INTRODUCTION

Nepal is a tiny landlocked mountainous country, located on the mid Himalayan mountain section of Asia, lying between 26°22' N to 30°27' N latitude and 80° 4'E to 88°12'E longitude. It covers an area of approximately 147181 sq km with an average length of 885 km east to west and 193 km width north to south and is bordered by the China to the north and India to the east, south, and west. The altitude ranges from 60 m in the south to 8848 m in the north. Consequently, the country has a wide range of climatic zones ranging from humid subtropical to alpine.

Nepal can be divided into three major ecological zones, namely the terai and siwaliks, the middle mountains and the high Himalayas. Because of the unique topography of the country, several types of wetlands are scattered throughout the country in all the ecological zones.

Concept of Wetlands

Generally rivers, lakes, reservoirs, marshy lands, ponds, swamps, floodplains and deepwater agricultural lands are called wetlands. The term "wetland" translates into "Simsar" in Nepali. Sim is a derivative of the Persian word 'Sih', which means low grade land not suitable for cultivation. 'Sar' is a Sanskrit word meaning water. Thus Simsar can be interpreted as land with water.

The Ramsar convention was held in 1971 in Ramsar, Iran and defined wetland broadly to include "areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed six meters" (Ramsar, 1971). This definition is broad and includes the diverse types of wetlands that occur around the world.

A wetland is an ecosystem that arises when inundation by water produces soil dominated by anaerobic processes and forces the biota, particularly rooted plants, to exhibit adaptations to tolerate flooding (Keddy, 2000).

Wetlands are essential for the free ecosystem services that they provide to human community. The most obvious are maintenance and improvement of water quality,

ground water discharge and recharge, erosion control, flood protection and flow stabilization, storm dampening, healthy ecosystem functions, soil building, food chain production, nutrient cycling and biogeochemical processes, habitat for wildlife and numerous socioeconomic qualities such as food, forage, hunting and trapping, sites for research and environmental education, cultural heritage, open space preservation, aesthetics, tourism and recreation. They are also important because attention has been turned recently to use the wetland systems and the plant species occurring therein as bio-energy sources and also for use in pollution abatement projects to filter sewage, agricultural run-off, leachate from landfills, and mine drainage mitigation (Oliver and Hill, 1998).

Unfortunately, the wetlands are being degraded today mainly due to pollution from sewage and industrial effluents, and from over exploitation of resources. The wetlands are rapidly disappearing because of the general notion that they are waterlogged and unproductive lands which harbor disease-carrying insects, pests and poisonous snakes. They are drained and/or filled for agriculture, human settlements and industries besides being rapidly silted due to large scale deforestation in surrounding areas, and they are also being dried up in many places as rivers are dammed and channelzed for the generation of hydroelectricity and other purposes.

Wetlands of Nepal

Nepal has only freshwater wetlands and broadly classified into two categories: natural and man-made. The natural wetlands includes rivers, lakes and ponds, riverine floodplains, swamps and marshes and the man made are water storage areas and deep water agricultural lands.

The Department of Agriculture Development (1992) has estimated that wetlands occupy 743563 ha or roughly 5 % of Nepal's total land area (Table 1)

Table 1 Estimated area of various wetlands in Nepal (DOAD, 1992)

Wetland types	Estimated area (ha)	Percent
Rivers	395000	53.1
Lakes	5000	0.7
Reservoirs	1380	0.2
Marshy lands	12000	1.6
Village ponds	5183	0.7
Paddy fields	325000	43.7
Total	**743563**	**100.0**

The country has approximately 6000 rivers and rivulets, including permanent and seasonal rivers, streams and creeks (WECS, 2002). The major river systems namely the Mahakali, the Karnali, the Gandaki, the Koshi originate in the high altitude snow covered mountains and are 'permanent' in nature. On the other hand, rivers/rivulets originating in Siwalik/Terai are seasonal in nature. All the rivers of Nepal drain into the Ganges River System in India through the Terai region, giving rise to ox-bow lakes and floodplains.

The lentic water bodies are classified as glacial, tectonic and ox-bow types depending on their geological origin. The lakes that occur above 3500 m altitude are mostly of glacial origin. They are generally moraine dammed, but some like the Thulagi glacial lake of the Manaslu area are dammed by ice body (Hanisch and Hunger,1998). The largest glacial lake is Rara (1036 ha) located at an altitude of 3000 m, followed by Shey Phoksundo (452 ha) and Tilicho Lake (4919 m, area 40 ha). Lakes and ponds of mid-hill and mountain regions (below 3000 m) of Nepal are considered tectonic in origin and are thought to have been created in depressions caused by land subsidence. The famous lakes of Pokhara valley – Phewa, Begnas, Rupa, Khaste, Dipang, Gunde, Kaalpokhari and Maidi belong to the tectonic category. Mostly the ox-bow lakes occur in the terai plain of Nepal. In many places these lakes have converted into marshes (ghols) or swamps due to siltation and plant succession.

Marshes are extensive near the streams and rivers of the terai floodplains. Some notable hot springs (geothermal springs) include Tatopani in Sindhupalchok districts as well as in Annapurna Conservation Area occur in mid-hills and mountains. Alpine

and Tundra type wetlands occur above 4000 m. These wetlands are restricted to Alpine meadows and shrubberies, where environmental factors such as low temperature, high acidity, low nutrient supply, water logging and oxygen deficiency slow the decomposition of the organic matter and favour peat formation.

Physico- chemical Parameters

The physico-chemical parameters of water bodies influence directly or indirectly (the number, varieties, distribution, metabolic activities, growth, size, forms etc.) of the aquatic organisms in various ways. Functioning of the aquatic ecosystem is regulated by the interaction among the physico-chemical and biological components of the system. Hence, it is essential to have the knowledge of physico-chemical parameters for identifying suitability and fertility of an aquatic ecosystem. Reid (1961) has stated that the successful development and maintenance of a population of organisms depends upon harmonious ecological balance between environmental conditions and tolerance of the organism to variations in one or more of these conditions.

The physico-chemical parameters of a water body change due to seasonal change, diurnal changes and pollutants. These bring significant seasonal and diurnal change in abundance of aquatic organisms.

Among the physico-chemical parameters (factors) air temperature, water temperature, transparency, P^H, dissolved oxygen, free carbon dioxide, alkalinity, hardness, chloride and BOD mainly determine the hydrological condition of water body.

The air temperature directly influences water temperature and the latter influences the biotic activities of aquatic flora and fauna. The P^H is also responsible for the productivity. The P^H of water gets drastically changed with time due to exposure to air, biological activities and temperature change. Alkalinity range determines the range of productivity of water bodies. Dissolved oxygen is one of the important parameter in water quality assessment and reflects the physical and biological process prevailing in the water. Carbon dioxide by combining with water forms weak acid and serves as more or less buffer system against rapid shifts in acidity and alkalinity.

Chloride is usually present in low concentration in natural waters and the high concentration indicates the pollution in water bodies. The Biological Oxygen Demand (BOD) indicates the organic pollution and therefore, helps in deciding the suitability of water for consumption.

Regarding Physico-chemical parameters, very few works have been done in Nepal. Some of the works are those of Loffler (1969), Lohaman *et al.* (1988), McEachern (1994) and Hickel, (1973).

Macro- Biota

Macrophytes

The aquatic macrophytes are the backbone of wetland ecosystems as these provide habitat, food and energy to the aquatic organisms. These are the most important constituents for the regulation of cycling of minerals and organic compounds in the natural aquatic ecosystem. These are also a primary agent in bio-geochemical cycles and succession. One of the significant properties of the aquatic macrophytes is their capability of accumulating the heavy metal pollutants present in water bodies (Carpenter and Adam, 1977).

The aquatic macrophytic vegetation of Nepal includes a wide array of taxonomic groups, growth forms and representative species of different biogeographic floristic realms. This can be attributed to remarkable variation in bioclimatic and limnological parameters. But no detail study has been done in Nepal. The total recorded aquatic macrophytes of Nepal are 240 species, 124 genera and 58 families (Shrestha, 1999).

Annelids and Arthropods

Annelids and arthropods are important constituents of aquatic ecosystems. They form the different feeding levels (trophic levels), act as pollinators, some annelids make soil more porous, loose and aerated. These are the major partners for the maintenance of healthier environment in aquatic and terrestrial ecosystems. Malla *et al.* (1978), Smith (1978), Yadav *et al.* (1983), Sharma (1996) and others have done preliminary works on annelids and arthropods in Nepal.

Molluscs

Molluscs are the major constituent of aquatic ecosystem. Many species of mollusca form the useful diet of fishes and also for human beings. Open billed storks depend on molluscs for their diet. The shells are useful in button industry, ornaments, decoration, etc. Not all molluscs are beneficial however, some snails and slugs feed on cultivated plants. Certain freshwater snails serve as intermediate hosts for parasitic trematode worms of domestic animals.

Despite their importance no comprehensive work on molluscs has been done in Nepal. However a number of workers like Subba and Ghosh (2000, 2001), Subba (2003) and Chhetry (2003) have contributed to the knowledge of molluscs study.

Fish fauna

Fishes are the major food resources for the protein and are available throughout the world. In Nepal also traditionally majority of people consume fish as food. A total of 179 species of fishes belonging to 30 families are found in the wetlands of Nepal (Shrestha, 1994). Nepal, being a landlocked country and being situated about 960 km away from the nearest sea- port, has to depend largely on the exploitation of available fresh water resources for the production of fish. The present production level is still below the potentiality of existing water resources. The Government of Nepal has given priority to aquaculture development throughout the kingdom. The Fishery Development Division under the Department of Agriculture of the Government of Nepal is technically responsible for the implementation of fishery activities in the country through thirteen fishery development centres located in different regions.

Herpetofauna

Although Nepal is small in size, the diversity of its herpetofauna is rich due to the greater diversity of physical features. These fauna are the sources for meat, hides, eggs, and medicine and even companionship. The field of herpetology offers many opportunities for research, be it the ecology and habits of the threatened species or the development of anti-venom.

A total of 125 different species of reptiles and 52 different species of amphibian have been found in Nepal (Schleich and Kaestle, 2002). A great variety of herpetofauna

have been reported from Terai wetlands. All the species of amphibians depend on wetlands to complete their life cycle. But many species of herpetofauna have become rare due to loss of habitat and their collection for meat and medicinal purposes.

Aves

The aves of Nepal are highly diverse due to the diversity of geographical features. A total of 841 species of birds has been recorded in Nepal (Inskipp and Inskipp, 1991). As many as 193 species of birds are dependent on wetlands. Among them 187 species are dependent on the terai wetlands of Nepal (Bhandari, 1998). Baral (2000) studied the birds of Koshi Tappu area.

Mammals

A total of 181 species of mammals belonging to 12 orders and 39 families have been recorded from Nepal (Suwal and Verheught, 1995). The most notable mammals of terai wetlands are Greater one horned rhino (*Rhinoceros unicornis*), Wild water buffalo (*Bubalus bubalis*), Gangetic dolphin (*Platanista gangetica*), Fishing cat (*Prionailurus viverrinus*) Smooth coated otter (*Lutrogale perspicillata*) etc. All these species are being decreased in number due to the loss of habitat, hunting and shortage of food.

Description of study areas (Koshi Tappu Wildlife Reserve and its surroundings)

Koshi Tappu Wildlife Reserve (KTWR) was established and gazetted in 1976, primarily for the protection of the last remnant population of Wild water buffaloes (*Bubalus bubalis*) and their habitat. Realizing the importance of the site, it was designated as a wetland of international importance and added to the Ramsar list on 17 December 1987 (IUCN, 1990). It is the first Ramsar site in Nepal.

The reserve, extends between 86°55'-87°05'E longitude and 26°34'-26°45'N latitudes on the alluvial flood plain of the Sapta Koshi river or simply Koshi river which is fed by seven tributaries, the Indrawati , Bhote Koshi , Tama Koshi , Dudh Koshi , Liku , Arun and Tamor rivers. The reserve covers part of Sunsari, Saptari and Udayapur districts of the eastern development region. It is touched by twelve Village

Development Committees (Fig.1). Eastern and western embankments of 5-7 m high were constructed by the Koshi dam project to control flood. On the south of the reserve is a large expanse of open water, marshes and reed-beds, created by the construction of Koshi barrage between 1958 and 1964.

The reserve is rectangular in shape, 16.3 km long and 9.3 km wide running along the Koshi river. The area lies between 75 to 100 m altitudes above mean sea level. It is drained by the Koshi river, a major tributary of the Ganges, and Trijuga river which joins the Koshi in this area. Because of the Koshi barrage, a large expanse of open water remains throughout the year between the barrage and the reserve, while the most part of the reserve is subject to flooding during the monsoon. Shallow ditches along the sides of the embankments retain water for most of the year and support dense reed-beds. A 10 km long seepage stream and 125 m to 250 m wide stripe of marshes are situated along the eastern embankment. The reserve, which extends along the Koshi river, consists of extensive mud flats and marshes. Five different types of soil *viz.* sandy, sandy loam, loam, sandy clay loam, and clay loam were described from the surrounding villages of Koshi Tappu Wildlife Reserve (Pradhan *et al.*, 1976).

The climatic condition of this area is tropical monsoonal type and experiences three distinct seasons summer (February to May), rainy (June-September) and winter (October-January).

Some notable wetlands in the Koshi Tappu Wildlife Reserve and its surroundings are as follows.

Rivers

The perennial Sapta Koshi river which originates from the Himalayas in Tibet, represents the main wetland habitat in Koshi Tappu region. It is a staging site for thousands of waterfowls as well as other birds. The Trijuga river which originates in the Mahabharat region of the Udayapur district, enters in the reserve from the northwest (Fig. 2).

Floodplain

The floodplain is a periodically flooded flat area. The floodplain gradually dries up during the post monsoon period. It remains saturated with water in certain places, while in other places it dries out. The floodplain is characterized by marshes, oxbow lakes, back swamp lakes and many other depressions which retain water throughout the year. The Koshi Tappu Wildlife Reserve is situated on the floodplain of the Sapta Koshi river.

Oxbow lakes and riverine marshes

The meandering nature of the Sapta Koshi river have given rise a large number of oxbow lakes along its course. One such lake, Kamalpokhari, meaning 'lotus pond', is situated to the far west of the reserve near the village Kamalpur. The Titrigachhi daha is another lake situated in the eastern part of reserve along the eastern embankment near the village Kushaha. An extensive marshy area lies on the fringes of these lakes. Some of the oxbow lakes in the region have a short life span as a result of regular siltation by the river.

Fresh water marshes and ponds

The seepage of water from the Sapta Koshi river has given rise to a 10 km long seepage stream along eastern embankment. The seepage stream has 125- 250 m wide marshes on its fringe. It flows from Prakashpur village to south. The marsh supports dense reed-beds. Several man made ponds of 0.5-2 ha size are also located along the embankment outside the reserve. The marsh and ponds are notable nesting sites for several bird species in this region.

Seasonally flooded grassland

A portion of the wildlife reserve becomes flooded annually during the monsoon and rest of the time of the year, it remains as grassland. Some portion of the grasslands represent a savanna habitat (have been formed through the degradation of the forest) with tree remnants scattered throughout.

Swamp forest

Forests in patches consisting mainly of *Dalbergia sissoo, Acacia catchu* and *Bombax cebia* are found in the floodplains of the Sapta Koshi river. These forests are flooded

annually during the monsoon and represent seasonally flooded forest, a type of freshwater swamp forest. Besides the swamp forest there are many permanent swamp areas located east to Koshi barrage near the southern region of KTWR.

Reservoir

A large reservoir is constructed on the upper side of the Koshi barrage. From the reservoir, water is drained through two canals, for irrigation. The water level in the reservoir varies seasonally. The open water of the reservoir is the major staging and nesting site for the several bird species, including waterfowls.

Paddy fields

The low lands around the Koshi Tappu Wildlife Reserve are utilized as paddy fields. These paddy fields generally remain under water during the monsoon. Some areas may remain submerged at other time also. These temporary wetlands are important not only for birds but also offer an opportunity for paddy cum fish culture.

Sampling sites for the study of physico- chemical parameters

The water samples were collected from four sites (Site1, Site 2, Site 3 and Site 4) every month at regular intervals for analysis.

Koshi river (Site 1)

The Koshi river site is inside the Koshi Tappu Wildlife Reserve, lies between 26° 37' 14.4" N latitude and 87° 01' 26.1" E longitude. It is perennial originated from the Himalayas. Generally, it has clear water except rainy season. It is located near the Kushaha, The head quarters of Koshi Tappu Wildlife Reserve (Fig. 2 and 3).

Seepage stream at Kushaha area (Site 2)

It is situated east to the eastern embankment of Sapta Koshi river, lies between 26°37' 10.6" N latitude and 87° 01' 38.2" E longitude (Fig. 2 and 4). It is a perennial seepage stream. It has 125 m to 250 m wide marshes on its fringe. The depth of water of seepage stream varies in different seasons. This area is rich in biodiversity.

Seepage stream at Shripur area (Site 3)

This site is located outside the reserve area and it is an extension of the seepage stream which flows from the Kushaha area (Site 2). It is about 2.7 km down than the Site 2. It is located between 26° 35' 55.3" N latitude and 87° 00' 46.2" E longitude (Fig. 2 and 5). This site is also rich for marshy plant and animal species.

Titrigachhi daha (Site 4)

It is an oxbow lake, located within the Koshi Tappu Wildlife Reserve. It lies between 26° 36' 11.7" N latitude and 87° 00' 53.8" E longitude. Water enters from the Koshi river in rainy season. It covers about 3 ha area (Fig. 2 and 6). It is rich in aquatic plants and animals.

Objectives

The main objectives of this study are as follows:

1) To study some physico-chemical parameters of water of some selected sites of the wetlands of the Koshi Tappu Wildlife Reserve and its surroundings.
2) To study and record the macro-biota of wetlands of Koshi Tappu Wildlife Reserve and its surroundings.

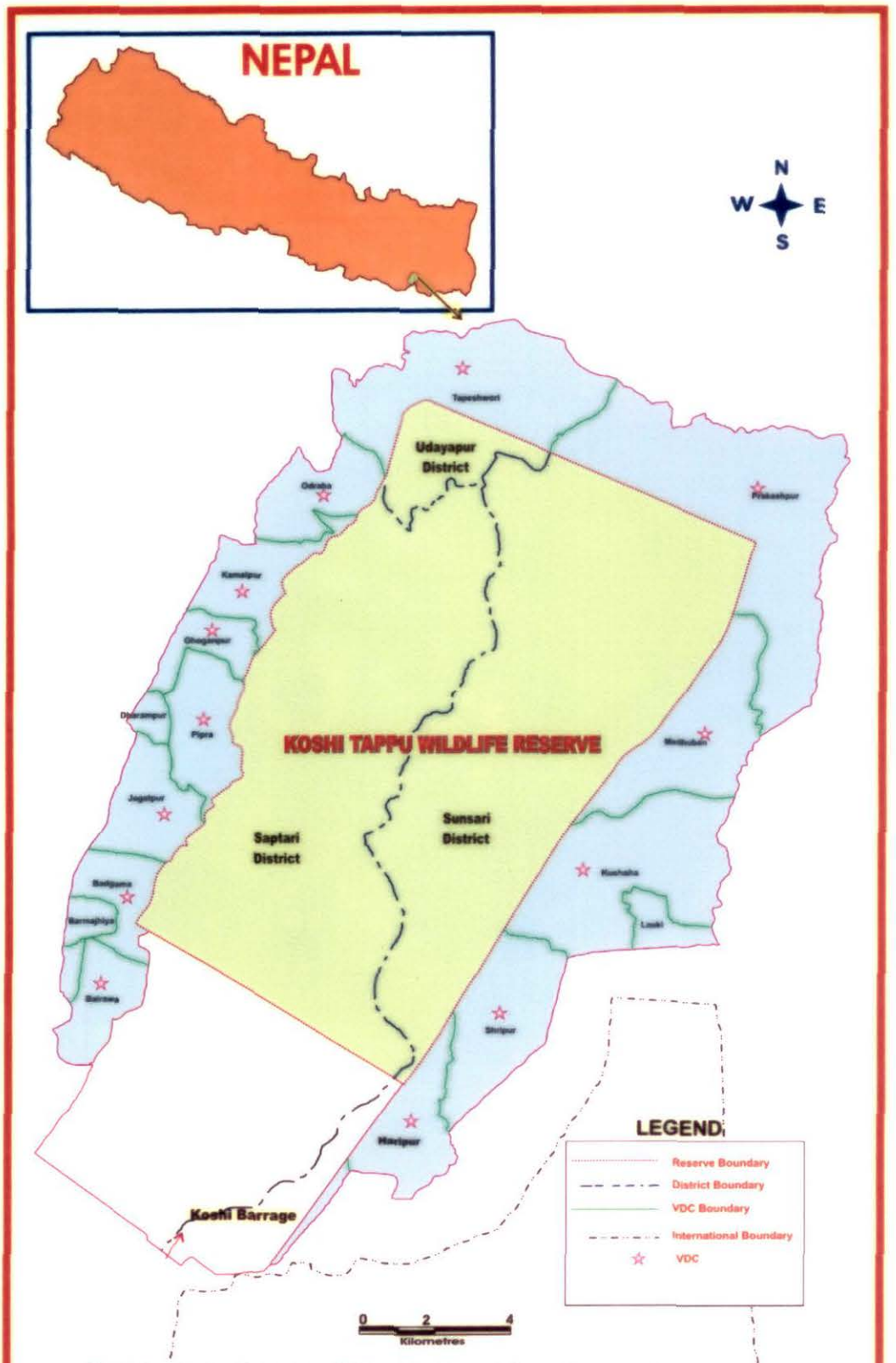

Fig. 1 Map showing the location of Village Development Committees around Koshi Tappu Wildlife Reserve.

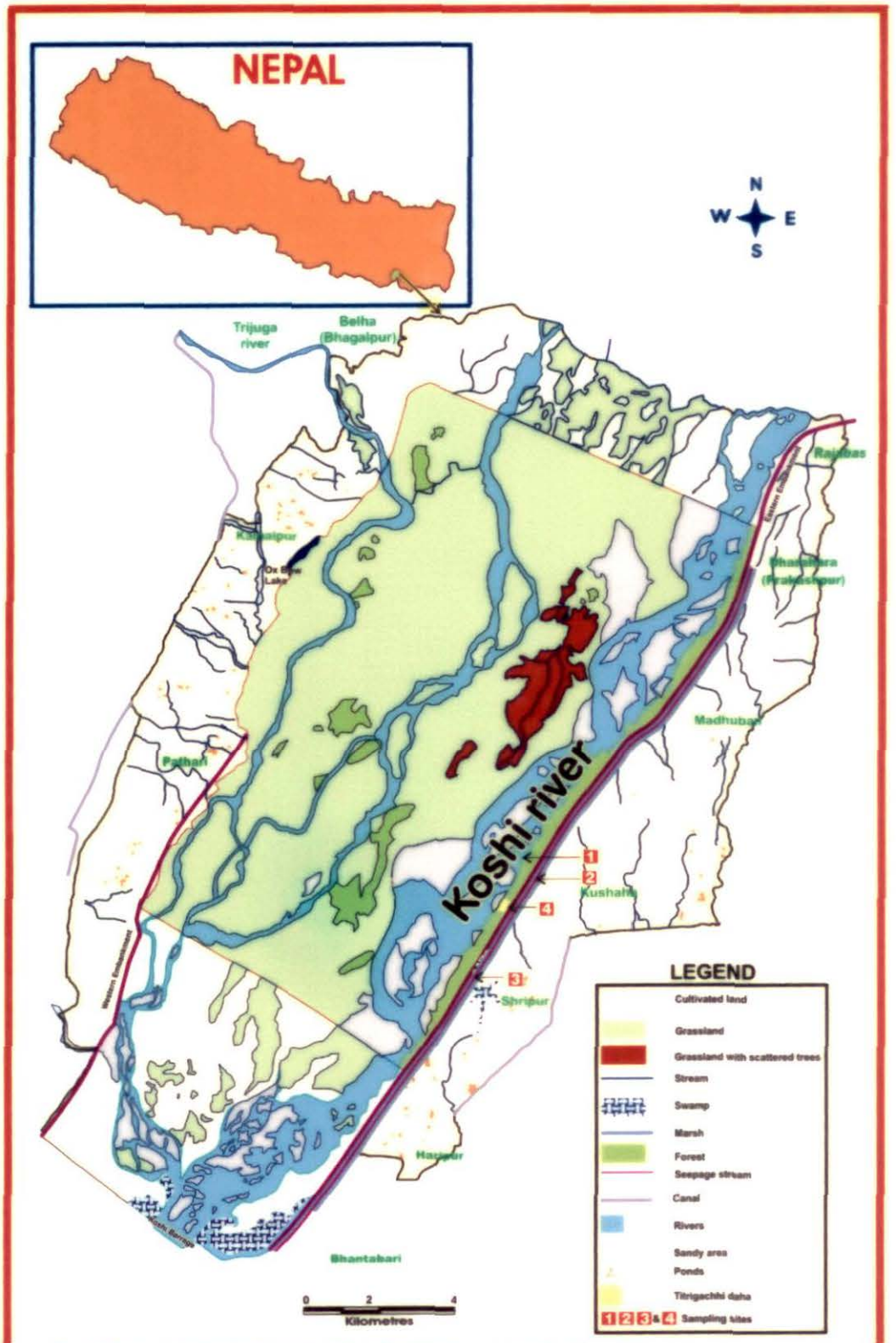

Fig. 2 Map showing the location of Koshi Tappu Wildlife Reserve and its surroundings.

Plate 1

Explanation of figures

Fig. 3. shows the researcher, performing experiment for the analysis of physico- chemical parameters of water of Koshi river.

Fig. 4. shows the Seepage stream at Kushaha area.

Fig. 5. shows the Seepage stream at Shripur area.

Fig. 6. shows the Titrigachhi dah (oxbow lake).

Plate 1