Status and Human Impact Assessment of Jagdishpur Reservoir - A Ramsar Site, Nepal

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LETTER OF RECOMMENDATION

This dissertation entitled with **"Status and Human Impact Assessment of Jagdishpur Reservoir - A Ramsar Site, Nepal"** has successfully completed by Ms. Mangleswori Dhonju under my supervision and guidance. Therefore, I hereby recommend that this dissertation is submitted for partial fulfillment of Master of Science (M. Sc.) Degree in Environmental Science. To the best of my knowledge, this dissertation work has not been submitted to any other degree.

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LETTER OF APPROVAL

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ABSTRACT

Jagdishpur Reservoir is one of the most important wetland of Nepal designated as Ramsar Site in 2003. It is also highlighted in the Directory of Asian Wetlands. A very few attempts have been made to evaluate the ecological quality of wetlands using benthic macroinvertebrates as scientific parameters for water quality, spatio-temporal variation of benthic community and their relationship with environmental parameters. In this connection, this study was intended to determine the ecological status and analyze seasonal variation of the benthic fauna in relation to environmental variables. Social survey was also conducted around the settlement areas in order to know human impact on the reservoir.

The study was conducted for one year period from September 2008 to August 2009. Field study and samplings were carried out in three season i.e. post-monsoon (November, 2008), pre-monsoon (April, 2009) and monsoon (July, 2009). In total, twelve samples from littoral zone, fourteen samples from profundal zone, three samples from inlet and five samples from outlets of the reservoir were taken. Similarly, four samples were taken from the littoral zones of surrounding wetland. Shannon's diversity index (*H'*) and Piélou's evenness index (*e*) were used to determine taxa richness while GRS-BIOS was used to determine the ecological quality class of the study site. Canonical Correspondence Analysis (CCA) was carried out for investigation of direct relationship between macroinvertebrate assemblages and environmental variables. Spearman correlation coefficients between environmental variables were determined and significant differences in taxa richness (no. of taxa) and density among different zones of wetlands were conducted by using One Way ANOVA from package R 2.9 versions.

Altogether 50, 53 and 42 macroinvertebrates taxa were recorded from reservoir (littoral and profundal zone), inlet and outlets and littoral zone of surrounding wetlands respectively. Likewise 46, 38 and 38 taxa with an average density of 230 ind./m^2, 391 ind./m^2 and 346 ind./m^2 were recorded from the reservoir (including littoral and profundal zone) in post-monsoon, pre-monsoon and monsoon season respectively. The study showed significant difference in taxa composition number and density among different zones (Littoral, Profundal and Littoral zones of surrounding wetlands) of Jagdishpur reservoir for all season.

The Jagdishpur reservoir including its inlet, outlets, and surrounding wetlands was categorized as 'Quality class IV' and described as poor quality. The GRS BIOS/ASPT for all sample sites ranged between 2.50 and 3.99.

Canonical correspondence analysis (CCA) resulted that faunal assemblages and composition structures were influenced by different environmental variables depending on season for same wetland zone/type and was not possible to draw concrete and general result for particular zone/type of wetlands for overall year. The number of taxa differed significantly among different zones of the reservoir in all three seasons as given by One Way ANOVA analysis. The spearman correlation analysis for all season showed significant positive correlation between number of taxa and abundance.

Human activities like commercial fish farming, excessive use of pesticides and fertilizers, bathing and washing clothes aggravate deteriorating ecological condition of reservoir.

The present study helps to give status of benthic macroinvertebrates of Jagdishpur reservoir. The outcomes can be widely applied to assess Nepalese lentic ecosystems.

Key Words; *Jagdishpur reservoir, Ramsar site, Ecological water quality, Benthic macroinvertebrates, Canonical Correspondence Analysis (CCA)*

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ACRONYMS/ABBREVIATIONS/SYMBOLS

$AgNO_3$	: Silver Nitrate
APHA	: American Public Health Association
AWWA	: American Water Works Association
BCN	: Bird Conservation Nepal
BOD	: Biological Oxygen Demand
$CaCO_3$	: Calcium Carbonate
CBIP	: Central Board of Immigration and Power of India
CCA	: Canonical Correspondence Analysis
Chl a	: Chlorophyll a
cm^3	: Cubic Centimeter
CO_2	: Carbon dioxide
DNPWC	: Department of National Parks and Wildlife Conservation
DO	: Dissolved Oxygen
DoFD	: Directorate of Fisheries Development
DOI	: Department of Irrigation
EDTA	: Ethylene Diamine Tetra-Acetate
GPS	: Global Positioning System
GRS-BIOS/ASPT	: Ganga River Biotic Score System/ Average Score Per Taxon
H_2SO_4	: Sulphuric Acid
ha	: Hectare
HCl	: Hydrochloric acid
HKH BENSO	: Hindu Kush Himalayan Benthological Society
IUCN	: International Union for Conservation of Nature
KI	: Potassium Iodide
Km	: Kilometer

m : Meter

MHS : Multi Habitat Sampler

mg/L :Milligram Per Liter

ml : Milliliter

µm : Micro meter

$MnSO_4$: Manganese Sulphate

$Na_2S_2O_3$: Sodium Thiosulphate

NaCl : Sodium Chloride

NaOH : Sodium Hydroxide

NH_3 : Ammonia

NO_3^- : Nitrate

OMC : Organic Matter Content

PO_4^-P : Phosphate Phosphorus

UNESCO : United Nations Educational, Scientific and Cultural Organizations

VDC : Village Development Committee

WPCF : Water Pollution Control Federation

WWF : World Wildlife Fund

% : Percentage

ºC : Degree Centigrade

CHAPTER I

INTRODUCTION

1.1 General

Water is the fundamental resource on which our life-support depends. The interactions between water, soils, plants and animals, enable the wetland to perform many vital physical, biological and chemical activities of wetland. Example includes water storage, storm protection and flood mitigation, shoreline stabilization and erosion control, groundwater recharge, water purification through retention of nutrients, sediments and pollutants and stabilization of local climatic conditions, particularly rainfall and temperature (UNESCO- IUCN, 2005).

The term wetland encompasses a variety of environments; inland marshes, wet meadows, mudflats ponds, bogs, bottomlands, wooded swamps, fens, alpine ponds and lakes. Wetlands in Nepali called *Simsar*. According to IUCN-Nepal (1996), '*Sim'* is a derivative of the Persian word *'Sih',* which means low- grade land not suitable for cultivation and '*Sar'* is a Sanskrit word meaning water. Thus, *Simsar* can be interpreted as land with water.

The Convention on Wetlands of International importance especially as waterfowl habitat was signed in 1971 in Ramsar (Iran) and provides a framework for international cooperation for the conservation of critical global wetland habitats. According to Convention, Wetlands are defined as *"areas of marsh, fen, peatland or water whether natural or artificial, permanent or temporary with water that is static or flowing; fresh, brackish or salty , including areas of marine water, the depth of which low tide does not exceed six meters".* Nepal signed Ramsar site in 1987 and the first wetland was designed as Koshi Tappu and added in the list on 17th December 1987. The three sites in Nepal designated as wetlands of International Importance on 13th August 2003 are Ghodaghodi Tal, Jagdishpur Reservoir and Beeshazar Lake. Rara Lake, Phoksundo Lake, Gosainkundo associated Lake, and Gokyo and associated Lake were designated as Ramsar site in 2007. Maipokhari was recently designated as the first mid-hill wetland of International Importance site of Nepal in 2008 (www.wetlands.org).

Nepal is rich in wetland resources and is endowed with several types of wetlands. Nepal's wetlands can be divided into five categories;

- The trans-Himalayan wetlands comprising of lakes such as Rara, Tilicho and Phoksundo.
- The relatively shallow midland- mountain wetlands lakes such as Phewa, Begnas and Mai Pokhari.
- The lowland tropical wetlands which are seasonally flooded riverine flood plains, including Koshi Tappu.
- The human managed wetlands such as ponds, rice fields, ghols etc.
- Artificial wetlands such as reservoirs (viz; Jagdishpur), irrigation canals and sewage ponds.

Wetlands cover about 5 % (816954 ha) of total land area of Nepal. Out of total wetlands in Nepal, river cover 48.35% (395000 ha), irrigated paddy fields cover 48.71% (398000 ha), marginal lands/swamps/ghols cover 1.4% (11500 ha), reservoirs cover 0.18% (1500 ha), lakes cover 0.61% (5000 ha) and village ponds cover 0.72% (5954 ha) (DoFD, 2002).

Wetlands are among the most productive ecosystems in the world and are important in terms of their ecological, economic, cultural and recreational values. These ecosystems produce a wide range of goods and services as well as income generating activities for people all over the world, including Nepal. The wetlands serve as an important habitat for endangered, rare and endemic plant and animal species (Majupuria and Majupuria, 2006). But in recent years, the wetlands are under threat of human activities. Human disturbances (such as deforestation, unregulated hunting, dam construction and increased pollution level from the discharge of untreated effluents and agriculture practices) bring about change in water quality which has direct impact in the life pattern of living species. The wetlands of Nepal also have faced serious environmental problems; loss of species, erosion, deforestation, draining, sedimentation, washing and bathing etc.

Lakes/reservoirs have a more complex and fragile ecosystem than rivers; they do not have "self cleaning" ability and therefore they readily accumulate pollution. Because of their ecological and economic significance and their relevant vulnerability to degradation, lakes require more attention than is applied to rivers and stream basins. Sustainable use of lakes and reservoirs and is being threatened around the globe (The World Bank, 1995).

The ecological quality of a river/lake/reservoir is accurately depicted by the macro-invertebrates living in it. In recent years using macro-invertebrates as an indicator of aquatic ecosystem health has become increasingly popular for numerous reasons. The most important reason among all others is that such an indicator accurately reflects the integrated environmental effects in an aquatic ecosystem.

Water quality characteristics of aquatic environment arise from a multitude of physical, chemical and biological interactions. The physico-chemical characteristics of an aqueous phase have direct influence on the type and distribution of aquatic biota. Conversely, they are also influenced by the activity of the aquatic biota (De, 2000). The floristic and faunal diversity of wetland is influenced by several physico-chemical parameters such as water transparency, velocity, depth, pH, nutrients etc (CBIP, 1979).

1.2 Background

Reservoirs have been built in many parts of the world in naturally lakeless regions to increase availability of water resources. In Nepal, man-made reservoirs and ponds are mainly for hydropower and irrigation purposes. Reservoirs are mainly created for irrigation and hydropower development. Jagdishpur Reservoir also known as Sagar Taal is one of the most important wetlands of Nepal designated as Ramsar site in 2003 and is also highlighted in the Directory of Asian Wetlands chiefly because of their support for threatened and endangered species of birds and mammals. The reservoir was constructed in the early 1970s over Jakhira Lake and agricultural land for irrigation and is fed by the Banganga River in the Churia hills catchments area. It is surrounded by cultivated land and a few smaller lakes (Nepal Biodiversity Resource Book, 2006).

The reservoir provides important resident, wintering and stopover habitats for waders, other water birds, and small passerines. Noteworthy are the grebes, cormorants, herons and egrets (terns and gulls, birds of prey, rails, coot and waterhens, Jacanas, as well as cranes and kingfishers. The wetland supports a small population of the globally threatened Smooth-coated Otter *Lutogale perpsicillata*. Like other water bodies, the reservoir has also received immense encroachment from human activities. Frequent visit for grass cutting and intensive commercial fish cultivations are being major threats for good ecological quality and sustainability of the reservoir.

Jagdishpur reservoir provides tremendous economic benefits to local people, for example: supply of water for irrigation in 6,200 ha of surrounding cultivated land (Fact sheet of

Nepal, 2005); fisheries; agriculture, through the maintenance of water tables and nutrient retention in surrounding wetlands of Jagdishpur reservoir; timber production; energy resources (fuel wood and fodder collection), domestic use (e.g. laundry), harvesting of wetland products and recreation (e.g. have a picnic, bathing) and tourism opportunities. Its surroundings are mainly used for farming. In addition, it has special attributes as part of the cultural heritage of humanity. They are related to religious and cosmological beliefs and are also a place of beauty. The water body has a great potential for commercial stock fish production (DNPWC &WWF NP, 2005). Department of Irrigation (DOI) issued a license to a private contractor to start exotic fish farming in the reservoir. Since then, the open water stocking is being managed by a group of private enterprises in the reservoir.

This study aimed to elucidate faunal inventory, their composition in different habitats and their interaction with associated environmental factors in Jagdishpur Reservoir. The lake has lost submerged vegetation due to intensive fish farming. This gradient should influence the present macroinvertebrate community structure in the lake. Among environmental factors, DO, pH, Temperature, conductivity, Hardness, Chloride, Free Carbon dioxide, Ammonium-Nitrogen, Nitrate, Ortho-phosphate were focused.

1.3 Literature Review

a. Limnological Study on Lakes and Reservoir of Nepal

The limnological research on Nepal's lake and reservoir has initiated since six decades. Brehm (1953) was the first to report limnological work from Nepal and studied on some aquatic fauna in Kalipokhari from eastern Nepal. The first comprehensive limnological investigation in Nepal was initiated by Loffler (1969) in high mountain lakes of Khumbu Himal (Pradhan, 2009). Lohaman et al. (1988) carried out detail investigation on limnological parameters of lakes of Kathmandu and Pokhara valley. Lake Phewa was categorized as mesotrophic while lake Rupa and Begnas as eutrophic. Similarly they categorized Taudaha as mesotrophic and Nagdaha as eutrophic based on total nitrogen and total phosphorus.

Acharya (1997) found productive nature of Ghodaghodi Lake and Nakrodi Lake based on physico-chemical parameters of water which was also evident by a luxuriant growth of macrophytes. The study concluded that water was acidic in nature with high free CO_2

content but medium oxygen content. High value of total nitrogen and total phosphorus showed eutrophic nature of the lakes.

Jayana (1997) found a maximum density (637 individuals/m²) of *Chironomous species* in January and a minimum of 7 individuals/m² in April in Beeshazar Lake.

Niraula (2007) has analyzed on surface water, bottom sediments and *Chironomous species* for understanding the water quality status of Beeshazar Lake. She found that high concentration of N, P, and transparency was major factor for the degradation of wetland habitat in the Beeshazar Lake leading to the gradual conversion into marshy areas and high abundance of the *Chironomous species.*

Shrestha (2007) has carried a dissertation work in Taudha. She studied on water quality parameters and benthic macroinvertebrates of Taudha Lake. She concluded that the lake is hypertrophic in nature. The productivity of lake is increasing and diversity of benthic macroinvertebrates was highest in gravel and silty sediment rather than in muddy sediments. Chironomidae species had the highest dominancy in all months than other benthic organisms.

Tachamo et al., (2007) have carried out investigation in three artificial ponds namely Bhaju Pokhari (Dudhpati, Bhaktapur), Rani Pokhari (Ratnapark, Kathmandu) and Jawala Pokhari (central Zoo, Jawalakhel) and one natural lake Taudaha (Bhutkhel V.D.C., Kirtipur) and prepared the inventory list of macroinvertebrates and described the ecological status of the studied ponds and lake.

Nesemann et al., (2008) carried out detailed investigation on macroinvertebrates of Phewa Lake. Altogether 37 taxa based on family level identification and 26 genera have been recorded. The composition and taxa richness of the watershed are giving an overview of the subtropical ecosystem. Saprobic water quality classes of inlets, outlets and Phewa itself have been identified. Phewa lake is a thermal waterbody due to the presence of numerous warm springs with 21 to 24˚ celsius. Macro-invertebrate diversity is high due to presence of numerous warm-water species.

Shah et al., (2008) have documented the zoobenthos diversity from Gosaikund lake. Altogether 8 taxa were recorded that includes Baetidae, Chironomidae (Diamesinae, Orthocladiinae, Tanytarsini), Lumbriculidae (*Lumbriculus variegates*), Enchytraeidae (*Fridericia perrieri*), Megascolecidae (*Perionyx fluviatilis*) and Planariidae (*Polycelis* *spec*.). Baetidae was documented from the inlet of the lake. Chironomidae was common along the banks of the lake.

b. Benthic Macroinvertebrates, Fish, and Environmental variables

Gopal (1987) found that water hyacinth plants have a tremendous growth and reproductive rate and the free-floating mats cause great problems for wetland biodiversity. In Koshi habitats, the rapidly expanded its coverage resulted in heavy loss in biodiversity primarily for the avian biodiversity. The substantial coverage of water hyacinth can lead dissolved oxygen levels which might influence the community dynamics of the benthic community and ultimately to bird species that are dependent on insects and fish.

Corcoran (2005) studied Lesser Scaup Nesting Ecology in Relation to Water Chemistry and Macroinvertebrates on the Yukon Flats, Alaska. The comparison study was conducted between the period of 1985–1989 and 2001–2003 from 9 wetlands for chemical and biological parameters which found total nitrogen and most metal cations (Na, Mg, and Ca, but not K) increased between these periods, while total phosphorus (TP) and chlorophyll *a* (Chl *a*) declined. These changes were greater in wetlands that had experienced more drying (decreased surface area). Compared to 1985–1989 biomasses of amphipods, gastropods, and chironomid larvae were generally lower in both June and August 2002–2003.

Smokorowski *et* al. (2006) studied effects on periphyton and macroinvertebrates from removal of submerged wood in three Ontario lakes. They removed 40%-70% of nearshore wood habitat from three lakes, specifically focusing on the provision of substrate for periphyton and invertebrate production by submerged wood. The investigation found invertebrate biomass was greater on wood than in sediment. Highly decayed wood supported greater chlorophyll ‘a’ concentrations and more invertebrate biomass and diversity than fresh wood. The removal had no measurable effect on whole lake water chemistry, nor did it result in a response in residual epixylic periphyton and invertebrate biomass but permanently reduced a dynamic and concentrated biomass of primary and secondary productivity in lakes. Takamura, *et*. al (2009) studied the effects of environmental variables on the distribution of benthic macroinvertebrates inhabiting sediments at 25 sites along the shoreline of Lake Takkobu in the Kushiro wetland of northern Japan in summer 2003. Their result clearly showed that four environmental variables (submerged plant biomass, bottom sediment organic matter content (OMC), distance from the mouth of the Takkobu River and bottom layer pH) explained the significant variation in the macroinvertebrate species composition. Schilling et al., (2009) compared the macroinvertebrate communities in fishless lakes found in two biophysical region of Maine (U.S.A.) and identified unique attributes of fishless lake macroinvertebrate communities compared to lakes with fish. Fishless and fish containing lakes had numerous differences in macroinvertebrate community structure, abundance, taxonomic composition and species richness. Communities in fishless lakes were more species and abundant than in fish-containing lakes, especially taxa that are large, active and free-swimming. Naturally fishless lakes warrant conservation because they provide habitat for a unique suite of organisms that thrive in the absence of fish predation.

c. Jagdishpur Reservoir

Mc Eachern (1996) studied the regional and seasonal characteristics of water chemistry, algal biomass and nutrient limitation in different lakes of Nepal including Jagdishpur Reservoir and other wetlands during period of 1993 to1995. Water quality analysis report of the samples taken on July 12, 1997 (Fact sheet, 2003) revealed that

- According to Secchi disc measurement the reservoir is hypertrophic.
- The total phosphorus content indicates that the lake is hypertrophic.

However, with respect to nutrient content and Secchi depth the lakes can be considered to be eutrophic to hypertrophic. This conclusion is based on a one-time analysis during monsoon. A total of 42 species of birds and 25 fish species were recorded during the July 1997 survey.

DNPWC and WWF NP, 2005, Fact sheets of Wetlands of Nepal have mentioned that there is leaching of inorganic fertilizers and pesticides from farms into Jagdishpur Reservoir.

Gautam (2007) has studied a seasonal variation of water quality of Jagdishpur Reservoir. The study concluded that the reservoir is in acceptable condition from the physico-chemical characteristics. The trophic status of reservoir was found to be hypertrophic based on PO_4-P and eutrophic based on Secchi disc transparency and total nitrogen.

Shah et al., (2007) have documented macroinvertebrates and also described the ecological condition of Beeshazar Tal including Khageri Khola, Ghodaghodi Tal and Jagdishpur Reservoir. Among the studied invertebrates, there were several genera and species, found in Nepal for the first time (*Cercothmetus* species, *Oosthuizobdella mahabiri*) and others are very rare and endangered species (*Camptoceras lineatum, Hirudinaria manillensis*).

1.4 Objectives

1.4.1 General objective

The general objective of this study is to assess limnological parameters with reference to seasonal variation of benthic macroinvertebrates, ecological water quality and conducting social survey around settlement areas of reservoir for the ecological sustainability of the reservoir.

1.4.2 Specific Objectives

The specific objectives of this study include:

- To determine seasonal ecological quality status of the reservoir, inlet, outlets and surrounding wetlands
- To determine relationship between physico-chemical parameters and benthic fauna
- To document human impact on the Jagdishpur reservoir

1.5 Rationale

At present Nepal has only a small number of reservoirs; Jagdishpur, Trishuli, Marshyandi, Kulekhani, Gandaki, Saptakoshi, Andhikhola and Panauti. These reservoirs are mainly created for irrigation and hydropower development. Among these, Jagdishpur Reservoir is one of the most significant wetlands of Nepal and was declared as Ramsar site in 2003 chiefly because of their support for threatened and endangered species of birds and mammals. At the same time it also supports livelihood of many wetland dependent people. It is also highlighted in the Directory of Asian Wetlands. Therefore information on physical, chemical and biological characteristics of water is very important as these characteristics determine the spatio-temporal dynamics of the water quality, aquatic biodiversity, health quality and sustainable use of reservoir. A wide range of environmental factors like geology, hydrology, watershed area, landscape, climate, land use pattern, land cover and so on can transform the physical, chemical and biological states of water quality in the reservoir which alter sooner or later.

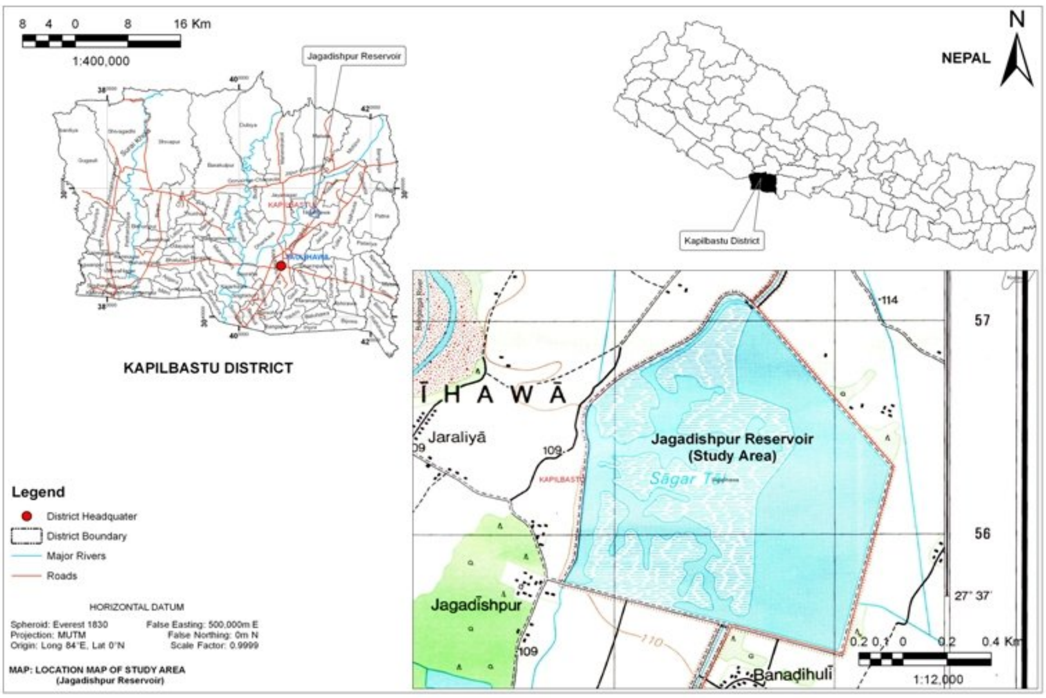
To date, little work has been done on Lake Macroinvertebrates in contrast to the large volume of research carried out on lotic (running waters) ecosystem. There have been less ecological and environmental studies of the wetlands including Jagdishpur Reservoir. However, a very few attempts have been there to evaluate the ecological quality of wetlands using benthic macroinvertebrates as scientific parameters for water quality, spatio-temporal variation of benthic community and their relationship with environmental parameters. Realizing these facts, the present research is intended to record the inventory of benthic fauna and to generate the database of seasonal limnological parameters such as physico-chemical components, and composition pattern of benthic macroinvertebrates community of reservoir so as to identify ecological status of the Jagdishpur Reservoir. It establishes biota-environmental relationship which may be extremely useful information for the conservation and sustainable management of the reservoir. DNPWC and WWF Nepal, 2005, Fact sheets of Wetlands of Nepal have reported that there is leaching of inorganic fertilizers and pesticides from farms into Reservoir. To know such type of human interference on the reservoir, present study is attempted. The obtained data and analysis can be further utilized and extrapolated for prosperous management of lakes and reservoirs.

CHAPTER II

MATERIALS AND METHODS

2.1 Study Area

Jagdishpur reservoir lies in the Indo-Malayan biogeographical realm of the Terai physiographic zone and is the extension of the Gangetic plain in the outer foothills of the Churia or Siwaliks in the Central Himalaya. The site lies 10 km north of the City Taulihawa in Kapilvastu District, Lumbini Zone of Central Nepal as shown in Map 1. It lies at 27º 35' 00" N latitude and 83 º 05’ 00’’ E longitude with an elevation of 197m and the area is characterized by its low elevation (i.e. 197m) and a tropical monsoon climate with hot rainy summers and cool, dry winters. It was created over the location of Jakhira Lake and surrounding agricultural land in the early 1970s. The construction of a rock-filled dyke took place in the early 1980s. The water in the reservoir is fed from the nearby Banganga River that has a catchment area in the Churia Hills. Incoming suspended silts and nutrients are deposited in the reservoir mouth. The reservoir's surface area is 157 ha and is surrounded by cultivated land and there are two small lakes known as Sagarhawa and Niglihawa situated in the area that serves as a buffer habitat for bird movements.



Map 1: Location of study area (Jagdishpur Reservoir)

The reservoir bank is planted with *Dalbergia sissoo* and *Acacia catechu*. The aquatic vegetation is represented by extensive coverage of floating leaved species, mainly *Nelumbo nucifera*, followed by *Hygrorhiza aristata* and *Potamogetan nodusa*. The abundant submerged species include *Naja minor*, *Certophyllum demersum* and *Hydrilla verticillata, Ipomea carnea ssp. fistulosa* and *Typha angustifolia* grow around the reservoir margin. The site provides important resident, wintering and stopover habitats for waders, other water birds, and small passerines. Noteworthy are the grebes, cormorants, herons and egrets (terns and gulls), birds of prey, rails, coot and waterhens, Jacanas, as well as cranes and kingfishers. The wetland supports a small population of the globally threatened Smooth-coated Otter *Lutogale perpsicillata*.

2.2 Preliminary survey of study area

Preliminary survey was carried out around the Jagdishpur Reservoir area through the corridor survey. During survey, the sketch of the reservoir including various features such as bank condition and structure, bed materials riparian vegetation, wetland use, inflow and outflow conditions etc, and stressors like water abstraction, solid waste disposal, washing, bathing, open defecation etc were noted down to locate sampling station evenly in all habitat types around the reservoir including inlets, outlets and surrounding wetland.

2.3 Sampling Period

The sampling of this research was conducted for the period of one year from September, 2008 to August 2009. Sampling from different sites within reservoir was taken for three season i.e. post-monsoon (November, 2008), pre-monsoon (April, 2009) and monsoon (July, 2009).

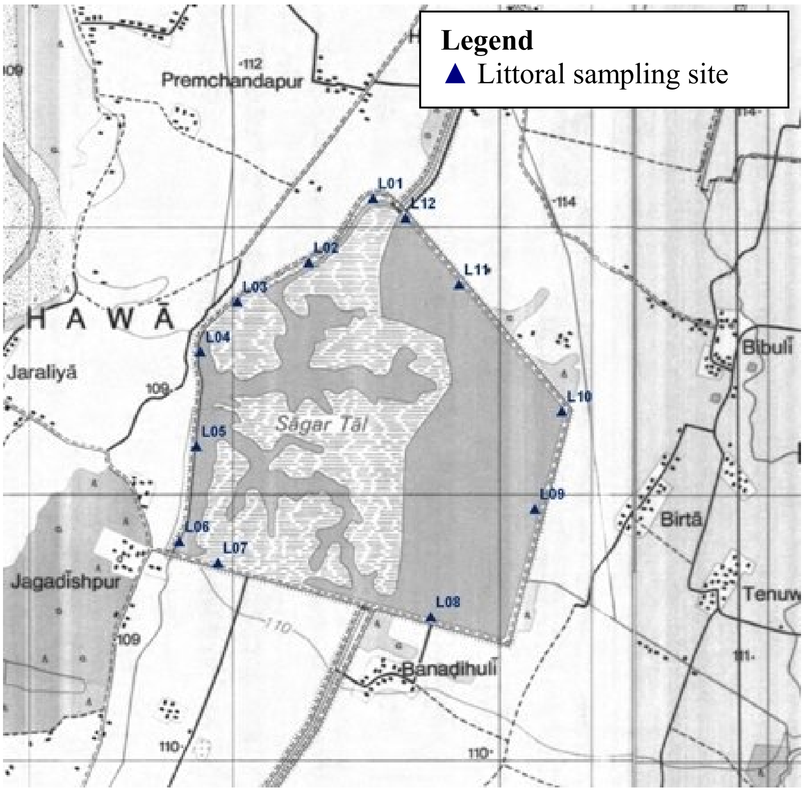
2.4 Sampling Design and Sites

Biological as well as physico-chemical samples were designed into four categories viz; Inlet and Outlets, Littoral Zones, Profundal Zones of the reservoir and Littoral Zones of surrounding wetlands of the Jagdishpur reservoir. Then the sampling sites were determined from each category uniformly.

2.4.1 Sites Description

a. Littoral Zone

Altogether twelve samples were taken from the littoral zone of Jagdishpur reservoir in around five kilometer perimeter as shown in Map 2. The first (L01) and second (L02) samples had similar habitat. These sites were covered by macropytes (80%) and the mineral habitat consists of pebbles, sand and mud. The third (L03) sample was taken in the north west direction, a 80m ahead from the second sample where riparian trees were present sparsely and covered by 70% microlithal and akal, 10% macrophytes, 10% sand and 10% mud. The habitat condition of the fourth (L04) and fifth (L05) sample sites were nearly the same but with sparse and dense riparian vegetation.

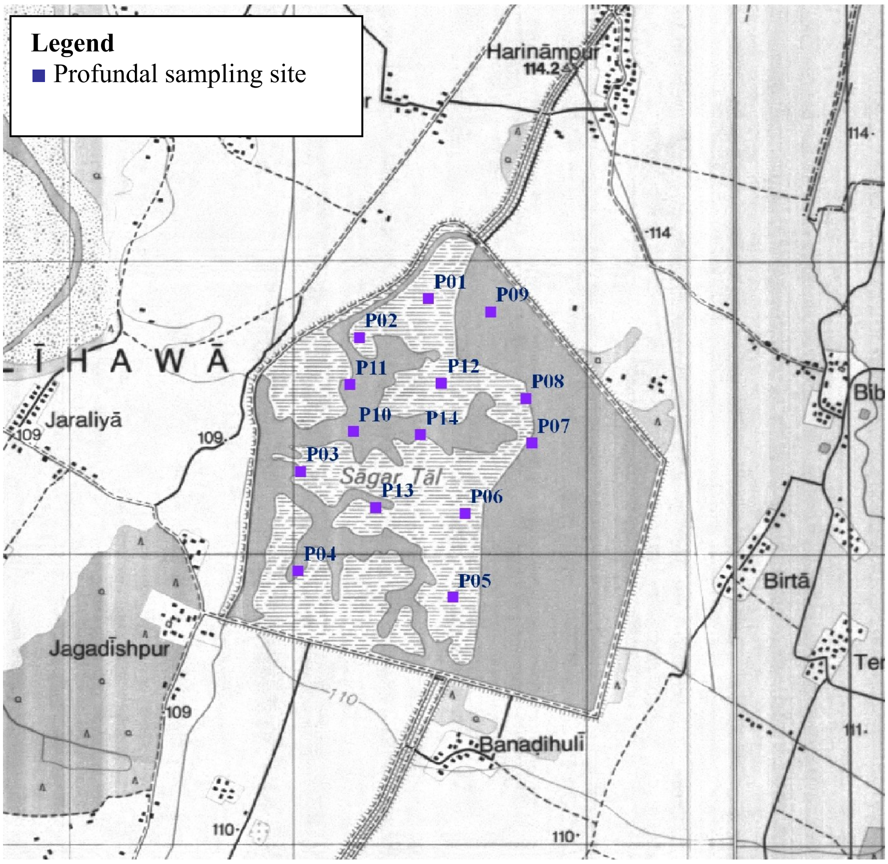


Map 2: Sampling sites in Littoral zones of Jagdishpur Reservoir

The sixth (L06) and seventh (L07) sites were covered by 85% mesolithal, 15% akal, sand and mud and partly with macrophytes. Likewise the eighth (L08) sample site was covered by 70% mesolithal, 30% by sand and mud and macrophytes (15%). Near eastern outlet ninth (L09) sample site was situated and covered by 100% stones, with 20% macrophytes and algae. The tenth (L10) sample site was covered by 75% stones and 25% sand with 20% macrophytes and algae. In the eleventh (L11) sample site, 10% stones, 30% pebbles, 25% sand and 30% Sandy mud substrate was present with 30% covered by macrophytes including algae. The last sample site (L12) was located on the left side of the inlet to the reservoir where 20% coverage of macrophytes including algae, and with 65% stones and 35% by Sandy mud. But in pre-monsoon and monsoon season, the habitats of all sites were quite different due to lowering of water level of Reservoir except the sites L01 and L02 that were nearly same in habitat as in post-monsoon. In pre-monsoon and monsoon season, the habitats of sites were filled by Sandy mud and pelal. These habitat conditions were determined arbitrary.

b. Profundal zone

Fourteen samples were taken in the profoundal zone as shown in Map 3 based on the depth and uniformity of sample sites. For each sample site, the GPS data was taken in the post-monsoon season and with reference to this GPS data the sampling were done in the pre-monsoon and monsoon season.



Map 3: Sampling sites in Profundal zones of Jagdishpur Reservoir

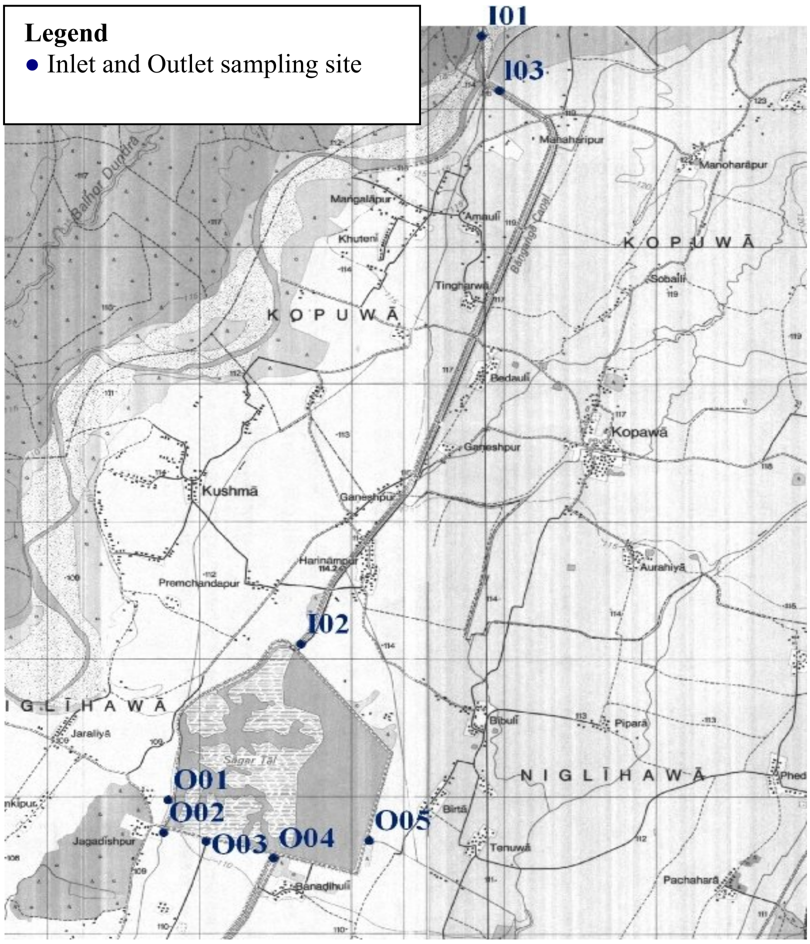
c. Inlets and Outlets

Three samples were taken from the inlet of the Jagdishpur Reservoir as shown in Map 4. First site (I01) is located in the Banganga River. Sample was taken from about 200m above the dam and diversion canal for the Jagdishpur Reservoir. In Banganga River, the semi qualitative sample was taken from the coverage of 10% pebbles, 50% gravels, 20% sand, 10% sandymud and 10% mud including macrophytes (10%) and algae covered habitat.

The second sampling site (I02) is located in the diversion canal at about 100m below the dam. The site was covered with dense macrophytes containing Sandy mud and mud substrate.

The third sampling site (I03) was located near to the mouth of Jagdishpur Reservoir. The macrophytes covered almost 50% of the surface. The mineral habitat was dominated by mud.

One sample from each outlet was taken at a distance of 100m downstream from the reservoir. The substrate type (100% mud with 40% macrophyte coverage) was similar for four outlets (O01, O02, O03 and O05) while the fifth outlet (O04) had different mineral habitat (100% gravel with 80% macrophyte coverage).

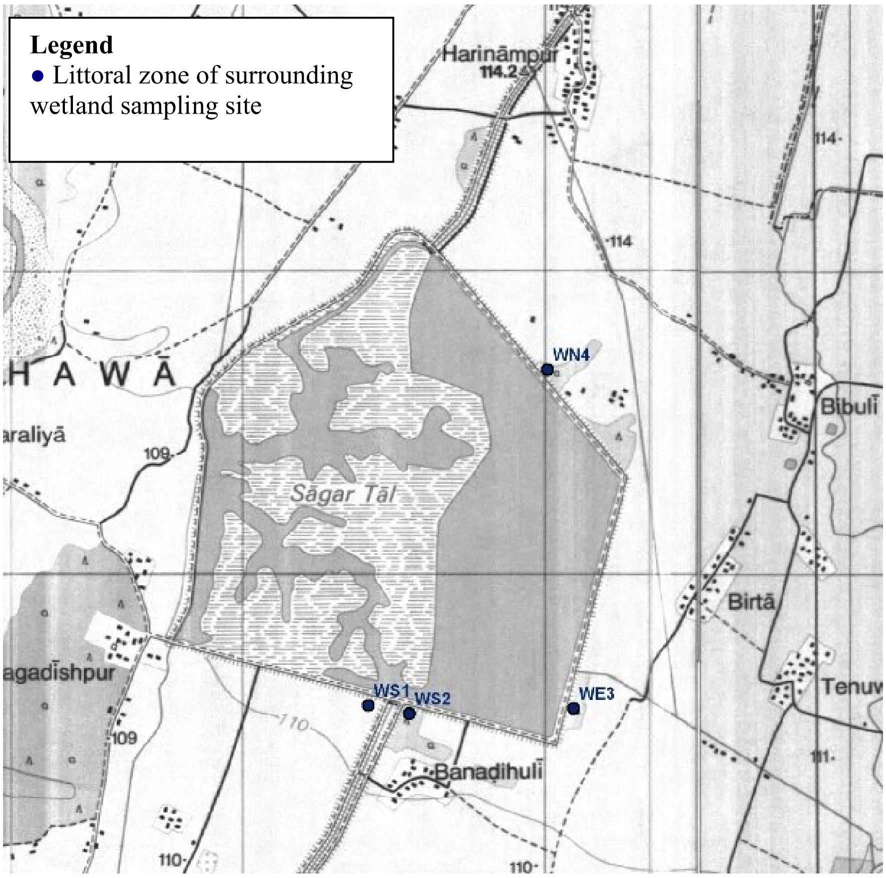


Map 4: Sampling sites in Inlet and Outlet of Jagdishpur Reservoir

d. Surrounding wetlands

Altogether four samples were taken from the littoral zones of surrounding wetlands of the reservoir as shown in Map 5. WS1 and WS2 are located at right and left to the main outlet of reservoir in the southern direction. The WS1 and WS2 were covered by 85%

macrophytes such as *Eicchornia, Nelumbo nucifera, Typha angustifolia, Hygrorhiza aristata* and surrounded by agricultural land. WE3 site is located in eastern part of the reservoir close to eastern outlet. The site was covered by 75% macrophytes and dominated by *Typha angustifolia.* WN4 site is located northern part of reservoir and surrounded by agricultural land and heavily dominated by *Typha angustifolia (*Pater).



Map 5: Sampling sites in Littoral zones of surrounding wetlands of Jagdishpur Reservoir

2.5 Benthic macroinvertebrate Sample collection

A total of ten sampling units were distributed in 20 meter stretch covering all microhabitat with at least 10% coverage at each sampling site. The 10 sampling units were chosen according to the relative share of the microhabitat. Sub-samples were transferred into the bucket and made one composite sample of each site.

***Qualitative sampling* -** Sampling was done by using varying mesh size of 1 mm and 0.5 mm and hand picking from different substrates. Ten sub-samples were taken based on multi habitat approach with minimum habitat coverage of 10% for each sampling unit.

***Quantitative sampling* -** Quantitative samples were carried out by using Ekman grab sampler with the area of 225 cm^2. In total, 10 sub samples were collected from various depths and macrophyte habitats in proportion of habitat coverage of 10% for each sampling unit.

Semi-quantitative sampling - Multi-habitat sampling was performed by using multi-habitat sampler (MHS) net with mesh size of 500µm in inlet and out let (lotic system) of Jagadispur Reservoir. In total twenty sub-samples were taken based on multi-habitat approach with minimum habitat coverage of 5% for each sampling unit.

2.5.1 Sample Processing in field

The sub-samples of each site was transferred into the bucket and made one composite sample. The coarse particulate matters like woody debris, stones and twigs were checked properly whether any benthic individuals were attached or not. The separated coarse materials were removed from samples. The samples were stirred in water filled bucket and floated animals were sieved with net of mesh size 500µm then samples were transferred into plastic container. The sample container was labeled with site location and date and preserved in 4% of formaldehyde.

2.5.2 Sample Processing in laboratory

After a week of preservation in formaldehyde, the samples were washed thoroughly by using mesh size of 0.5 mm and kept in white enameled tray. Animals visible with naked eyes were picked and kept in various petridishes depending on various morphological forms. Later, the animals were identified upto family level by referring to various Identification keys and preserved in 70% ethanol. All the preserved animals are stored in Hindu Kush Himalyan Benthological Society (HKH BENSO) laboratory.

2.6 Water Sample Collection, Processing and Analysis

Water samples from different sampling sites (Littoral Zone, Inlets and Outlets and Surrounding Wetlands) of the reservoir were collected from the surface in clean and rinsed plastic bottles. While water samples from the profundal zone were taken with help of Van Dorn Water Sampler (Ruttner) and transferred into clean and rinsed plastic bottles. Physico-chemical parameters viz. depths at sample site, Temperature, DO, Free CO_2, Chloride, pH, Conductivity, Hardness and Alkalinity were determined in the field and other remaining parameters like, BOD_5, Phosphate, Nitrate, $N\text{-}NH_4$, Iron were determined in the laboratory of Central Department of Environmental Science, Tribhuvan University.

These all physico-chemical parameters were determined according to the methods described in APHA, AWWA, WPCF (1995) and Trivedy and Goel (1984).

a.)Water Temperature - The temperature of surface water and atmosphere of sampling site was recorded by a mercury thermometer graduated with accuracy of ±0.1ºC.

b.) pH - The pH of water was recorded by an automatic digital pH meter (HI 8314 portable pH meter, HANNA instrument with an accuracy of ±0.01 at 20ºC/68ºF. The probe of which was dipped in beaker with half filled sample water. The displayed reading was noted down.

c.) Conductivity - Conductivity of water was recorded with a digital conductivity meter (Model 4150 by Wagtech with accuracy of ±0.5%). The probe of conductivity meter was dipped in sample water and the displayed reading was noted down.

d.) Chloride - Chloride was determined by titration method. It was done by titrating 50ml of sample containing 4-5 drops of potassium chromate with 0.02N silver nitrate solution. The yellow color produced by indicator was converted to brick red at the end point. Concurrent readings were noted for all samples. Chloride was calculated by the formula as:

$$\text{Chloride (mg / L)} = \frac{\text{ml} \times 0.02\text{N of } AgNO_3 \times 35.5 \times 1000}{\text{Volume of sample taken}}$$

e.) Total Hardness - Total hardness of water was determined by titration method. 50ml of sample water was taken in a clean conical flask and added 1ml of buffer solution (pH 10) and pinch of Erichrome black T indicator in it. The content was shaken well and titrated with standard EDTA solution until the wine red of solution turned blue. Concurrent readings were noted for all samples. Total hardness was calculated by using formula as:

$$\text{Total Hardness (mg/L) as } CaCO_3 = \frac{\text{Volume of 0.01of EDTA used} \times 1000}{\text{Volume of sample in ml}}$$

f.) Total Alkalinity - Total alkalinity of water was determined by titration method. 100ml of sample was taken in a clean conical flask and added few drops of Phenolphthalein indicator to it. If there was no any color change then two drops of methyl orange indicator was added and the content was titrated against 0.1N HCl until the yellow color changed into pink. The total alkalinity was calculated by using formula as:

$$\text{Total Alkalinity (as } CaCO_3\text{) mg/L} = \frac{\text{ml} \times 0.1\text{N of HCl} \times 1000 \times 50}{\text{Volume of sample taken in ml}}$$

g.) Free CO_2 - 100 ml of sample water was taken in a clean conical flask and added two to three drops of phenolphthalein indicator. The color didn't change which showed the presence of free CO_2 in water. So the content was titrated against the 0.05N NaOH solution until the pink color appeared. Concurrent readings for all the samples were noted. Free CO_2 was calculated by using following formula:

$$\text{Free } CO_2 \text{ (mg/L)} = \frac{\text{ml} \times 0.05\text{N of NaOH} \times 1000 \times 44}{\text{Vol. of sample taken}}$$

h.) Dissolved Oxygen (DO) - The dissolved oxygen was determined by Winkler idiometric method. The sample of water was filled in the BOD bottle of 300 ml. The stopper was placed tighten and checked on air bubbles inside the bottle. The stopper was removed and dissolved oxygen was fixed at sampling spot by adding 2 ml of Manganese Sulphate and alkaline potassium iodide solution through the wall of the bottle to form precipitate. The content was shaken well in eight shapes by inverting the bottle repeatedly and precipitate was allowed to settle down. Then 2 ml of concentrated sulphuric acid was added to dissolve the precipitate and shaken well. 50 ml of content was taken in a conical flask and titrated with 0.025 N of sodium thiosulphate solution using starch as an indicator until the dark blue color changed to colorless. The concurrent readings were noted for all the samples. The dissolved oxygen is calculated by the following formula:

$$\text{DO (mg/L)} = \frac{\text{ml} \times 0.025 \text{ N of titrant} \times 1000 \times 8}{V_2(V_1 - V)/V_1}$$

i.) Biological Oxygen Demand (BOD) - The sample water filled in the BOD bottle was incubated in the incubator at 20° C for five days. DO content of this incubated sample was determined. The difference between the initial and final DO (after 5 days incubation) was noted as BOD_5 of the water. The BOD of the water sample was calculated as:

BOD_5 (mg/L) = (DO_0-DO_5) x Dilution factor

Where, DO0 = Initial DO, and DO5 = Final DO after 5 days.

j.) Ammonia (NH_3) - 25 ml of filtered sample was taken in a conical flask and one ml of phenol solution, one ml of sodium nitropruside and 2.5 ml of oxidizing agent were added. The mouth of flask was covered by wrapper and kept in dark light for an hour. The blue color was developed after an hour and was measured at 635nm to find absorbance. Same procedure was repeated for the standard solution of different concentration and for distilled water. The standard curve was plotted and concentration of ammonia of water sample was determined.

k.) Nitrate (NO_3^-) - 50 ml of filtered sample was taken in porcelain basin. 10 ml of Silver Sulphate was added and heated slightly and the precipitate of silver chloride was filtered. The filtered sample was evaporated to dryness. Then 2 ml of phenoldisulphonic acid was added to the residue and it was dissolved with distilled water and stirred thoroughly. Before taking the reading 2 ml of 30 percent ammonia was added to it. And its absorbance was noted on the spectrophotometer at 410nm taking distilled water as blank. The concentration of nitrate was determined with the help of standard curve.

l.) Phosphate - The phosphate content in the given water sample was determined as inorganic phosphorus by colorimetric method. In this method, 100 ml of filtered sample was taken in a volumetric flask. 4 ml of Ammonium Molybdate was added to it. 10 drops of stanus chloride was also added to it. After 10 minutes the blue color appeared. The absorbance of color at 690nm was measured in a spectrophotometer. Same procedure was repeated for standard solution of different concentration and for distilled water was made. The concentration of the phosphate in a water sample was calculated from the calibration curve.

2.7 Social Survey

The social survey was conducted to get information on threat identification by anthropogenic activities around the reservoir area. For this purpose the primary data was collected using questionnaire around settlement areas of the Jagdishpur reservoir in six villages of Niglihawa VDC. This questionnaire survey was conducted by using random sampling technique. Similarly daily activities of local people on and around the wetland were observed and recorded.

The secondary data was acquired from various publications and documents published by Government of Nepal, Nepal's Department of National Parks and Wildlife Conservation (DNPWC), IUCN, WWF Nepal, Bird Conservation Nepal (BCN), National Newspaper report and various websites.

2.8 Data analysis

2.8.1 Biological Analysis

Taxa obtained from qualitative/semi-quantitative/quantitative samplings were used to prepare seasonal faunal inventory list for Jagdishpur reservoir. Only data obtained from semi-quantitative and quantitative samples were taken into account for data analysis. To obtain standardized data from each sampling site, all data were converted to density (ind./m^2) using the following formula;

Number of individuals per square meter (ind./m^2) = N/ A

Where, *N* is the total number of individuals in each sample and *A* is the total sampling surface area (0.625m^2).

A list of taxa sampled at each station was first established. Then, Shannon's diversity index (*H'*) and Piélou's evenness index (*e*) (Magurran 1988) were calculated according to the following formulae:

$$H' = -\Sigma pi * \log_{10}(pi)$$

Where, *pi* is the proportion of individuals of the taxon *i*th relation to the total number of individuals and

$$e = H'/\log_{10}S$$ Where *S* is the total number of taxa

2.8.1.1 Ecological Quality Class Determination

The GRS BIOS (Nesemann et al., 2007) which is specially developed for the use in lowlands and middle mountains below 2000 meter above sea-level and focused on the stagnant water fauna of wetlands, lakes and ponds is used to determine the water quality class of the study site. This method of analysis involves the determination of average score per taxon (ASPT) of indicator species in a sample of macroinvertebrates. Total Ganga river system scores summed up when divided by number of taxa scored gives GRS BIOS/ ASPT. Description of ecological water quality based on quality class was extracted from Pradhan, 1998.

2.8.2 Multivariate analysis

Biological data (x=density) were transferred in $\log_{10}(x+1)$ for multivariate analysis. Canonical Correspondence Analysis (CCA) were analyzed by PC ORD 5.16 version (McCune and Mefford, 2006). The CCA was carried for investigation of the relationship between macroinvertebrate assemblages and environmental variables. Spearman correlation coefficients between environmental variables and significant differences in taxa richness (no. of taxa) and density among types of wetlands were determined using one way ANOVA in package R 2.9 version.

2.8.3 Social Data Analysis

Microsoft Excel 2007 was used for the interpretation of primary data collected from the questionnaire survey.

CHAPTER III

RESULT

3.1. Seasonal Faunal Inventory

Altogether 50 macroinvertebrates taxa belonging to 16 orders were found on the Jagdishpur reservoir including littoral and profundal zones. The highest taxa was found in post _monsoon season (46 taxa) while the least was found in pre-monsoon and monsoon season (38 taxa) (Annex 2.a). From the inlets and outlets of Jagdishpur reservoir, 53 macroinvertebrates taxa belonging to 17 orders were recorded. The monsoon season (47 taxa) had recorded highest taxa among the pre-monsoon (46 taxa) and post-monsoon season (38 taxa) (Annex 2.b). Likewise, 42 macroinvertebrates taxa belonging to 15 orders were obtained from the surrounding wetlands of Jagdishpur reservoir. In post-monsoon season, there were found to be highest taxa (35 taxa) where as 31 and 32 taxa were recorded in pre-monsoon and monsoon season respectively (Annex 2.c).

3.2 Faunal composition

Forty six families belonging to fourteen orders in post-monsoon and thirty eight families belonging to fifteen orders each in pre-monsoon and monsoon seasons are documented (Table 1). The highest diversity index and evenness were obtained for post-monsoon while the highest density was obtained for pre-monsoon season. The total number of family documented in littoral and profundal zone of Jagadishpur reservoir and littoral zone of surrounding wetlands are shown in figure 1a. The diversity of taxa is recorded higher in Mollusca (8), Heteroptera (8 taxa), and Diptera (8) for post-monsoon; Mollusca (9), Heteroptera (8 taxa) and Diptera (7) for pre-monsoon and monsoon season respectively (figure 1b).

Table 1: Community attributes in seasons

Community attributes in seasons	Post-monsoon (2008)	Pre-monsoon (2009)	Monsoon (2009)
Total no. of taxa	46	38	38
Density (ind/m^2)	230 (6.4±812.8)	391 (12.8±1785.6)	346 (3.2±1886.4)
H'	1.31	1.25	1.22

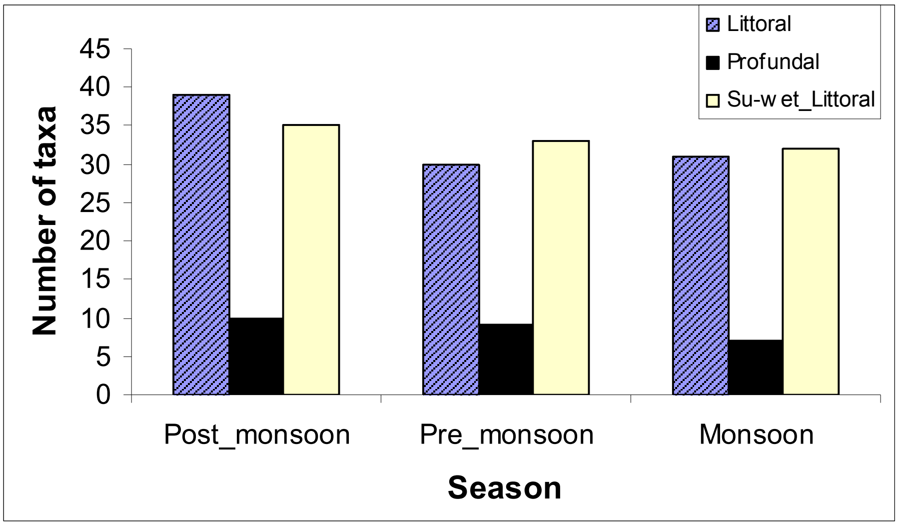


Figure 1a: Spatio-temporal distribution of taxa in Jagdishpur Reservoir

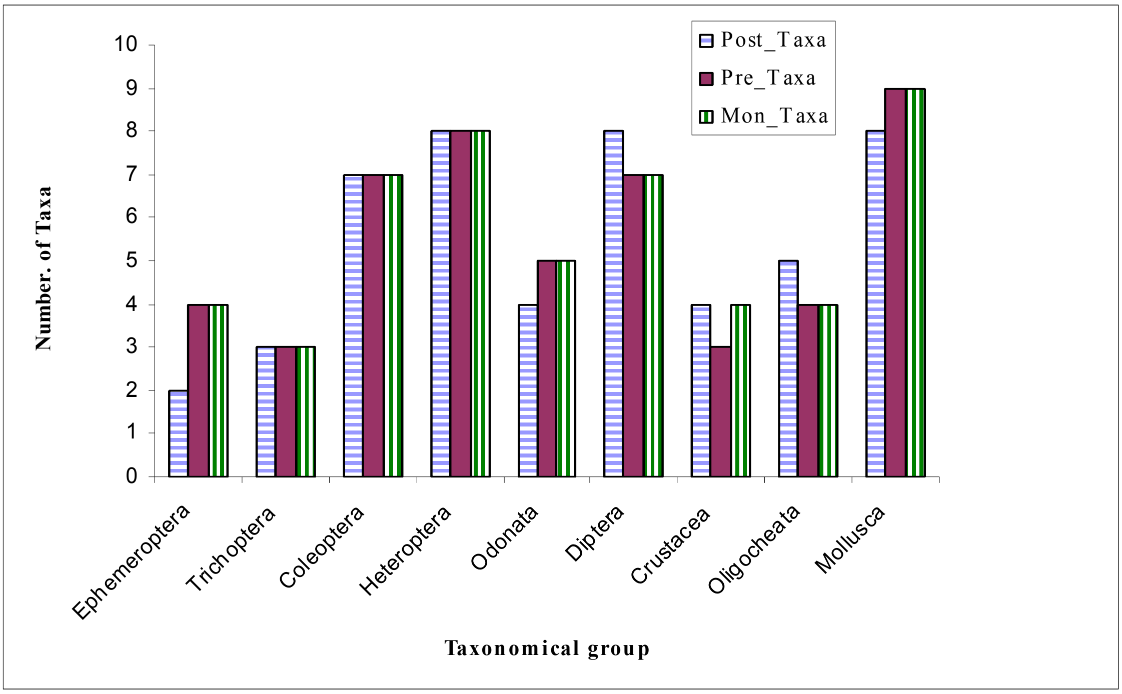


Figure 1b: Comparison of taxonomical group for each season

3.3 Ecological Quality class determination

The inlet, outlets, surrounding wetlands and the Jagdishpur Reservoir were categorized as 'Quality class IV' and were described as poor quality. The GRS BIOS/ASPT for different sample sites ranged between 2.50 and 3.99. The northern side has higher biotic score/ average score per taxon than the southern side of the reservoir.

3.4 Seasonal variation of macroinvertebrates

3.4.1 Taxa richness

The number of taxa differed significantly among different regions of the reservoir in all three seasons as given by One Way ANOVA analysis which revealed $F_{(2, 27)}$=27.76 ($p<0.001$) for post-monsoon, $F_{(2, 27)}$= 50.4 ($p<0.001$) for monsoon and $F_{(2, 27)}$=84.00 ($p<0.001$) for pre-monsoon (figures 2, 3 and 4) respectively.

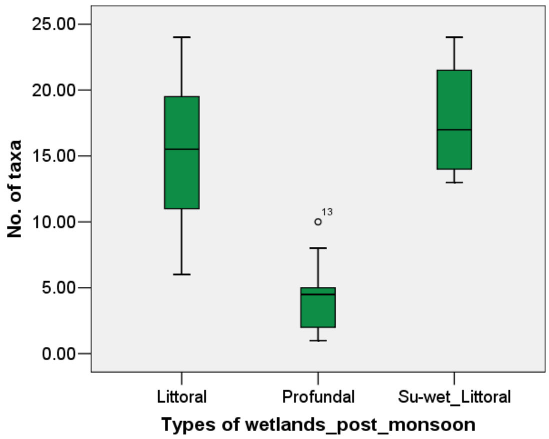


Figure 2: Distribution of taxa among the zones of reservoir for post-monsoon season (2008)

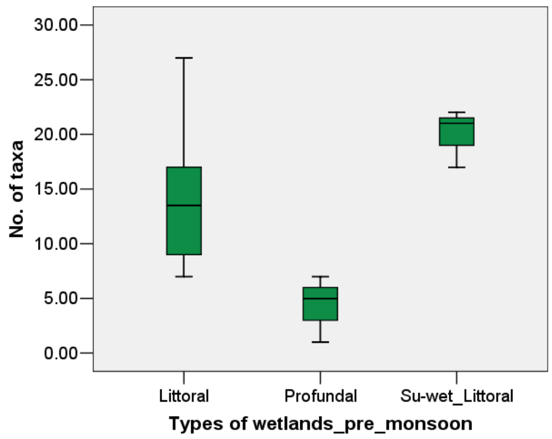


Figure 3: Distribution of taxa among the zones of reservoir for pre-monsoon season (2009)

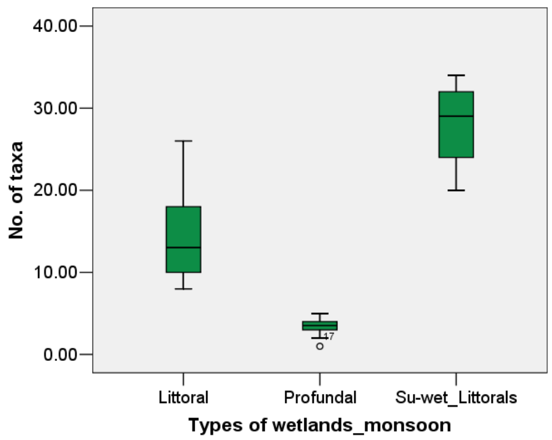


Figure 4: Distribution of taxa among the zones of reservoir for monsoon season (2009)

3.4.2 Density

The density of Chironomidae was highest in the littoral as well as in the profundal zone of the reservoir in all three seasons. The taxon with highest density per season for different regions of the reservoir is tabulated in table 2.

Table 2: Spatial and temporal density occurrence

Seasons/Density	**Littoral (ind/m^2)**	**Profundal (ind/m^2)**	**Su-wet_Littoral (ind/m^2)**
Post_monsson	Chironomidae = 64 (0±256)	Chironomidae = 47 (0±201.6)	Bithyniidae = 77.4 (0±230.4)
pre-monsoon	Chiroonomidae = 237.5 (6.4±982.4)	Chironomidae = 45.5 (0±249.6)	Tubificidae = 345.6 (14.4±1100)
Monsoon	Chiroonomidae = 203.9 (4.8±854.4)	Chironomidae = 31.6 (0±217.6)	Dytiscidae = 282.2 (0±732.8)

The result shows significant difference in density among different parts of reservoir for all seasons as shown in figures 5, 6, and 7. One Way ANOVA analysis revealed $F_{(2, 27)}$=8.58 ($p<0.01$) for post-monsoon, $F_{(2, 27)}$=12.04 ($p<0.001$) for pre-monsoon and $F_{(2, 27)}$=13.74 ($p<0.01$) for monsoon respectively.

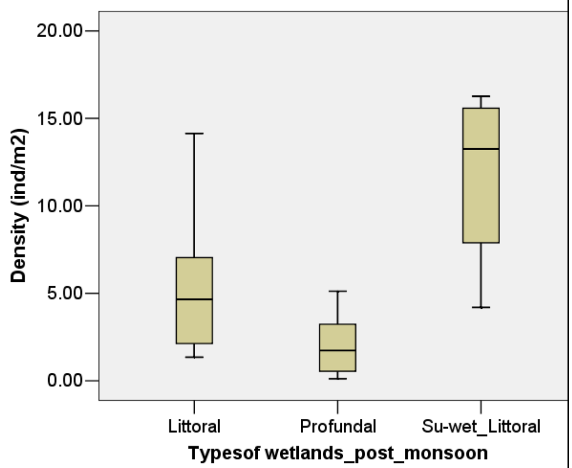


Figure 5: Macroinvertebrate density among zones of reservoir for post-monsoon (2008)

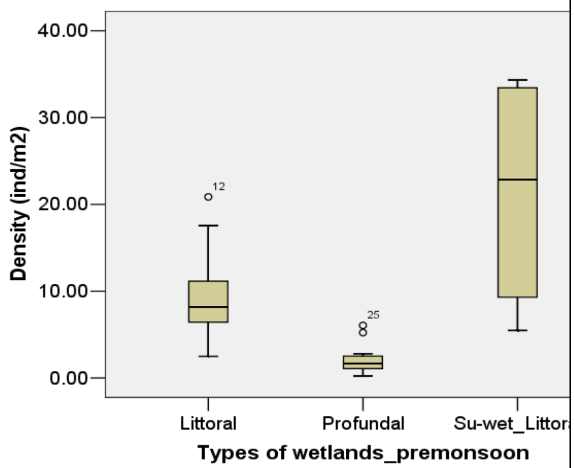


Figure 6: Macroinvertebrates density among zones of reservoir for pre-monsoon (2009)

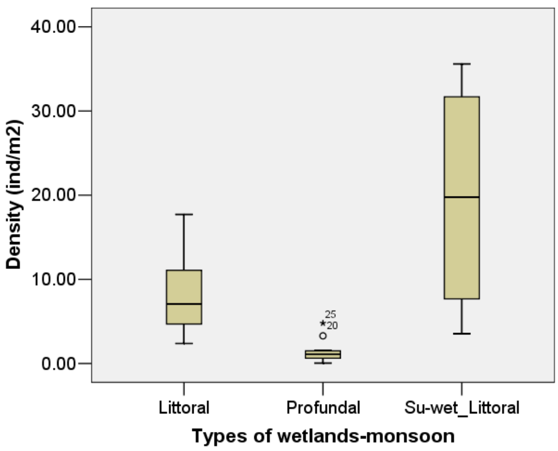


Figure 7: Macroinvertebrates density among zones of reservoir for monsoon (2009)

3.5 Macroinvertebrates composition and environmental variables

In the CCA, the first and second canonical axes explained 21.93% (eigen value 0.32) and 11.9% (eigen value 0.174), respectively for post-monsoon season as shown in figure 8. The faunal composition of surrounding wetlands is influenced by calcium hardness and conductivity while profundal zone of Jagdishpur Reservoir fauna is influenced by ammonium concentration. Spearman correlation shows significant correlation between conductivity and pH ($r=-.566$, $p<0.01$) while others are not significantly correlated (details in table 3).

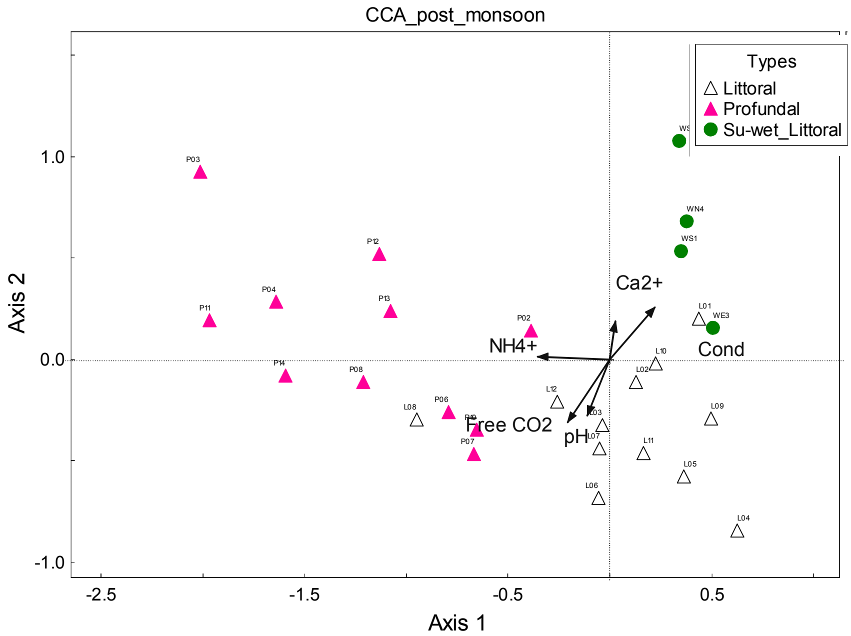
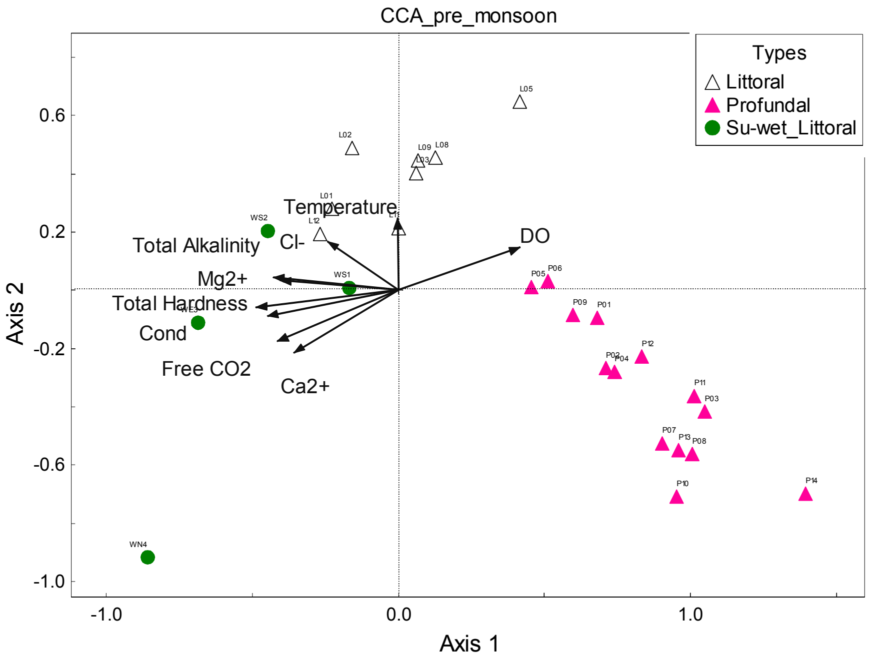


Figure 8: Canonical correspondence analysis (CCA) showing relationship between environmental variables and macroinvertebrates composition in sites for post-monsoon (2008)

In the CCA for pre-monsoon, dissolved oxygen, temperature, magnesium and calcium hardness, total hardness, alkalinity, conductivity and free carbondioxide explained the variation in the macroinvertebrate species composition (Figure 9). The first and second canonical axes explained 21.9% (eigen value 0.32) and 11.9% (eigen value 0.174), respectively, of the variance in the species data. Conductivity was positively correlated with total hardness, free CO_2, calcium hardness, chloride while negatively correlated with dissolved oxygen (details in table 4).



igure 9: Canonical correspondence analysis (CCA) showing relationship between environmental variables and macroinvertebrates composition in sites for pre-monsoon (2009)

CCA revealed free carbondioxide, temperature, magnesium and calcium hardness, total hardness and alkalinity as influencing factors for structuring the macroinvertebrate species (Figure 10) during monsoon season. The first and second canonical axis explained 25.2% (eigen value 0.362) and 12.0% (eigen value 0.173), respectively, of the variance in the species data. The positive correlation is seen between total alkalinity and total hardness, alkalinity with calcium and magnesium hardness and between temperature and magnesium hardness (details in table 5).

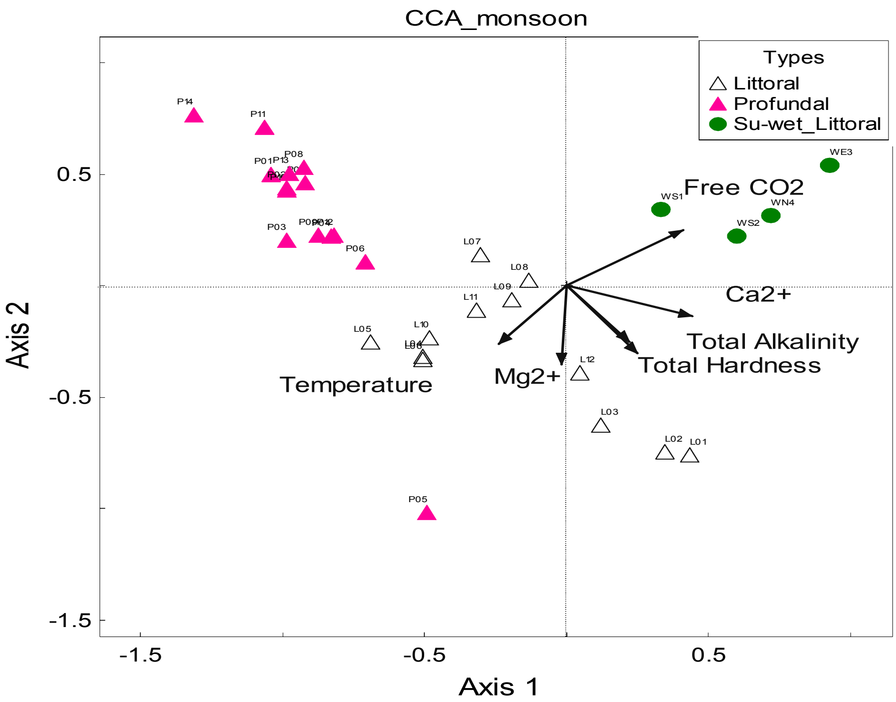


Figure 10: Canonical correspondence analysis (CCA) showing relationship between environmental variables and macroinvertebrates composition in sites for monsoon season (2009)

3.6 Relationships between number of taxa and environmental variables

Number of taxa and abundance were positively correlated ($r<=0.80$, $p<0.01$) in all seasons. Abundance and no. of taxa were significantly correlated with various chemical parameters in pre-monsoon (table 4) rather than for post-monsoon and monsoon (table 3 and 5).

Table 3: Spearman correlation coefficient (r) for post-monsoon, 2008. ** means significance level (p)<0.01

Parameters	No. of taxa	abundance	pH	Cond	Temp	DO	Total alkalinity	Ca hardness	Cl^-
Abundance	.829(**)								
Cond.			-.566(**)						
DO					.456(**)				
CO_2					.662(**)	.571(**)			
Total alkalinity			-.460(**)	.643(**)					
Ca-hardness			-.526(**)				.482(**)		
Total hardness				.466(**)			.693(**)	.700(**)	
Ammonia	-.571(**)	-.542(**)							
Iron									-.466(**)

Table 4: Spearman correlation coefficient (r) for pre-monsoon, 2009. ** means significance level (p)<0.01

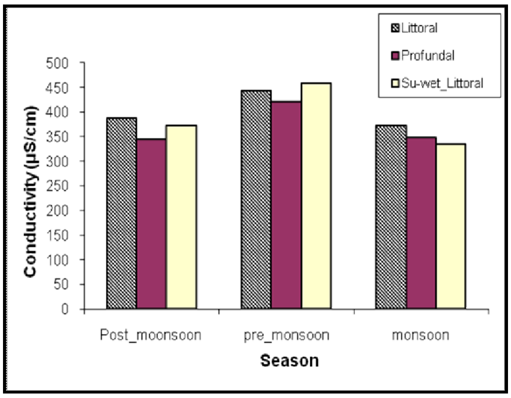
Parameters	No. of taxa	Cond	DO	Co_2	Total alkalinity	Mg hardness	Total hardness	Cl^-	PO_4-P
Abundance	.845(**)	.512(**)	-.606(**)		.581(**)	.687(**)	.604(**)	.646(**)	
Cond.	.609(**)								
DO	-.574(**)	-.763(**)							
CO_2		.641(**)	-.570(**)						
Total alkalinity	.640(**)								
Ca-hardness		.647(**)	-.614(**)	.472(**)					
Mg-hardness	.711(**)	.591(**)	-.516(**)	.540(**)	.539(**)				
Total hardness	.688(**)	.689(**)	-.597(**)	.648(**)	.562(**)	.913(**)			
Cl^-	.532(**)	.475(**)							
Ammonia				.530(**)		.522(**)	.525(**)		
Iron									.455(**)

Table 5: Spearman correlation coefficient (r) for monsoon, 2009. ** means significance level(p)<0.01

Parameters	No. Of taxa	pH	Cond	Temp	Total alkalinity	Ca hardness	Mg hardness	Total hardness	Cl^-	PO_4-P
Abun-dance	.808 (**)									
DO		.405(*)								
CO_2		-.418(*)								
Total alkalinity			.446 (**)							
Ca-hardness	.606(**)		.457 (**)		.545(**)					
Mg-hardness				.693 (**)	.579(**)					
Total hardness	.494(**)				.642(**)	.921(**)	.553(**)			
Cl^-	.559(**)									
PO_4-P									-.525(**)	
Nitrate		-.587(**)								
Ammonia								-.463(**)		
Iron										.576 (**)

3.7 Spatio-Temporal changes in Physico-Chemical parameters

Physico-chemical properties such as pH, Temperature and Ortho-phosphate were found higher among different parts of the reservoir in all seasons as shown in figure 11.



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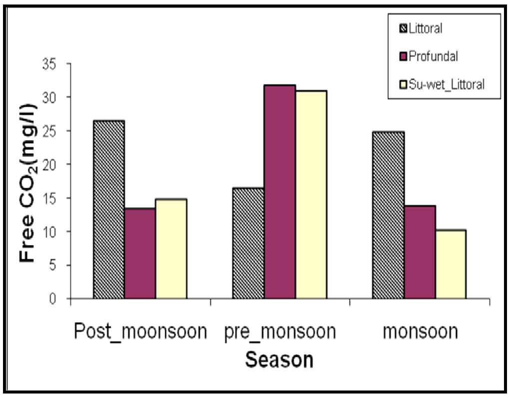

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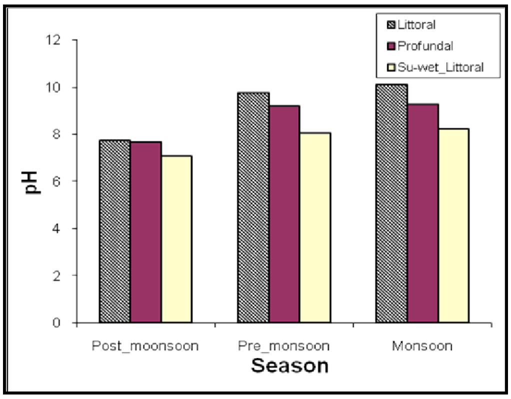

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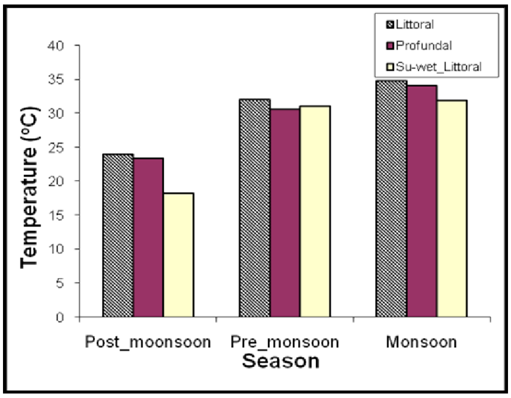

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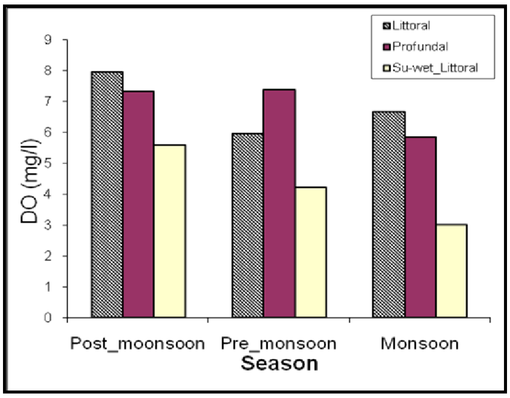

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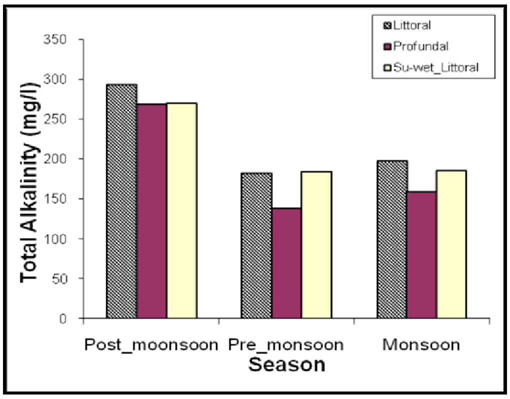

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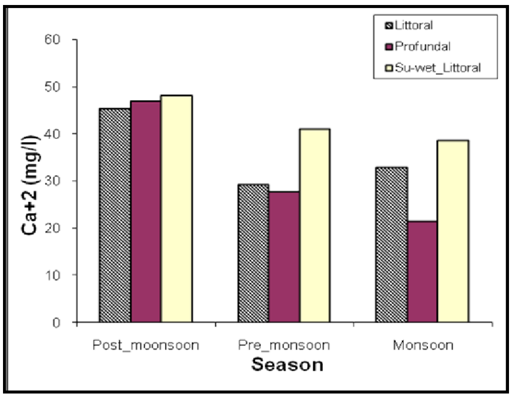

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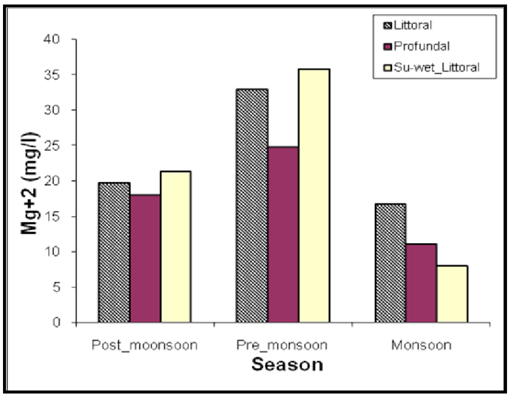

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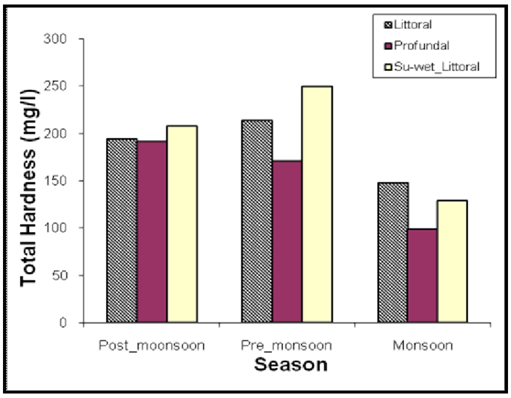

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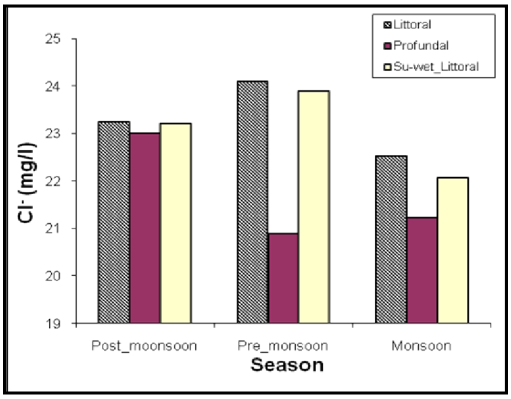

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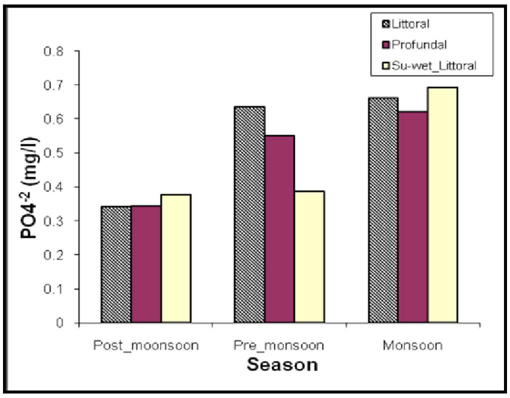

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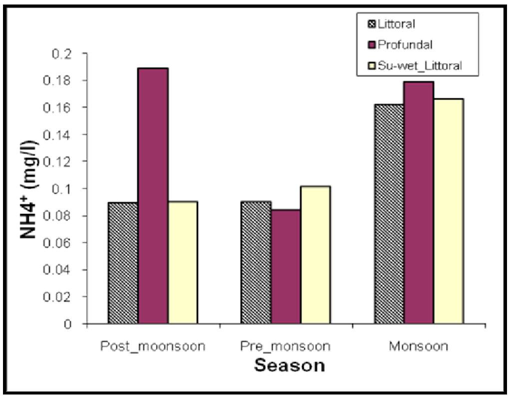

A 12

Figure 11: Bar diagram showing physico-chemical parameters for different seasons

3.8 Social Survey

The questionnaire survey was conducted in six villages surrounding Jagdishpur Reservoir viz Banduhuli, Bikuli, Birta Harnampur, Jagdishpur and Pipara of Niglihawa VDC in Kapilvastu District. The respondents were Farmer, Laborer, Business man, Students, Security guards and other fields of different age groups from different religions.

Regarding land type 86.89% had their own irrigated land, 22.95% had non-irrigated land and 4.92% had other types of land. Similarly 18.03% had leased irrigated land and 11.48% had leased out irrigated land (as shown in figure 12).

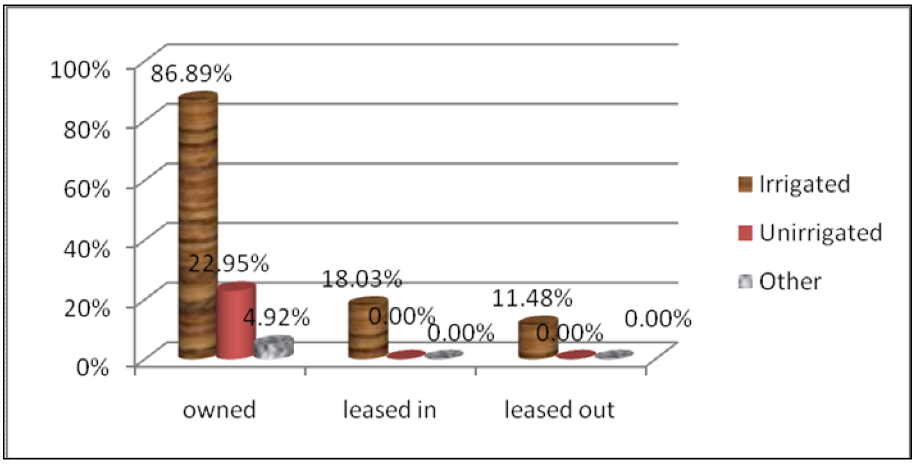

Figure 12: Land use for Agriculture purposes

The major income in the family of the Niglihawa VDC is as shown in following figure 13.

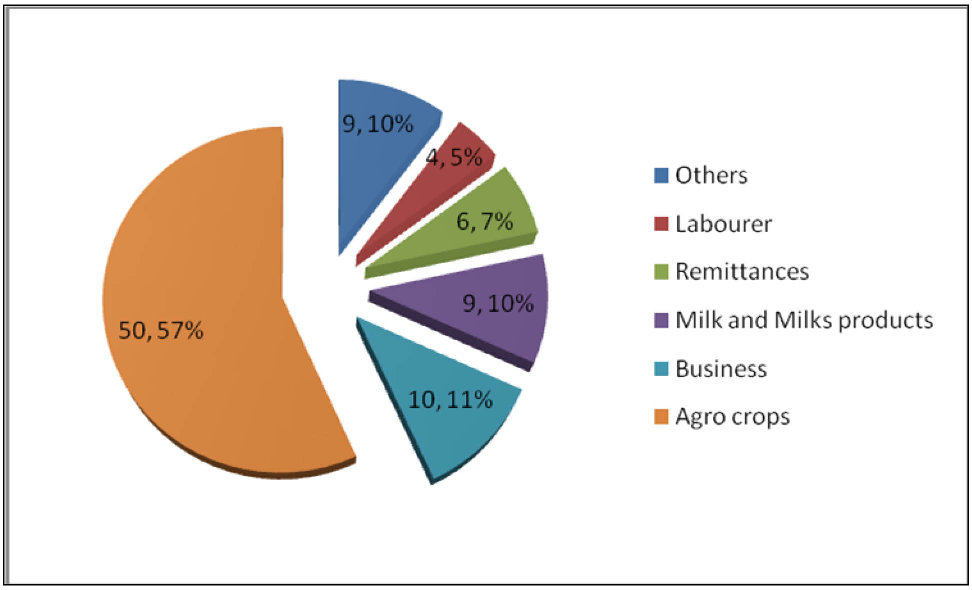

Figure 13: Sources of income in the family

People having agriculture as occupation used fertilizers and pesticides like compost, Urea, Potash, Zinc, Cow dung, DAP etc for agro crops. About 27.86% of people could identify the type of pesticides used, 27.86% had been using pesticides but could not specify, 8.19% had no idea and 36.06% never used any pesticides. Slight majority of respondents (57.37%) believed that over use of fertilizer or pesticides is more effective than optimum use whereas 42.63% did not believe in this assumption. While using pesticides, 80.33% took the precaution, 19.67% did not take any precaution. Among respondents 34.42% knew about side effect of pesticide and fertilizer use to environment while 65.58% were unaware about any hazard to environment.

Regarding commercial fish farming in the reservoir, 98.36% of the respondents knew the fact while 1.64% did not know about it. Among total respondents 55.73% were aware about the removal of carnivore fishes and other indigenous fishes before introducing exotic fishes for commercial fish farming in the reservoir by contractors. Remaining 27.87% did not know any of these activities and its negative or positive impact and 16.39% had no idea about commercial fish farming. Respondents (44.26%) knew that the contractor fed the fish with grains, fishlets, husk, grass and etc while 55.74% had no any idea about this. Among respondents 73.77% believed that the lake fish diversity declined by fish farming while 6.56% of them didn't agree and 19.67% supposed, there was no effect from commercial fish farming. About 77.05% of respondent confirmed about the presence of indigenous fishes of lake in the past. They also added about absence of such species now. While 22.95% did not think over this. According to the respondents there are three varieties of turtles in the reservoir. 37.70% of respondents were aware about the hunting of turtles as illegal while 62.29% did not know the fact.

Among respondents 72.13% did not have latrine of any type in their home and they went to open field for their comfort while 26.23% of them had latrine on their home. For household solid waste management, 55% of respondents managed the solid waste by composting, burning, ditching while 45% of them threw haphazardly.

Only 16.39% of respondents were aware about the reservoir being listed in Ramsar site as wetland of international importance and while 83.61% did know the fact. About 60.66% believed that the water level of reservoir is fluctuating, 34.43% said that the water level is the same and 4.91% did not know anything about it.

From the direct observation of the researcher during survey it was observed that wetland was used for cattle washing, washing clothes, bathing, defecation, fodder collection from the riparian vegetation, grass cutting, fish harvesting.

CHAPTER IV

DISCUSSION

4.1 Seasonal Macroinvertebrate Inventory, Diversity and its Composition

In Jagdishpur reservoir, the benthic macroinvertebrate community structure has high faunistic groups (50 taxa) but with the majority of species having very low abundance. Reservoirs have generally a reduced diversity of benthic fauna as compared with natural lakes (Lindergaard, 1995). Food availability and quantity, sediment type (organic, sandy, clay), substrate (rock, wood, aquatic macrophytes), water quality (temperature, oxygen, and dissolved substances (Callisto et al 2005) as well as lake morphometry affect community structure of macroinvertebrates (Rasmussen, 1988).

The Dipteran family together with the Oligochaetes, are in fact the most conspicuous and relevant components of benthic communities in almost all freshwaters (Pamplin, et al., 2006). In addition to the environmental degradation, it is possible that the low abundance of insects found in sediment of reservoir is due to the preference of these organisms for the free floating vegetation banks (Tavares, et al., 2006).

Consistent water level and higher micro-habitat diversity influenced the increased taxa composition during post monsoon season.

In general, littoral areas (those in relatively shallow water) are far more diverse than deeper (profundal) areas, which have a relatively simple fauna of macroinvertebrates comprising mainly Oligochaete Worms, Amphipods, Diptera larvae, Sphaerid and Unionid Clams (Bivalve Molluscs) (Convention on Biological Diversity, 1997) and large quantities of dry Molluscan shells were found in each site of this study too. For most lakes and reservoirs, the numbers of benthic taxa are highest in the littoral zone and decreases as the depth increases (Salmoiraghi *et.* al. 1984). Among littoral zones, the density and diversity of benthic fauna were higher in the northern bank than in the southern bank of littoral zone as southern bank is paved with boulders while the northern bank has natural habitat with macrophytes. In littoral zones, these differences of substrate (e.g., stone, cobbles, sand, silt, aquatic plants, or woody debris) are considered most important in determining the density, size structure, species composition, and higher species richness of the macroinvertebrate community (Hanson, 1990).

An aquatic vegetation substrate has been shown to develop a unique macroinvertebrate fauna in littoral areas compared with other substrates such as stone, sand, or silt (Tolonen et al. 2001, Takamura et al. 2009). Not only the presence or absence of vegetation but also the life form, species, and biomass of aquatic macrophytes greatly influenced the abundance, taxonomic composition, and size structure of the macroinvertebrate community (Hanson 1990; Rasmussen 1993; Strayer et al. 2003) of the reservoir. Presumably, vegetation is important to the benthic community because it provides refuge from predators, physically stable habitats, better food conditions, and DO. Among these, the roots of some macrophytes have been shown previously to provide benthic macroinvertebrates with DO (Sa´gova´-Mareckova´ and Kvet, 2002).

4.2 Ecological Quality Class

The reservoir has poor ecological water quality due to heavy fish farming and pollution through inlet and seepage from surrounding farmlands. It is also due to variation in the water level as it forms unstable bottom. However, the excellent ecological quality of lowland wetlands is not possible due to the natural organic load and stagnancy of water.

4.3 Relationship between Benthic Macroinvertebrates and Environmental variables

According to Ravera (1996), the structure of aquatic communities depends on a setting of environmental variables and on the species adaptation to specific environments. Jagdishpur reservoir embankments are paved with boulders and the fluctuation of water level occurs in different seasons which might be the cause for low abundance. As mentioned in the Slavevska-Stamenkovic *et*. al., 2010, as a result of water level declining, the lake coast region become unsuitable for many benthic species and their disappearance occurred. The invertebrate communities in the ponds appeared to be influenced mainly by widely acting environmental factors (e.g. area, regionalization of assemblages) with little evidence that pond use (e.g. cattle watering) generally influenced assemblage composition. (Ce´re´ghino et al., 2008).

4.4 Seasonal Changes in physico-chemical Parameters

The optimum pH value for fishery in fresh water is between 6.5 and 8.5 (Edmonson, 1991). In our study, pH was found convenient only for post monsoon while it was above 9 in case of pre-monsoon and monsoon. This change in pH is most likely brought on by an increase in the amount of algae in spring. The algae utilize carbon dioxide, which creates more basic conditions. As such, the alkalinity and calcium concentrations in the lake are lowered because of precipitation of Calcium Carbonate, driven by the increase in pH (Ce´re´ghino et al., 2008). The amount of the dissolved oxygen (DO) in water is vital for the living beings in the water. The ideal for the fish is assumed to be between 6.0 and 7.0 mg/l in fresh water (Edmonson, 1991). Water with dissolved oxygen concentrations below 2 mg/l is not able to support life. Low oxygen concentrations will also affect the types of fish and invertebrates that inhabit the area (Anonymous, 2005a) however, the recorded DO (mg/l) for all seasons was found suitable for aquatic biota. The productivity of the lakes varies depending on the amount of phosphorus in water. As the amount of phosphorus increases, the biological productivity of the lakes increases as well which might be reason for having sustainable fish farming in the reservoir. Nitrogen does not occur naturally in soil minerals, but is a major component of all organic matter. The ammonia (NH_4) in water is formed as a result of the decomposition of the organic substances. Particularly flood water is rich in terms of ammonia. The ammonia has toxic effect in water with high pH value and low oxygen amount. The increase in the amount of ammonia is the indicator of the presence of organic pollution. Especially, profundal zone had higher amount of ammonia compared to littoral zone of the reservoir and resulted lower diversity of taxa, well represented mainly by Oligochaetes and Chironomidae.

4.5 Social Survey

According to DNPWC &WWF NP, 2005, Jagdishpur reservoir provided water supply for irrigation in 6,200 ha of surrounding cultivated land. Study results also showed that 86.89% of respondents possess their own irrigated land as most of respondent were farmers and their main income sources were agro crops. As from the result, 55.72% of respondents used pesticides and fertilizers in their agricultural fields knowingly or unknowingly. Also 57.37% of respondents believed that over use of fertilizer or pesticides are more effective than optimum use. Hence it reveals the leaching of inorganic fertilizer and pesticides from surrounding farm lands to the reservoir. This is also pointed out in the literature of DNPWC &WWF NP, 2005. Due to this, nitrate, ammonia and phosphate contents were found to be in high concentration during low water level in pre monsoon and monsoon season. The water body of reservoir has a great potential for commercial stock fish production and the exotic open water stocking is being managed by a group of private enterprises. Respondents (55.73%) knew carnivores and other indigenous fishes were removed from the reservoir before introducing exotic fishes for commercial fish farming. Also 44.26% of the respondents were aware that the contractor fed fish with artificial foods like grains, fishlets, husk, grass and etc. Due to the commercial fish farming on contract basis, 73.77% of respondent believed that the indigenous fish diversity has declined. Respondents also pointed out that not only indigenous fish diversity has declined but different macrophytes haven't grown properly in the reservoir. It has also influence on the diversity and abundance of benthic macroinvertebrates and ultimately it causes decline of water birds which are dependent on insects and fish. Lakes with dense growths of water hyacinths support larger and more diverse invertebrate populations than lakes with little or no vegetation and even than lakes with endemic macrophytes (Yule *et.* al. 2004). According to the local people there are three types of turtles in reservoir area. All types of turtles were harvested for flesh, medicine and eating purposes since 62.29% of respondents did not know hunting of turtles as illegal in Nepal.

Besides these, human activities like cattle washing, washing clothes, bathing, defecation, excess fish harvesting has deteriorated ecological condition of reservoir. Excessive sediment loading can result in the loss of water clarity and in turn limit aquatic plant growth, degrade spawning areas, decrease feeding efficiency for sight-feeding fish, and facilitate the transport of phosphorous, heavy metals, pesticides and other organic compounds (Edsall and Charlton 1997). Heavy siltation was observed in all parts of reservoir which has further declined wetland's diversity.

CHAPTER V

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Jagdishpur reservoir is rich in biodiversity in terms of benthic macroinvertebrates taxa composition. There was a significant variation in taxa composition and density among types (zones) of wetlands and among seasons. The study found that post-monsoon sampling is the most appropriate season for assessment of biodiversity (benthic macroinvertebrates). Similarly, post-monsoon and pre-monsoon seasons are important seasons for determining ecological status of wetlands. Littoral zones of reservoir accompany higher number of taxa compared to profundal zones.

In post-monsoon and pre-monsoon, the inlet of the Jagdishpur reservoir was heavily polluted while the outlets and littoral zones of northern side of the reservoir were critically polluted. Similarly, the profundal zone and littoral zones of eastern, western and southern sides were heavily polluted.

Abundance and number of taxa were significantly correlated with various chemical parameters. It implies that if chemical parameters of water are in good condition, increase in both abundance and number of taxa will occur in the Jagdishpur reservoir.

Canonical correspondence analysis (CCA) resulted that faunal assemblages and composition structures were influenced by different environmental variables depending on season for same wetland zone/type and was not possible to draw concrete and general result for particular zone/type of wetlands for overall year. However, Free CO_2, Ca^{+2}, Hardness, Conductivity and Temperature were found major environmental variables for structuring benthic fauna for littoral zones in general. Most of the physico-chemical parameters of water were in acceptable condition hence these support diverse aquatic flora and fauna.

It can be concluded that humans are the key factor for degrading the wetland. Human activities like commercial fish farming, excessive use of pesticides and fertilizers, bathing, washing clothes and over harvesting of wetland resources only aggravate deteriorating ecological condition of Jagdishpur reservoir.

This annual study provides baseline data from which future comparisons could be made in relation to the effects of surrounding landuse and climate change on the water/ecological quality. It can be further utilized to compare with alpine wetlands in terms of biodiversity, productivity, sedimentation and so on. The generated data will be great help for site-specific action plans to the government systematic planning at both national and local levels for preservation, restoration and ecological sustainability of wetland ecosystem in Nepal.

5.2 Recommendation

- For sustainable management and utilization of reservoir, regular monitoring is essential. Biological water quality monitoring programme would be effective method to assess the health of water bodies based on aquatic biota and check efficacy of water quality restoration programme.
- Organic farming should be promoted in surrounding farm lands of Jagdishpur reservoir.
- Awareness campaign should be launched to local people by different GOs and NGOs on values of wetland resources and sustainable utilization of these resources.
- Public participation should be launched for the conservation and monitoring program.

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ANNEXES

1. Glimpses of the research activities

A. Photographs showing different parts of Jagdishpur Reservoir


Jagdishpur Reservoir (south face near main outlet)


Jagdishpur Reservoir (north face)


Jagdishpur Reservoir (center)


Jagdishpur Reservoir (north face close to inlet)


Jagdishpur Reservoir (north face close to inlet)


Jagdishpur Reservoir (south west face)

B. Photographs showing field activities


Biological Sampling using Grab


Water sampling from different depths


Water sample analysis in field


Qualitative sampling from Littoral zone


Interview with locals


Fish farming at Jagdishpur Reservoir

2. Seasonal Faunal Inventory

Seasonal taxa recorded in study area. The cross indicates presence of family. The last row in each table provides actual taxa number in each season.

2.a Jagdishpur reservoir

Class	Order	Family	Season		
			Post-monsoon	Pre-monsoon	Monsoon
Insecta	Ephemeroptera	Baetidae	×	×	×
		Caenidae	×	×	×
	Trichoptera	Ecnomidae	×		
		Hydropsychidae	×		
		Leptoocheridae	×		
	Coleoptera	Gyrinidae	×	×	×
		Dytiscidae	×	×	×
		Elmidae		×	×
		Curculionidae	×	×	×
		Hydrophilidae	×	×	×
	Odonata	Coenagrionidae	×	×	×
		Corduliidae	×		
		Dolicopodidae	×	×	×
		Gomphidae	×	×	×
		Libellulidae		×	×
		Protoneuridae	×	×	×
	Heteroptera	Belastomatidae	×		
		Corixidae	×	×	×
		Gerridae	×	×	×
		Hydrometridae		×	×
		Micronectidae	×	×	×
		Nepinae	×	×	×
		Notonectidae	×	×	×
		Pleidae	×	×	×
		Ranatrinae	×		
	Diptera	Ceratopogonidae	×	×	×
		Chironomidae	×	×	×
		Culicidae	×	×	×
		Limonidae	×	×	×
		Muscidae	×		
		Stratiomyiidae	×	×	×
		Tabanidae	×		
	Lepidoptera	Pyralidae	×	×	×
Malacostraca	Decapoda	Aytidae	×		×
		Paleomonidae	×	×	×
		Potamidae	×	×	×
Arachnida	Acariformes	Hydrocarina	×	×	
Oligochaeta	Plesiopora	Naididae	×	×	×
		Tubificidae	×		
	Opisthopora	Megascolecidae		×	×
Hirudinea	Rhynchobdellida	Glossophonidae	×	×	×
Hirudinea	Arhynchobdellida	Hirudinea	×		
		Salifidae	×	×	×
Gastropoda	Mesogastropoda	Ampullariidae	×	×	×
		Bithynidae	×	×	×

		Thairidae	×	×	×
		Viviparidae	×	×	×
	Bassomatophora	Lymnaeidae	×	×	×
		Planorbiidae	×		
Bivalvia	Veneroidea	Sphaeriidae	×	×	×
		50	**46**	**38**	**38**

2.b Inlet and Outlets of Jagdishpur reservoir

Class	Order	Family	Season		
			Post-monsoon	Pre-monsoon	Monsoon
Insecta	Ephemeroptera	Baetidae	×	×	×
		Caenidae	×		×
		Ephemeridae		×	×
		Leptophlebiidae		×	×
	Trichoptera	Ecnomidae		×	×
		Hydropsychidae		×	×
		Leptoceridae		×	×
	Coleoptetra	Curculionidae		×	×
		Dolicopodidae	×		
		Dytiscidae	×	×	×
		Elimidae	×	×	×
		Gyrinidae	×	×	×
		Hydraenidae	×		
		Hydrophilidae	×		
		Noteridae	×		
		Psephenidae		×	×
	Odonata	Coenagrionidae		×	×
		Corduliidae	×	×	×
		Gomphidae	×	×	×
		Libellulidae		×	×
		Protoneuridae	×	×	×
	Heteroptera	Belastomatidae	×	×	×
		Gerridae		×	×
		Hydrometridae	×	×	×
		Mesoveliidae	×		
		Micronectidae	×	×	×
		Nepinae	×	×	×
		Notonectidae		×	×
		Pleidae	×	×	×
		Ranatrinae	×	×	×
	Diptera	Ceratopogonidae	×	×	×
		Chironomidae	×	×	×
		Limonidae	×	×	×
		Muscidae	×	×	×
		Tabanidae	×	×	×
	Megaloptera	Corydalidae		×	×
	Lepidoptera	Pyralidae	×	×	×
Arachnida	Acariformes	Hydrocarina	×	×	×
Malacostraca	Decapoda	Paleomonidae	×		×
		Potamidae	×	×	×
Oligochaeta	Plesiopora	Naididae	×	×	×
		Tubificidae	×	×	×
Hirudinea	Rhynchobdellida	Glossophonidae		×	

	Arhynchobdellida	Salifidae		×	×
Gastropoda	Mesogastropoda	Ampullariidae	×	×	×
		Bithynidae		×	×
		Thairidae	×	×	×
		Viviparidae	×	×	×
	Bassomatophora	Lymnaeidae	×	×	×
		Planorbiidae	×	×	×
Bivalvia	Veneroida	Sphaeriidae	×	×	×
	Unionnoidea	Unionidae	×	×	×
		Amblemidae	×	×	×
		53	38	46	47

2.c Surrounding wetlands of Jagdishpur Reservoir

Class	Order	Family	Season		
			Post-monsoon	Pre-monsoon	Monsoon
Insecta	Ephemeroptera	Baetidae	×	×	×
		Caenidae	×	×	
	Trichoptera	Ecnomidae	×		
	Coleoptera	Curculionidae	×	×	×
		Dytiscidae	×	×	×
		Gyrinidae	×	×	×
		Hydrophilidae		×	×
	Odonata	Coenagrionidae	×	×	×
		Corduliidae		×	×
		Gomphidae	×	×	×
		Libellulidae	×		
		Protoneuridae	×	×	×
	Heteroptera	Belastomatidae	×	×	×
		Corixidae			×
		Gerridae	×		
		Micronectidae	×		
		Naididae		×	×
		Nepinae	×	×	×
		Notonectidae	×	×	×
		Pleidae	×	×	×
		Ranatrinae	×	×	×
	Diptera	Ceratopogonidae	×	×	×
		Chironomidae	×	×	×
		Culicidae	×		
		Limonidae		×	×
		Muscidae	×	×	×
		Stratiomyiidae	×	×	×
		Tabanidae	×	×	
	Lepidoptera	Pyralidae	×	×	×
Arachnida	Acariformes	Hydrocarina	×	×	×
Malacostraca	Decapoda	Potamidae			×
		Paleomonidae	×	×	×
Oligochaeta	Plesiopora	Tubificidae	×	×	×
Hirudinea	Arhynchobdellidea	Salifidae			×
	Rhynchobdellida	Glossophonidae	×		
Gastropoda	Mesogastropoda	Ampullariidae	×	×	×
		Bithynidae	×	×	×
		Thairidae	×	×	×

		Viviparidae	×		
	Bassomatophora	Lymnaeidae	×	×	×
		Planerbiidae	×	×	×
Bivalvia	Veneroida	Sphaeriidae	×		
		42	**35**	**31**	**32**

3. GRSBIOS Taxa list with Scores assigned (Nesemann 2006)

Taxon	score
Acroneuria sp. (Perlidae)	10
Aeshnidae	6
Agriolimacidae (*Deroceras* spec.)	6
Alboglossiphonia heteroclita (Linnaeus, 1761)	4
Alboglossiphonia hyalina (O.F.Muller, 1774)	5
Alboglossiphonia pahariensis n. sp.	5
Alboglossiphonia shillongensis n. sp.	5
Alboglossiphonia weberi (Blanchard, 1897)	4
Allonais gwaliorensis (Stephenson, 1920)	5
Allonais inaequalis (Stephenson, 1911)	5
Allonais paraguayensis (Michaelsen, 1905)	5
Amblemidae	7
Amphiterygidae	N.A.
Ampullariidae	4
Amynthas corticis (Kienberg, 1867)	7
Apataniidae	9
Aphelocheiridae	7
Arcidae	8
Asiaticobdella birmanica birmanica (Blanchard, 1894)	5
Asiaticobdella fuscolineata (Moore, 1924)	5
Asiaticobdella punyamataensis n. sp.	7
Assiminea francesiae (Wood, 1828)	6
Assimineidae	6
Athericidae	9
Atyidae	6
Aulodrilus limnobius Bretscher, 1899	9
Aulodrilus pigueti Kowalewski, 1914	6
Aulodrilus pluriseta (Piguet, 1906)	4
Aulophorus carteri Stephenson, 1931	7
Aulophorus flabelliger Stephenson, 1931	8
Aulophorus furcatus (O. F. Müller, 1773)	7
Aulophorus hymanae Naidu, 1963	8
Aulophorus indicus Naidu, 1963	7
Aulophorus michaelseni Stephenson, 1923	7
Aulophorus tonkinensis Vejdovsky, 1894	8
Baetidae	6
Baetiella sp. (Baetidae)	7
Baetis sp. (Baetidae)	7
Barbronia nepalensis meghalayaensis n. ssp.	3
Barbronia nepalensis nepalensis n. sp.	3
Barbronia weberi (Blanchard, 1897)	4
Barythelphusa lugubris (Wood-Mason, 1871)	5
Batracobdelloides reticulatus (Kaburaki, 1921)	4
Bellamya (Filopaludina) bengalensis (Lamarck, 1822)	6
Belostomatidae	7
Bithyniidae	5
Blephariceridae	10
Bothrioneurum iris Beddard, 1901	7
Bothrioneurum vejdovskyanum Stolc, 1888	10
Brachycentridae	8
Branchiodrilus hortensis (Stephenson, 1910)	5
Branchiodrilus semperi (Bourne, 1890)	6
Branchiura sowerbyi Beddard, 1892	2
Brotia costula (Rafinesque, 1833)	7
Caenidae	3
Calamoceratidae	8
Calicneuria sp. (Perlidae)	10
Calopterygidae	7
Camptoceras lineatum Blanford,	7

1871	
Capniidae	10
Caridina (cf. *nilotica)*	7
Carychiidae (Freshwater)	10
Carychium minusculum Gredler, 1887	10
Centroptilum sp. ((Baetidae)	8
Ceratopogonidae	5
Chaetogaster cristallinus Vejdovsky, 1883	5
Chaetogaster diaphanus (Gruithuisen, 1828)	5
Chaetogaster diastrophus (Gruithuisen, 1828)	5
Chaetogaster langi Bretscher, 1896 (? syn: *C. spongillae* Annandale, 1905)	6
Chaetogaster limnaei bengalensis Annandale, 1905	5
Chaetogaster limnaei limnaei Von Baer, 1827	5
Chironomidae (red)	1
Chlorocyphidae	N.A.
Chlorolestidae	N.A.
Chloroperlidae	9
Cincticostella sp. (Ephemerellidae)	7
Cinygmina sp. (Heptageniidae)	7
Cirolana parva Hansen, 1890	7
Cirolanidae	7
Clavidae	6
Cloedodes sp. (Baetidae)	7
Coenagrionidae	5
Corbicula assamensis Prashad, 1928	6
Corbicula bensoni Deshayes, 1854	8
Corbicula cashmiriensis Deshayes, 1854	5
Corbicula striatella Deshayes, 1854	4
Corbiculidae	5
Cordulegasteridae	9
Corduliidae	5
Corixidae	2
Corydalidae	7
Culicidae	2
Cyclestheria hislopi (Baird, 1859)	7

Cyclestheriidae	7
Dendrodrilus rubidus Savigny, 1826	5
Dendronereides heteropoda Southern, 1921	6
Dero cooperi Stephenson, 1932	5
Dero digitata (O. F. Müller, 1773)	5
Dero dorsalis Ferroniere, 1899	5
Dero nivea Aiyer, 1930	6
Dero pectinata Aiyer, 1930	6
Dero phewatalensis n. sp.	6
Dero sawayai Marcus, 1943	5
Diamesinae (Chironomidae)	8
Digoniostoma cerameopoma (Benson, 1830)	5
Digoniostoma lithoglyphoides n. sp.	5
Digoniostoma pulchella (Benson, 1836)	5
Dinobdella ferox (Blanchard, 1896)	N.C.
Dixidae	7
Dolichopodidae	N.A.
Dorylaimiodea	N.C.
Drawida nepalensis Michaelsen, 1907	6
Drunella sp. (Ephemerellidae)	10
Dryopidae	10
Dytiscidae	N.A.
Ecnomidae	3
Eisenia fetida (Savigny, 1826)	5
Eiseniella tetraedra (Savigny, 1826)	8
Electrogena sp. (Heptageniidae)	6
Ellobiidae (Brackish water)	6
Elmidae	10
Empididae	4
Enchytraeidae	9
Enchytraeus indicus Stephenson, 1912	N.A.
Epeorus bispinosus (Heptageniidae)	8
Epeorus rhithralis (Heptageniidae)	10
Ephemerellidae	6
Ephemeridae	7

Epiophlebiidae	10
Erhaia banepaensis n. sp.	10
Erhaia chandeshwariensis n. sp.	10
Erpobdella bhatiai n. sp.	7
Erpobdellidae	7
Euphaeidae	8
Euthraulus sp. (Leptophlebiidae)	5
Ferrissia baconi (Bourguignat, 1853)	6
Ferrissia verruca (Bourguignat, 1859)	6
Fredericella indica Annandale, 1909	8
Fredericellidae	8
Fridericia perrieri (Vejdovsky, 1877)	9
Gabbia orcula (Frauenfeld, 1862)	5
Gabbia stenothyroides (Dohrn, 1857)	5
Galba truncatula (O.F. Müller, 1774)	8
Gammaridae	8
Gammarus aff. *lacustris*	8
Gangemysis assimilis (W.M. Tattersall, 1908)	8
Gangetia miliacea (Nevill, 1880)	9
Gerridae	4
Glossiphonia complanata (Linnaeus, 1758)	4
Glossiphoniidae	4
Glossosomatidae	9
Glyphidrilus gangeticus Gates, 1958	7
Goeridae	7
Gomphidae	N.A.
Gordiidae	10
Grapsidae	4
Gyraulus convexiusculus (Hutton, 1849)	4
Gyraulus euphraticus (Mousson, 1874)	4
Gyraulus labiatus (Benson, 1850)	5
Gyrinidae	7
Habrophleboides sp. (Leptophlebiidae)	9
Haemadipsa sylvestris Blanchard, 1894	8
Haemadipsa zeylanica agilis	8
Moore, 1927	
Haemadipsa zeylanica montevindicis Moore, 1927	8
Haemadipsidae	8
Haemonais waldvogeli Bretscher, 1900	7
Haemopidae	8
Hebridae	N.A.
Helicopsychidae	9
Helobdella stagnalis (Linnaeus, 1758)	7
Helophoridae	N.A.
Hemiclepsis marginata asiatica Moore, 1924	4
Heptageniidae	7
Heteroceridae	N.A.
Himalayapotamon atkinsonianum (Wood-Mason, 1871)	9
Himalayapotamon emphysetum (Alcock, 1809)	9
Himalayapotamon sunkoshiense Brandis & Sharma, 2005	9
Hippeutis umbilicalis (Benson, 1836)	4
Hirudinaria manillensis (Lesson, 1842)	8
Hirudinidae	7
Hydracarina	7
Hydraenidae	7
Hydrobiosidae	9
Hydrometridae	6
Hydrophilidae	N.A.
Hydropsychidae	3
Hydroptilidae	4
Hydroscaphidae	N.A.
Hymenicoides carteri Kemp, 1916	8
Hymenosomatidae	8
Idiopoma dissimilis (O.F. Müller, 1774)	6
Ilyodrilus templetoni (Southern, 1909)	5
Indoplanorbis exustus (Deshayes, 1834)	4
Isonychiidae	5
Isotomidae	N.A.
Lamellidens phenchooganjensis Preston, 1912	6

Lamellidens consobrinus (Lea, 1859)	7
Lamellidens corrianus (Lea, 1834)	7
Lamellidens jenkinsianus jenkinsianus (Benson, 1862)	6
Lamellidens jenkinsianus daccaensis (Benson, 1912)	N.C.
Lamellidens lamellatus (Lea, 1838)	8
Lamellidens mainwaringi Preston, 1912	7
Lamellidens marginalis (Lamarck, 1819)	6
Lamellidens narainporensis Preston, 1912	6
Lamellidens rhadineus Annandale & Prashad, 1919	6
Lepidostomatidae	7
Leptophlebiidae	8
Lestidae	8
Leuctridae	10
Libellulidae	3
Limnephilidae	5
Limnichidae	N.A.
Limnocentropodidae	9
Limnodrilus claparedeanus Ratzel, 1868	4
Limnodrilus hoffmeisteri Claparede, 1862	2
Limnodrilus profundicola (Verill, 1871)	3
Limnodrilus udekemianus Claparede, 1862	4
Limoniidae	8
Lophopodella carteri (Hyatt, 1866)	7
Lophopodidae	7
Lumbricidae	5
Lumbriculidae	7
Lumbriculus variegatus (O.F.Muller, 1774)	8
Lymnaea kashmiriensis Annandale & Rao, 1925	6
Lymnaea acuminata (Lamarck, 1822)	4
Lymnaea andersoniana simulans (Preston, 1912)	8
Lymnaeidae	4
Macrobrachium spec.	8

Marionina riparia Bretscher, 1899	10
Megascolecidae	7
Mekongia crassa (Benson, 1836)	6
Melanoides pyramis (Hutton, 1850)	4
Melanoides tuberculatus (O.F. Müller, 1774)	4
Mermithidae	8
Mesopodopsis orientalis (W.M. Tattersall, 1908)	N.C.
Metaphire houlleti (Perrier, 1872)	7
Microchaetidae	7
Micronectidae	N.A.
Microtendipes sp. (Chironomidae)	4
Monoligastridae	6
Muscidae	N.A.
Musculium goshaithanensis Nesemann & Sharma 2005	4
Musculium indicum (Deshayes, 1854)	4
Mysidae	8
Myxobdella annandalei Oka, 1917	10
Myxobdella nepalica Nesemann & Sharma, 2001	10
Naididae	7
Nais alpina Sperber, 1948	10
Nais bretscheri Michaelsen, 1899	6
Nais communis Piguet, 1906	6
Nais elinguis (O. F. Müller, 1773)	N.A.
Nais pardalis Piguet, 1906	7
Nais simplex Piguet, 1906	5
Nais variabilis Piguet, 1906	N.A.
Namalycastis fauveli Rao, 1981	6
Namalycastis indica (Southern, 1921)	6
Naucoridae	4
Nemouridae	8
Neoephemeridae	9
Neoniphargus indicus (Chilton, 1923)	10
Neorhynchoplax nasalis (Kemp, 1916)	8
Nephthydae	8
Nephthys oligobranchia Southern, 1921	8

Nephthys polybranchia Southern, 1921	8
Nepidae	4
Nereididae	6
Nereis chilkaensis Southern, 1921	6
Neritidae	8
Neritina (Dostia) violacea (Gmelin, 1791)	8
Neritina smithi Wood, 1828	8
Niphargidae	10
Noteridae	N.A.
Notocanthurus cristatus (Heptageniidae)	7
Notonectidae	3
Novaculina gangetica Benson, 1831	8
Octochaetidae	N.C.
Odontoceridae	8
Onchidiidae	8
Onchidium typhae Buchannan, 1800	8
Oosthuizobdella garoui (Oosthuizen, 1981)	7
Ozobranchidae	8
Ozobranchus shipleyi Harding, 1909	8
Palaemonidae	7
Paludinella (Schuettiella) daengswangi Brandt, 1968	6
Paludomus blanfordiana Nevill, 1877	7
Paludomus conica (Gray, 1834)	7
Paraclepsis praedatrix Harding, 1924	7
Parathelphusa martensi (Wood-Mason, 1871)	6
Parathelphusa panningi Bott, 1966	6
Parathelphusidae	6
Parreysia corrugata laevirostris (Benson, 1862)	7
Parreysia favidens favidens (Benson, 1862)	7
Parreysia favidens chrysis (Benson, 1862)	7
Parreysia favidens deltae (Benson, 1862)	N.C.
Parreysia favidens pinax (Benson, 1862)	7

Parreysia sikkimensis (Lea, 1859)	7
Parreysia triembolus (Benson, 1855)	7
Parreysia viridula (Benson, 1862)	7
Peltoperlidae	10
Perionyx excavatus Perrier, 1872	7
Perionyx fluviatilis n. sp.	7
Perlidae	9
Perlodidae	9
Philopotamidae	8
Phryganeidae	8
Physa (Haitia) mexicana (Phillipi, 1889)	2
Physidae	2
Phytia plicata (Gray, 1825)	8
Pila globosa (Swainson, 1822)	4
Piscicolidae	N.C.
Pisidium annandalei Prashad, 1925	9
Pisidium atkinsonianum Theobald, 1876	8
Pisidium casertanum (Poli, 1795)	10
Pisidium clarkeanum dhulikhelensis Nesemann & Sharma, 2005.	6
Pisidium clarkeanum G. & H. Nevill, 1871	4
Pisidium ellisi Dance, 1967	10
Pisidium kuiperi Dance, 1967	9
Pisidium nevllianum Theobald, 1876	5
Pisidium prasongi Kuiper, 1974	9
Placobdelloides fulvus (Harding, 1924)	4
Placobdelloides multistriatus (Johansson, 1909)	7
Planariidae	9
Planorbidae: Planorbinae	4
Planorbidae: Bulininae (former: Ancylidae)	6
Platorchestia platensis (Kröyer, 1868)	8
Platycnemididae	8
Platystictidae	N.A.
Pleidae	4
Pleuroceridae	7
Plumatella casmiana Oka, 1907	7

Plumatellidae	7
Poecilobdella granulosa (Savigny, 1822)	8
Polycentropodidae	3
Polypedilum sp. (Chironomidae)	4
Pomatiopsidae	10
Potamidae	9
Potamiscus sikkimensis (Rathbun, 1905)	N.C.
Pristina breviseta (Bourne, 1891)	
Pristina cf. *biserrata* Chen, 1940	6
Pristina longiseta (Ehrenberg, 1828)	
Pristina macrochaeta Stephenson, 1936	
Pristina synclites Stephenson, 1925	6
Pristinella acuminata Liang, 1958	6
Pristinella jenkinae (Stephenson, 1931)	
Pristinella menoni (Aiyer, 1929)	
Protoneuridae	8
Psephenidae	8
Psychodidae (black)	6
Psychodidae (white)	1
Psychomyiidae	N.A.
Pyralidae	8
Quickia spec.	5
Radiatula andersoniana (Nevill, 1877)	8
Radiatula bonneaudi (Eydoux, 1838)	8
Radiatula caerulea (Lea, 1831)	6
Radiatula gaudichaudi (Eydoux, 1838)	6
Radiatula keraudreni (Eydoux, 1838)	7
Radiatula lima (Simpson, 1900)	7
Radiatula occata (Lea, 1860)	7
Radiatula olivaria (Lea, 1831)	8
Radiatula pachysoma (Benson, 1862)	7
Radiatula shurtleffiania (Lea, 1856)	7
Radix brevicauda (Sowerby, 1873)	5
Radix hookeri (Reeve, 1850)	8

Radix luteola (Lamarck, 1822)	4
Radix ovalis (Gray, 1822)	4
Radix persica (Issel, 1865)	4
Rhithrogena nepalensis (Heptagennidae)	10
Rhitrogena sp. (Heptageniidae)	8
Rhyacophilidae	6
Salifa (Herpobdelloidea) lateroculata (Kaburaki, 1921)	5
Salifa (Nematobdella) biharensis Nesemann et al., 2003	6
Salifidae	3
Sartoriana spinigera (Wood-Mason, 1871)	6
Scaphula celox Benson, 1836	8
Scaphula deltae Blanford, 1867	8
Scirtidae	10
Segmentina calatha (Benson, 1850)	4
Segmentina trochoidea (Benson, 1836)	5
Septaria tesselata (Lamarck, 1816)	8
Septariidae	8
Sericostomatidae	6
Sermyla riqueti (Grateloup, 1840)	4
Simuliidae	5
Siphlonuridae	10
Sisyridae	8
Solecurtidae	8
Sphaeriidae	5
Spongillidae	7
Stenopsychidae	7
Stenothyra deltae (Benson, 1836)	8
Stenothyra monilifera (Benson, 1856)	8
Stenothyra nana Prashad, 1921	8
Stenothyra ornata Prashad, 1921	8
Stenothyridae	8
Stratiomyidae	4
Stylaria fossularis Leidy, 1852	6
Succinea spec.	5
Succineidae	5
Tabanidae	4
Taeniopterygidae	10
Talitridae	8

Thiara granifera (Lamarck, 1822)	4
Thiara lineata Gray, 1828	4
Thiara scabra (O.F. Müller, 1774)	5
Thiaridae	4
Thremmatidae	8
Tipulidae	7
Torleya nepalica (Ephemerellidae)	6
Tricula godawariensis n. sp.	10
Tricula montana (Benson, 1843)	10
Tubifex tubifex (O. F. Müller, 1774)	N.C.
Tubificidae (*Limnodrilus hoffmeisteri, Branchiura sowerbyi*)	2
Tylenchida	N.C.
Uenoidae	9
Unionidae	6
Varuna literata (Fabricius, 1774) (Grapsidae)	4
Veliidae	8
Viviparidae	6
Whitmania laevis (Baird, 1869)	8

3. JAGDISHPUR RESERVOIR SURVEY FORM-2009
(Human Impact Assessment)
QUESTIONNAIRE

1. Household Information:

Name of village development Committee: Date:
Village:
Name of Respondent:
Age: Cast:
Occupation:
Education:
Religion:

2. Type of Land:

Land Ownership	Type of Land		
	Irrigated Land	Unirrigated Land	Other
Owned Land			
Land rented in			
Land rented out			

3. What are the sources of income in your family?

a. Fishing
b. Agro crops
c. Milk and Milk Products
d. Business
e. Public services/Job
f. Remittances
g. Labourer
h. Others

4. Do you use fertilizers/pesticides in farm land? If yes, what types of fertilizers or pesticides you used for growing crops?

a. ....
b. ....
c. ....
d. ....
e. ....
f. ....
g. ....
h. ....

5. Do you have any idea of correct quantities of fertilizers/pesticides that should be applied?

a. Yes b. No

6. Do you take any precautions during handling of fertilizers or pesticides?

a. Yes b. No

7. Do you know any impact of the fertilizers or pesticides to environment?

a. Yes b. No

8. What is the system of fish harvesting? Do you know fishing in this lake is given in tender?

a. Yes b. No

9. Do you have any knowledge on introduction of exotic or cultivated fish from outside by anybody else in the past? If yes, what procedure they followed during introduction?

a. Yes b. No c. No Idea

11. For what purposes fishes are introduced,

a. For commercial purpose c. Deliberates to use natural food
b. For research purposes d. To eliminate unwanted fishes

10. If commercial fish production does natural food of lake sufficient? If no what types of food given?

a.......................
b.......................
c.......................
d.....................

11. What impact do you think on the fish diversity of the lake by introduction of more productive species of outside?

a. Increase b. Decrease c. No effect

12. Can you compare the composition of fish in the past and present? Can you name fish which are hardly seen in the present day but were abundance in the past?

a. Yes b. No

13. Are there any turtle in the lake? If yes, can you say how many types are there? Are they harvested? If yes, do you know that harvesting is illegal/ legal?

a. Yes b. No c. .... d........................

14. Do you have latrine in your home? If yes, what kind of latrine is in your home?

a. Borehole b. Dugwell c. Water seal d. No

15. How do you manage household solid wastes?

a. Composting c. Ditching/Pit
b. Burning d. Throwing any where

16. Have you heard about Ramsar site? If yes, do you know this wetland is listed in Ramsar site?

a. Yes b. No

17. Do you have any idea about fluctuation of water level of this lake?

a. Increasing b. Decreasing c. Same

18. How often do you visit this wetland?

a. Daily b. Rarely c. Once in a while

19. Why do you visit wetland (purpose)?

a. Fishing b. Fuel wood/ Fodder collection
c. Livestock grazing d. Washing and Bathing
e. Boating f. Grassing
g. Recreation h. Other