore necessary that MoALD and MoFE amend the Forest Act, National Parks and Wildlife Conservation Act, Plant Protection Act and Animal Health and Animal Service Act to include appropriate provisions relating to prevention and control of invasive species. MoALD should ensure prevention and control of invasive species relating to agriculture, livestock and exotic fish, while MoFE should ensure prevention and control of native invasive and alien invasive species relating to plant, wildlife and aquatic biodiversity.

5.14 INSTITUTIONS AND ARRANGEMENTS

The NBSAP names MoFE as the government focal agency tasked with leading Nepal in biodiversity conservation negotiations and coordinating overall conservation activities in the country. MoFE is also the focal agency for many international conventions related to biodiversity, including invasive management. The NBSAP strategy to establish linkages among federal, provincial and local level institutions, and respective action plans are emphasized to conserve terrestrial plants and animals. It focuses on *ex-situ* conservation of fish genetic resources rather conserving habitats and fish in wild states. Currently, MoFE does not have institutional capacity in terms of institutional structure, human

resources and links with research, academic and extension organizations to address issues of aquatic invasive and aquatic biodiversity conservation, in general.

The NBSAP establishes a National Biodiversity Coordination Committee (NBCC) with representation from key government and academic institutions: the National Planning Commission, MoALD, Tribhuvan University, and Agriculture and Forestry University, among others. In spite of this august representation, the institutional members of the NBCC – particularly from MoFE and MoALD – have not given priority to prevention and control of invasive species.

MoALD has a mandate to monitor aquaculture and fisheries development in the country and should be made responsible to aquatic invasive risk management. The institutional and technical capacity of MoALD at the national level and the Ministry of Land Management, Agriculture and Cooperative (MoLMAC) at the provincial level need to address invasive species in a proactive manner and in collaboration with the Department of Agriculture, the Department of Livestock Services (DoLS), and the Directorate of Livestock and Fisheries Development. With regard to the fishery sector, there is an urgent demand for technical assistance to MoALD, DoLS and NARC to flesh out a sector-specific plan of action for invasive management. Building institutional and technical capacity within MoALD related to invasive impacts, vulnerability and adaptation will also provide a comparative advantage to better represent the fishery and aquaculture sector in national level biodiversity conservation and invasive management planning facilitated by MoFE.

National level consultation meetings organized by Paani in 2018 and 2019 have clearly identified the roles and responsibility of different organizations to address aquatic invasive species.

5.14.1 RESEARCH

- Nepal Agricultural Research Council (NARC): risk analysis of introduction, multi-year, multi-location verification studies; invasion assessment at molecular level; environmental economic assessment of the introduction and dispersal.
- Universities (AFU, TU, KU): core research on biology, habitat preferences, and food-webs; impact on native species, invasion characteristics, and outlines for verification studies.
- Central Animal Quarantine Office (within MoALD): create database of invasive species; conduct risk analysis of introduction.
- Department of National Parks and Wildlife Conservation (DNPWC): create database on spread of species, and naturalization of invasion in new environments.
- Local governments: offer support to multi-location studies; restrict invasive release; adopt standard protocols.
- Community Based Organizations (CBOs), NGOs, INGOs: offer support to multi-location studies; adopt standard protocols; disseminate research findings.

5.14.2 CAPACITY BUILDING AND EXTENSION

- MoALD: formulation of acts, policies and guidelines.
- DNPWC: patrol and monitor, law enforcement, information sharing

- NARC: *Ex situ* and *in situ* conservation of threatened gene pools; outreach activities on invasive management; dissemination and demonstration of research results.
- Central Fisheries Promotion and Conservation Centre (CFPCC): plan, monitor and supervise
- Fisheries Development Centre, Bhairahawa: breed fish for genetic improvement; *ex situ* gene pool maintenance.
- Human Resource Development and Fisheries Training Center, Janakpur: develop informal curriculum and awareness-raising material.
- Natural Water Fisheries Center, Hetauda: plan conservation, community sensitization and awareness programs on invasive species.
- Central Animal Quarantine Office: screening, risk assessment, information sharing
- Veterinary Hospital and Livestock Expert Center at Province: enforce quarantine measures and conduct disease risk assessment for invasive species.
- Livestock Training Center: provide training on risk assessment of aquatic invasive animals, novel control prevention and control measures, and operate awareness campaigns.
- Fisheries Development Centers: monitor responsible aquaculture.
- Municipalities: monitor the activities of private organizations related to aquatic environment; enforce laws and regulations.
- CBOs, NGOs, INGOs and private sector: comply with laws and regulations, and promote communication among agencies.

5.15 GAPS IN INVASIVE MANAGEMENT

Access to scientific information is important to ensure an effective response to biological invasions (Browne et al. 2009, Simpson et al. 2009). This information needs to be used judiciously alongside legislative and socio-economic information and local knowledge to inform decision-making (Segan et al. 2011). The scientific information generated through research activities can be broadly described as relating to the processes, impacts or management of invasive species (Kueffer and Hirsch-Hadom 2008). Across all the ecosystems in Nepal, freshwater ecosystems have received little attention. This gap in information is due to the limited research in these ecosystems, especially on aquaculture. Thus, prior to introducing and managing a species, it should be required to prove a species invasive and detrimental (or not) to the ecosystem. This requirement will generate scientific research and experimentation.

5.15.1 KNOWLEDGE GAP

National level consultation meetings organized by Paani in 2018 and 2019 have clearly identified several knowledge gaps on these topics related to invasive management:

- The biodiversity of natural water before and after a bio-invasion
- Invasive species studies
- Impacts of intervention (e.g., hydropower, illegal fishing, water channelizing, loss of riparian area, and ecological and environmental flows) on aquatic biodiversity and invasion of species.
- Studies of other invasive species in other taxonomic groups (i.e., not fish).
- Economic impacts of aquatic bio-invasion in Nepal.
- Modelling and mapping of invasive species.

- Multi-location and multi-year experiment research and verification trials on the effect of target invasive species.

5.15.2 GAPS IN POLICY AND REGULATIONS GAPS

Management of invasive species in aquatic ecosystems is a global challenge (Chandra and Gerhardt, 2008) and therefore given special attention in the Strategic Plan for Biodiversity for 2011-2020 by the Convention on Biological Diversity (CBD). Target 9 (which is listed under Goal B) of this plan deals specifically with invasive alien species: "By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment." Across the world there are many policies, management approaches and awareness campaigns involving citizens to deal with invasive species (Piria *et al.,* 2017). However, in Nepal, there is no comprehensive plan to tackle this growing menace.

National level consultation meetings organized by Paani in 2018 and 2019 have clearly identified policy-related gaps pertaining to invasive management:

- Lack of or inadequate multi-disciplinary studies on aquatic species.
- Existing policies are not consistent on controlling expansion of invasive species already introduced in the country.
- Existing or in pipeline-sectoral policies, acts and laws do not explicitly address the issue of aquatic invasive species.
- Lack of follow-up legal documents to implement policy and act.
- Lack of technical procedures and legal measures for promoting responsible aquaculture, including the release of potential invasive species into natural water.
- Lack of technical procedures and standards for release of waste and effluents from aquaculture farms and aquarium houses, which is the most common form of accidental exotic fish release.
- Appropriate legislation is needed for regulating import of aquatic fauna and flora.
- Policy should provide scope for establishment and strengthening appropriate institutions at different levels for purposes of managing invasive species.
- Policy should make provision for nomination or recruitment fisheries inspector with sufficient power and functions.
- Policy should promote research for the promotion of native fish species for aquaculture.
- Law should empower local communities to manage and benefit from conservation of designated river stretches and associated biodiversity.

6. RECOMMENDATIONS

Based on case studies and reviews made in this report, the following recommendations can be made:

- Require strict adherence to quarantine measures, the guidelines of the Convention of Biological Diversity (CBD), and immediate response measures for controlling invasive species.
- Create a federal- and provincial-level database of invasive species, including management strategies for controlling importation and spread.

- Analyze the risk and impacts of already-introduced fish species. The Nepal Agricultural Research Council (NARC), Central Fisheries Promotion and Conservation Center (CFPCC) should lead this analysis to inform policy and consult with stakeholders to gain a range of perceptions about the effects of invasive species.
- Amend and enforce accordingly the National Parks and Wildlife Conservation Act, the Plant Protection Act, and the Animal Health and Animal Service Act to address issues of aquatic biodiversity conservation and invasive species.
- Build capacity of local managers and extension agents to understand the impacts of invasive species and the control measures needed for restricting their importation and spread.
- Conduct awareness programs for secondary school and college students on the topic of invasive species.
- Prepare a comprehensive management plan for invasive species, including a special committee within the Central Fisheries Promotion and Conservation Center, to monitor the impacts of invasive species.

7. CONCLUSION

The International Union for Conservation of Nature (IUCN) describes the impacts of invasive species as "immense, insidious, and usually irreversible." Freshwater systems in Nepal could face major losses of biodiversity, mainly due to biological invasion, and a wide array of associated ecological and economic issues.

Though Nepal lacks much formal research on invasive species, this report – through fieldwork and literature review – identifies major pathways for the entry of invasive species into aquatic ecosystems and the lack of adequate regulation and control measures. Introduction of species for aquaculture, aquarium and ornamental trade are the leading pathways of entry of invasive species. Invasive species deliver negative impacts natural systems upon which communities depend for their livelihoods.

As a developing country, Nepal has often opted for importing exotic fish for boosting aquaculture and fishing, but these acts have been short-sighted. There is an urgent need to develop appropriate policies and action plans to manage the invasive species to reduce the possible impacts on indigenous species and ecosystems. Furthermore, these policies and plans must be built about good research, including a national level database on invasive species. Researchers must be engaged and incentivized to work on identified knowledge gap areas. Education, awareness, and the spread of scientific knowledge among local residents, aquaculturists and aquarium traders will hopefully control exotic species' dispersion in the wild. Use of endemic species needs to be promoted for aquaculture instead of exotic species to reduce ecological loss of natural ecosystems. Scientific monitoring invasive fish species is needed to achieve conservation goals.

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