# 1. INTRODUCTION

## 1.1 Definition

Wetlands denotes a diversity of ecosystem where high water availability, seasonally or perennially has a significant influence on the fauna, flora and soil characteristics. Wetlands are among the most productive but highly threatened ecosystem of the world.

Nepal is home to a wide range of wetlands located in a diverse climates, stretching from mountain conditions near the Himalayan in the North to tropical condition in the south.

Wetlands are as varied as the landscapes in which they occur, hence their myriad names. They are called as Simsar in Nepali. Because they take different forms under different conditions there are nearly a dozen Nepali colloquialisms and numerous English terms to describe wetlands.

The Ramsar convention defines wetland as: areas of marsh, peat lands 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 tides does not exceed six meter (Dugan, 1990).

Nepal's National Wetland Policy (2003) defines wetlands as "natural or artificially created areas, such as swamp marsh, riverine flood plain, lake, water storage area and agricultural land containing water from underground water resources or atmospheric precipitation that may be permanent or temporary, static or flowing and freshwater or saline."

## 1.2 Concept of lakes and ponds

Lakes and ponds are classified by the Ramsar convention according to their size, seasonality and whether they are freshwater or saline lake is generally defined as an open water bodies with distinct littoral and limonitic zone and area more than eight ha. But ponds are open water bodies with shallow depth, containing only the littoral zone and have an area less than eight ha (Wetzel, 1983). Lakes in Nepal are commonly called Pokhari, Tal, Rah, Dah, Kund etc.

Nepal's permanent lakes are broadly categorized into three main categories based on their geological origin (Sharma, 1977).

1. Glacial or Himalayan lakes e.g. Rara, Gosainkunda, Shey Phoksundo
2. Tectonic or sub Himalayan lakes e.g. Phewa, Begnas, Rupa
3. Ox-bow or Terai lakes e.g. Ghodaghodi tal, Bishazaree tal, Rani tal

## 1.3 Classification of Wetlands

There are several classification of wetlands developed by Odum *et al.* (1974), Miller (1976) and Cowardin *et al.* (1979) etc. Scott (1989) classified wetlands into 23 categories for describing the Asian wetlands but later, based on the range of wetlands, which come under the mandate of Ramsar convention. Dugan (1990) recognized 30 categories of natural wetlands and a artificial (man made) ones. Wetlands in Nepal have been classified into following types: (1) lakes, (2) ponds (3) reservoirs (4) river flood plain (5) swamp (6) marsh and (7) rice paddies for the sake of convenience (Shrestha and Bhandari, 1992). But later, Sah (1993) in his work in Koshi Tappu, Nepal described 8 categories of Nepalese wetlands including rivers in the above classification. HMG/N (1995) classified Nepalese wetlands into three categorizes as; Lacustrine systems, Palustrine system, Riverine system and Man made system.

## 1.4 Status of wetlands

It is estimated that roughly 6 percent of the global land area (570 million ha fall under various wetland categories of which 2 percent are lakes, 30 percent bogs, 26 percent fens, 20 percent swamps and 15 percent flood plains Encyclopedia Wikipedia (2008).

Encyclopedia Wikipedia (2008) estimated the total area of water bodies to be 148,939,063 $km^2$ (29.2% of the total land coverage of earth's surface) in countries among which Nepal lies at 93 position with a share of 0.10 percent area.

Shiklomanov (1993) estimates that freshwater lakes in the world have a total area of about $1.5 \times 10^{12} m^2$. Including saline inland seas in this total area add another $1 \times 10^{12} m^2$.

Nepal is the second richest country in the world in terms of water resources; about 2.27 percent of the world water is found in Nepal. The total area occupied by fresh water in Nepal has been estimated to be approximately 743,183 ha out which lotic ecosystem covers an area of about 395,000 ha and lentic ecosystem covers on area of about 350,000 ha. Paddy field (325,000 ha), marshy land (12,000 ha), reservoirs (1,380 ha) and village ponds (5,183 ha) comprising approximately 5.05 percent of the total land area of Nepal (Rajbanshi and Gurung, 1994).

Lakes that occur above 3,500 masl are mostly of glacial origin. Altogether 2,223 glacial lakes covering a total area of 750ha have been recorded in areas above 3500masl in Nepal (IUCN, 2004).

Bhandari (1992) complied several data and listed 295 wetland sites in Nepal. Altogether 126 wetland have been reported from Terai region among which 50 percent are found in Far-western Development Region followed by 24 percent in Western Development Region. The eastern Nepal Harbours only a few number of wetlands.

51 Wetland sites were surveyed in 12 districts of Terai by Biodiversity profile project (BPP, 1994) to prepare biodiversity assessment of Terai wetlands. Many (42) of them were ox-bow lakes. Among, 51 wetland sites, 21 are in Kailali district alone. In addition, it should also be noted that most of the 21 sites surveyed in Kailali district are hydrologically interconnected which provide important ecological services of national importance through their scenic view and rich biodiversity.

The extensive marshes associated with ox-bow lakes and flood plain in the lowland areas are protected in National Parks and Reserves (Manandhar, 1991). According to Maskey (1992), there are over 36 wetlands within Nepal's National Parks and Reserves.

After acceding to Ramsar convention on December 17, 1987, Nepal designated Koshi Tappu Wild Reserve (KTWR) for inclusion on the list of wetlands of International Importance (LWII), which come under the mandate of convention. Recently Beeshazaree Tal, Chitwan; Jagdishpur Reservoir, Kapilvastu; and Ghodaghodi Tal, Kailali are included in Ramsar list on Oct. 13, 2003 (Lekhak and Lekhak, 2005).

## 1.5 Wetlands: prejudices to predilections

The concept of wetlands as productive ecosystem which can play a pivotal role in strategies for sustainable socio-economic development contracts with the traditional image of inaccessible water logged marginal lands harboring disease carrying mosquitoes, where the first available funds should be allocated to drainage and conversion. Historically, they are regarded as breeding grounds for the natural enemies of man and therefore of little importance (value).

Now it is widely understood that wetlands are far from being wastelands and they provide a wide array of benefits to people without necessarily having to go to them. They have hydrological, biological, economic aesthetic, recreational and medicinal value providing many benefits at nominal cost.

For their diverse and key role they are regarded as kidneys of the planet, biological supermarket and nature's civil engineer.

Productivity per unit area is one of the highest of any ecosystem in the world. They produce over eight times as much biological mass as European wheat fields and fifty times more plant matter than grasslands. The net primary productivity of low land wetlands may be as high as 4,00g/$m^2$/yr which equals that of tropical rain forests (Richardson, 1994).

While all Nepalese people benefit directly or indirectly from wetlands, the livelihoods of several communities are based on wetland products or services. Among 103 ethnic caste groups of Nepal 20 of these are traditionally wetland dependent (IUCN, 2004).

Majestic, splendid and holy, the lakes of Nepal reverred not only for their exquisite beauty but also for their spiritual, historical, cultural and recreational importance attached to them. They regard wetlands as manifestations of gods and goddesses. The river confluences and shore areas of lakes, ponds and rivers are considered as holy places to purify sins and earn merits for blissful eternal life (Siwakoti, 2007). The ancient cities of Katmandu valley owed their prosperity to the fertile flood plains of Bagmati and Bishnumati rivers and the valley's geological history as a lake.

Dugan (1990) also considered that wetland play important role for maintaining ecosystem and environmental quality such as pollution filter, purification of water, removal of sediments and regulation of microclimates. Water resources play a vital role for development of countries and in socio-economic values providing water for hydroelectricity, irrigation, agriculture supply of drinking water, fishing, livestock grazing and other benefits.

## 1.6 Objectives of the Study

The present study was designed to carry out ecological study of Rupatal in two different season and to suggest the possible measures for its environmental management.

The specific objectives are as follows:

1. To enumerate vegetation pattern of Rupa lake by quantitative method.
2. To analyze limnological characteristics of the lake.
3. To estimate the growth and productivity of vegetation in the lake
4. To assess people's socio-economic condition and it's relation with their dependency on wetland vegetation and their attitude toward lake conservation.

## 1.7 Justification of the Study

Almost all the research carried out in wetlands of Nepal are concentrated in limnology and vegetation analysis. Seasonal macrophytic biomass change with respect to limnological parameters has not been adequately done. This research gap has implored this researcher to identify the relationship between biomass and limnological parameters and soil characteristics of watershed area to identify status, and current issues of one of the most scenic and breathtaking but deteriorating lake of Nepal. The lake is facing severe problem due to siltation, encroachment, agricultural drainage and invasive weeds. Furthermore, the research findings will give a complete picture about status of lake and will certainly help in boosting existing knowledge about the lake and will contribute very much in aspect of sustainable management of lake.

# 2. LITERATURE REVIEW

## 2.1 Review on Vegetation Analysis

Nepal is richly endowed with a wide range of wetland vegetation. Out of 7000 species of plant recorded, 25% are reported to be wetland dependent (Bhandari 1992). In Nepal study of wetland flora started with the pioneer work of Hamilton and Wallich (D. Don, 1985), Hooker (1972) and Burkill (1920).

Generally high mountain lakes are Oligotrophic and support only few species of acquatic macrophytes. Lakes in midhills and valleys are mesotrophic to eutrophic and support rich growth of acquatic macrophytes and algal flora. The lakes of Pokhara valley were once mestrophic but now have become entrophic because of high nutrient flow from adjacent upland area. The ox-bow lakes in the terai are eutrophic with luxuriant growth of acquatic macrophytes due to high nutrient value.

Wetland vegetation may be categorized into three groups on the basis of their habitat, as :

1. Free floating and rooted submerged hydrophytes.
2. Amphibious or emergent hydrophytes.
3. Suspended and rooted submerged hydrophytes.

Whittaker's (1975) study in American wetland had shown that each plant species is distributed in unique pattern in the landscape and that this pattern results from the interaction of each species with its physical and biological environment. As a result, the composition of plant community changes more or less continuously along environmental gradients as changing conditions causes species to enter or leave.

Sankhala and Vyas (1982) studied moist bank community of Banghela tank, Udaipur, India and observed 21 species of angiosperms belonging to 20 genera and 12 families. In their study, the highest number of species in the community occurred in September while lowest number of species in March and April. On the basis of IVI they found that different species were dominant during different seasons; as *Phyla nodiflora* in winter and *Polygonum glabrum* during summer and rainy seasons.

Handoo and Kaul (1982) studied frequency, density, standing crop and IVI in four wetlands of Kashmir which differ in depth and fluctuation of water level. The seasonal change in floristic composition and relative frequency and density in four wetlands were significantly different among one another. The density decreased rapidly after September in three sites. The study also showed a gradual increase in species richness from 1.2 - 4.76 with decrease in water depth.

Thibodeau (1985) recognized that in any wetland, the hydrology of the area determine the distribution pattern of vegetation. His study showed that there are often distinct grouping of species associated with different degree of flooding.

Vander Valk and Peterson (1989) studied the Delta marsh in Manitoba, Canada and observed that high water periodically eliminates most of the emergent vegetation and a subsequent period of low water allows emergent vegetation to establish on exposed mud flats. It mean that emergent vegetation survives primarily in shallow water along the peripheries.

Scott (1989) describing the Nepalese wetlands mentioned principal vegetation in some important wetlands. According to him, high mountain lakes are oligotrophic (least productive) and support only few species of aquatic macrophytes, while the mid mountains lakes are mesotrophic to eutrophic (highly productive) supporting luxuriant growth of aquatic vegetation.

Tsuyojaki and Tsujii (1990) studied grassy marshland in Sichuvan, China. According to them, abundance decreases as the vegetation cover decreases. They also observed that species richness in each quadrat tended to decrease gradually with vegetation cover. From their observation, they postualated that optimal grazing intensity maintains high plant biomass and the species composition may change over in lightly grazed vegetation sites.

Acharya (1997) carried out research on seasonal variation, composition and distribution pattern of wetland vegetation of Ghodaghodi and Nakrodi Tal of Kailali, Nepal. Altogether, 13 different aquatic macrophytes were recorded in Ghodaghodi and 78 species in Nakrodi Tal. The highest species diversity was found in rainy season than summer and winter. Similarly, species richness increases from aquatic to terrestrial habit.

Sah (1997) made a comprehensive study of Koshi Tappu wild life Reserve, Nepal's first Ramsar site in Eastern Nepal. He recorded 236 plants (angiosperms) from the flood plains of the Koshi river, among which 96 are aquatic macrophytes.

Shrestha (1998) reported altogether 65 species of aquatic macrophytes from seven lakes of different morphometry and limnological feature of Pokhara, among which 10 species belong to troublesome aquatic weeds of the Indian sub-continent. Among these Rupa recorded highest number of species (48) followed by Phewa (39), Dipang (25), Khaste (16) Begnas (15), Maidi (13) and Gunde (12). Based on area of coverage and plant mass *Hydrilla verticillata* and *Trapa quadrispinosa* found dominant in lake phewa and lake Rupa respectively. *Oryza rufipogon* and *Leerisa hexandra*; wild relative of rice reported were recorded from both the lakes.

Oli (2000) recorded the highest number of invasive aquatic weeds (6 species) in Rupa lake followed by Begnas (5 species) Dipang (4 species), Khaste (3 species) Tal Khola (3 species) and Gunde (2 species). Notable aquatic weeds include *Hydrilla verticiallata, Potamogeton crispus, Potamogeton pectinatus, Echinochloa colona* and *Panium repens*.

Joshi *et al.* (2001) explored 41 wetland sites in Kathmandu valley and collected 36plant species belonging to 20 families. Among which, 28 species belonged to dicotyledons, 7 moncotyledon and one pteridophyte. With regard to ethno-botanical uses of recorded plants, 17 species were used by local communities for various purpose.

Shrestha (2002) investigated physio-chemical characters, macrophytes and management of Nagdaha pond in Lalitpur. Altogether 146 species of plants belonging to 46 families and 111 genera were recorded. According to his findings *Nymphoides indica* was the most dominant species in all season.

Adhikari (2002) studied the Khaste and Dipang lakes of Pokhara valley and carried out seasonal variation, composition, frequency and distribution pattern of wetland vegetation in these lakes. According to his findings *Hydrilla verticilla* was the most dominant species in both the lakes in all seasons. Altogether 65 species were recorded from these lakes (59 from Khaste and 52 from Dipang)

Simkhada (2003) studied ecology and management issues of Gaindahawa lake, Rupandehi, Nepal. He recorded altogether 59 plant species in and around the lake. Based on the quantitative data, he found that *Hydrilla verticillata, Ipomoea aquatia, Utricularia aurea* and *Eichornia crasspies* were dominant in winter and *Cyonodon dactylon, Ipomoea fistula, Imperata cylindrica* were dominant in summer season. Highest diversity was observed in rainy season followed by winter and summer season.

Maltchik *et al.* (2005) studied the diversity and stability of aquatic macrophytes community in shallow lakes associated to a flood plain system in Southern Brazil. The number of flood events was different among three shallow lakes they studied. They found that the lowest resistance to disturbance by flood and the absence of dominance was in the lake with the highest number of flood events. The result indicates the importance of flood regime on the macrophyte stability and composition in the shallow lakes.

Asaeda *et al.* (2006) found in their study that water velocity plays an important role in shaping plant community structure in flowing water. First some emergent macrophytes re-configure their shoot distribution in fast currents and forms clumps and secondly, the shape and morphology of such clumps minimize drag caused by the current. The study focused on the three emergent macrophytes: *Typha angustifolia, Zizania latifolia* and *Phragmites australis* which co-occur along a gradient of water velocity. They showed that every species responded to flowing water.

## 2.2 Review on Limnology

Even though it is small and landlocked, this Himalayan nation is rich in fresh water resources due to its vast topographical contrast. Due to their peculiarity, importance and they have attracted scientists and researchers. Scientists and researchers from across the globe regard it as an ideal place for comparative investigation on the influence of altitude and climate in physico-chemical properties of water.

Loffler (1969) studied the limnology of high altitude of lakes of Kathmandu and Pokhara valley. He categorized the lakes as eutrophic on the basis of phosphorus ranges 10-15mg/l and 50-100mg/l respectively in premonsoon and mesotrophic (range 4-9mg/l) in post monsoon.

Kaul *et al.* (1978) showed hydrological factors to be important in governing the occurrence and growth of wetland species in Kashmir. From their study they postulated that freshwater macrophytes had a more dominant influence upon the physico-chemical characteristics of water. High nutrient level favours dense growth of macrophytes and low nutrient level results in sparse growth of macrophytes.

Swar (1980) found that the mid hill lakes (Phewa, Begnas, and Indrasarobar) were moderately deep with nitrogen and phosphorus deficient ($3<N: p<50$) and categorized as mesotrophic. Nitrogen ratios changed when stratification was disrupted demonstrating the importance of internal processes in these lakes.

Singth *et al.* (1982) studied limnology of shallow water lakes during 1977-1978 in Kumaon, India and observed alkanity, phosphate-P and nitrate -N level. They also observed other parameter of water like dissolved oxygen, free $CO_2$, nitrogen, phosphorus, potassium, calcium and silicate. The nature of water was alkaline in all lakes (above 8.0 pH for most of the year in Nainital and Bhimtal) except during the winter in Naukuchital where it was slightly acidic (pH = 6.0). According to them Nainital is eutrophic while Naukuchital is oligotrophic were as, Bhimtal showed intermediate value.

Nakanishi *et al.* (1988) studied some of the limnological variables in subtropical lakes of Pokhara valley. Their limnological data indicated that the lake Phewa, Begnas and Rupa are eutrophic in nature.

Lohman *et al.* (1988) analyzed seasonal variation (pre and post monsoon) in limnological parameters of lakes of Kathmandu valley. They reported that low alkanity and conductivity was due to dilution from monsoon rain which change the ionic composition.

Jones *et al.* (1989) worked on the limnological reconnaissances of water bodies in Central and Southern Nepal. According to them, chlorrphyll 'a' and total phosphorus value categorize the lake (Begnas and Rupa) as eutrophic, while on the basis of total nitrogen reading Begnas lake was categorized as oligotrophic and Rupa lake as mesotrophic.

Mishra *et al.* (1996) studied physio-chemical features of water in Makhara pond in Northern Bihar, India. They observed high free carbondioxide concentration (37.4 - 45.0 mg/l) in June-September. Similarly, they conclude that high dissolved oxygen during winter (3.7 - 17.3mg/l) is due to high solubility of oxygen in lower temperature.

McEachern (1996) studied the regional and seasonal characteristic of water chemistry, algal biomass and nutrient limitation in different lakes of Nepal including Gaindahadwa Tal, Ghodaghodi Tal, Jagadishpur Reservoir, Rani Tal, Bishhazaree Tal and Koshi Tappu during the period (1993-1995). On the basis of total nitrogen and total phosphorus; he categorized all these lakes as eutrophic.

Oli (1996) complied limnological characters of Begnas and Rupa lake of Pokhara valley. His information shows that lake Rupa becomes eutrophic during the winter on the basis of mean annual oxygen production at a rate of 235.06 mg/ $cm^2$/yr.

Kafle (2000) studied growth and clump maintenance of *Trapa quadrispionsa* in response to physico-chemical parameters of Phewa and Rupa lakes of Pokhara valley. His findings shows that physico-chemical parameters in both the lakes, like water temperature, total nitrogen, $PO_4$-P, pH and DO were more or less similar with each other. He observed higher transparency in lake Phewa and higher chl-a concentration in lake Rupa during the experiment periods. The overall experiments showed that both the lakes are towards eutrophication.

Adhikari (2002) studied the limnology of two lakes: Khaste and Dipang of Pokhara valley. The value of chlorophyll-a, total nitrogen, phosphorus and Secchi disc visibility categorizes these lakes to be eutrophic.

Taoufic and Dafir (2005) studied physio-chemical parameters especially nitrogen and phosphorus in lower Oum Rabiaa basin of Morocco, characterized by three dams in series. They concluded that the presence of three dams were responsible for the nitrogen and phosphorus loads in the dams because of the reduction of fluvial contributions to the lower sector. The eutrophication status was evaluated by N/P ratios. Mean N/P ratio at the three dam showed a high likelihood of P-limitations. The highest values were observed primarily during winter and early spring season.

Mukhopadhayay and Dewanji (2006) studied two fresh water pond of Kolkata and analyzed the relation between presence of macrophytes and limnological parameters (secchi disc visibility, pH, dissolved oxygen, electric conductivity, total kjeldahl nitrogen, total phosphorus and chlarophyll-a concentration) during a three year period. The dominant flora in the ponds namely. *Alternanthera philoxeroides, Nymphoides hydrophylla, Lemna acquinoctialis* and *Vallisneria sprialis* were found to subsist over wide amplititude of nutrient levels thereby sharing their adaptability to high eutrophic ecosystems, a common feature of the tropics. However, the presence of some minor species could be associated with a narrow range of specific limnological variables proposed by them.

## 2.3 Review on Biomass Estimation

The rate at which the green plants produce biomass or store energy is referred to as primary productivity. Primary productivity of aquatic ecosystem gives the quantitative details regarding energy fixation and its availability to support bioactivity of the total system (Goldman, 1968).

The balance between the biomass of aquatic macrophytes and consumer is essential to maintain the stability of aquatic ecosystem. Macrophytes generally confine themselves to the shallow zone of the aquatic ecosystem and contribute significantly to the total primary production and accelerate eutrophication (Adani and Yadav, 1985).

Vandervalk and Davis (1976) studied composition structure and production of plant communities in Big Kettle, USA. They observed that standing crop pattern for both years (1973 and 1975) along two transects (A and B) was that the meadow zone had the highest average standing crop biomass (541-792g/$m^2$) followed by emergent zone. (511-541g/$m^2$) and submerged zone (156-225g/$m^2$). They concluded that depth at which an individual grows has a significant impact on its biomass and productivity.

Kaul *et al.* (1978) studied on macrophyte biomass production in Kashmir lakes such as Dal lake, Anchar lake, India. They concluded that emergent macrophytes contributed most of the biomass (3161.94t) followed by submerged species (802.78t) and rested floating species (247.335).

Sankhala and Vyas (1982) while studying moist bank community of Banghela tank in Udaipur, India found maximum biomass (315.8g/$m^2$) in October and minimum biomass (132g/$m^2$) in April. Data on seasonal variation in biomass showed that biomass peaked (266.2g/$m^2$) per month in rainy season and was at a minimum (149.5 g/$m^2$) per month in summer season.

Nohara and Tsuchya (1990) studied the effect of water level fluctuation on biomass of *Nelumbo nucifera* in Japan and showed two seasonal peaks of the plant biomass. The maximum total biomass was in July (294 g/$m^2$) and minimum between two peaks was in August (75g/$m^2$ dry wt.). The above ground biomass was 169g/$m^2$ dry wt. for *Nelumbo nucifera*.

Sharma (1995) while studying ecology, conservation and management of Kawar lake, Bhagalpur, India recorded maximum biomass (11.24g/$m^2$) during

October and minimum biomass (487g/$m^2$) during June among emergents and maximum biomass of 114g/$m^2$ during November and minimum biomass of 6g/$m^2$ during July among submerged macrophytes. His findings suggests that macrophytic production decreases from shoreline to deeper area and the emergent region of the littoral zone is the highest productive ecosystem.

Acharya (1996) while studying wetlands vegetation and its utilization in Ghodaghodi and Nakrodi Tal, Kailali, Nepal, recorded maximum biomass in rainy season (935.53g/$m^2$) followed by winter season (492.8g/$m^2$) and summer (310/5g/$m^2$). His findings shows biomass increases from early rainy season to winter and decreases with the advent of summer.

## 2.4 Review on Management Aspect

The background formation about socio-economic condition of the people residing in the watershed area reflects a clear picture of people dependency on wetland, conservation attitude, awareness and other contemporary issues. Wetland management can never be sustained without people's participation. It has been envisaged that activities related to wetland management programme should aim for sustainability by developing and designing social and community initiatives and self reliance mechanism. Only after their daily necessities are quenched can the people aspire to better their socio-economic conditions. Long ecologically sustainable only if it caters adequately to the people's needs.

Wetland conservation is a buzz word today. So its meaning should not be ambiguitely taken but concepts should be materialized by epistemic communities at different level.

Sah (1993) has stated that the vegetation change in structure and cover by degradation is due to several natural and human disturbances, especially when the local communities are dependent on this resource for their basic needs. He observed that the wetland site provided pastures for thousands of cows and buffaloes and other construction materials which constitute considerable percent of the local economy in his study in Koshi Tappu wildlife resources.

Bhandari (1998) studied the buffer zone of Royal Chitwan National Park and reported that the local people heavily use forest resource for many purposes. Siltation and vegetation succession are the main threats to the lake. The man-made threats include, over fishing, grazing, plant harvesting, collection of building materials and use of toxic substances in the water. The suggested conservation actions include the preparation of a community based management plan, demarcation of the conservation area, establishment of a conservation education center strategic environment assessment confidence building and community awareness.

IUCN (1998c) after identifying a wide array of problems of Ghodaghodi Tal established a community centered management plan, "Ghodaghodi Tal conservation area" in collaboration with NAHSON and "Ghoda ghodi Samrakshan Tatha Bikas Samiti" to mitigate these problems and conserve the biodiversity and cultural diversity of the area.

Shrestha and Janauer (2001) studied the management of resource of aquatic macrophytes at Phewa lake. They reported that these species possess several socio-economically beneficial and adverse attributes. They suggested management approaches including integrated land use planning of the lake shoreline and conservation through utilization of aquatic plant resource.

Podder *et al.* (2001) suggested that the fairly fertile and productive soils of wetlands can be agronomically utilized for cultivation of several food crops like *Oryza sativa, Colocasia esculenta, Trapa bispinosa, Nelumbo* sp. *Eurayale ferox* etc. and for commercially important non food crops like *Cyperus* sp, *Typha sp, Aeschynomene aspera, Clinogyne dichotoma* etc. Besides these, they can be effectively utilized for cultivation of medicinal plants; there is also further scope of integrated farming in wetlands particularly for paddy-cum fish culture or paddy fish-vegetable farming. Therefore, contingent crop planning and sustainable management and development of the wetlands is necessary for economic welfare and betterment of the populations.

Smardon (2006) studied the heritage values and function of wetlands of Southern Mexcio, considering that these are used from multicropping and agriculture to fishing, hunting, freshwater supplies, salt extraction and nature tourism. He argued that particular attention should be paid to wetland use, which combines both traditional and new uses including partial restoration, agro ecology and ecotourism.

Ogutu-ohwayo *et al.* (2006) studied management challenges of freshwater fisheries in Africa. Their report discusses the experience of challenges faced by 8 African freshwater ecosystems. The overall experience indicates a lack of effective management actions as a result of limited accessibility and application of scientific information, poor dissemination of management information, inappropriate and an unharmonized fishing laws and regulation and weak institutional processes.

Reddy *et al.* (2006) studied management of lakes in India and considered that lakes all over the country are exhibiting varying degree of environmental degradation caused by encroachments, eutrophication and siltation. The high population density ensures that many water bodies are under severe direct pressure from anthropogenic activities in their catchments. They ask for a bold and uncomprimising role of national and information institution.

Chaudhary, R.K. (2007) studied ecology and management of Jagdishpur reservoir, Kapilvastu, Nepal. His findings discusses the experiences of problems/challenges faced by lake. The result point out siltation, eutrophication, encroachment, excessive growth of invasive weeds and lack of awareness as major challenges to be overcomed for proper conservation and management.

# 3. THE STUDY AREA

Pokhara is one of the most remarkable scenic beauty of the mother nature. This subtropical valley, nestled at the lap of majestic and panoramic Himalayas is full of turquoise lakes, gushing rivers, dense green forests, and picturesque villages inhabitated by simple and friendly people. Due to this it is regarded as a major tourist hub of the country.

The most famous lakes in Nepal's mid hills are the subtropical lakes of Pokhara valley, which collectively cover an area of app. 3.68 miles (Gurung, 2002). Among these, only three lakes (Phewa, Begnas, and Rupa) are important for their economic potentiality, biodiversity and are reasonably large than other. Most of these lakes are considered tectonic in origin and are thought to have been created in depression caused by land subsidence.

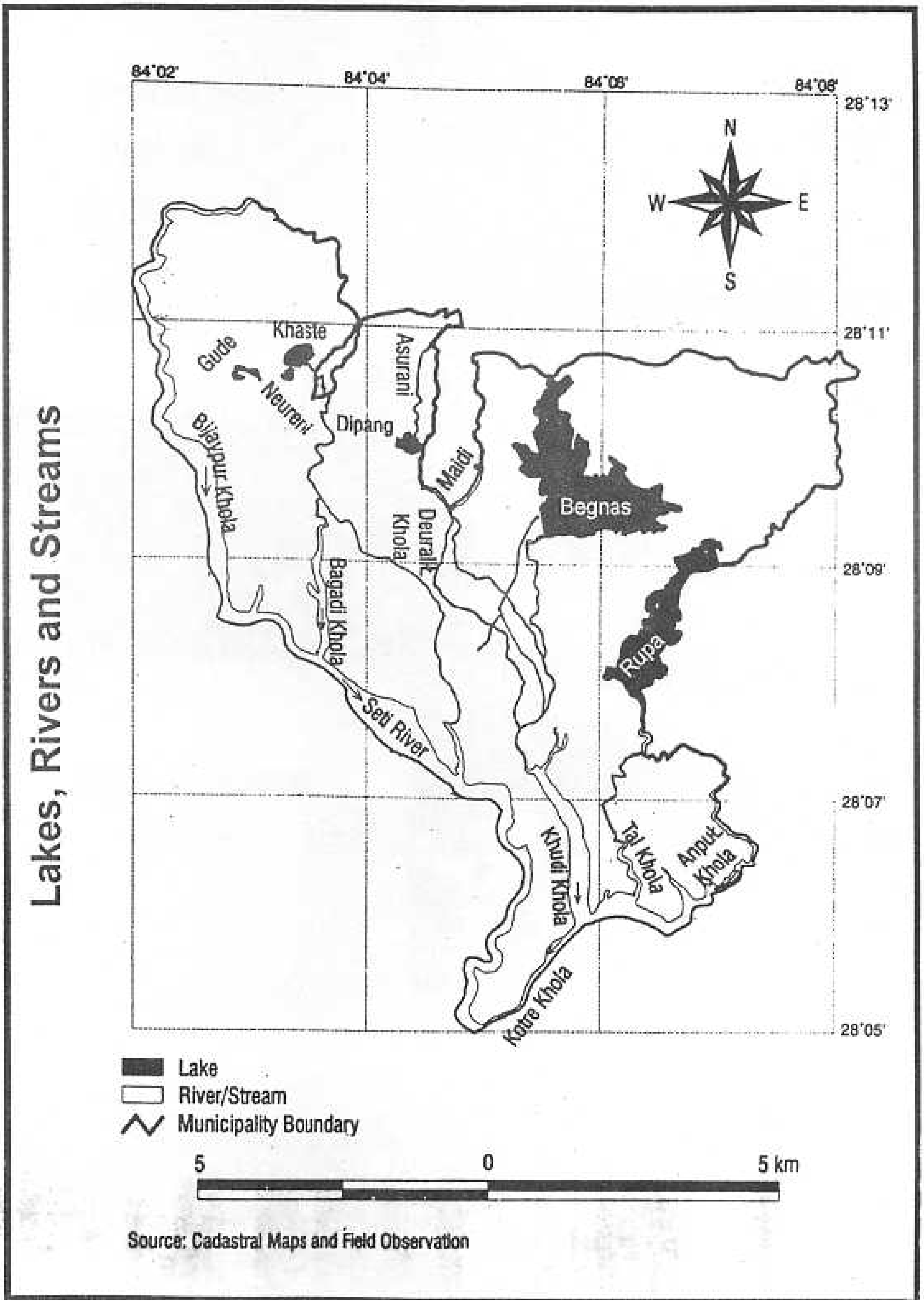
The majestic lake Rupa has received it's name due to its mysterious phenomenon of changing the colour of water many times in a single day. The exquisite appearance of the lake particularly in twilight and dawn seems to miraculous and wonderful. The visual image of the lake has greatly contributed to its name 'Rup' in Nepali which means the external appearance or 'face'. Due to the fairly, unrevised and beautiful appearance the lake was named Rupa.

## 3.1 Location

The panoramic Rupa lake lies in Lekhnath Municipality and part of its eastern and north eastern side touches the outskirts of Rupakot Village Development Committee.

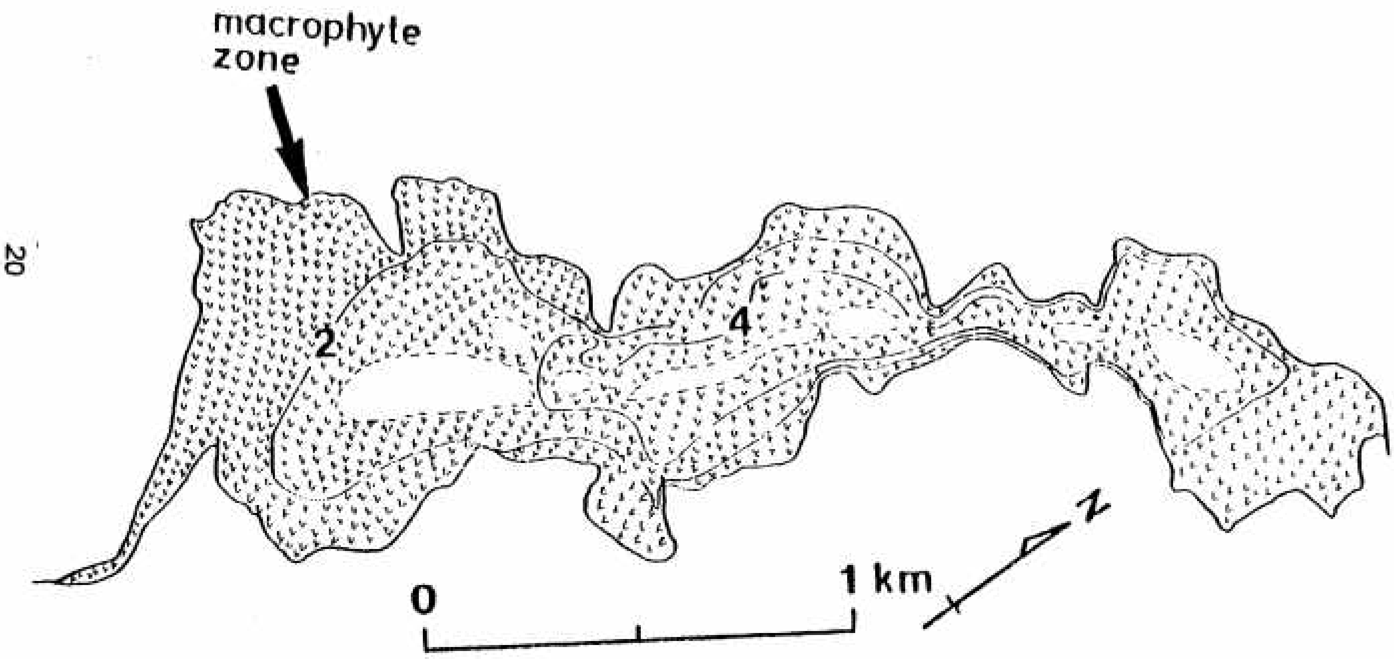
It is situated about 18km southeast of the Pokhara sub-metropolitan city and can be approached through three access points. The lake is just two km away from Begnas bus stop through a motorable road from the Begnas bus stop leading to Lamjung along Sundare Danda and Pachabhaiya. Another way to the lake is through Gagangaunda on the Prithvi highway. The third way is through Sisuwa Bazar along to the Satmuhane and up to the exit of "Kholako Chheu."

**Map**




*Cited source: Souvenir, Pokhara Darpan*

Fig. 3 Bathymetric maps of Lake Rupa showing macrophyte zone




RUPA LAKE

Source: Modified after Nakanishi et.al. 1984

## 3.2 Boundaries

The eastern side of the lake is covered with thick vegetation of *Castanopsis indica, Schima wallichi* and *Shorea robusta* forest. The hill east of the lake is covered partially with vegetation and partially by cultivated land. The hill slope north of the lake is heavily cultivated. The lake is elongated N-S with zigzing outline, with its outlet at sisteni which joins the Seti river further. The lake is shallow near the outlet and inlet.

## 3.3 Topography

Lake Rupa is the third largest lake in Pokhara valley. The lake is situated at an elevation of 600m above the sea level with an area of 135ha (Rai *et al.* 1995) and average depth of 3m. The lake is elongated from N-S having zigzag outline. Tal Besi khola is the only feeder stream of the lake. It has a single outlet: Tal khola which joins stream Kotre downwards ultimately joining with Seti river.

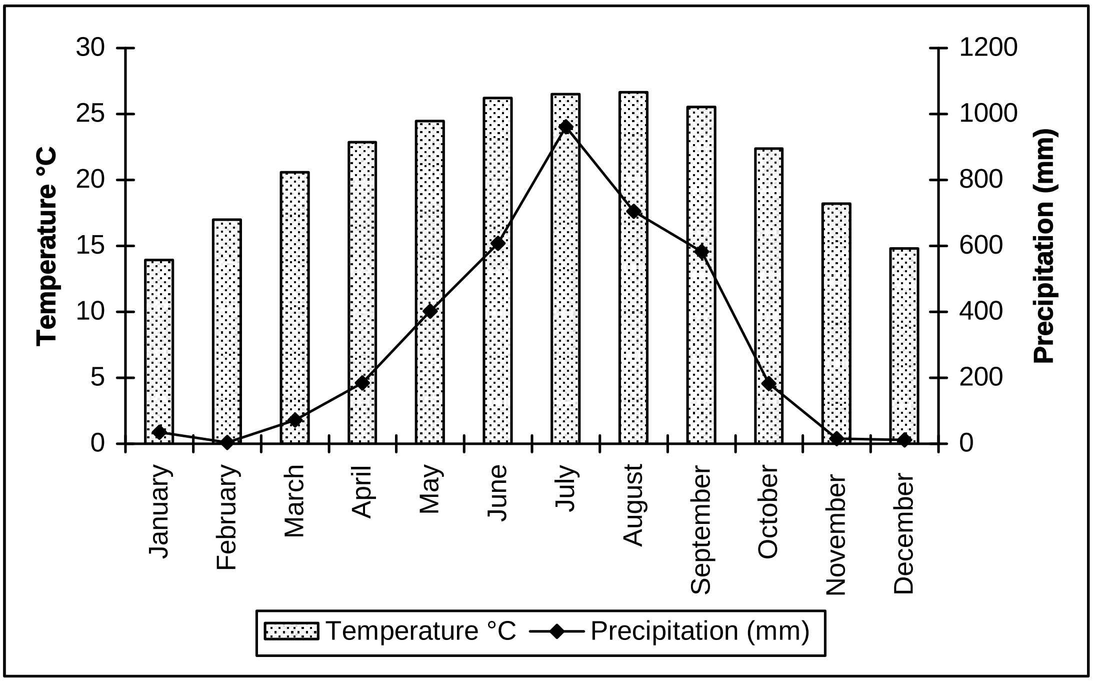
Bathymetric maps of the lake were prepared for the first time by (Ferro and Swar, 1978) and second by (Rai *et al.* 1993). Data from the two studies (Ferro and Swar, 1978 and Rai *et al.* 1993) indicate that the total watershed area of the lake decreased from 117ha to 115ha. The maximum depth also increased from 4.5 to 6.0m, with a mean depth of 2.3 - 2.4m. The volume of the lake is reported $2.7 \times 10^6 m^2$ by Ferro and Swar (1978) but Rai *et al.* (1993) reported as $3.25 \times 10^6 m^2$.

## 3.4 Climate

The average maximum temperature for Pokhara Airport during the last five year period (2002-2006) was seen in the month of August i.e. 26.67°C. Similarly, the average minimum temperature was in the month of January i.e. 13.95°C. The average of last five year (2002 - 2006) showed that the highest and lowest precipitation occurred in the month of July (961.22) and December (11.84) respectively, with the average total precipitation of 3793.27mm per annum.

The average summarized climatic data revealed that, the present site falls under *Shorea robusta* zone with a warmth index (wi) value of 199.12.

Similarly with precipitation of 3793.27, PER of 0.033 and Bio temperature of 21.59, the study site falls within a wet forest life zone in Holdrige's lower montane altitudinal belt.




*(Source: Department of Hydrology and Metrology, Babar Mahal, Kathmandu)*

**Average climatic data for Pokhara Airport from (2002 - 2006)**

## 3.5 Major Flora

The lake is endowed with a wide variety of aquatic macrophyts. Plant species are distributed according to their adaptability to the depth of the lake. The shallower region of the lake is accommodated by luxuriant growth of free floating species like *Trapa bispinosa. Trapa quadrispinosa, Nelumbo neccifera, Nymphoides indica* and *Eichornia crassipes* etc., while the shoreline is inhabitated by emergents, mostly by members of Poaceae. Similarly, the deeper region of the lake is inhabitated by submerged species like *Hydrilla, Potamogeton, Ceratophyllum* etc. Wild variety of rice *Oryza rufipogon* has also been reported from the lake (Shrestha, 1998).

## 3.6 Major Fauna

The lake provides an ideal place for aquatic fauna due to its strategic location and luxuriant growth of aquatic macrophytes. The occurrence of 450 different species of flora and fauna reveals its rich bio diversity (Oli, 1996). The lake also provides a habitat for threatened animals like otter and more than 24 indigenous sps. of freshwater fish diversity. Ferro and Swar (1980) recorded 22 major native fish species.

The species of fish raised in the cages include Silver carp (*Hypophthalmichthys molitrix*) and Bighead carp (*Arostocytyus nobilis*). Other stocked species include grass carp (c*tenopharyngodon idella*), common carp (*Cyprinus carpiol*, Rohu (*Labeo rohita*, Naini (*Cirhina mrigala*), Bhakur (*Catla catla*), Mahaseer (*Tor puttitara*) and others. Likewise, over 200 species of local and migratory birds viz. hawks, teal, goose, egret, king fisher, cranes etc. are reported from the lake.

# 4. MATERIALS AND METHODS

The field work was designed to obtain a quantitative data regarding acquatic macrophytes, floristic composition, limnological parameters, productivity (biomass), soil of different land use and socio-economic characteristics of the watershed area. The socio-economic survey was made by Participatory Rural Appriasal Method (PRA) technique and analyzed as per the objective.

## 4.1 Reconnaissance Survey

The comprehensive field study was taken in two different year season i.e. (June-July, 2006) and (Oct. 2007) for analyzing floristic composition, limnology, soil characteristics and productivity of the lake.

To cover overall quantitative data four sides of lake (East, West, North and South) were studied/selected.

**Table 1: Status of study site**

| S.N. | Face (site) | Characteristics |
|---|---|---|
| 1. | East | Dense forest |
| 2. | West | Forest + agriculture land |
| 3. | North | Agriculture land |
| 4. | South | Agriculture land + settlements |

## 4.2 Sampling Technique

Systematic partial random sampling technique along the several transects was applied.

## 4.3 Layout

The vegetation analysis of different plant communities of the lake was done by quadrat method. At each face of the lake, two long imaginary transects of 30m were made from shoreline to the centre at 10m apart and quadrat of 1m×1m was plotted in submerged, free floating to emergent forms from shoreline to the centre at 1.5m interval. Altogether one hundred and sixty quadrats were laid (10 quadrats on each transect) in two different season to determine frequency, density and coverage of aquatic macrophytes. Individual plant was counted and presence or absence and coverage of species were noted.

### 4.4 Quantitative analysis

The information and data collected after sampling was analyzed on the basis of quantitative characters. Parameters like frequency, density, coverage, Importance value index were analyzed as described by Zobel *et al.* (1987).

#### 4.4.1 Frequency and Relative Frequency

The frequency of a species refers to the degree of dispersion in terms of percentage occurrence. Relative frequency is the frequency of one species as a percentage of total frequency.

$$\text{Frequency (F\%)} = \frac{\textit{Number of quadrats in which species 'A' occured}}{\textit{Total number of quadrats studied}} \times 100$$

$$\text{Relative frequency (RF)\%} = \frac{\textit{Frequency of species 'A'}}{\textit{Sum of frequencies of all species}} \times 100$$

#### 4.4.2 Density and Relative Density

Density is the number of individuals per unit area, which gives the numerical strength of species. In general density is the total number of individuals of a species relative to total area examined. Relative density is a proportion of total number of individuals of a species with total number of all species with an area.

$$\text{Density (D) pl/m}^2 = \frac{\textit{Total number of individual of species 'A'}}{\textit{Number of quadrat sampled} \times \textit{size of quadrat}}$$

$$\text{Relative density (RD)\%} = \frac{\textit{Density of species 'A'}}{\textit{total density of all species}} \times 100$$

#### 4.4.3 Coverage and Relative Coverage

Coverage is simply the percentage of area covered by a species. More precisely coverage is defined as the vertical projection of crown of shoot area of a species to the ground surface expressed as percentage to the total ground surface.

$$\text{Coverage of a species (\%)} = \frac{\textit{Mid point value of species 'A'}}{\textit{Total area studied}} \times 100$$

$$\text{Relative coverage of a species (\%)} = \frac{\textit{Coverage of species 'A'}}{\textit{Total coverage of all the species}} \times 100$$

### 4.4.4 Importance Value Index

Importance value index was introduced by Curtis and Macintosh (1951) as a index of vegetation importance within a stand. It is a function of relative frequency, relative density and relative coverage of each species. This index provides a quantitative basis for the classification of community. The IVI value of any species in a community ranges between 0 -300.

$$IVI = RF + RD + RC$$

### 4.4.5 Index of Similarly (IS)

The simplest similarity indexes compare samples of vegetation only in terms of which species are present. It gives the degree of similarity between any two stands which depends on the quantitative physiological characters of species common to both stands. This index equals to one in case of complete similarity and zero if the set is completely dissimilar. Index of similarity was obtained between four sides of lake. It was calculated by applying formula given by Sorenson's index modified by Gregsmith (1964).

$$\text{Index of similarity (IS)} = \frac{2C}{A+B}$$

Where, A = Total no. of species in one sample

B = Total number of species in other sample

C = Total number of species in both the samples.

### 4.4.6 Diversity Index

Species diversity index is defined as a function of the number of species present in a given area and the evenness with which the individuals were distributed among the species richness and abundance. Diversity index was obtained for each side of lake.

For the calculation of species diversity index, Shanon Wiener's (1963) Index (H) was used.

$$\text{Diversity index (H)} = 3.3219 \left\{ \frac{N \log_{10} N - \sum_{i=j}^{k} ni \log_{10} ni}{N} \right\}$$

Where,

N = Total sample size

ni = Number of individuals of a species

k = Number of species

3.3219 = Factor converting $\log_{10}$ values to log2.

### 4.5 Limnological Sampling and Analysis

Water is the prime medium in which physical and chemical transformations particularly those of biological significance take place (Turk *et al.* 1978). Physico-chemical quality of any water body is the major deciding factor of the pattern of aquatic biota as well as primary and secondary productivity. It determine the habitability, abundance, seasonality and distribution of flora and fauna. Sixteen samples of water in each season were collected from four different sites i.e. four face (E, W, N, S) of the lake. Water sample was taken at a depth of one meter from the surface of lake in precleaned plastic bottles. Parameters like pH and temperature was measured on the spot. DO was analyzed in the lab of Fisheries Research Centre (FRC), Pokhara, Kaski. Nutrient analysis of water was done in the laboratory of water engineering and training centre Pvt. Ltd., Dillibazar, Kathmandu.

**Limnological Parameters**

#### 4.5.1 pH

pH is the negative logarithms of hydrogen ion concentration.

$$pH = -\log [H^+]$$

pH of water was measured by standard portable pH meter in the field.

### 4.5.2 Water Temperature

Temperature of water was recorded with the help of standard mercury thermometer in the site.

### 4.5.3 Dissolved oxygen (D.O.)

The dissolved oxygen in water was determined by using Winkler's method. This titrimetric method was originally developed by Winkler in 1988. Although the procedure is time consuming, it enables the storage of samples and has high degree of precision and accuracy. 200ml of water sample was poured in a conical flask. To this, 1ml of $MnSO_4$ solution and 1ml of potassium iodide solution was added. Then the flask was shaken thoroughly and precipitate was allowed to settle down. Then precipitate was dissolved by adding 2ml of concentrated sulphuric acid. Now, the solution was titrated against 0.025N Sodium thiosulphate solution using starch as an indicator till the blue colour disappeared. The total amount of titrant used in the process was noted.

The final calculations were made by the following formula (Zobel *et al.*1987)

$$\text{Dissolved Oxygen(mg/lit)} = \frac{V_1 \times N \times 8 \times 1000}{V_4\left(\frac{V_2 - V_3}{V_2}\right)}$$

DO = dissolved oxygen, N = Normality of titrant, $V_1$ = Volume of titrant (ml), $V_2$ = Volume of sampling bottle after placing the stopper (ml), $V_3$ = Volume manganous sulphate + potassium iodide solution added (ml), $V_4$ = Volume of fraction of the contents used for titration (ml)

### 4.5.4 Total Nitrogen

To determine the total nitrogen, macro Kjeldahl method was used as described in Trivedy ad Goel (1986) by using formula.

$$\text{TN (mg/l)} = \frac{(a-b) \times 0.01 \times 1000 \times 14 \times D}{\text{ml. of sample distilled}}$$

Where

a = ml. of HCL used with sample

b = ml. of HCL used with blank

D = dilution factor

0.01 is the normality of HCL used.

### 4.5.5 $PO_4$-P

Phosphorus occurs in the form of phosphate in natural water. The phosphate in water react with ammonium molybdate and form complex heteropoly acid (molybdophosphoric acid), which get reduced to a complex of blue color in the presence of $Sncl_2$. The absorption of light by this blue colour can be measured of 690nm to calculate the concentration of phosphate as mentioned in Trivedy and Goel (1986)

## 4.6 Biomass Estimation of Aquatic Macrophytes

Aquatic macrophytic vegetation include different species of herbaceous plants in the lake. At the seasonal sampling time, one-fourth ($1/4^{th}$) biomass within the quadrats which were previously laid for vegetation analysis were collected in separate bags. Altogether 160 biomass samples (80 during each experimental period), representing different growth form (emergent, submerged and free floating) were taken. The collected samples were dried in the hot air oven for 24 fours at 72°C. The oven dried biomass was weighed in an electric balance and were analyzed as described by Zobel *et al.* (1987).

## 4.7 Soil Sampling and Analysis

Five sides of lake were selected representing agricultural upland, agricultural lowland, forest and rangeland of watershed area. Quadrat of $50\times50cm^2$ was laid and soil from about 10cm depth (after removal of litter) was taken. Altogether forty sample were taken in each season.

The soil samples collected from each subplot were air dried in shade for one week and packed in air tight plastic bags till laboratory analysis completed. Soil was analyzed for pH, total nitrogen (%) and total organic matter (OM)% at laboratory of Central Department of Botany, Tribhuvan University, Kirtipur.

### 4.7.1 Organic Matter (Walkey Method)

Soil OM (%) was determined by Walkely and Black rapid titration method as described in Gupta (2000).

In this method, 0.5g air dried soil was taken in a dry 500ml conical flask. Then 5ml of 1N $K_2Cr_2O_7$ was pipetted in and swirled gently. 10ml of conc.

$H_2SO_4$ was added and swirled again two to three times. The flask was then allowed to cool down for 30 minutes and then 100ml distilled water was added on it. After that 5 ml of orthophosphoric acid (pure) was added and then 0.5ml of diphenylamine indicator was added in the conical flask containing the mixture of soil and reagents. The colur of the solution of the flask was obtained blue violet. Now the content was titrated with 0.5N ferrous ammonium sulphate till the colour changed from blue violet to green. A blank was also run simultaneously for each batch of soil samples tested for OM%. The soil organic carbon (%) of the sample was determined by using following formula.

$$\text{Soil organic carbon estimated (\%)} = \frac{0.003 \times 10\ (\text{Blank reading} - \text{Titration reading})}{\text{Blank reading} \times \text{Mass of soil (g)}} \times 100$$

The organic carbon (%) obtained by above formula was multiplied by a factor 1.3 (based on the assumption that there is incomplete oxidation of the organic matter in this procedure and only 77% recovery occurs through this method).

Hence, organic carbon (%) = organic carbon estimated (%) x 1.3

Now, to determine organic matter content (%) of soil, this value of organic carbon (%) was multiplied by Van Bemmelen factor of 1.724 (because organic matter is assumed to contain 58% organic carbon).

Hence, organic matter content (%) = organic carbon (%) x 1.724

### 4.7.2 Total Nitrogen (%)

The total nitrogen (%) of soil was determined by microjeldahl method with techniques described by Gupta (2000). This method includes following 3 steps:

**Digestion**

One gram of air dry and fine soil (passed through 0.425 mm sieve was taken in a dry kjeldahl digestion flask of 300ml. Then 3.5g potassium sulphate and 0.4g copper sulphate (i.e. catalysts) were added to the flask containing soil. Now, 6ml of conc. $H_2SO_4$ was added to the mixture of soil and catalyst in flask and shaken gently.

The flask was then placed on the preheated (30°C) heating mantle for digestion. Temperature was raised to about 310°C after the bubbles started disappear on the contents of the flask. The end of digestion process was known as the colour changed from black to brownish and ultimately greenish. Then the flask was removed immediately from the mantle and allowed to cool down for 30 minutes. To the digest, 50ml of distilled water was added and the mixture was shaken well. A blank without soil sample was also run for each batch of soil samples digested through this process.

**Distillation**

The diluted digest of kjeldahl digestion flask was now transferred to kjeldahl distillation flask. A beaker of 100ml capacity with 10ml of boric acid indicator was placed below the nozzle of the condenser in such a way that the end of the nozzle dipped into the indicator. After the digest become warm, 30mL of 40 percent NaOH solution was added and mouth of distillation flask was closed with cork making the system air tight. The temperature of the mantle was now raised to about $310^0$C. The distillate eveporated through distillation flask began to condense and the colour of boric acid indicator changed from pink to green. The distillation was continued until the volume of distillate in beaker reached to about 50 ml.

**Titration**

The distillate removed out from distillation plant was titrated with 0.1N HCL. The volume of HCL consumed in titrating distillate was recorded. The volume of acid consumed by both blank and soil samples were noted and on the basis of which the total nitrogen content (N%) of the soil sample was calculated by using following formula.

$$\text{Soil N (\%)} = \frac{14 \times N \times (S - B) \times 100}{M}$$

Where, N = normality of HCL

S = Volume of HCL consumed with soil sample (mL)

B = Volume of HCL consumed with blank (mL)

M = Mass of soil taken (mg)

### 4.7.3 pH

Soil pH was determined by the potentiometric method, using a pH meter (Digital pH meter, 802, systronics (89-92) Naroda Industrial Area, Ahmeda Bad, India). Before pH measurement, the electrode of the pH meter was dipped for 24 hours in tap water. Then, buffer solutions of pH tablet 7.0 and 4.0 were prepared freshly. The pH meter was warmed up for 15 minutes before starting pH measurement. 10g of air dried fine soil was mixed in 100ml of distilled water and stirred well by the help of glass rod. Then, the mixture of soil and water was left for decantation about half an hour and hence solution of soil sample was made ready for pH measurement. Now, the pH meter was callibrated through buffer solution of pH 4.0 and 7.0 and pH measurement was taken for each solution of soil sample. Electrode of pH meter was flushed by distilled water and wiped by cotton each and every time before dipping it from anyone solution either buffer or of soil sample to next.

## 4.8 Socio-economic Survey for Environmental Management

The ecosystem cannot be set aside exclusively for conservation purposes without social and economic consideration (Whitehead *et al.*, 1990). Since socioeconomic characteristics of the respondents from surrounding area provides background information for regarding their dependency on wetland vegetation, conservation attitudes, and awareness, a socioeconomic survey was carried out. The socioeconomic characteristics include information on: demography, education, occupation, livestock holding, and attitudes and awareness of local people.

### 4.8.1 Selection of informants

Respondents of different age groups (15 - 75) were randomly selected as key informants at three sites (Kholako Chheu, Jamunkuna and Sistanighat). Altogether 65 respondents were asked different questions pertaining to management problems, benefits and threats of lake. Information was also gathered through informal talks with Municipality officer, RCFC members as well as other concerned authorities (LI-BIRD, SORUP Nepal and FRC, Pokhara).

### 4.8.2 Interview

A semi structured questionnaire was used to interview respondents of different caste and creed in the watershed area (Appendix- 8). The data obtained was compiled, analyzed and discussed for the best output. The questionnaire used for the respondents.

## 4.9 Taxonomic Identification

The vascular and non vascular plants encountered in the study area were collected and herbaria were prepared by following standard technique (Lawrence, 1967). Plant specimens were identified by using relevant literatures (flora of Bhutan, flora Kathmandu valley), consulting taxonomists, and cross checking the herbarium housed in TUCH and National Herbarium and Plant Laboratory (KATH), Godavari, Lalitpur.

## 4.10 Statistical Analysis

Correlation coefficient (r) value between different parameters (species diversity, biomass, pH, water temperature, DO, Total nitrogen and $PO_4$-P) were obtained by using statistical programme for social science (SPSS, 2001 version 11.5)

Correlation coefficient (r) can also be obtained by using following formula, as suggested by Bailey (1995).

$$r = \frac{\Sigma(x-\overline{x})(y-\overline{y})}{\Sigma(x-\overline{x})^2(y-\overline{y})^2}$$

r = correlation coefficient

## 5. RESULT

### 5.1 Plant Diversity in Rupa lake

Present investigation revealed that the lake Rupa was inhabitated by different species of aquatic macrophytes. A total of 43 species were recorded during research period, which belongs to 26 families, 40 genera and 43 species. The highest number of species were represented by Gramineae (7) followed by Compositae (5) Cyperaceae (3) and Trapaceae, Umbelliferae, Commelinaceae and Polygonaceae each having 2 species. According to the growth form, the highest number of species was recorded by emergents (30) followed by rooted-floating and submerged, each having 5 species and free floating species (3). Among the recorded plant species; one belongs to algae, 3 pteridophyte, 22 dicot and 17 monocot. Highest number of species (28) were found in eastern side of the lake during both the experimental period and the lowest number of species was found in southern side of lake (20 during pre monsoon and 21 during post monsoon (Table 2).

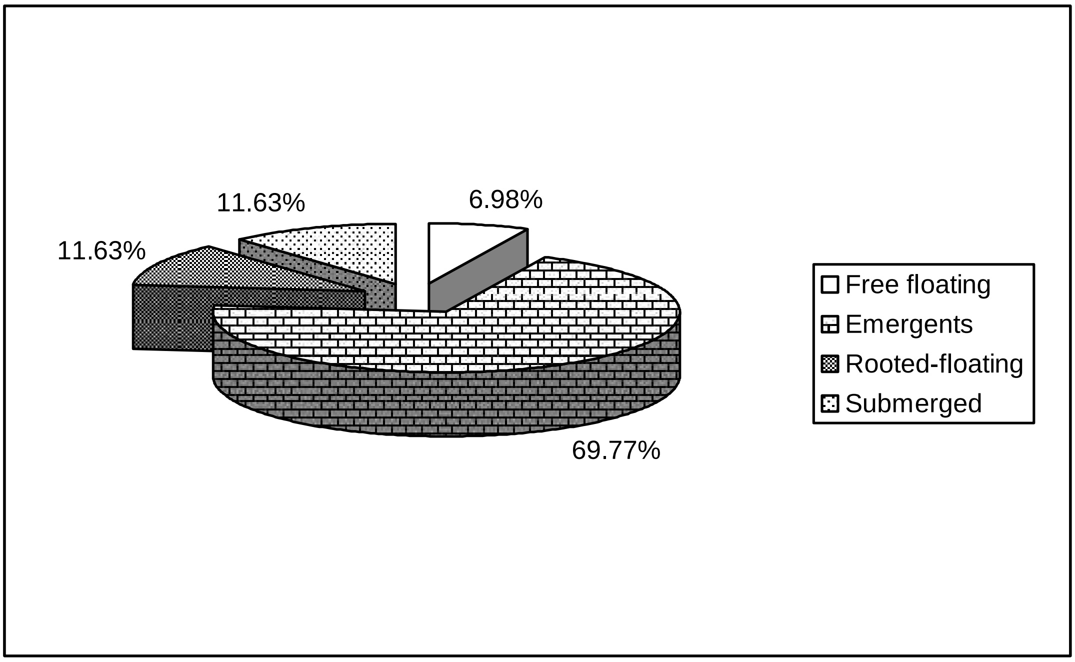



**Fig. 1. Number of species by growth form.**

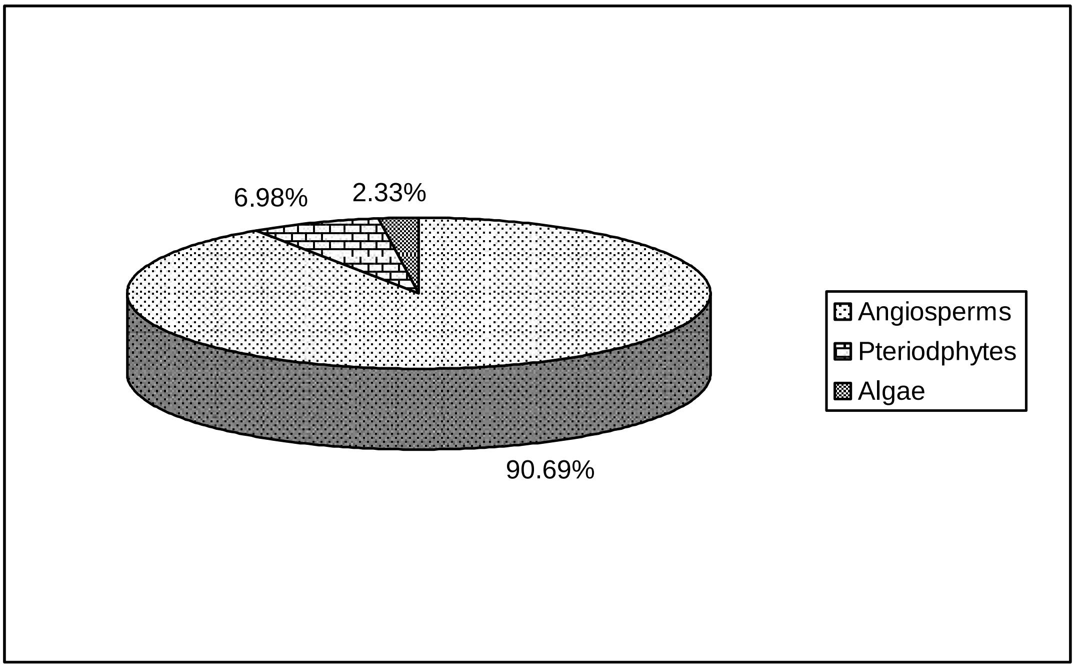



**Fig.2. Species number by taxonomic group**

**Table 2: Species composition in two season at different faces (sides)**

| | Number of species recorded | | | |
|---|---|---|---|---|
| **Side** | **Pre monsoon** | **Post monsoon** | **Total species** | **Grand total** |
| West | 25 | 24 | 29 | |
| North | 27 | 25 | 26 | 43 |
| East | 28 | 28 | 30 | |
| South | 20 | 21 | 21 | |

Aquatic macrophytes were distributed according to their adaptability to the depth of the lake. Shallower region of the lake is accommodated by emergent macrophytes while deeper region of the lake is habitated by rooted floating species. *Trapa quadrispinosa, Nelumbo nucifera, Leersia hexandra, Hydrilla verticillata, Nymphoides indica* are the most dominant species of the lake and were found in almost all sides of the lake. Luxuriant growth of *Nelumbo nucifera* and *Eichornia crassipes* can be seen at the inlet and outlet of the lake respectively.

## 5.2 Vegetation Analysis

### 5.2.1 Frequency and Relative frequency

**North**

*Nymphoides indica,* a rooted floating species showed the highest value of frequency and relative frequency (40 and 8.25) and (40 and 8.60) during pre monsoon and post monsoon respectively. The lowest value of frequency and relative frequency was obtained for *Eichornia crassipes*, during pre monsoon and *Trapa bispinosa*, a floating species during post monsoon period respectively.

**West**

Two rooted floating species: *Nymphoides indica* and *Trapa bispinosa* showed the highest value of frequency and relative frequency in both seasons. The value was (40 and 9.76) during pre monsoon and (40 and 10.96) during post monsoon period. During pre monsoon period, *Azolla imbricata*, a free floating species showed the lowest value of frequency and relative frequency (5 and 1.22). Similarly, *Ageratum conyzoides, Oxalis corniculata, Bidens pilosa, Cyanodon dactylon, Azolla imbricata, Gleichenia dichotoma* and *Paspalum scrobiculatum* possessed the lowest value of frequency and relative frequency (5 and 1.37) during post monsoon period.

**East**

A rooted floating species *Nymphoides indica* possessed the highest value of frequency and relative frequency during both season. The value was 40 and 8.42 during pre monsoon and 40 and 8.99 during post monsoon period. Similarly, the lowest value was obtained for *Trapa bispinosa* (5 and 1.05) during pre monsoon period and *Mimosa pudica, Artemisia vulgaris, Cheilanthes bicolar, Trapa bispinosa, Lindernia* sp. and *Azolla imbricata* obtained lowest value (5 and 1.37) during post monsoon period.

**South**

During both the seasons, *Nelumbo nucifera*, a rooted floating species possessed the highest value of frequency and relative frequency. The value was 65 and 17.51 during pre monsoon and 65 and 16.45 during post monsoon period. Similarly, *Centella asiatica*, possessed the lowest value of frequency and relative frequency (5 and 1.35) during pre monsoon period and *Ageratum cornyzodies*, oxalis, *Bidens pilosa*, *Centella asiatica* and *Oryza sativa* possessed the lowest value (5 and 1.26) during post monsoon period. (Appendix 2)

### 5.2.2 Density and Relative density

**North**

*Leersia hexandra*, an emergent species was the most abundant species during both the season. The value of density and relative density was 26.35 and 22.93 during pre monsoon period and 35.86 and 37.57 during the post monsoon period. Similarly the lowest value was obtained for *Eichornia crassipes* (0.1 and 0.08) during pre monsoon period and *Trapa bispinosa* (0.1 and 0.07) during post monsoon period.

**West**

The highest value of density and relative density was obtained for *Leersia hexandra* an emergent species, in both the season. The value was 22.6 and 22.30 during pre monsoon and 21.7 and 28.74 during post monsoon period. Similarly the lowest value 0.7 and 0.69 was possessed by three spp. viz. *Chara*, *Bidens pilosa* and *Eleocharis congesta* during post monsoon period.

**East**

*Leerisa hexandra* an emergent species possessed the highest value of density and relative density during both the season. The respective density and relative density value was 24.1 and 25.77 during pre-monsoon period and 25.9 and 31.47 during post-monsoon period. the lowest density and relative density value during pre-monsoon period was obtained for *Trapa bispinosa*, a rooted floating species. The density and relative density value for *Trapa bispinosa* was 0.05 and 0.05. Similarly, during post monsoon period, *Artemisia vulgoris* and *Trapa bispinosa* showed the lowest value of density and relative density (0.1 and 0.12).

**South**

The highest density and relative density value was obtained for *Leersia hexandra* during both the experimental period. The value was 20 and 34.39 during pre-monsoon period and during post-monsoon period the value was 20.6 and 27.99. The lowest density and relative density value of 0.55 and 0.94 was obtained for *Centella asiatica* during pre-monsoon period. Similarly, during post-monsoon period the lowest density and relative density of 0.25 and 0.33 was obtained for *O. sativa*.

### 5.2.3 Coverage and Relative Coverage

**North**

The highest value of coverage and relative coverage was obtained for *Trapa quadrispinosa*, a rooted floating species in both the season. The value was 28.0 and 36.24 during pre monsoon period and 25.75 and 30.92 during post monsoon period. Similarly, the lowest value of coverage and relative coverage during pre monsoon was obtained for *Ageratum conyzoides, Typha, Bidens pilosa, Centella asiatica, Oxalis* sp., and *Paspalum scrobiculatum* all having the same value of (0.25 and 0.32). During post monsoon period, the lowest value of 0.25 and 0.30 was possessed by: *Ageratum conyzoides, Bidens* pilosa, Commelina, Azolla imbricata, Centella asiatica and Typha anguistifolia.

**West**

*Trapa bispinosa*, a rooted floating species possessed the highest value of coverage and relative coverage value during both the experimental period. The value was 35.5 and 41.56 during pre monsoon period and 35.5 and 41.14 during post monsoon period. An emergent species *Typha* showed the lowest value of coverage and relative coverage value of 0.13 and 0.15 respectively during pre monsoon period but during post monsoon period *Azolla imbricata, Ageratum conyzoides, Bidens pilosa, Gleichenia dichotoma* and *Palpalum scrobiculatum* possessed the lowest value (0.13 and 0.15) (App. 2).

**East**

*Trapa quadrispinosa* possessed the highest value of coverage and relative coverage during both the experimental period. The value was 25.75 and 30.86

during pre monsoon period and 30.63 and 31.80 during post monsoon period. Similarly, the lowest value of coverage and relative coverage (0.13 and 0.13) during post monsoon period was obtained for *Cheilanthes bicolar* and *Azolla imbricata*. And, during pre monsoon the lowest value (0.25 and 0.29) was possessed by *Ageratum conyzoides, Bidens pilosa, Artemisia vulgaris,* and *Oxalis corniculata*.

**South**

*Nelumbo nucifera,* a rooted floating species showed the highest value of coverage and relative coverage during both the experimental period. The coverage and relative coverage value was 39.50 and 47.93 and 43.87 and 55.49 during pre monsoon and post monsoon respectively. Similarly, *Centella asiatica* possessed the lowest value of coverage and relative coverage (0.13 and 0.16) during pre monsoon period. And, during post monsoon period the lowest value of coverage and relative coverage (0.13 and 0.16) was possessed by: *Ageratum conyzoides, Bidens pilosa, Centella asiatica* and *Oryza sativa*.

### 5.2.4 Importance Value Index (IVI)

**North**

During pre monsoon period, the highest value of IVI (43.64) was obtained for *Trapa quadrispinosa*, a rooted floating species. *Leersia hexandra*, an emergent species showed the highest IVI value (41.12) during post monsoon period. Similarly, the lowest value of IVI was showed by *Typha anguistifolia* during both the seasons. The IVI value was 2.27 and 2.99 during pre monsoon and post monsoon period respectively.

**West**

The highest value of IVI was obtained for *Trapa bispinusa,* a rooted floating species during both the seasons. The value was 52.9 and 53.89 during pre monsoon and post monsoon period respectively. Similarly, the lowest value of IVI (1.61) was obtained for *Typha anguistifolia* during pre monsoon and during post monsoon the lowest value was possessed by *Gleichenia dichotoma* (1.65).

**East**

During pre monsoon period the highest value of IVI was obtained by *Trapa quadrispinosa*, a rooted floating species. The value was 38.77 during the experimental period. And, during post monsoon period *Leersia hexandra* possessed the highest IVI value of 44.49. Similarly, the lowest IVI value during pre monsoon and post monsoon period was possessed by *Artemisia vulgaris* (2.55) and *Mimosa pudica* (1.95) respectively.

**South**

*Nelumbo nucifera* possessed the highest value of IVI during both the season. The value was 68.25 during pre monsoon period and 74.39 during post monsoon period. Similarly, the lowest IVI value was obtained by *Centella asiatica* (2.45) and *O. Sativa* (1.75) during pre monsoon and post monsoon period respectively.

## 5.3 Indices

### 5.3.1 Similarity index between four sides of the lake in two season

During pre monsoon period, western part of the lake was closer to southern part (IS = 0.84) than to the eastern and southern part in terms of similarity in species composition. The similarity index value of northern with eastern and southern side was 0.72. The similarity index (Is) value between eastern and southern side was 0.71(Table 3).

The western face of the lake resembles more with northern (inlet) face of lake in terms of species composition with a similarity index (IS) value of 0.86 during post monsoon period. Similarly, IS value of 0.76 and 0.74 were obtained between north and east and north and south face respectively (Table 3). The IS value was 0.69 between east and south face.

**Table 3: Similarity Index (IS) between four side of lake in two season**

| Side | Pre monsoon | | | | Side | Post monsoon | | | |
|---|---|---|---|---|---|---|---|---|---|
| | W | N | E | S | | W | N | E | S |
| **West** | – | 0.81 | 0.76 | 0.84 | **West** | – | 0.86 | 0.77 | 0.76 |
| **North** | – | – | 0.72 | 0.72 | **North** | – | – | 0.76 | 0.74 |
| **East** | – | – | – | 0.71 | **East** | – | – | – | 0.69 |
| **South** | – | – | – | – | **South** | – | – | – | – |

### 5.3.2 Species Diversity Index

The diversity index of species in western part of the lake was 3.52 and 3.68 during pre monsoon and post monsoon period respectively. Similarly, the diversity index in northern part was 3.56 and 3.41 during pre monsoon and post monsoon period respectively. The eastern and southern part have diversity index of 3.84 and 3.78 and 3.41 and 3.35 during pre monsoon and post monsoon period respectively (Table 4).

**Table 4: Diversity index of species in four sides of the lake**

| Side | Season | |
|---|---|---|
| | Pre monsoon | Post monsoon |
| West | 3.52 | 3.68 |
| North | 3.56 | 3.41 |
| East | 3.84 | 3.78 |
| South | 3.49 | 3.35 |

## 5.4 Limnological Characteristics of Water in Rupa lake

### 5.4.1 Water Temperature

The average value of water temperature for Rupa lake was 22.57 ± 0.95°C. Water temperature value was observed lower in post monsoon period (21.90 ± 0.13°C) than in the pre-monsoon period (23.24 ± 0.62°C). During pre-monsoon period the highest and lowest water temp. value was obtained for southern and northern site, with an average value of 23.39 ± 0.03°C and 23.10 ± 0.03°C respectively. Similarly, during post-monsoon period the highest and lowest value was represented by eastern and northern site, with an average value of 22.7 ± 0.02°C and 21.57 ± 0.02°C respectively. The comparative study of air temperature with water temperature shows the similar rise and fall in mercury during both the experimental period (Fig. 3).

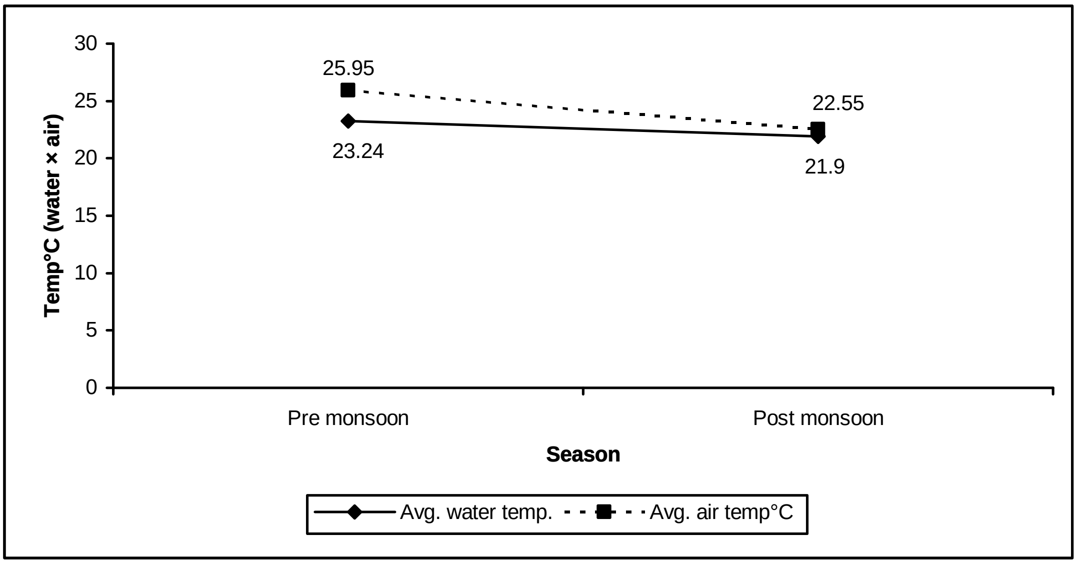



**Fig. 3: Seasonal Variation of atmospheric and water temperature**

### 5.4.2 Water pH

The average pH value of water for Rupa lake was 5.98 ± 0.44. pH value was observed lower during pre monsoon period (5.67 ± 0.14) than the post monsoon period (6.29 ± 0.35). During pre-monsoon period the highest and lowest pH value was obtained for southern and eastern site with an average value of 5.83 ± 0.02 and 5.50 ± 0.03 respectively. Similarly during post-monsoon period the highest and lowest pH value was represented by Southern and Western site, with an average pH value of 6.67 ± 0.05 and 5.92 ± 0.02 respectively.

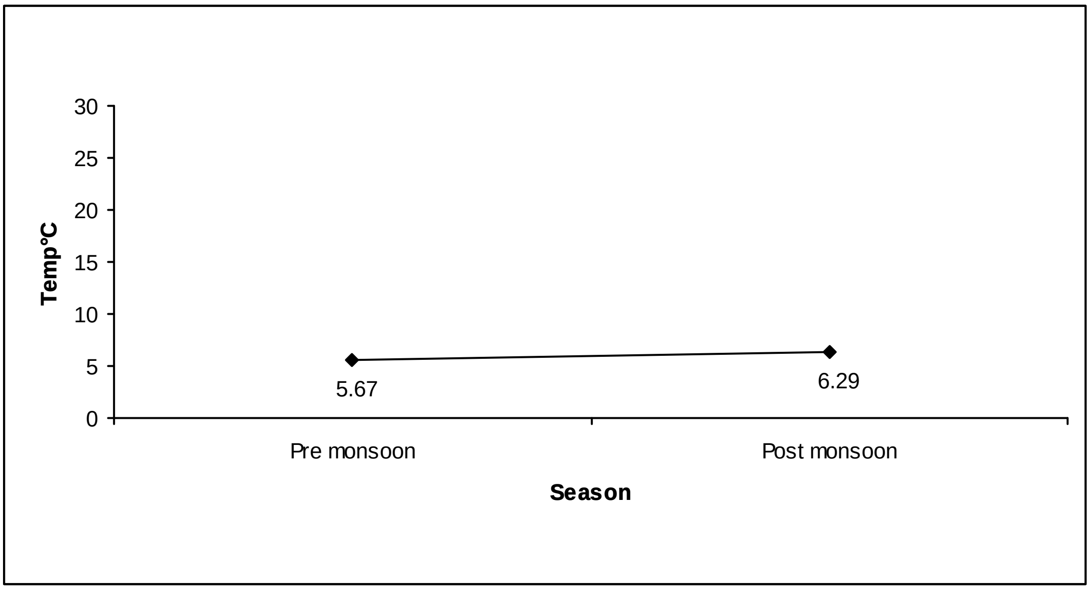



**Fig. 4: Seasonal variation of pH**

### 5.4.3 Dissolved Oxygen (DO)

The mean value of DO for Rupa lake was 5.92 ± 2.49mg/l. The dissolved oxygen value was observed lower during pre-monsoon period (4.16 ± 0.39mg/l) than the post monsoon period (7.68 ± 0.28mg/l). During pre monsoon period, the highest and lowest 'DO' value was obtained for northern and western site, with an average value of 4.71 ± 0.02mg/l and 3.81 ± 0.001mg/l respectively. Similarly during post monsoon period, the highest and lowest DO value was represented by northern and eastern side, with an average value of 8.10 ± 0.02mg/l and 7.49 ± 0.05mg/l respectively.

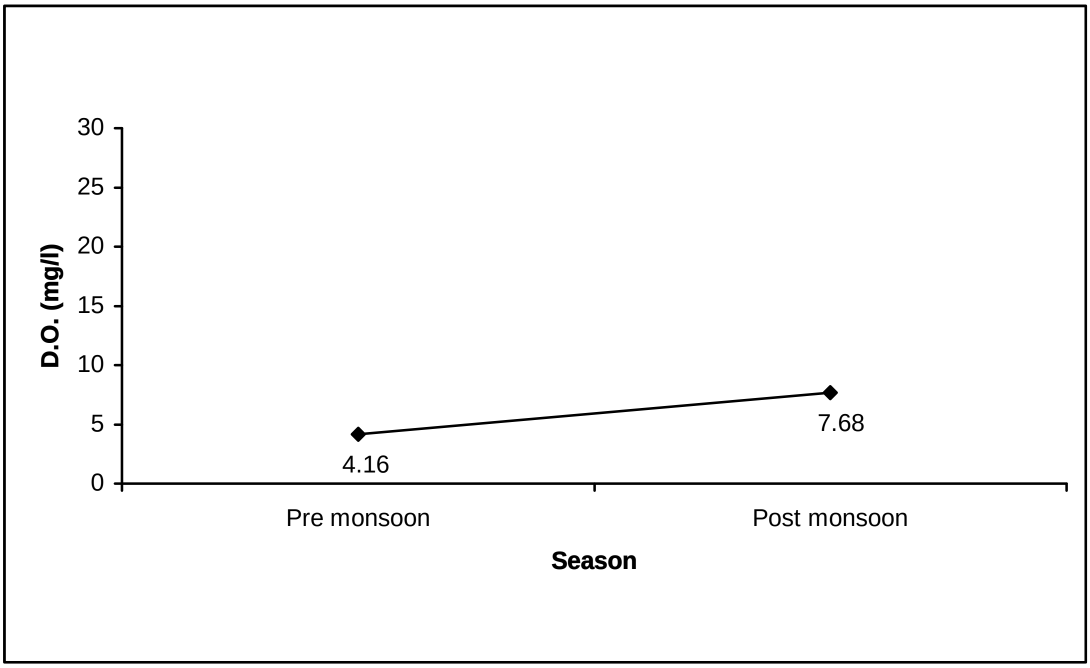



**Fig. 5: Seasonal variation of DO in water**

### 5.4.4 Total nitrogen concentration

The mean value of total nitrogen for Rupa lake was 0.15 ± 0.05mg/l. Total nitrogen value was observed lower during post monsoon period (0.11 ± 0.03mg/l) than the pre-monsoon period (0.184 ± 0.06mg/l). During pre-monsoon period, the highest and lowest total nitrogen value was obtained for northern and southern site, with an average value of 0.194 ± 0.002mg/l and 0.179 ± 0.00mg/l respectively. Similarly, during post monsoon period the highest and lowest value was represented by western and eastern site, with an average value of 0.15 ± 0.04mg/l and 0.08 ± 0.03mg/l respectively.

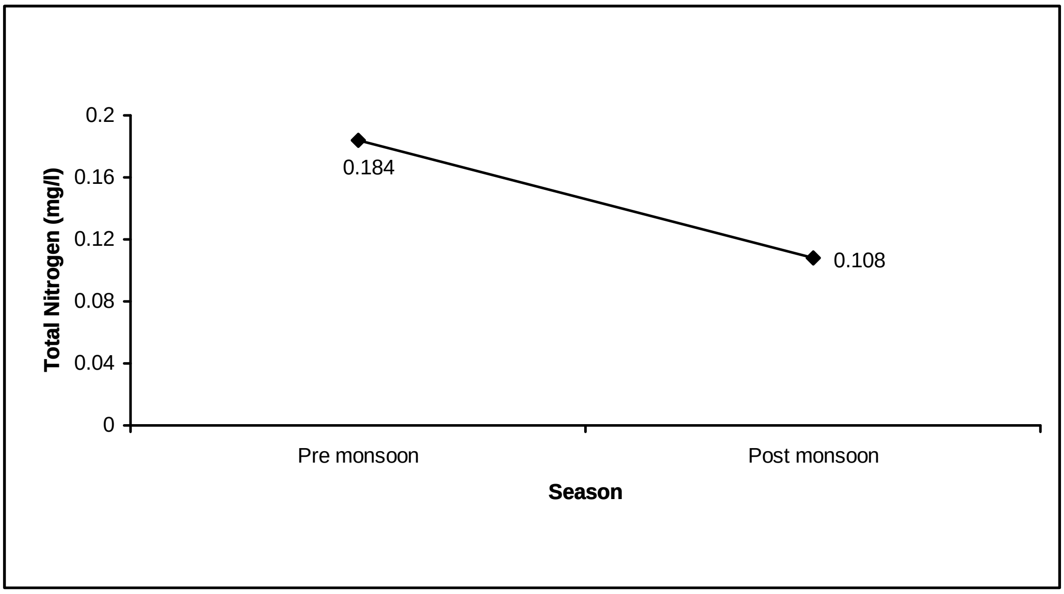



**Fig. 5: Seasonal variation of total nitrogen in water**

### 5.4.5 $PO_4$-P

The total mean average of $PO_4$-P for Rupa lake was 0.004 ± 0.002mg/l. The $PO_4$-P value was observed higher during pre monsoon period (0.005 ± 0.0004mg/l) than the post monsoon period (0.002 ± 0.0005mg/l). During pre monsoon period, the highest and lowest $PO_4$-P value was obtained for southern and northern site respectively, with an average value of 0.0052 ± 0.00mg/l and 0.0041 ± 0.002mg/l. Similarly, during post monsoon period, the highest and lowest value was obtained for eastern and western side, with an average $PO_4$-P value of 0.0023 ± 0.0001mg/l and 0.0011 ± 0.00mg/l respectively.

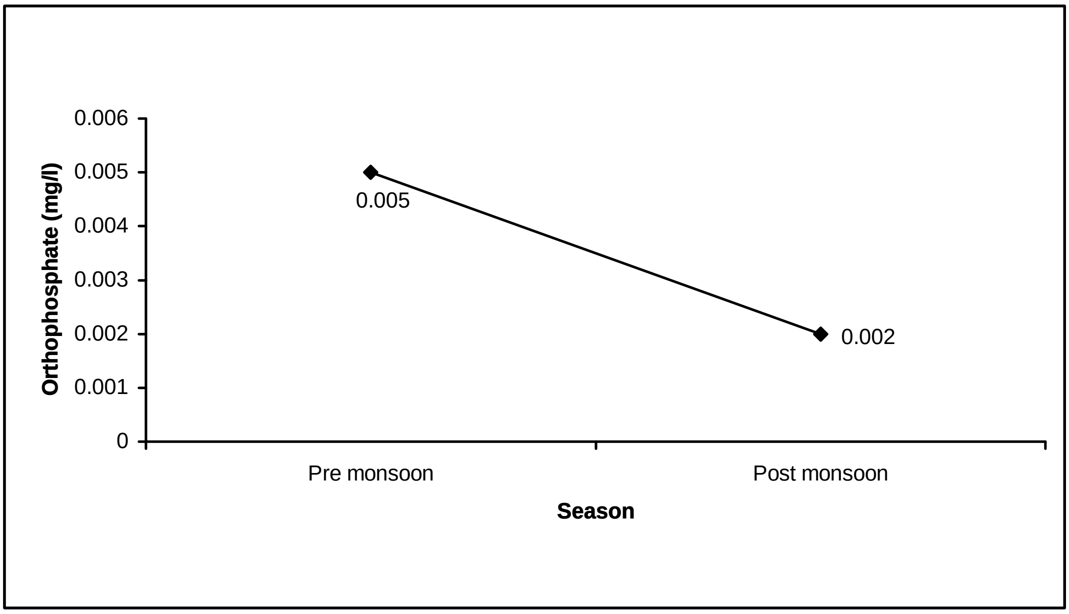



**Fig. 6: Seasonal variation of $PO_4$-P in water**

## 5.5 Productivity Estimation of Aquatic Macrophytes

Biomass of aquatic macrophytes was taken in four sides of lake during each experimental period. The detail pictures of biomass of aquatic macrophytes were illustrated in figure 7, 8 and 9.

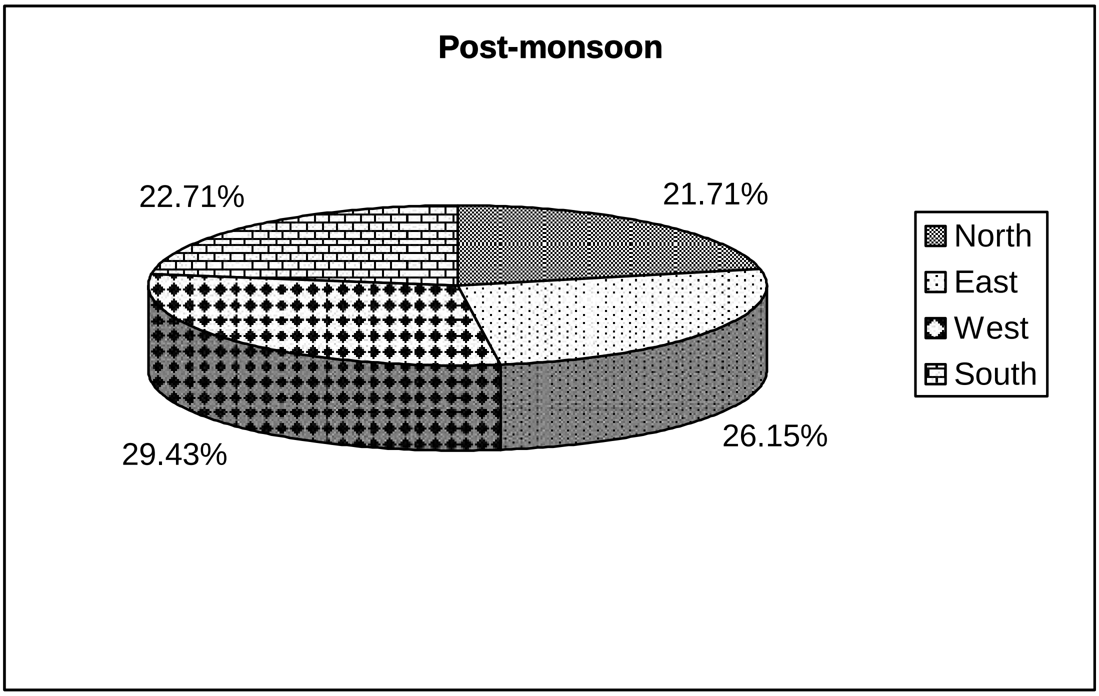
The highest above ground biomass of aquatic macrophytes was obtained during post monsoon period than the pre monsoon with a respective dry wt. value of 171.18 ± 24.03g/m$^2$ and 98.35 ± 1.69g/m$^2$.

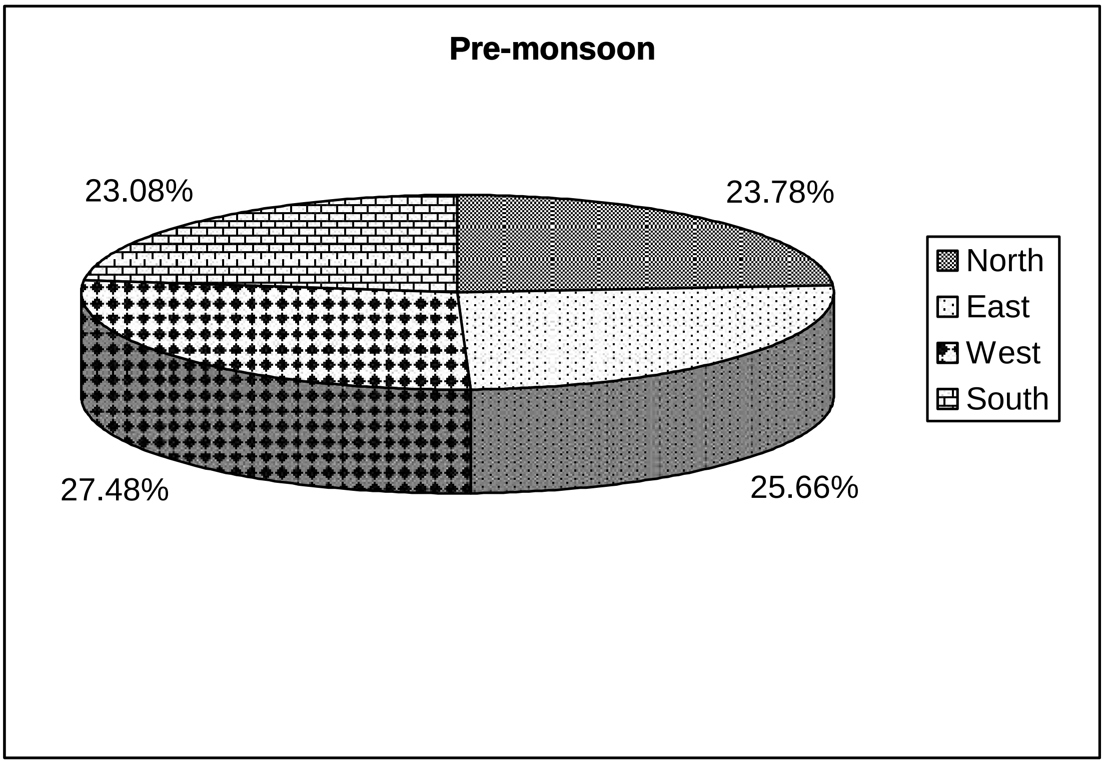
During pre monsoon period, the highest and lowest average biomass was obtained on western and southern site, with a mean value of 107.97 ± 47.40g/m$^2$ and 90.67 ± 44.43g/m$^2$ respectively. The range of dry weight for the above two sites was 29.91g/m$^2$ - 187.19g/m$^2$ and 32.35g/m$^2$ - 191.56g/m$^2$ respectively, and for the lake as a whole, the value ranges from 27.25g/m$^2$ - 228.28g/m$^2$ in which the highest biomass was represented by emergent species and the lowest by submerged species (Fig. 9).

Similarly during post monsoon period, the highest and lowest biomass value was represented by eastern and northern site, with a mean average dry wt. value of 201.49 ± 118.61g/m$^2$ and 148.65 ± 84.73g/m$^2$ respectively. The range of dry wt. value for the above respective sites was 41.23g/m$^2$-389.25g/m$^2$ and 34.71g/m$^2$ - 298.25g/m$^2$ respectively. Similarly, during the same period, the dry wt. value ranges from 34.71g/m$^2$, 389.25g/m$^2$ for the lake as a whole in which the highest biomass was constituted by the emergent species, followed by rooted floating and submerged species (Fig. 9)

According to the growth form, the highest average aboveground biomass was represented by the emergent species followed by rooted floating and submerged species with an average mean value of 251.16 ± 95.54g/m$^2$, 104.76 ± 28.02g/m$^2$ and 48.39 ± 7.27g/m$^2$ respectively (Fig.9).

**Plant biomass in different sides of Rupa Lake**



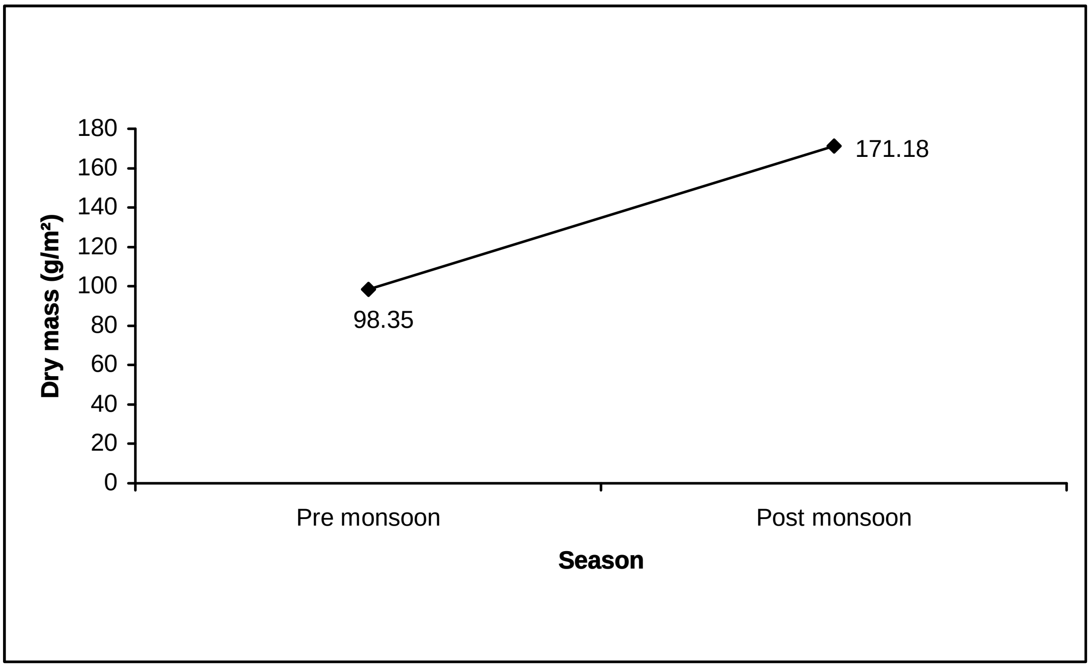



**Fig. 7: Seasonal total productivity of aquatic macrophytes in lake Rupa**

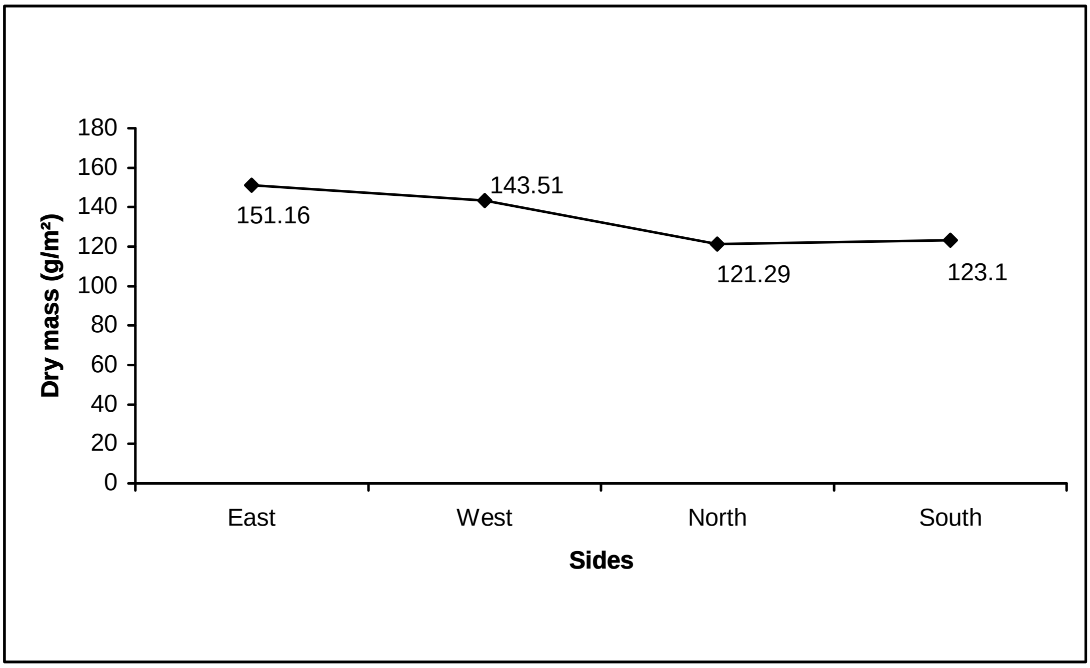



**Fig. 8: Total average above ground biomass in different sides of lake**

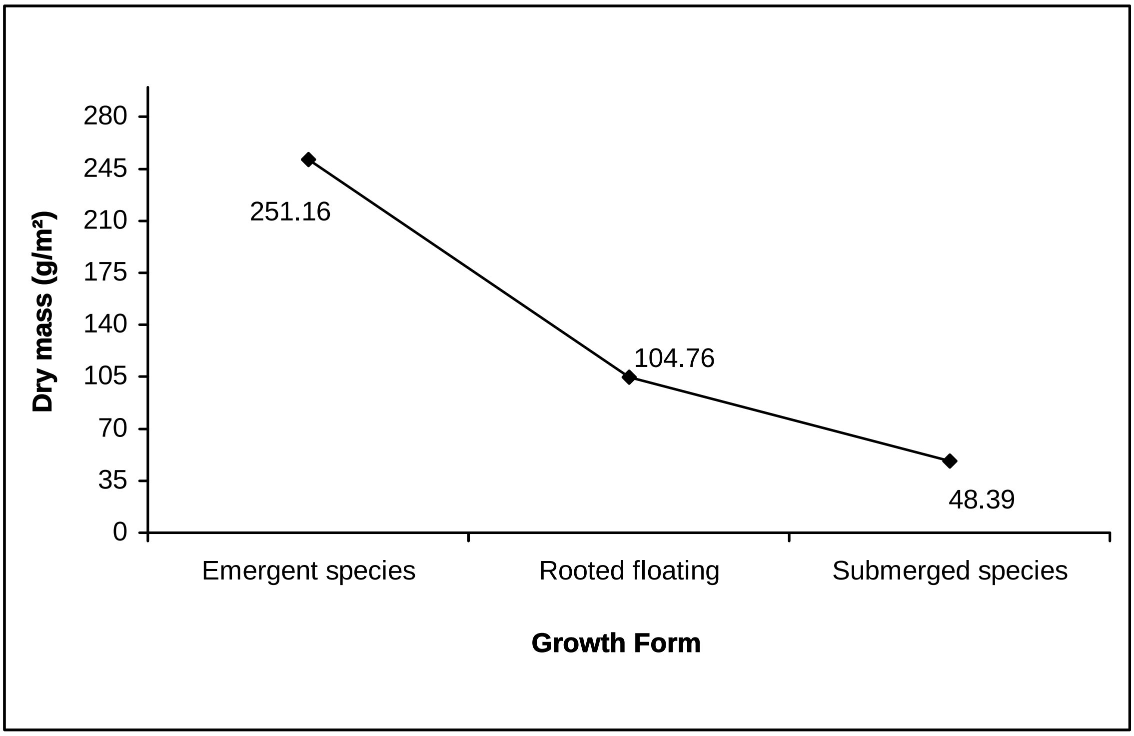



**Fig. 9: Total average above ground biomass according to growth form**

### 5.6 Soil Analysis

The soil of the study area was found quite acidic during both the experimental period. However, the pH value was obtained higher during pre monsoon period than the post monsoon period. The highest and lowest pH value was obtained for north inlet and outlet east forest area with a mean pH value of 6.87 and 5.17 respectively. The total mean pH value of study area was 6.15.

Organic matter content (%) was found higher during post monsoon period than the pre monsoon period in all sampled sites. The highest and lowest organic matter (%) value was obtained for outlet east forest and inlet area with a mean value of 8.43 and 4.79 respectively. The average organic matter content (%) was 6.62 during post monsoon period and during pre monsoon it was 6.48. The total average value of organic matter (%) for the study area was 6.56.

Soil nitrogen content (%) was found higher in all sampled sites during post monsoon period than the pre monsoon. The average value was 2.206 and 0.196 during post monsoon and pre monsoon period respectively. The highest and lowest value of nitrogen content (%) was obtained for outlet east forest and north-inlet area, with a mean value of 0.30 and 0.13 respectively. The total mean average value of nitrogen content of the study area was 0.204.

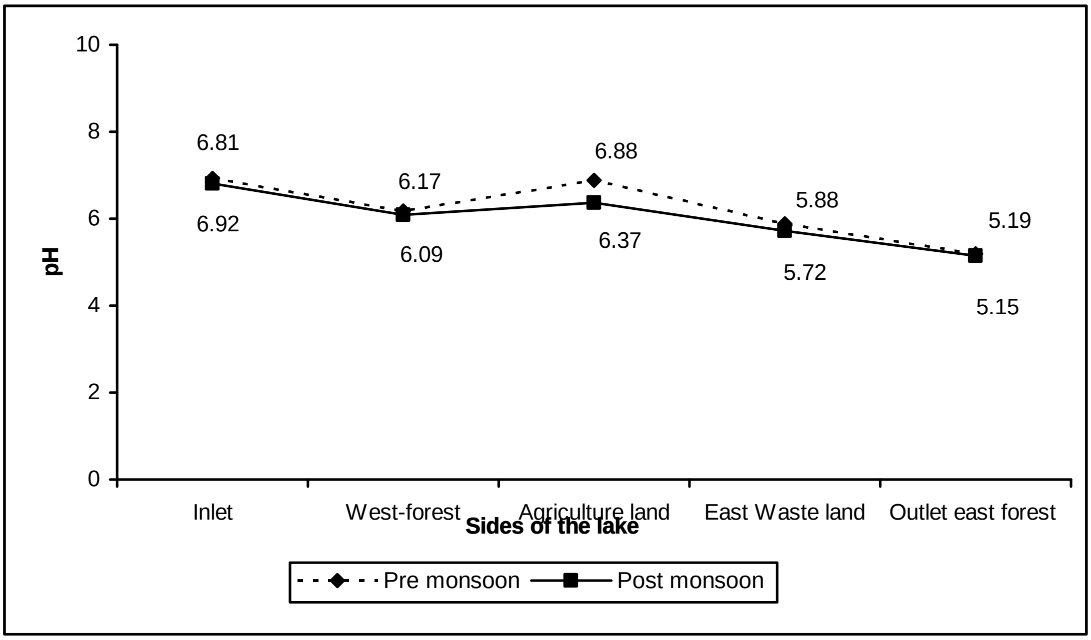



**Fig. 10: Variation in Soil pH at different sides of lake in two different seasons**

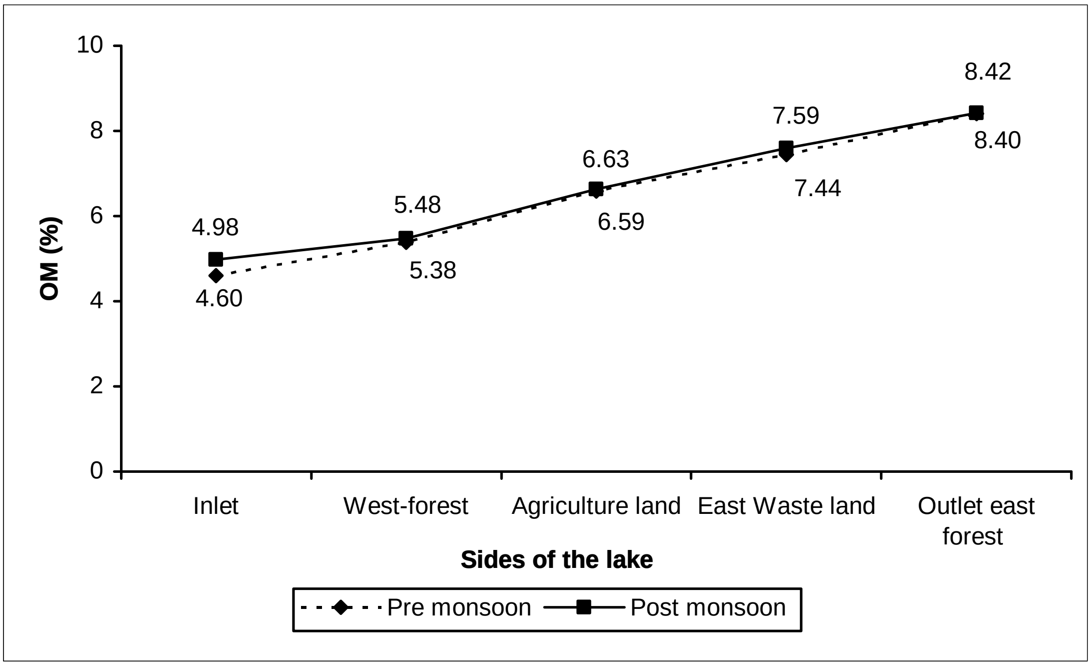



**Fig. 11: Variation in soil organic matter (%) at different sides of the lake in two different seasons**

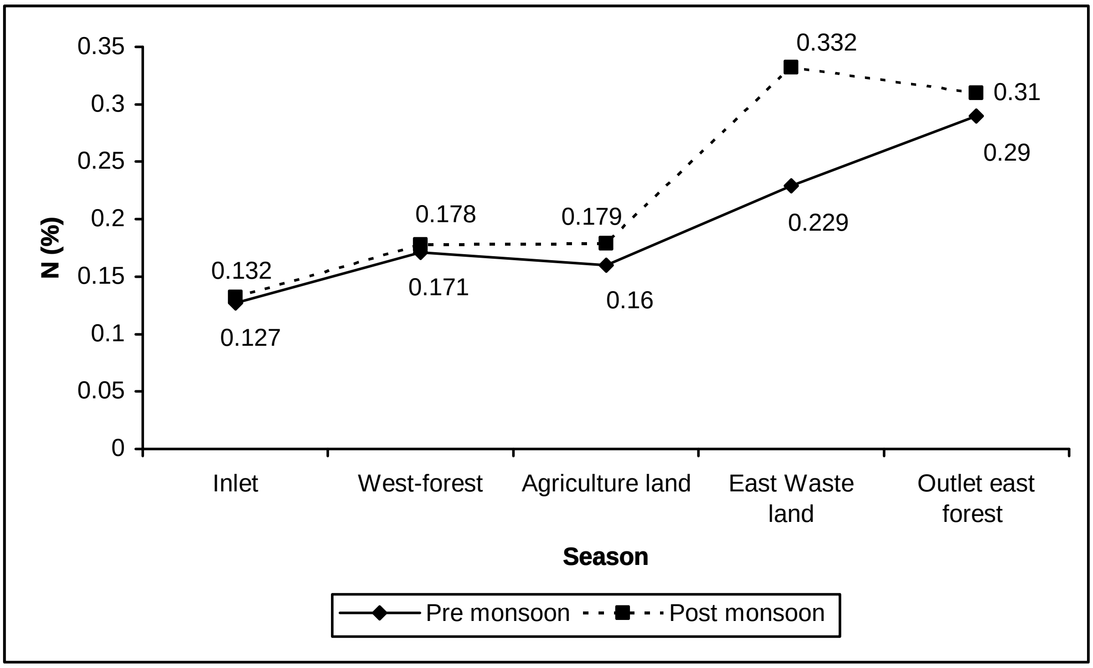



**Fig. 12: Variation in Nitrogen Content (%) at different sides of the lake in two different season**

## 5.7 Correlation between Species Diversity and Limnological Parameters

Diversity index was found positively correlated with water temperature (r = 0.271), TN (r = 0.151) and $Po_4$-P (r = 0.130), while it shows negative correlation with pH (r = -0.634), and DO(r = -0.199). Among the limnological parameters, temperature was found positively correlated with total nitrogen (r = 0.607) and $PO_4$-P (r = 0.939, p= 0.01) and DO (r = -.0883, p = 0.01). Similarly, pH was found to be positively correlated with DO (r = 0.820, p = 0.05), but with total nitrogen and $PO_4$-P, it shows negative correlation (Table 5). DO of water was also found to be negatively correlated with total nitrogen r = -0.877, p = 0.01 and $PO_4$-P (r = -0.958, p = 0.01). But, a positive correlation was obtained between total nitrogen and $PO_4$-P (r = 0.474, p= 0.05)

**Table 5: Annual Karl Pearson correlation co-efficient between different ecological attributes**

| | Biomass | Water temp. | pH | DO | TN | $PO_4$-P |
|---|---|---|---|---|---|---|
| **DI** | 0.159 | 0.271 | -0.634 | -0.199 | 0.151 | 0.130 |
| **Biomass** | – | -0.699 | 0.561 | 0.873** | -0.834** | -0.879** |
| **Water temp.** | – | – | -0.678 | -0.883** | 0.607 | 0.939** |
| **pH** | – | – | – | 0.820* | -0.809* | -0.698 |
| **DO** | – | – | – | – | -0.877** | -0.958** |
| **TN** | – | – | – | – | – | 0.747* |

** Correlation is significant at the 0.01 level (2-tailed)

* Correlation is significant at the 0.05 level (2-tailed)

DI = Diversity Index

DO = Dissolved oxygen

TN = Total Nitrogen

A positive correlation was obtained between biomass and pH (r= = 0.561) and DO (r = 0.873, p = 0.01. While with other limnological parameters viz. total nitrogen, $Po_4$-P and temperature it shows negative correlation (Table 5).

## 5.8 Socio-economy and Environmental Management

### History of lake

The history of lake was traced by counseling with local inhabitants. The discussion revealed that two feeder stream. Dovan Khola and Talbensi Khola used to meet on the lake itself. The local points out that Samiko Tundo and Sami bhatti are the original boundary of the lake. According to them, people used to boat upto these above points and the lake was even expanded up to Satmuhane (outlet), which was presently converted into farmland. Likewise the current farmland such as: Bhainsikuno, Sisteni, Kharbari Tundo, Bhangar Kuna, Tinmune and Niyaljhapro were once under lake. These facts tells that the lake has been expanded to longer area than at present.

At present, water volume in the lake has been substantially reduced due to sedimentation, macrophytic coverage and human encroachment.

According to the local, about 30 ha. area of the lake has been depleted and changed to agricultural land from 2032-2060 B.S. This clearly reflects the pathetic condition of the lake and of course, over helming greed of local people to expand their agriculture land.

### 5.8.1 Settlements

In the present field visit, communities have been found to reside in clusters but in some cases, households were found even in isolated and distant places from their neighbour. These clusters were formed largely through land fragmentation as far as possible. The settlements in the inlet site; Dhitalgaun, Aarubot and Capase were found to be old age while the settlements outlet site; Kholakochheu and Sisteni quite recent.

### 5.8.2 Socio-economic issues

A total of 65 people were identified as respondents. In the spheres of socio-economy, more people of 21-40 age group have been found quite active than old people and children whose involvement were found to be very Scanty (Fig.13) .

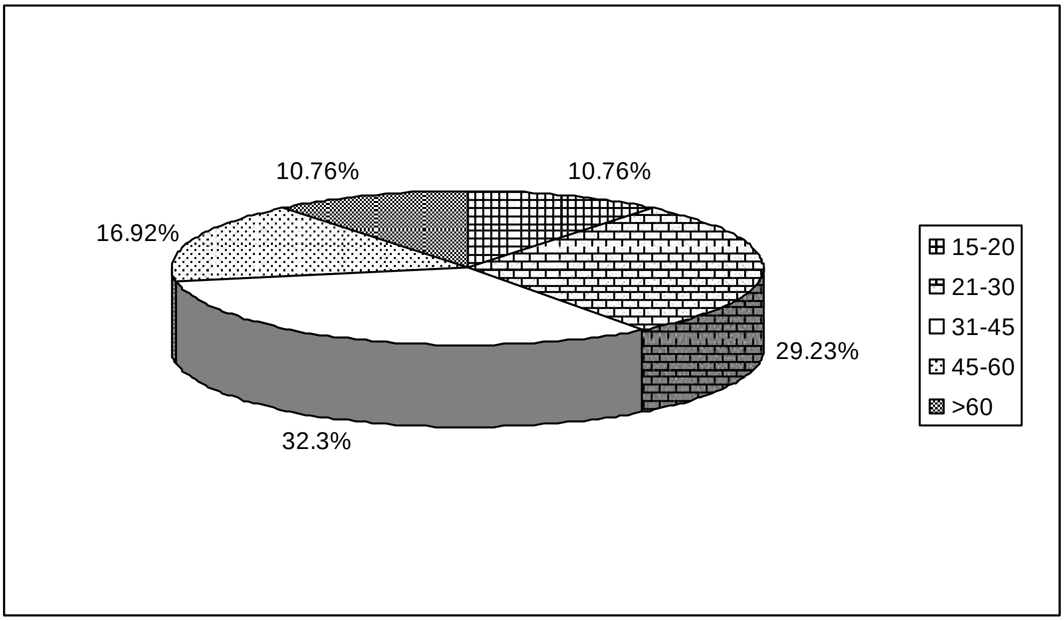



**Fig. 13: Respondents classification according to age group**

Regarding caste and ethnicity majority of respondents belong to Indo-Aryan tribe, followed by Tibeto-Burmese and Newars Fig.14. The marginalized groups like Bote, Mizar, Jalari forms the minority.

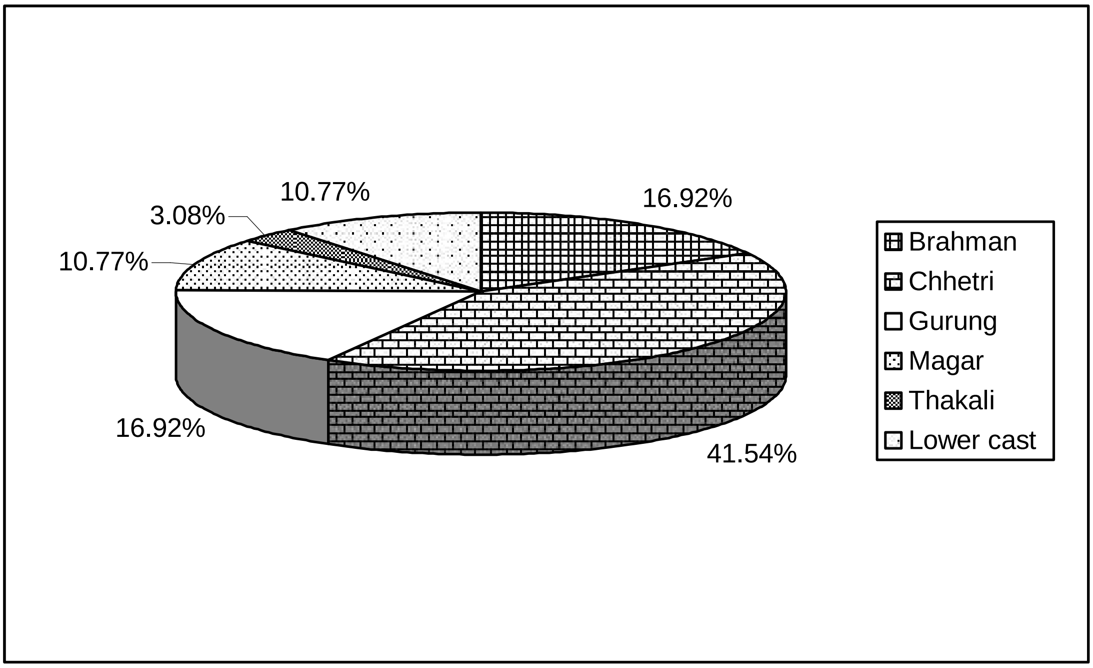



**Fig. 14: Respondents classification according to caste and ethnic groups**

Among the above age group people (fig. 13), most were engaged in agriculture (33) and spent most of time by indulging in agricultural chores (fig.15). People engaged in other occupation include business (29), government services (7) student (13) and employment related to tourism (2).

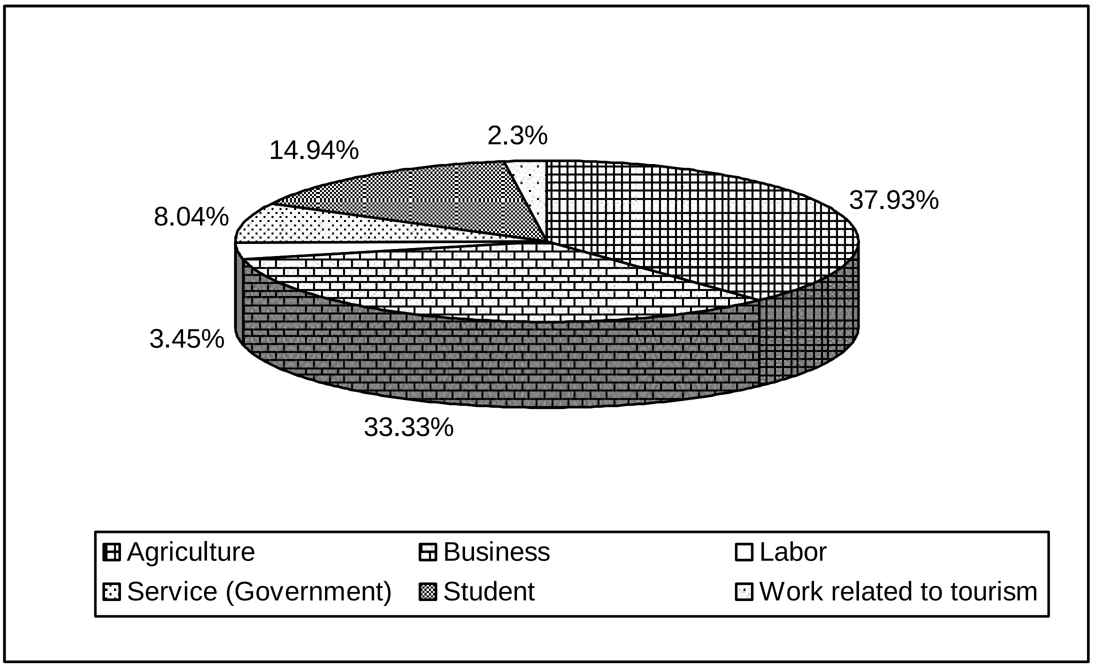



**Fig. 15: Respondent classification according to occupation**

Majority of respondents (39) told that they owe a limited number of livestock (1-5) which might be due to their easy access to fodder in their agricultural land/near by forest or lake shoreline. But a number of respondents (35.38) deny any domestication of pet animals which might be due to their unwillingness to grow pets/unavailability of fodder in their periphery or involvement in other occupation.

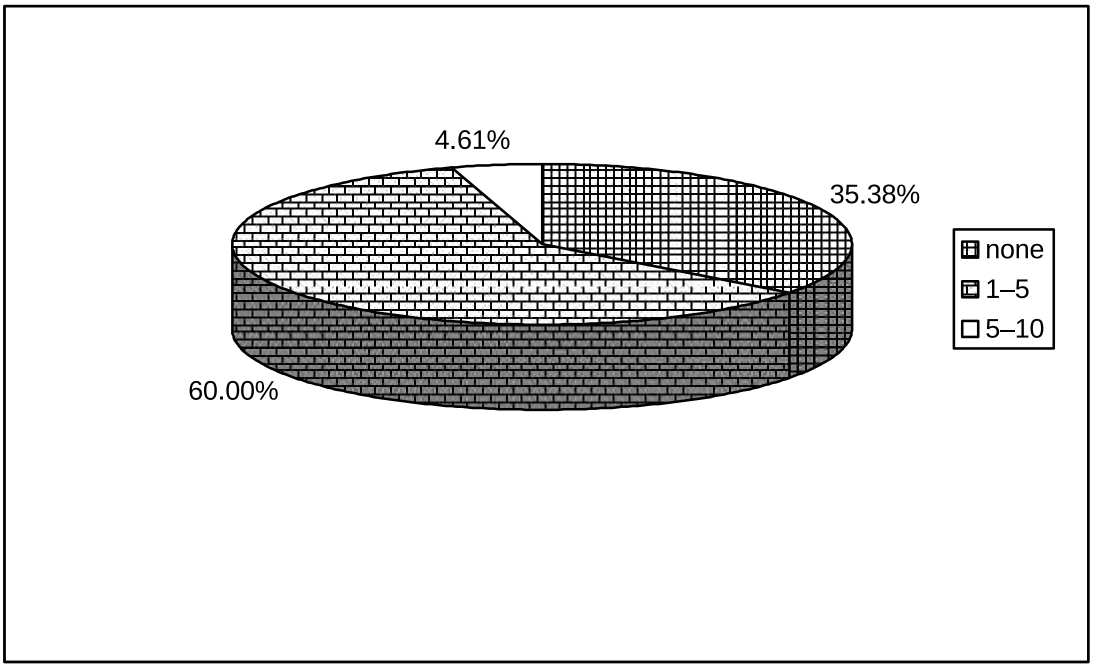



**Fig. 16: Respondent classification according to livestock population**

Regarding education it was found that a whooping number of respondents (39) have only completed/just enrolled in primary and secondary level. They confess that, unavailability of school in their near periphery and dawn-dusk arduous work in agriculture/farmland are the main cause of their illiteracy or low education. Graduated and post graduate scholar are less in number i.e. 6 and 1 respectively.

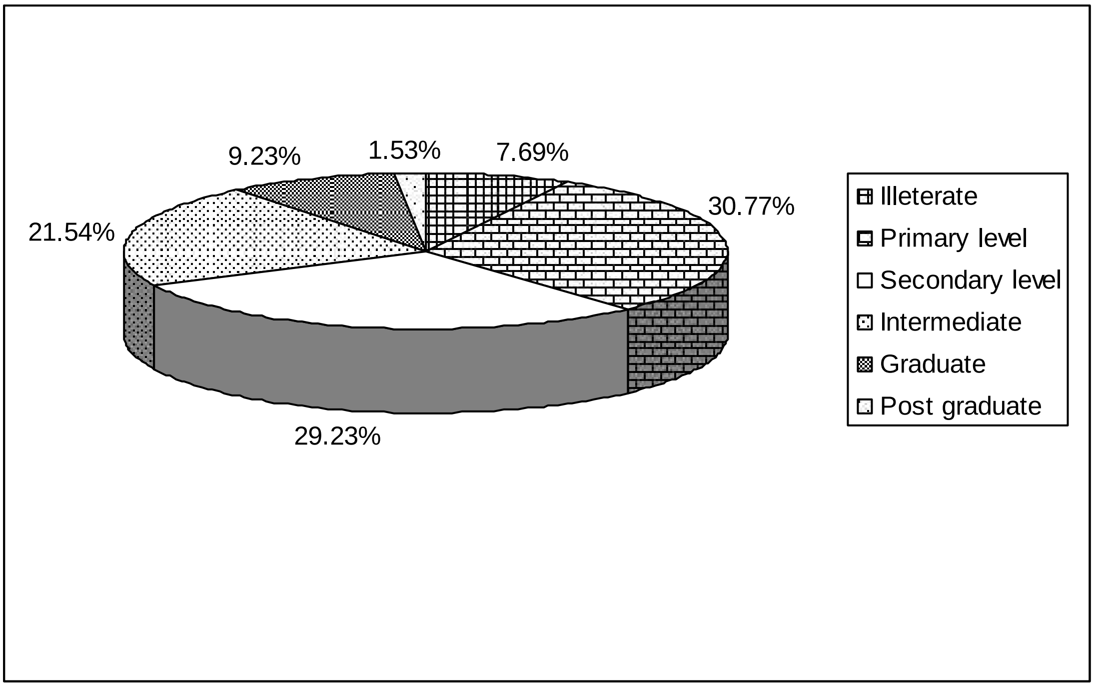



**Fig. 17: Respondent classification according to education**

### 5.8.3 Local people's dependency and management of lake

From the time immemorial, Rupa lake was not under any institution/ committee/organization. Most part of the lake lies in Lekhnath Municipality while north-western outskirt touches the boundary of Rupakot Village Development Committee. Both of these communities are claiming for the authority of this lake. In December, 2001, a community based committee called "Rupatal conservation fishery community" have been established to mitigate further deterioration of the lake. The community is now authorized by District Development Committee, Kaski under Self Governance Act, 2005 B.S. This community comprising local stakeholders is responsible for conservation and utilization of lake resources. Technical, equipmental and other necessary supports are provided by Fisheries Research Centre (FRC) Pokhara under NARC. The community is authorized for marketing and monitoring of captured fish.

Decisions on natural resource management are highly influenced by the perception and attitude of the local people. Majority of respondents argues that sedimentation, lack of awareness and agricultural runoff are the major causes behind lake deterioration. They perceive that unabatement of these attributes in timely could lead the lake in verge disappearance, in very near future. Other opines that soil excavation by construction of road, settlements and grazing in the lake periphery only add woes to the natural heritage.

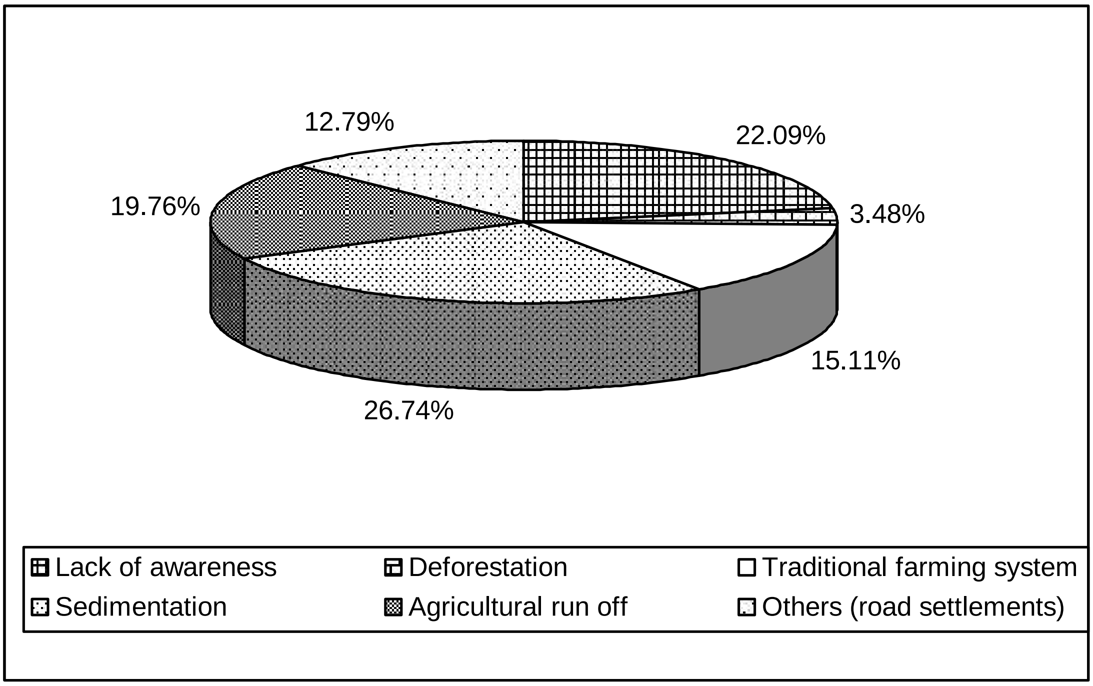



**Fig. 18: Activities influencing deterioration of lake Rupa**

Majority of respondents did not depend directly on wetland resource for earning livelihood. Only a small number of people have privilege to earn livelihood by catching fish in the lake.

Majority of respondents (51) are in ecstasy mood to tell fish culture as the best benefit achieved from the lake (fig.19). Only a few people in the watershed area were found to be dependent on vegetation resources of the lake for fodder. Some people use rhizome and petiole of *Nelumbo nucifera* for medicinal purpose and fruits of *Trapa* spp. as food. Other opines that irrigating their farmland is the best benefit they achieved from the lake.

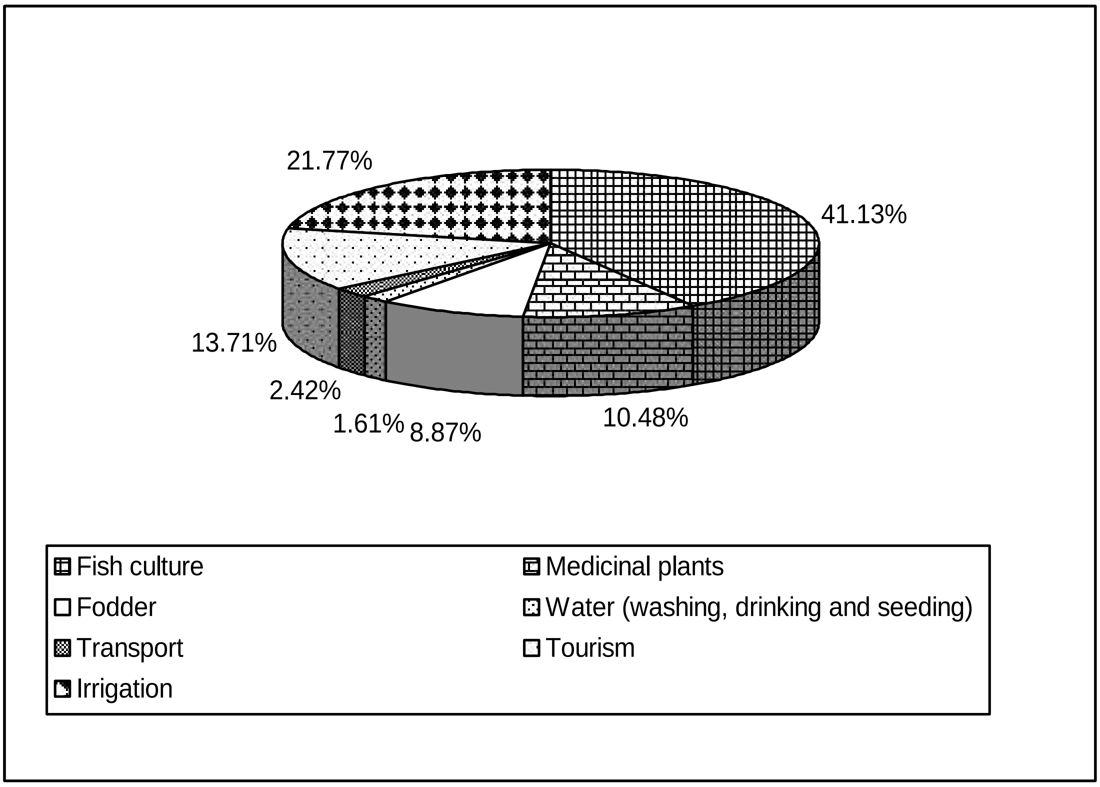



**Fig. 19: Benefits accrued from the lake**

### 5.8.4 Awareness toward sustainable Management of lake

In the past due to inadequate technical and institutional capacity, information base and awareness among local people residing in watershed area of lake, management of wetland biodiversity.

By then, local people even can't endure to listen management plans and are totally ignorant towards its conservation and management. Now with the burgeoning number of conservation oriented community groups and wetland specific interested groups people have become more conscious and responsible toward wetland values and issues. The awareness campaign and lake management and conservation education disseminated by local NGOs like, LI-BIRD, SORUP-Nepal, Seed foundation and IUCN (The World Conservation Union) has tremendously contributed in boosting of existing knowledge on wetland values, capacity and incentives. Today, they are open-hearted to provide any type of assistance for the well being of their Natural capital and more importantly, they are rooting for big development funds so that lake Rupa could be an undisputed first-choice ecotouristic destination.

## 5.9 Economic values of aquatic macrophytes

With regard to valuation of aquatic macrophytes in terms of economic uses and ecological functions, most weeds posses beneficial aspects and a few have nuisance potential (Appendix 5). From the study it was envisaged that higher number of aquatic plants constitute food values to fishes, water birds, fauna and humans. The rhizome, petiole and seeds of *Nelumbo nucifera* and fruits of *Trapa* are used as food and medicine. Species like *Eichornia crassipes*, and *Artemisia vulgaris* also possess medicinal potential. Many emergent grass and sedges are used as fodder to animal. Leaves of *Hydrilla verticillata* and *Leersia hexandra* (cut grass) are applied as fish food item. Some species used as bio-fertilizer are viz.: *Azolla imbricata*, *Eichornia crassipes, Ceratophyllum demersum* and *Lemna minor*.

# 6. DISCUSSION

In present study, an attempt has been made to study variation in vegetation pattern and limnological parameters of lake in two seasons. Socio-economy of the people residing in areas adjacent to the lake boundary (watershed) area was also studied to identify issues, problems and status about lake management and suggest possible measures for lake conservation.

## 6.1 Vegetation Analysis

In a shallow lake Rupa, open water is limited and almost whole lake area is covered by different species of aquatic macrophytes. In different depth contour of the lake from shoreline to the centre, plant species gradually changes in their abundance patterns in terms of their relative frequency, relative density and relative coverage. Altogether 43 species were recorded during the experimental period. Among the recorded plant species, *Oenathe javanica* was observed only during pre-monsoon period while *Oryza rufipogon*, *Chielanthes bicolar*, *Echinochloa crusgalli*, *Gleichenia dichotoma* and *Oryza sativa* were found only in post-monsoon period. The number of species recorded were less than those recorded by Shrestha (1998). Plant species such as Sagittaria graminea (arrowhead), Pistia stratiotes (water lettuce) and Vallisneria sp. (tape grass) which were previously recorded by Oli (1996) were not observed during the present experimental period. It might be due to change in substrata along the change in biotic and abiotic condition of lake, over-exploitation and removal of these species, their elimination by invasive alien species or their replacement by overgrowth of other species. The number of plant species recorded during the pre monsoon period and post monsoon period were 38 and 40 respectively. Among the four sides of the lake, the highest number of species were represented by Eastern face (30) and western face (29) respectively. It may be due to substrate with fine sediment, rich nutrient content in the soil and low tearing effect of water current. The water depth, substrate texture and turbidity are important interrelated factors affecting the growth and distribution of aquatic plants in a lake Schmid (1965), and Nichols (1992).

The value of importance value index (IVI) is directly related to the distribution and dominance of species in a community. *Leersia hexandra, Trapa quadrispinosa, Trapa bispinosa, Nelumbo nucifera* and *Nymphoides indica* had higher IVI value in both seasons.

Vegetatively propagating species like *Cyanodon dactylon, Centella asiatica* and *Paspalum scrobiculatum* were dominant in dry and open areas. It may be due to their generating parts which continuously get good supplies of nutrients than other species (Dinerstein, 1979).

*Trapa quadrispinosa*, a rooted, floating species is the most dominant macrophyte in the lake. In the lake, *Trapa quadrispinosa* has been found in association with *Ceratophyllum demersum* a submerged species capable of clonal propagation. This findings agrees with the idea of Belavskaya and Serafimovich (1978) who postulated that *Trapa* prefers to associate with other macrophytes capable of clonal propagation.

*Trapa bispinosa*, a rooted floating species was dominant in western fringes of the lake, where the water level is quite higher. The result is supported by the findings of Handoo and Kaul (1982) who postulated that *Trapa bispinosa* is dominant in high water level areas.

Low frequency and coverage value of free floating species like *Azolla imbricata* and *Lemna minor*, as compared to other species might be due to their characteristic preference to still and shallow water with high organic load. Similar result has been expressed by Gopal and Sharma (1990).

*Oryza rufipogan*, a wild relative rice has been found only in marshy area of the eastern fringe at Navo Dhan Conservation area during post-monsoon period. Though Shrestha (1998) observed luxuriant growth of plant in a wide area, during present study it was limited only to one place. It might be due to over exploitation and replacement by other alien species. Its higher dominancy during post monsoon than pre monsoon might be because of abundant organic matter during post monsoon period.

According to Nohara and Tsuchiya (1990) *Nelumbo nucifera* survives and grow well in shallow site than deep water sites. During the experimental period, *Nelumbo nucifera* and *Nymphoides indica* were abundant in south eastern and northern fringes which were comparatively shallower regions of the lake. This could be attributed to their capacity to withstand turbidity and tearing action caused by high water velocity which agrees with the findings of Papastergiadon and Babaloans (1992).

*Ludwigia adscendens* was found to grow luxuriantly in areas where free floating leaves were rare and when temperature and water level is low. Similar findings were reported by Handoo and Kaul (1982).

*Potamogetun crispus*, a submerged species was dominant in areas, where the level of water is high. In high water level with more suspended solids submerged and free floating species grow densely.

The outlet of the lake was choked with dense growth of *Eichornia crassipes*; the worst aquatic weed of the world. But the findings of Shrestha (1998) and Kafle (2000) didnot mention any record of water hyacinth. Water hyacinth was also not recorded by Oli (1996) in Rupa lake. It seems the plant has invaded the lake very recently. It may be due to human interferences which causes cultural eutrophication in the water body. The water hyacinth shows its reciprocal relation with the level of cultural entrophication (Gopal and Sharma, 1990).

The floating mats, which were in sporadic number were found in high sedimentation zone, which indicate the high rate of sedimentation from death and decay of plant bodies.

Observations in different zones of lakes suggest that the species richness (no. of sp/$m^2$) increases from free floating-submerged-emergent forms. This may be attributed to the increase in species richness with decrease in water depth (Grime, 1973; Vander Valk and Davis, 1976, Handoo and Kaul. 1982). According to Grime (1973) species richness declines by competitive exclusion in those land where environmental stress is low and productivity is high. As observed in the present study, the very dense cover of rooted floating species like *Nelumbo nucifera, Nymphoides indica* and *Trapa* spp. exclude other species in the low depth region and shoreline of the lake.

The deep water regions of the lake were either devoid of any plant species or species richness was very low. This may be due to their inability to fix roots rhizome in the substratum. The result agrees with the findings of Miller (1978) who postulated that the growth of emergent form in greater depth require extra energy for reaching surface and if this added energy demand is great enough, plant would be weakened to the point where other environmental factor could be detrimental.

There exists substantial spatial difference in species composition distribution and frequency percentage of aquatic macrophytes in morphometrically and limnologically different opposite shorelines of the lake. This is manifested by higher species richness and frequency percentage in stands belonging to agricultural and urban land use portions inlet, and Jamunkuna (Eastern fringe) having relatively shallow depth and influence of cultural eutrophication in contrast to relatively lower species richness and frequency percentage in shady forested land use area, having more depth and low human impact. This implies habitat preference of aquatic macrophyte species (Nichols 1992) and cumulative impact of multiple environmental and anthropogenic factors.

## 6.2 Physico-chemical characteristics of water

Quality of an aquatic ecosystem is dependent on the physical and chemical qualities of water as well as the biological diversity within the system. Forbes (1913) considered biological parameters to be more dependable in certain ways to chemical determination. Sculthorpe (1967) and Hutchinson (1975) showed that the aquatic macrophytes influence the physico-chemical parameters of littoral and shallow water and correspondingly, the physico-chemical parameters influence the aquatic macrophtye distribution. Hence, the physico-chemical characteristics of water influence the macrophytic productivity in the lake.

Temperature is an important limiting factor of the aquatic ecosystem and a good indicator of water quality. All metabolic and physiological activities are influenced by temperature. A rise in temperature of water accelerates chemical reactions, reduces solubility of gases, amplifies taste and odour and elevates metapolic activities of organisms (Gupta, 2000).

During the present investigation, the average value of water temperature was 22.57°C which ranges from 21.90°C- 22.34°C. The highest value of water temperature was obtained during pre-monsoon period and the lowest value was obtained during post-monsoon period. The lowest water temperature during post monsoon might be due to shallowness of the lake low air temperature and high atmospheric pressure. Similarly the higher value during pre monsoon period might be due to high air temperature and low atmospheric pressure. The present study did not show considerable changes in temperature from previous studies by Nakanishi *et al.* (1984), Rai *et al.* (1996), Fisheries Research Centre, Pokahra (1994, 1998 and 2006), Jones *et al.* (1989), and Kafle (2000).

Temperature shows positive correlation with diversity index (DI) (r = 0.69). Similarly a positive correlation between DI and pH (0.213) and DI and DO (0.182) was obtained. But diversity index is negatively correlated with TN and $PO_4$-P. Temperature is negatively correlated with DO (r = -883, p= 0.01) and pH (r = -0.678).

The pH value of water is the most important factor, which is used in measuring water quality in the chemical and biological systems of natural water. Wetzel (1983) considered that the range of pH of the majority of open lakes were 6-9 and most of these lakes are bicarbonate type and favourable for the aquatic inhabitation.

The value of pH ranged from 5.67-6.29, with an average value of 5.98. Maximum pH value was obtained during pre-monsoon period than the post monsoon period. Similarly, the higher pH value in Southern and Northern site might be due to their existence in the vicinity of agricultural land or by human activities. Lower pH during post monsoon period might be due to the wash out of the chemical fertilizer. The pH value recorded where slightly acidic in nature. The range of pH difference might be attributed to the precipitation of calcium carbonate by the planktons which agrees with the ideas of Zutshi *et al.* (1980) Similar trend was observed by Nakanishi *et al.* (1984), Kafle (2000), FRC (1994 and 2006). According to WHO/UNDP (1988) the tolerance limit of pH for drinking purpose is 6.5 and for irrigation it is 6.5 -

8.4. Hence, the lake water is not suited for irrigation of agricultural land and for drinking purpose. pH is strongly positively correlated with DO (r = 0.820, p = 0.05).

Dissolved oxygen is one of the most important parameter in water quality assessment. Dissolved oxygen depends upon the physico-chemical and biological activities of water bodies. It's presence is essential to maintain the biological life.

During the present study, dissolved oxygen was higher in post monsoon period than the pre monsoon. The lower DO value in the pre monsoon period might be due to higher temperature and low atmospheric pressure which reduces oxygen content in the water. Low DO in pre monsoon might also be attributed to the higher water temperature and vigorous decomposition of organic matter in warm temperature as suggested by Badge and Verma (1985). Besides, lower DO value in pre monsoon might also due to higher photosynthetic activity of phytoplanktons. Higher value during winter period might due to the cooling of water. Similar results were obtained by Rai *et al.* (1996), Kafle (2000) and FRC (2006) in Rupa lake. But, the present DO value was lower than the DO value obtained for Phewa, Begnas and Rupa lake by (FRC, 1994) and Jagdishpur reservoir by Chaudhary (2007). The higher 'DO' value of water in the inlet of lake might be due to its flowing nature. The lowest 'DO' value in western and southern site during post monsoon and pre monsoon period might be attributed to the organic pollution, influx of inorganic nutrients from adjacent agricultural land or higher temp. of water.

A low concentration of DO in an aquatic ecosystem indicates organic pollution of water quality. Tolerance limit of DO is not less than 6mg/l (Kudesia, 1985). In general fish thrive best at DO greater than 7mg/l but happens anoxia if DO level is reduced to 2mg/l in mid hill lakes (Gyawali, 1998). The value of DO during the present investigation reveals quite satisfactory result for the growth of aquatic fauna.

DO is positively correlated with pH (0.820, p = 0.05). But it is negatively correlated with TN (-0.877, p = 0.01) and $PO_4$-P (r = -0.958, p = 0.01).

Phosphorus as $PO_4$-P occur in natural and waste water as inorganic and organically bound phosphate. Higher concentration of phosphorus in the lake stimulates the growth of aquatic flora which finally leads to eutrophication. The chief source of phosphorus in the lake is pollutants carried out to the lake by rain water from surrounding agricultural land.

During the present investigation the higher value of $PO_4$-P in pre monsoon period (0.005) might be attributed to the rapid bacteria metabolism and decomposition of organic matter, disintegration and leaching of phosphate rocks and soil due to high temperature, surface run off from adjacent agricultural land, death and decay of flora and fauna. Similarly, the higher value might also be due to the high concentration of zooplankton excreta and higher human activities also. The lower value of $PO_4$-P during post monsoon period might be due to biological uptake or explosive growth of algae. Similarly, lower value might be attributed to the insignificant amount of 'P' carried out by rain water and washout of phosphorus from the lake similar result was obtained by Kafle (2000) and FRC (2006). $PO_4$-P is positively correlated with temperature (0.939, $p= 0.01$). The concentration of $PO_4$-P clearly suggests its eutrophic nature, which agrees with the findings of Fisheries Research Centre (1994, 2006) and Kafle (2000) in Rupa lake. The present was much lower than the $PO_4$-P value obtained by Simkhanda (2003) in Gaindahawa lake. It may be due to difference in lake geomorphology and altitude from sea level. However, the present $PO_4$-P value resembles close with the findings of Adhikari (2002) in lake Khaste and Dipang of Pokhra.

Nitrogen occurs in the aquatic system both as a result of the bacterial oxidation of atmospheric nitrogen and from the decomposition of organic matter in the watershed (Lind, 1974). Nitrogen-nitrite is an intermediate oxidation state of nitrogen formed during the process of decomposition of organic materials. This nitrites are rapidly and easily converted organic materials. nitrite appears in water chiefly as a result of biochemical oxidation of ammonia or reduction of nitrate. Nitrogen-ammonia is produced largely by de-amination of nitrogenic compounds and hydrolysis of urea. The N-ammonia present in aquatic system mainly as $NH4^+$.

The total nitrogen value ranges from 0.108 to 0.184 in lake Rupa. The higher total nitrogen value in the pre monsoon period might be due to the higher microbial activity and excretory products of aquatic animals. However, the minimum value during the post monsoon period might be attributed to the greater washout of nitrogen from the lake, storage by aquatic macrophytes or less microbial activity due to fall in temperature. The TN value resembles close with the value obtained by Kafle (2000) in Phewa and Rupa lake and Adhikari (2002) in lake Khaste and Dipang of Pokhara valley. But the present TN value is much lower than the TN value obtained by Simkhanda (2003) in Gaindahawa lake and Chaudhary (2007) in Jagdishpur reservoir. Total nitrogen shows strong positive correlation with $PO_4$-P (r = 0.747, p = 0.05).

As described in Foresberg and Ryding (1980) lake Rupa can be categorized as eutrophic based on $PO_4$-P. Similar result was demonstrated by Fisheries Research Centre (FRC, 1994, 2006) and Rai *et al.* 1996 on lake Rupa.

### 6.3 Productivity estimation of aquatic macrophytes

In the present study, an attempt has been made to record the seasonal variation in biomass in different sides of the lake.

The dry weight value of aquatic macrophytes ranges from 27.25g/m$^2$ to 389.25g/m$^2$ throughout the experimental period. The maximum dry weight value during the post monsoon and pre monsoon period was 389.25g/m$^2$ and 228.28g/m$^2$ respectively. Similar results were demonstrated by Sankhala and Vyas (1982), in moist bank community of Bangela tank in Udaipur, India, in which they recorded maximum biomass (315.8g/m$^2$) in October and minimum in April (132g/m$^2$). Similar trend of biomass production was also recorded by Handoo and Kaul (1978) in Kashmir lakes, India, and Acharya (1996) in Ghodaghodi tal, Nepal. But, their value was quite higher than the present obtained value in Rupa lake. The differences in the biomass of present study and the above ones may be due to the differences in species composition, lake morphometry and geology. The major cause of macrophytic growth in the lake could be attributed to the large amount of influx of fertilizers from the adjoining cultivated land, and surface run off which brings large amount of litter from the catchment areas having dense forest. Highest biomass in the post monsoon period might be due to the phenology of plants; in which majority of plants start blooming in spring, takes rapid growth in rainy season and again ceases growth vigour with the advent of chilling winter. Conversely, high water and atmospheric temperature coupled with low water level, which adversely affected the growth and biomass of plants may be the reason behind low dry weight value in pre-monsoon period.

Shallower areas near the shoreline were found to be more productive than the deeper zone of the lake. According to growth form, highest biomass was recorded for emergent species (251.16g/$m^2$), followed by rooted floating (104.76g/$m^2$) and submerged species (48.39g/$m^2$). The result agrees with the idea of Sharma (1995) in Kawar lake, India, and Whittaker and Likens (1975), who stated that emergent macrophyte of littoral wetlands in the shore regions of lakes are among the most productive habitat of biosphere.

The highest biomass value recorded by the emergents might be due to their high photosynthetic rate because of exposed condition in fertile soil and better utilization of nutrients. Moisture content is also higher in marshy and terrestrial habitat along the shoreline which might be another reason behind high productivity. The low productivity of submerged species can be attributed to their lower photosynthetic rate because of their incapability to utilize incident solar radiation coupled with other detrimental environmental condition.

The highest average biomass in the eastern, side of the lake (151.16g/$m^2$) might be due to high nutrient value, that might have leached from the surrounding agricultural land and human disturbances. This is the area of lake where local people frequently cut grass as a fodder.

Biomass is strongly positively correlated with pH ($r = 0.960$, $p = 0.01$) and DO ($r = 930$, $p = 0.01$). But it is negatively correlated with total nitrogen ($r = 0.855$, $p = 0.01$) and $PO_4$-P ($r = -0.853$, $r = 0.01$). Kafle (2000) also obtained negative correlation between biomass and total nitrogen in lake Phewa and Rupa.

## 6.4 Soil Attributes

Soil acidity is associated with the presence of hydrogen and aluminum ions on the exchange complex and the existence of an equilibrium solution of hydrogen ions in the interstial water of soil.

The average pH of the study area was found to be 6.15 which was slightly acidic in nature. The fluctuation of pH values may be due to variation of microbial activity in different season. The occurrence of low pH in pre monsoon season might be due to the high microbial activity causing release of fulvic acid compounds, thereby lowering pH value. The value obtained contradicts with the idea of Vezina (1965) who postulated that pH of soil increases in midsummer and decreases with the onset of winter. But, the value obtained was comparable to the result of Tamot (1998) in Shivapuri watershed area and Gurau (2004) in Bandarjula Island of Chitwan National Park. Regarding the sampling site, the lowest pH in outlet east forest might be due to the high microbial activity of soil organisms on the accumulated leaf litter, releasing acidic compounds which drops the pH value. Similarly, highest pH value in inlet area might be attributed to the deposition of inorganic ions from the adjacent agricultural land and lower microbial activity. Besides, there is higher human and animal activities which might have caused rise in pH value.

Organic matter is the chief source of mineral's return to soil. It represents the equilibrium between input, originating from primary photosynthetic production, and the degradative and resynthetic processes associated with soil organisms Sharma (2004). Organic matter to soil is contributed by surface living plants and animals as well as by micro and macro-organisms living in the soil. Rickard (1967) showed that higher soil moisture content in winter was due to the decrease in transpiration loss by plants, which thereby accounts for greater Nitrogen and organic matter value. Thus, higher organic matter in post-monsoon period might be due to the effect of temperature and rainfall which mineralize the accumulated litter before the advent of winter reason. Similarly, higher organic matter (%) in outlet east forest area might be due to the greater rate of humus formation and its accumulation governed by higher microbial activity in decomposition of leaf litter and other remains of animals and plants. The higher organic matter content (%) might also be due to the suitable temperature, higher moisture, and aeration of soil.

The least value of OM (%) in the inlet area might be due to the incomplete mineralization of litter owing to retarded microbial activity. Further, there is meager accumulation of leaf litter; a chief source of mineral's return to the soil. The active growth of perennial grasses, and the representation of sampled area as a grassland which gets seasonally inundated and frequently washed, might be the another cause of low organic mater content.

Nitrogen content was found higher in post-monsoon period than the pre-monsoon. As the content of organic matter in the soil increase the content of Nitrogen also increases proportionality (Foth, 1984). The higher nitrogen content in post monsoon period might be due to the deposition of soil nitrogen by nodulus bacteria, higher soil organic matter content and higher microbial activity. Lower nitrogen in pre monsoon period might be due to the uptake and incorporation of minerals by plants due to active growing period, which agrees with the idea of Larcher (1995). Burke (1989) found that both soil microclimate and organic matter quality control nitrogen turnover, with soil microclimate limiting mineralization to a short season in early spring and summer. Therefore, the highest N(%) of outlet east forest soil might be due to the higher microbial activity accompanied by greater accumulation of leaf litter, higher moisture due to close canopy and good aeration. Similar result was obtained by Gurau (2004) in Bandarjula Island of Chitwan National Park and Tamot (1998) in Shivapuri watershed area. Least nitrogen in inlet area might be due to low microbial activity, less litter and direct exposure to sunlight which triggers oxidation of nitrogenous compounds.

## 6.5 Socio-economy and Environmental Management

Socio-economy of the people residing in lake periphery area revealed that the most dominant population groups are Brahmins, Chhetris and Gurungs. Majority of them have migrated from upland areas since a long time for better life and amenities. People with medium economic status mostly served in government jobs and some hold their own business. The poor and oppressed group of people have small land holdings, so they have no alternative other than to serve as a labor. Although the local people are not directly dependent upon the lake resources for their livelihood they confess that the ecological values and other opportunities provided by the lake is beyond their expectations. In the present study though the livelihood of local communities did not depend directly on lake resource for earning livelihood they are indirectly blessed  with the services provided by the lake. A small number of people have earned their livelihood by getting employment as expert fisherman. The oppressed groups like Jalahari, earn substantial amount by boating. Similarly, few households in the lake periphery area cut grass as a fodder from the sedimentation zone of lake. Contrary to the past, locals have witnessed that they see fewer no. of water fowls and aquatic fauna in these days. They attribute the cause to be fluctuation in water depth, shrinkage in lake area, human disturbances and more importantly, decrease in vegetation cover.

Particular attention should be paid to wetland use which combines both traditional and new uses including partial restoration, agro ecology and ecotourism (Smardon, 2006). During the socio-economic survey the local people opine that though the lake has enough potentiality to attract naturalists, trekkers, tourists and researchers, till now the potentiality has not been exploited and no foundation stone has been laid. They opined that for years safe guarding and developing Rupa lake has remain on paper not on task. Most of them, revealed their frustration and wrath the way developing agencies and government concentrating only in lake Phewa and Begnas ignoring the apathy of their natural heritage.

The sustainable management of wetland flora demands detailed understanding of species composition, distribution patterns, succession trends, productivity and monetary and non-monetary values (Shrestha, 1993). According to the local people, siltation, eutrophication, agricultural runoff and lake area encroachment are the formidable challenges faced by the lake for its sustainable development. They opined that if these arduous challenges are not resolved on time, lake management and conservation difficulty reach to a new level. Now it's the time for development agencies and conservation oriented epistemic communities to turn the "vicious circle" of lake deteriorating factors like; sedimentation, agricultural runoff, cultural eutrophilation and encroachment into a "virtuous one" by implementing coherent and coordinated institutional framework.

Majority of people residing in lake periphery argues that they have nothing to do with the lake management and are unaware of deteriorating condition of the lake. Bhandari (1998) suggested some conservation actions for sustainable management which include; preparation of community based management plan, community awareness and establishment of a conservation education centre. Therefore the appropriate local NGOs/INGOs and the government working for the welfare of lake should vigorously pursue rural non farm employment opportunities to poor and marginalized communities, only then the unabated lake deteriaration could be arrested.

Further, the local people dependent on wetlands and other people residing in watershed area are important partners in designing appropriate conservation actions. So, while designing and drafting management measures, the traditional and indigenous knowledge they possess should be fabricated.

### 6.6 Economic values of Aquatic macrophytes

Aquatic weeds encountered in the lake have different economic and ecological values. Most of them are beneficial while some impart adverse impacts too. This indicates the prospect of conservation of aquatic plants through utilization by local communities residing in lake periphery. The fruits of *Trapa* spp., rhizome, petiole and fruits of *Nelumbo nucifera* are used as human food as well as medicine (Sculthorpe, 1967 and Chatterjee *et al.* 1999). Aquatic plants like; *Eichornia crassipes, Lemna minor, Potamogeton* spp. *Trapa quadrispinosa, Ceratophyllum demersum* are used as fish food (Singh 1967). *Azolla imbricata, Lemna minor, Eichornia crassipes* are good fertilizer. (Basak, 1948). Fruits of *Potamogetun* spp. are a good source of food for water bird and the members of *Poaceae* and *Cyperaceae* family like, *Cyperus* spp., *Lerrisa hexandra. Oenathe javaninca* are used as fodder (Chatterjee *et al.* 1999 and Pirie, 1970). *Ludwigia adscendens* and *Nymphoides indicum* provide shelter for invertebrates.

Despite their huge economic and ecological services, dense mats of *Nelumbo nucifera, Nymphodies indica* and *Trapa* spp. are not only impending to boating but also loss in recreational value of lake.

# 7. CONCLUSION

Present study was carried out in Rupa lake of Pokhara valley to investigate physio-chemical parameters of water quality, floristic composition, productivity of aquatic macrophytes by harvest method and socio-economic of people, residing in the watershed area.

Altogether 43 species of aquatic macrophytes were recorded during the experimental period which belongs to 26 family and 40 genera. The study showed that *Nelumbo nucifera, Trapa quadrispinosa, Trapa bispinosa, Leersia hexandra* and *Ceratrphyllum demersum* were the most dominant species of the lake having high IVI value. By growth form, highest number of species was represented by emergents, followed by submerged and rooted floating species and lowest number of species was represented by free floating forms. This implies higher number of halophytes and prevalence of marshy habitat condition owing to shallowness of the lake.

Vegetation distribution pattern of the lake was found to be influenced by limnological parameters. The limnological study revealed the lake to be eutropic in nature, which was well supported by luxuriant growth of aquatic macrophytes. Biomass estimation of aquatic macrophytes revealed that with the increasing depth contour of the lake from shore to the centre, biomass decreases progressively and the highest and lowest productive region of the lake was represented by the emergent and submerged zone respectively. Socio-economic status of people residing in watershed area gave information about their conservation attitude, management constraints, awareness and dependency on wetland resources. From the study, it was envisaged that the grass root cause of lake deterioration include sedimentation, agricultural runoff and eutrophication. Though there have been substantial effort towards lake conservation and management the above imposing factors are always hindering to achieve a stupendous feat.

## 8. RECOMMENDATIONS

In order to conserve and exploit full potentially from the lake following recommendations should be seriously taken:

- Fluctuation in microphyte biomass with respect to limnological parameter should be carried out in each month (if possible).
- The awareness programme about the importance of biodiversity of Rupa lake should be given to local people.
- The lake area should be permanently demarcated in order to protect the lake from further encroachment.
- Heavy inflow of silt or sediments from the feeder stream towards the lake (mainly in the inlet) should be checked by constructing check dam, cage or other means.

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## Appendix 1

## Vegetation Composition of two season in different sides of the lake

| S.N. | Name of Species | Pre monsoon | | | | Post Monsoon | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | W | S | N | E | W | S | N | E |
| 1 | *Adenostemum angustifolium* | – | – | – | + | – | – | – | + |
| 2 | *Ageratum cornizoides* L. | + | + | + | + | + | + | + | + |
| 3 | *Artimisia velgaris* | – | – | – | + | – | – | – | + |
| 4 | *Azolla imbricata* (Roxb.) Nakai | + | – | + | + | + | – | + | + |
| 5 | *Bidens pilosa* L. | + | + | + | + | + | + | + | + |
| 6 | *Centella asiatica* (L.) Urban | + | + | + | – | + | + | + | – |
| 7 | *Ceratophyllum demersum* L. | + | + | + | + | + | + | + | + |
| 8 | *Chara vulgaris* | – | + | | – | – | + | + | – |
| 9 | *Chielanthes bicolar* | – | – | – | – | – | – | – | + |
| 10 | *Commelina paludosa* Blume | – | – | + | – | – | – | + | – |
| 11 | *Conyza bonariensis* | – | – | – | + | – | – | – | + |
| 12 | *Cyanodon dactylon* (L.) Pers. | + | + | + | + | + | + | + | – |
| 13 | *Cynoglossum* | – | – | – | + | – | – | – | + |
| 14 | *Cyperus haspan* L. | + | + | + | + | + | + | + | + |
| 15 | *Echinochloa crusgalli* (L.) P. Beauv | – | – | – | – | – | + | – | – |
| 16 | *Eichornia crassipes* (Mort.) | – | – | + | – | – | – | – | – |
| 17 | *Eleocharis congesta* D. Don | + | – | – | – | + | – | – | – |
| 18 | *Eriocaulon nepalense* prescot ex bong | – | – | – | + | – | – | – | + |
| 19 | *Floscarpa scandens* Lour. | + | + | + | + | + | + | + | + |
| 20 | *Gleichenia dichotuma* | | | | | + | | | |
| 21 | *Hydrilla verticillata* (L.F.) Royle | + | + | + | + | + | + | + | + |
| 22 | *Isachne globosa* (Thumb) Kuntze. Rev. Gen. | – | – | – | + | – | – | – | + |
| 23 | *Leersia hexandra* (Swartz) | – | – | – | – | + | – | – | – |
| 24 | *Lemna minor* L. | + | + | + | + | + | + | + | + |
| 25 | *Lindernia* sp. | + | + | + | + | + | + | + | + |
| 26 | *Ludwigia adscendens* (L.) Hara | + | – | + | + | + | – | + | + |
| 27 | *Mimosa pudica* L. | – | – | – | + | – | – | – | + |
| 28 | *Nelumbo nucifera* Gaerth | + | + | + | + | + | + | + | + |
| 29 | *Nymphea* sp. | + | + | + | + | + | + | + | + |
| 30 | *Nymphoides indica* (L.) Kuntze | + | + | + | + | + | + | + | + |
| 31 | *Oenathe javanica* (Blume) DC | – | – | + | – | – | – | – | – |
| 32 | *Oryza rufipogon* Griff. Notul | – | – | – | – | – | – | – | + |
| 33 | *Oryza sativa* | – | – | – | – | – | + | – | – |
| 34 | *Oxalis corniculata* L. | – | + | – | – | – | + | – | – |
| 35 | *Paspalum scrobiculatum* L. | + | – | + | – | – | – | + | – |
| 36 | *Persicaria barbata* (L.) Hara | + | + | + | + | + | + | + | + |
| 37 | *Persicaria hydropiper* | + | + | + | + | + | + | + | + |
| 38 | *Potamogetun crispus* L. | + | + | + | + | + | + | + | + |
| 39 | *Rotala rotundifolia* (Buch. Ham. ex. Roxb.) Koehne | + | + | + | + | + | + | + | + |
| 40 | *Trapa bispinosa* (Roxb.) | + | – | – | + | + | – | + | + |
| 41 | *Trapa quadrispinasa* Roxb. Fl. Ind (Roxburgh) | – | – | + | + | – | – | + | + |
| 42 | *Typha anguistifolium* | + | – | + | – | + | – | + | – |
| 43 | *Utricularia australis* R. Brum. | + | + | – | + | | + | – | + |

**Quantitative Analysis of aquatic macrophytes during Post-monsoon period in four side (North, West, East and South) of the lake.**

**Side: North** **Season: Post monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Hydrilla verticillata* | 4.30 | 4.69 | 2.10 | 11.69 |
| *Chara* | 4.30 | 1.54 | 1.36 | 7.20 |
| *Potamogeton crispus* | 4.30 | 3.07 | 3.60 | 10.97 |
| *Ceratophyllum demersum* | 3.22 | 2.49 | 2.70 | 8.41 |
| **Free-floating species** | | | | |
| *Azolla imbricata* | 2.15 | 0.54 | 0.30 | 2.99 |
| *Lemna minor* | 5.38 | 0.81 | 0.75 | 6.94 |
| **Rooted floating species** | | | | |
| *Nelumbo nucifera* | 2.15 | 0.19 | 7.50 | 9.84 |
| *Nymphoides indica* | 8.60 | 1.08 | 16.96 | 26.34 |
| *Trapa bispinosa* | 1.07 | 0.07 | 2.26 | 3.4 |
| *Trapa quadrispionsa* | 6.45 | 0.88 | 30.82 | 38.25 |
| *Nymphaea* | 7.53 | 0.96 | 6.30 | 14.79 |
| **Emergent species** | | | | |
| *Leersia hexandra* | 6.45 | 27.57 | 8.10 | 42.12 |
| *Lindernia* sp. | 4.30 | 19.15 | 2.86 | 26.31 |
| *Ludwigia adscendens* | 4.30 | 1.38 | 1.36 | 7.04 |
| *Echinochloa crusgalli* | 4.30 | 1.92 | 2.10 | 8.32 |
| *Cyperus haspan* | 4.30 | 1.23 | 0.60 | 6.13 |
| *Rotala rotundifolia* | 4.30 | 17.26 | 3.60 | 25.16 |
| *Persicaria barabata* | 4.30 | 2.84 | 2.10 | 9.24 |
| *Typha angustifolia* | 3.22 | 4.49 | 1.96 | 9.67 |
| *Paspalum scrobiculatum* | 2.15 | 0.69 | 0.30 | 3.14 |
| *Centella asiatica* | | | | |
| *Bidens pilosa* | 2.15 | 1.04 | 0.30 | 3.49 |
| *Ageratum cornyzoides* | 2.15 | 0.61 | 0.30 | 3.06 |
| *Commelina paludosa* | 2.15 | 1.99 | 0.30 | 4.44 |
| *Cyonodon dactylon* | 2.15 | 1.99 | 0.30 | 4.44 |
| *Persicaria hydropiper* | 4.30 | 1.46 | 1.03 | 6.82 |

**Side: West** **Season: Post monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Hydrilla verticillata* | 4.11 | 4.97 | 2.60 | 11.68 |
| *Utricularia australis* | 4.1 | 2.32 | 1.16 | 7.59 |
| *Potamogeton crispus* | 5.48 | 5.69 | 2.76 | 13.93 |
| *Ceratophyllum demersum* | 5.48 | 6.62 | 3.47 | 15.57 |
| **Free-floating species** | | | | |
| *Azolla imbricata* | 1.37 | 2.05 | 0.15 | 3.57 |
| *Lemna minor* | 5.48 | 1.98 | 0.58 | 8.04 |
| **Rooted-floating species** | | | | |
| *Nelumbo nucifera* | 2.74 | 0.26 | 7.24 | 10.24 |
| *Trapa bispinosa* | 10.96 | 1.79 | 41.14 | 53.97 |
| *Nymphoides indica* | 10.96 | 2.05 | 17.96 | 30.97 |
| *Nymphaea* | 5.59 | 1.52 | 8.69 | 15.8 |
| **Emergent species** | | | | |
| *Leersia hexandra* | 5.48 | 28.74 | 4.79 | 39.01 |
| *Lindernia* sp. | 2.74 | 11.12 | 1.74 | 15.6 |
| *Ludwigia adscendens* | 5.48 | 2.78 | 0.58 | 8.84 |
| *Cyperus haspan* | 4.11 | 1.92 | 0.44 | 6.47 |
| *Cyanodon dactylon* | 1.37 | 2.98 | 0.86 | 5.21 |
| *Eleocharis congesta* | 2.74 | 0.79 | 0.28 | 3.81 |
| *Rotala rotondifolia* | 2.74 | 1.26 | 1.74 | 15.74 |
| *Typha angustifolia* | 1.37 | 0.52 | 0.28 | 2.17 |
| *Persicaria barbata* | 5.48 | 5.16 | 2.03 | 12.67 |
| *Ageratum cornyzoides* | 1.37 | 0.99 | 0.15 | 2.51 |
| *Bidens pilosa* | 1.37 | 1.12 | 0.15 | 2.62 |
| *Paspalum scrobiculatum* | 1.37 | 1.12 | 0.15 | 2.64 |
| *Persicaria hydropiper* | 2.74 | 2.05 | 0.86 | 5.54 |
| *Gleichenia dichotoma* | 1.37 | 0.13 | 0.15 | 1.65 |

**Side: East** **Season: Post monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Hydrilla verticillata* | 4.49 | 7.17 | 3.11 | 14.77 |
| *Utricularia australis* | 3.37 | 2.00 | 2.34 | 7.71 |
| *Potamogeton crispus* | 4.49 | 4.86 | 3.11 | 12.46 |
| *Ceratophyllum demersum* | 4.49 | 6.32 | 3.11 | 13.92 |
| **Free-floating species** | | | | |
| *Azolla imbricata* | 1.12 | 1.76 | 0.13 | 3.01 |
| *Lemna minor* | 4.49 | 1.09 | 0.51 | 6.09 |
| **Rooted-floating species** | | | | |
| *Nelumbo nucifera* | 4.49 | 0.36 | 12.98 | 17.83 |
| *Nymphoides indica* | 8.99 | 2.61 | 13.62 | 25.22 |
| *Trapa quadrispinosa* | 7.86 | 1.46 | 31.80 | 41.12 |
| *Trapa bispinosa* | 1.12 | 0.12 | 1.95 | 3.19 |
| *Nymphaea* sp. | 6.74 | 1.39 | 4.67 | 12.8 |
| **Emergent species** | | | | |
| *Leersia hexandra* | 5.62 | 31.47 | 7.40 | 44.49 |
| *Lindernia sp.* | 1.12 | 7.23 | 0.77 | 9.12 |
| *Ludwigia adscendens* | 4.49 | 2.19 | 1.17 | 7.85 |
| *Cyanodon dactylon* | 3.37 | 8.20 | 1.69 | 13.26 |
| *Cyperus haspan* | 3.37 | 1.82 | 0.39 | 5.58 |
| *Mimosa pudica* | 1.12 | 0.06 | 0.77 | 1.95 |
| *Artimisia vulgaris* | 1.12 | 0.12 | 0.77 | 2.01 |
| *Persicaria barbata* | 4.49 | 4.68 | 2.47 | 11.64 |
| *Ageratum cornyzoides* | 2.25 | 1.21 | 0.91 | 4.37 |
| *Bidens pilosa* | 2.25 | 1.46 | 0.26 | 3.97 |
| *Persicaria hydropiper* | 3.37 | 1.64 | 1.69 | 6.7 |
| *Cynoglassum* | 3.37 | 2.37 | 0.39 | 6.13 |
| *Conyza* | 3.37 | 2.25 | 0.39 | 6.01 |
| *Eriocaulon nepalense* | 2.25 | 1.2 | 0.26 | 3.72 |
| *Oryza rufipogon* | 3.37 | 2.98 | 2.85 | 9.20 |
| *Cheilanthes bicolar* | 1.12 | 0.18 | 0.13 | 1.43 |
| *Adenostemum anguistifolia* | 2.25 | 1.76 | 0.26 | 4.27 |

**Side: South** **Season: Post monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Hydrilla verticillata* | 3.79 | 4.55 | 2.06 | 10.4 |
| *Potamogeton crispus* | 2.53 | 1.76 | 1.89 | 6.18 |
| *Utricularia australis* | 2.53 | 0.77 | 0.32 | 3.62 |
| *Chara* | 2.53 | 0.82 | 0.32 | 3.67 |
| *Ceratophyllum demersum* | 6.33 | 5.71 | 3.79 | 15.83 |
| **Free-floating species** | | | | |
| *Lemna minor* | 7.59 | 1.49 | 0.95 | 10.03 |
| **Rooted-floating species** | | | | |
| *Nelumbo nucifera* | 16.45 | 2.45 | 55.49 | 74.39 |
| *Nymphoides indica* | 12.6 | 3.13 | 12.33 | 28.12 |
| *Nymphaea* | 10.13 | 1.97 | 7.59 | 19.69 |
| **Emergent species** | | | | |
| *Leersia hexandra* | 5.06 | 27.99 | 6.64 | 39.69 |
| *Persicaria barbata* | 3.79 | 3.13 | 2.06 | 8.98 |
| *Ludwigia adseendens* | 3.79 | 2.24 | 0.48 | 6.51 |
| *Lindernia sp.* | 2.53 | 13.59 | 1.11 | 17.23 |
| *Cyperus haspan* | 5.06 | 2.44 | 0.48 | 7.98 |
| *Rotala rotundifolia* | 5.06 | 21.19 | 2.21 | 28.46 |
| *Oryza sativa* | 1.26 | 0.33 | 0.16 | 1.75 |
| *Centella asiatica* | 1.26 | 0.88 | 0.16 | 2.30 |
| *Ageratum cornyzoides* | 1.26 | 0.61 | 0.16 | 2.63 |
| *Bidens pilosa* | 1.26 | 0.75 | 0.16 | 2.17 |
| *Persicaria hydropiper* | 3.79 | 2.78 | 1.43 | 8.00 |
| *Oxalis corniculata* | 1.26 | 1.42 | 0.16 | 2.84 |

**Quantitative Analysis of aquatic macrophytes during Pre-monsoon period in four side (North, West, East and South) of the lake.**

**Side: North** **Season: Pre-monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Hydrilla verticillata* | 3.09 | 3.78 | 2.11 | 8.90 |
| *Ceratophyllum demersum* | 4.12 | 4.00 | 3.88 | 12.00 |
| *Potamogeton crispus* | 4.12 | 3.22 | 2.26 | 9.60 |
| *Chara* | 3.02 | 1.17 | 0.49 | 4.75 |
| **Rooted floating species** | | | | |
| *Trapa quadrispinosa* | 6.18 | 1.22 | 36.24 | 43.64 |
| *Nelombo nucifera* | 4.12 | 0.26 | 9.71 | 14.09 |
| *Nymphoides indica* | 8.25 | 1.74 | 14.24 | 24.23 |
| *Nymphaea* sp. | 0.18 | 1.48 | 8.74 | 16.4 |
| **Free-floating species** | | | | |
| *Azolla imbricata* | 2.06 | 2.44 | 1.14 | 5.64 |
| *Lemna minor* | 4.12 | 1.04 | 0.5 | 5.8 |
| *Eichornia crassipes* | 1.03 | 0.08 | 0.97 | 2.08 |
| **Emergent species** | | | | |
| *Leersia hexandra* | 5.15 | 22.93 | 6.31 | 34.39 |
| *Persicaria* barbata | 4.12 | 2.09 | 3.07 | 9.28 |
| *Lindernia* sp. | 5.15 | 20.32 | 0.80 | 26.27 |
| *Ludwigia adscendens* | 4.12 | 1.57 | 0.64 | 6.33 |
| *Cyanodon dactylon* | 2.06 | 4.35 | 1.14 | 7.55 |
| *Centella asiatica* | 2.06 | 0.69 | 0.32 | 3.07 |
| *Bidens pilosa* | 2.06 | 0.52 | 0.32 | 2.9 |
| *Ageratum cornizoides* | 2.06 | 0.69 | 0.32 | 3.07 |
| *Commelina paludosa* | 4.12 | 1.13 | 0.64 | 5.89 |
| *Oenathe javanica* | 4.12 | 1.65 | 0.64 | 6.41 |
| *Typha angustifolia* | 2.06 | 0.39 | 0.32 | 2.77 |
| *Floscarpa scandens* | 2.06 | 0.96 | 0.32 | 3.34 |
| *Paspalum scrobiculatum* | 2.06 | 1.13 | 0.32 | 3.51 |
| *Rotala rotundifolia* | 4.12 | 17.93 | 3.88 | 25.93 |
| *Cyperus haspan* | 4.12 | 1.52 | 0.64 | 6.28 |
| *Polygonum hydropiper* | 4.12 | 1.65 | 0.64 | 6.41 |

**Side: West** **Season: Pre-monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Hydrilla verticillata* | 3.66 | 2.96 | 1.91 | 8.53 |
| *Chara* | 2.44 | 0.69 | 0.32 | 3.45 |
| *Potamogeton crispus* | 4.88 | 3.75 | 2.05 | 10.68 |
| *Utricularia australis* | 2.44 | 0.79 | 1.03 | 4.26 |
| *Certapophyllum demersum* | 4.88 | 6.22 | 2.78 | 13.88 |
| **Free-floating species** | | | | |
| *Azolla imbricata* | 1.22 | 1.72 | 0.88 | 3.82 |
| *Lemna minor* | 2.44 | 1.33 | 0.32 | 4.09 |
| **Rooted-floating species** | | | | |
| *Nelumbo nucifera* | 2.44 | 0.14 | 4.39 | 6.97 |
| *Nymphoides indica* | 9.76 | 1.77 | 22.10 | 3.63 |
| *Nymphaea* | 7.32 | 1.13 | 8.05 | 16.5 |
| *Trapa bispinusa* | 9.76 | 1.58 | 41.56 | 52.9 |
| **Emergent species** | | | | |
| *Ageratum cornyzoides* | 2.44 | 1.04 | 0.32 | 3.8 |
| *Bidens pilusa* | 2.44 | 0.69 | 0.32 | 3.45 |
| *Eleocharis congesta* | 2.44 | 0.69 | 0.32 | 3.45 |
| *Paspalum scrobiculatum* | 2.44 | 1.77 | 1.03 | 5.24 |
| *Lindernia* sp. | 4.88 | 20.9 | 3.51 | 29.3 |
| *Ludwigia adscendens* | 4.88 | 1.48 | 0.58 | 6.94 |
| *Leersia hexandra* | 4.88 | 22.30 | 2.79 | 29.97 |
| *Cyperus haspan* | 3.6 | 1.53 | 1.17 | 6.36 |
| *Rotala rotundifolia* | 4.88 | 17.27 | 2.05 | 23.9 |
| *Oxalis corniculata* | | | | |
| *Cyanodon dactylon* | 2.44 | 5.08 | 1.03 | 8.55 |
| *Centella asiatica* | 2.44 | 0.79 | 0.32 | 3.55 |
| *Typha angustifolia* | 1.22 | 0.24 | 0.15 | 1.61 |
| *Persicaria barbata* | 4.88 | 2.81 | 0.58 | 8.27 |
| *Persicaria hydropiper* | 4.88 | 1.28 | 0.58 | 6.74 |

**Side: East** **Season: Pre monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Utricularia australis* | 4.21 | 1.92 | 2.09 | 8.22 |
| *Potamogeton crispus* | 4.21 | 3.10 | 1.19 | 8.5 |
| *Hydrilla verticillata* | 4.21 | 5.72 | 2.85 | 12.78 |
| **Free-floating species** | | | | |
| *Azolla imbricata* | 2.10 | 2.99 | 1.79 | 6.88 |
| *Lemna minor* | 3.15 | 0.80 | 0.45 | 4.40 |
| *Ceratophyllum demersum* | 4.21 | 5.13 | 2.09 | 11.43 |
| **Rooted-floating species** | | | | |
| *Nelumbo nucifera* | 2.10 | 0.16 | 4.49 | 6.75 |
| *Nymphoides indica* | 8.42 | 2.24 | 19.93 | 30.59 |
| *Trapa quadrispinosa* | 6.31 | 1.60 | 30.86 | 38.77 |
| *Trapa bispinusa* | 1.05 | 0.05 | 2.25 | 3.35 |
| *Nymphaea* sp. | 7.37 | 1.49 | 8.55 | 17.41 |
| **Emergent species** | | | | |
| *Adenostema anguistifolia* | 2.10 | 1.49 | 0.29 | 3.88 |
| *Leersia hexandra* | 5.26 | 25.77 | 7.19 | 38.22 |
| *Lindernia* sp. | 3.15 | 13.42 | 2.68 | 19.26 |
| *Ludwigia adscendens* | 4.21 | 3.53 | 1.35 | 9.09 |
| *Eriocaulon nepalense* | 2.10 | 0.85 | 1.79 | 4.74 |
| *Mimosa pudica* | 2.10 | 0.21 | 1.05 | 3.36 |
| *Artimisia vulgaris* | 2.10 | 0.16 | 0.29 | 2.55 |
| *Cyanodon dactylon* | 2.10 | 4.49 | 1.05 | 7.64 |
| *Isachne globosa* | 3.15 | 1.98 | 0.45 | 5.58 |
| *Cyperus haspan* | 4.21 | 1.39 | 1.35 | 6.95 |
| *Bidens pilosa* | 2.10 | 1.18 | 0.29 | 3.57 |
| *Ageratum cornyzoides* | 2.10 | 0.85 | 0.29 | 3.24 |
| *Persicaua barbata* | 3.15 | 2.51 | 1.19 | 6.91 |
| *Rotala rotundifolia* | 3.15 | 11.82 | 1.94 | 16.91 |
| *Conyza* | 4.21 | 1.82 | 0.59 | 6.62 |
| *Cynoglossum* | 3.15 | 1.87 | 0.45 | 5.47 |
| *Persicaria hydropiper* | 4.21 | 1.39 | 1.05 | 6.65 |

**Side: South** **Season: Pre monsoon**

| Name of Species | RF | RD | RC | IVI |
|---|---|---|---|---|
| **Submerged species** | | | | |
| *Utricularia australis* | 2.70 | 1.54 | 1.07 | 5.31 |
| *Potamogeton crispus* | 2.70 | 1.72 | 1.07 | 5.49 |
| *Ceratophyllum demersum* | 5.40 | 5.16 | 2.89 | 13.45 |
| *Hydrilla verticillata* | 5.40 | 7.57 | 2.89 | 15.86 |
| *Chara* | 2.70 | 1.03 | 0.30 | 4.03 |
| **Free-floating species** | | | | |
| *Lemna minor* | 6.76 | 1.72 | 0.30 | 8.78 |
| **Rooted-floating species** | | | | |
| *Nelumbo nucifera* | 17.57 | 2.75 | 47.93 | 68.25 |
| *Nymphoides indica* | 12.16 | 2.92 | 22.45 | 37.53 |
| *Nymphaea* sp. | 9.46 | 2.32 | 7.28 | 19.06 |
| **Emergent species** | | | | |
| *Leersia hexandra* | 5.40 | 34.39 | 6.37 | 46.16 |
| *Lindernia* sp. | 2.70 | 11.86 | 1.82 | 16.38 |
| *Ludwigia adscendens* | 2.70 | 1.89 | 0.30 | 4.48 |
| *Ageratum cornyzoides* | 2.70 | 1.54 | 0.30 | 4.54 |
| *Cyperus haspan* | 5.40 | 2.6 | 1.37 | 9.43 |
| *Persicaria barbata* | 4.05 | 3.87 | 1.21 | 9.13 |
| *Bidens pilosa* | 2.70 | 2.06 | 0.30 | 5.06 |
| *Rotala rotundifolia* | 2.70 | 8.08 | 1.07 | 11.85 |
| *Centella asiatica* | 1.35 | 0.94 | 0.10 | 2.45 |
| *Oxalis corniculata* | 2.70 | 2.06 | 0.30 | 5.06 |
| *Persicaria hydropiper* | 2.70 | 3.87 | 0.61 | 7.18 |

## Appendix 2

**i) Data sheet for frequency and density**

| S.N. | Name of Species | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ | $Q_5$ | $Q_6$ | $Q_7$ | $Q_8$ | $Q_9$ | $Q_{10}$ | Quadrats of occurrence | Total no. of individuals | F | RF | D | RD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

**ii) Data sheet for coverage and IVI values**

| S.N. | Name of Species | Mid point cover value in different quadrat | | | | | | | | | | | RC age | IVI (RF+RD+RC) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $Q_1$ | $Q_2$ | $Q_3$ | $Q_4$ | $Q_5$ | $Q_6$ | $Q_7$ | $Q_8$ | $Q_9$ | $Q_{10}$ | Average cover value | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | |

## Appendix 3

**Average climatic data for Pokhara Airport from (2002 - 2006)**

| S.N. | Months | Temperature °C | WI | Precipitation (mm) |
|---|---|---|---|---|
| 1 | January | 13.95 | 8.95 | 34.04 |
| 2 | February | 16.98 | 11.98 | 3.33 |
| 3 | March | 20.58 | 15.58 | 71.78 |
| 4 | April | 22.86 | 17.86 | 184.4 |
| 5 | May | 24.46 | 19.46 | 402.34 |
| 6 | June | 26.19 | 21.16 | 607.55 |
| 7 | July | 26.49 | 21.49 | 961.22 |
| 8 | August | 26.67 | 21.67 | 704.46 |
| 9 | September | 25.55 | 20.55 | 583.06 |
| 10 | October | 22.38 | 17.38 | 183.22 |
| 11 | November | 18.21 | 12.21 | 16.06 |
| 12 | December | 14.83 | 9.83 | 11.84 |
| Total | | | 199.12 | 3793.27 |

*Source: Department of Hydrology and Meteorology.*

## Appendix 4

| S.N. | Species Name | Family | Local Name |
|---|---|---|---|
| 1 | *Adenostemum anguistifolium* | Compositae | |
| 2 | *Ageratum cornizoides* L. | Compositae | Gandhe |
| 3 | *Artimissia vulgaris* L. | Compositae | Titepati |
| 4 | *Azolla imbricata* | Salvinaceae | Leu |
| 5 | *Bidens pilosa* L. | Compositae | Kuro |
| 6 | *Centella asiatica* (L.) | Unbelliferae | |
| 7 | *Ceratophyllum demersum* | Ceratophyllaceae | |
| 8 | *Chara Vulgaris* | Characeae | |
| 9 | *Cheilanthes bicolar* | Adiantaceae | |
| 10 | *Commelina paludosa* Blume | Commelianceae | |
| 11 | *Conyza bonariensis* | Compositae | |
| 12 | *Cyanodon dactylon* | Gramineae | Dubo |
| 13 | *Cynoglossum* sp. | Boraginaceae | |
| 14 | *Cyperus haspan* Linn | Cyperaceae | Mothe |
| 15 | *Echinochloa* crus-galli | Gramineae | |
| 16 | *Eichornia crassipes* (Mort.) Salms, Monogr. Phan | Pontederiaceae | Jal kumbhi |
| 17 | *Eleocharis congesta* D. Don | Cyperaceae | |
| 18 | *Eriocaulon nepalense* Prescot ex. bong | Eriocaulaceae | |
| 19 | *Floscarpa scandens* Lour. | Commelinaceae | |
| 20 | *Gleichenia dichotoma* | Gleicheniaceae | |
| 21 | *Hydrilla verticillata* (L.F.) Royle | Hydrocharitaceae | Kamal |
| 22 | *Isachne globosa* Ghumb/kuntze, Rev. Gen.) | Gramineae | |
| 23 | *Leersia hexandra* (Swartz) | Gramineae | Karaunte |
| 24 | *Lemna minor* Linn. | Lemnaceae | Panikhar |
| 25 | *Lindernia* sp. | Scrophulariaceae | |
| 26 | *Ludwigia adscendens* (L.) Hara | Onagraceae | |
| 27 | *Mimosa pudica* L. | Leguminosae | Lajjawati |
| 28 | *Nelumbo nucifera* Gaerth | Nymphaceae | |
| 29 | *Nymphaea nouchali* Burn. F. | Nympheaceae | Patkauli |
| 30 | *Nymphoides indica* (L.) | Gentianaceae | Pyakute |
| 31 | *Oenathe javanica* (Blume) DC | Umbelliferae | |
| 32 | *Oryza rufipogon* Griff. Notul | Gramineae | Navodhan |
| 33 | *Oryza sativa* | Gramineae | Dhan |
| 34 | *Oxalis corniculata* L. | Oxalidaceae | Chari, Anilo |
| 35 | *Paspalum scrobiculatum* (L. Mont.) | Gramineae | |
| 36 | *Persicaria barbata* (L.) Hara | Polygonaceae | |
| 37 | *Persicaria hydropiper (*L.) Spach. | Polygonaceae | |
| 38 | *Potamogetan crispus* Linn | Potamogetonaceae | |
| 39 | *Rotala rotundifolia* (Buch-Ham.ex Roxb.) Koehne | Cyperaceae | |
| 40 | *Trapa bispinosa* (Roxb.) | Trapaceae | Bhaisisimal kanda |
| 41 | *Trapa quadrispinosa* Roxb. Fl. Ind (Roxburghii) | Trapaceae | Gai simal kanda |
| 42 | *Typha anguistifolia* L. | | |
| 43 | *Utricularia australis* R. Brum | Lentibulariaceae | Simghans |

## Appendix 5

## Ecological values of Aquatic Macrophytes of Lake Rupa

| S.N. | Name of species | Family | Local Name | Human Food | Food for water bird | Medicinal value | Animal fodder | Fish food | Bio fertilizer | Obstruction in Boating | Weeds rice fields | Shelter for invertebrates |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Azolla imbricata* | Salviniaceae | | | | | | | + | | | |
| 2 | *Ceratophyllum demersum* | Ceratophyllaceae | | | | | | + | | | | |
| 3 | *Eichornia crassipes* | Pontederiaceae | Jalkumbhi | | | + | + | + | + | | | |
| 4 | *Hydrilla verticillata* | Hydrocharitaceae | Panikhar | | | | | + | | | | |
| 5 | *Lemna minor* | Lemnaceae | Leu | | | | + | + | + | | | |
| 6 | *Nelumbo nucifera* | Nelumbunaceae | Kamal | + | | + | | | | + | | |
| 7 | *Potamogeton crispus* | Potomagetonaceae | Pani ghans | | + | | | | | | | |
| 8 | *Trapa bispinosa* | Trapaceae | Bhaisi simal kanda | + | | + | | + | | + | | |
| 9 | *Trapa quadrispinusa* | Trapaceae | Gai simal kanda | + | | + | | + | | + | | |
| 10 | *Utricularia australis* | Lentibulariaceae | Simghans | | | | | + | | | | |
| 11 | *Vallisneria oustralis* | Hydrecharitaceae | Panikhar | | | | | + | | | | |
| 12 | *Oryza rufipogan* | Poaceae | Navo Dhan | + | | | | | | | + | |
| 13 | *Rotala rotundifolia* | Cyperaceae | | | | | | | | | | |
| 14 | *Eleocharis* | Cyperaceae | Suire | | | | | | | | | |
| 15 | *Leersia hexandra* | Poaceae | Karaunte | | | | + | | | | | |
| 16 | *Ludwigia adscendens* | Onagraceae | | | | | | | | | | + |
| 17 | *Nymphoides indicum* | Gentianaceae | Pyakute | | | | | | | + | | + |
| 18 | *Paspalum scrobiculatum* | Poaceae | | | | | | | | | | |
| 19 | *Floscarpa scondens* | | | | | | + | | | | | |
| 20 | *Artimisia vulgaris* | | Titepati | | | + | | | | | | |

**Appendix 6**

**Soil parameters with their mean average values in different sides of the lake**

| **Parameters** | **North Inlet** | **West forest** | **Agriculture land** | **East wasteland** | **Outlet east forest** | **Mean** |
|---|---|---|---|---|---|---|
| PH | 6.87 | 6.13 | 6.78 | 5.80 | 5.17 | 6.15 ± 0.707 |
| OM (%) | 4.79 | 5.43 | 6.61 | 7.52 | 8.43 | 6.56 ± 1.49 |
| N(%) | 0.13 | 0.18 | 0.18 | 0.23 | 0.30 | 0.204 ± 0.06 |

Where, $P^H$=Hydrogen Ion concentration

N=Nitrogen

OM=Organic matter

**Average above ground biomass (g/m$^2$) production in different seasons:**

| **Plots** | **Phase-I Pre-monsoon** | **Phase-II Post-monsoon** | **Mean** |
|---|---|---|---|
| North (Inlet) | 93.92 ± 54.40 | 148.65 ± 84.73 | 121.29 ± 38.70 |
| East | 100.82 ± 57.03 | 201.49 ± 118.61 | 151.16 ± 71.18 |
| West | 107.97 ± 47.40 | 179.04 ± 104.71 | 143.51 ± 50.25 |
| South | 90.67 ± 44.43 | 155.52 ± 112.83 | 123.10 ± 45.85 |
| Mean | 98.35 ± 1.69 | 171.18 ± 24.03 | 134.77 ± 14.87 |

**Average above ground biomass (g/m$^2$) production, according to growth form**

| **Growth form** | **Phase-I Pre-monsoon** | **Phase-II Post-monsoon** | **Mean** |
|---|---|---|---|
| Emergent species | 183.6 ± 12.54 | 318.72 ± 35.63 | 251.16 ± 95.54 |
| Submerged species | 43.26 ± 3.90 | 53.51 ± 5.07 | 48.39 ± 7.27 |
| Rooted floating species | 84.94 ± 9.57 | 124.56 ± 25.89 | 104.76 ± 28.02 |
| Mean | 103.93 ± 72.07 | 165.59 ± 137.28 | 134.77 ± 104.66 |

## Appendix 7

## Average value of physico-chemical characteristics of water in different sides of lake

**Pre-monsoon**

| S.N. | Parameters | West | North | South | East | Average |
|---|---|---|---|---|---|---|
| 1 | Temperature °C | 23.15 ± 0.02 | 23.11 ± 0.04 | 23.39 ± 0.03 | 23.32 ± 0.03 | 23.24 ± 0.13 |
| 2 | $p^H$ (mg/l) | 5.65 ± 0.02 | 5.71 ± 0.02 | 5.83 ± 0.02 | 5.50 ± 0.03 | 5.67 ± 0.14 |
| 3 | Dissolved oxygen (mg/l) | 3.81 ± 0.001 | 4.71 ± 0.02 | 4.15 ± 0.04 | 3.95 ± 0.02 | 4.16 ± 0.39 |
| 4 | Total Nitrogen (mg/l) | 0.180± 0.003 | 0.194± 0.002 | 0.179 ± 0.00 | 0.182 ± 0.004 | 0.184 ± 0.006 |
| 5 | Ortho phosphate (mg/l) | 0.0045± 0.00 | 0.0041± 0.00 | 0.0052± 0.0002 | 0.0049± 0.004 | 0.005 ± 0.0004 |

**Post-monsoon**

| S.N. | Parameters | West | North | South | East | Average |
|---|---|---|---|---|---|---|
| 1 | Temperature °C | 21.29 ± 0.00 | 21.57 ± 0.02 | 22.01 ± 0.04 | 22.71 ± 0.02 | 21.90 ± 0.62 |
| 2 | $p^H$ (mg/l) | 5.92 ± 0.02 | 6.48 ± 0.02 | 6.67 ± 0.05 | 6.08 ± 0.01 | 6.29 ± 0.35 |
| 3 | Dissolved oxygen (mg/l) | 7.59 ± 0.02 | 8.10 ± 0.02 | 7.53 ± 0.02 | 7.49 ± 0.05 | 7.68 ± 0.28 |
| 4 | Total Nitrogen (mg/l) | 0.15 ± 0.04 | 0.09 ± 0.00 | 0.11 ± 0.02 | 0.08± 0.03 | 0.108 ± 0.03 |
| 5 | Ortho phosphate (mg/l) | 0.0011 ± 0.00 | 0.0019 ± 0.0002 | 0.0021 ± 0.01 | 0.0023± 0.0001 | 0.0020 ± 0.0005 |

**Average limnological value of Rupa lake in two season.**

| S.N | Parameters | Pre-monsoon | Post monsoon | Average |
|---|---|---|---|---|
| 1 | Temperature °C | 23.24 ± 0.13 | 21.90 ± 0.62 | 22.57 ± 0.95 |
| 2 | $p^H$ (mg/l) | 5.67 ± 0.14 | 6.29 ± 0.35 | 5.98 ± 0.44 |
| 3 | Dissolved oxygen | 4.16 ± 0.39 | 7.68 ± 0.28 | 5.92 ± 2.49 |
| 4 | Total Nitrogen (mg/l) | 0.184 ± 0.06 | 0.108 ± 0.03 | 0.146 ± 0.05 |
| 5 | Ortho phosphate (mg/l) | 0.005 ± 0.0004 | 0.0020 ± 0.0005 | 0.004 ± 0.002 |

**Diversity Index (Shanon-Wiener) of species in two-seasons**

| S.N | Parameters | Pre-monsoon | Post monsoon | Average |
|---|---|---|---|---|
| 1 | West | 3.52 | 3.68 | 3.60 |
| 2 | North | 3.56 | 3.41 | 3.49 |
| 3 | East | 3.84 | 3.78 | 3.81 |
| 4 | South | 3.49 | 3.85 | 3.67 |
| 5 | Mean | 3.603 | 3.68 | 3.643 |

## Appendix 8

**Semi structured questionnaire for the socio-economic survey of the people in the watershed area of Rupa lake**

**Name:** **Household No:**

**VDC:** **Religion:**

**Tole:** **Irrigation type:**

1. Educational status of the respondents.

| S.N. | Respondent No. | Educational Degree |
|---|---|---|
| 1 | | Primary Level |
| 2 | | Secondary Level |
| 3 | | Graduate |
| 4 | | Post graduate |

2. Types and number of livestock owned by respondent.

| | Livestock type | | | |
|---|---|---|---|---|
| Livestock number | Cattle | Buffaloes | Goats/sheep | Chicken |
| 0-5 | | | | |
| 5-10 | | | | |
| > 10 | | | | |
| | | | | |

3. Status of respondent according to his/her occupation.

a) Student [ ] b) Business [ ]

c) Farmer [ ] d) Others [ ]

4. What types of energy source do use for cooking purpose ?

a) Wood [ ] b) Gas/stove [ ] c) Other [ ]

5. If wood, then from where do you collect ?

a) community forest [ ] b) Near-by forest [ ] c) Others [ ]

6. Do you use any alternative energy sources ? If yes, then mention name

7. What type of feeding practice do you use for your livestock ?

a) open-grazing [ ] b) stall-feeding [ ] c) others [ ]

8. What is the main source of fodder for your livestock ?

a) Agricultural land [ ] b) Community forest [ ]

c) Lake [ ] d) Others [ ]

9. Do you have any fodder trees in your courtyard ?

a) Yes [ ] b) No [ ]

10. Where do you dump your households wastes ?

a) anywhere [ ] b) pits [ ] c) others [ ]

11. Awareness toward conservation of lake.

a) High [ ] b) Medium[ ] c) Low [ ]

12. What do you feel about the status of lake ?

..................................................................................................

13. In your opinion, what are the major threats to the beauty of lake ? Mention.

..................................................................................................

14. What benefit do you get from the lake resources ? Mention.

..................................................................................................

15. What situation do you predict if the present conservation practice are unchanged ?

..................................................................................................

16. Are you satisfied with the ongoing conservation method/measure in the lake ? If no, give reason.

..................................................................................................

17. Have you adopted any conservation practices. If yes, what practices you have employed ?

..................................................................................................

18. What human related factors you think have enhanced deterioration of lake ?

..................................................................................................

19. Are you acquainted with the occasional conservation related fairs/ programs in the lake ?

..................................................................................................

20. Are you sure you will be happy to provide any type of assistance for the welfare of deteriorating lake ?

..................................................................................................

| **Inlet** Above ground biomass (g/m$^2$) (Pre-monsoon) | | | | | **West** Above ground biomass (g/m$^2$) (Pre-monsoon) | | | |
|---|---|---|---|---|---|---|---|---|
| S.N. | Quad. No. | $T_1$ Dry wt. | $T_2$ Dry wt | | S.N. | Quad. No. | $T_1$ Dry wt. | $T_2$ Dry wt |
| 1 | $Q_1$ | 184.88 | 188.64 | | 1 | $Q_1$ | 165.28 | 159.37 |
| 2 | $Q_2$ | 176.89 | 170.78 | | 2 | $Q_2$ | 179.25 | 187.19 |
| 3 | $Q_3$ | 142.28 | 172.25 | | 3 | $Q_3$ | 29.91 | 35.29 |
| 4 | $Q_4$ | 31.82 | 37.25 | | 4 | $Q_4$ | 143.36 | 193.39 |
| 5 | $Q_5$ | 64.72 | 53.56 | | 5 | $Q_5$ | 86.52 | 63.76 |
| 6 | $Q_6$ | 63.89 | 61.92 | | 6 | $Q_6$ | 81.52 | 83.76 |
| 7 | $Q_7$ | 62.96 | 67.45 | | 7 | $Q_7$ | 101.25 | 89.79 |
| 8 | $Q_8$ | 71.76 | 69.29 | | 8 | $Q_8$ | 89.25 | 94.59 |
| 9 | $Q_9$ | 65.16 | 6.27 | | 9 | $Q_9$ | 87.57 | 91.29 |
| 10 | $Q_{10}$ | 67.46 | 59.21 | | 10 | $Q_{10}$ | 95.75 | 101.29 |
| | | | | | | | | |
| | | Biomass in $T_1$ | Post monsoon $T_2$ | | | | Biomass in $T_1$ | Post monsoon $T_2$ |
| 1 | $Q_1$ | 285.97 | 298.25 | | 1 | $Q_1$ | 359.57 | 338.52 |
| 2 | $Q_2$ | 287.49 | 281.79 | | 2 | $Q_2$ | 388.56 | 379.89 |
| 3 | $Q_3$ | 198.91 | 239.57 | | 3 | $Q_3$ | 315.27 | 289.85 |
| 4 | $Q_4$ | 39.41 | 34.71 | | 4 | $Q_4$ | 46.31 | 45.32 |
| 5 | $Q_5$ | 132.17 | 142.12 | | 5 | $Q_5$ | 172.28 | 164.24 |
| 6 | $Q_6$ | 101.39 | 107.41 | | 6 | $Q_6$ | 158.28 | 108.76 |
| 7 | $Q_7$ | 95.42 | 97.25 | | 7 | $Q_7$ | 154.52 | 161.57 |
| 8 | $Q_8$ | 80.49 | 115.57 | | 8 | $Q_8$ | 160.21 | 149.29 |
| 9 | $Q_9$ | 105.29 | 121.81 | | 9 | $Q_9$ | 165.19 | 162.69 |
| 10 | $Q_{10}$ | 118.46 | 89.47 | | 10 | $Q_{10}$ | 151.21 | 154.29 |

| Limnological value in pre monsoon sample | | | | | Limnological value in pre monsoon sample | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | 1 | 2 | 3 | | Parameters | 1 | 2 | 3 |
| Water temp | 23.09 | 23.14 | 23.11 | | Water temp | 23.17 | 23.13 | 23.17 |
| pH | 5.70 | 5.70 | 5.72 | | pH | 5.63 | 5.67 | 5.64 |
| DO | 4.70 | 4.70 | 4.73 | | DO | 3.80 | 3.82 | 3.82 |
| TN | 0.195 | 0.192 | 0.195 | | TN | 0.179 | 0.177 | 0.182 |
| Orthophosphate | 0.0041 | 0.0041 | 0.0041 | | Orthophosphate | 0.0045 | 0.0045 | 0.0045 |

| Limnological value in post monsoon sample | | | | | Limnological value in post monsoon sample | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | 1 | 2 | 3 | | Parameters | 1 | 2 | 3 |
| Water temp | 21.58 | 21.55 | 21.58 | | Water temp | 21.29 | 21.29 | 21.29 |
| pH | 6.46 | 6.50 | 6.50 | | pH | 5.90 | 5.93 | 5.93 |
| DO | 8.12 | 8.12 | 8.08 | | DO | 7.57 | 7.61 | 7.61 |
| TN | 0.09 | 0.09 | 0.09 | | TN | 0.11 | 0.14 | 0.19 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Orthophosphate | 0.0017 | 0.0021 | 0.0018 | | Orthophosphate | 0.0013 | 0.0019 | 0.0009 |

| Soil parameters with their respective values (pre-monsoon) | | | | | Soil parameters with their respective values (pre-monsoon) | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | OM (%) | N(%) | | | pH | OM (%) | N(%) |
| 1 | 6.89 | 4.58 | 0.112 | | 1 | 6.63 | 7.37 | 0.182 |
| 2 | 6.99 | 4.58 | 0.14 | | 2 | 6.92 | 6.45 | 0.07 |
| 3 | 6.92 | 4.58 | 0.112 | | 3 | 7.26 | 6.73 | 0.224 |
| 4 | 6.92 | 4.68 | 0.154 | | 4 | 6.89 | 6.83 | 0.14 |
| 5 | 6.96 | 4.48 | 0.112 | | 5 | 6.68 | 6.02 | 0.196 |
| 6 | 6.90 | 4.68 | 0.112 | | 6 | 6.80 | 6.45 | 0.098 |
| 7 | 6.91 | 4.58 | 0.14 | | 7 | 7.06 | 6.45 | 0.224 |
| 8 | 6.92 | 4.68 | 0.14 | | 8 | 6.78 | 6.46 | 0.196 |
| | | | | | | | | |
| | Post monsoon | | | | | Post monsoon | | |
| | pH | OM (%) | N(%) | | | pH | OM (%) | N(%) |
| 1 | 6.81 | 4.89 | 0.131 | | 1 | 6.61 | 6.67 | 0.181 |
| 2 | 6.80 | 4.87 | 0.139 | | 2 | 6.59 | 6.81 | 0.171 |
| 3 | 6.81 | 4.89 | 0.133 | | 3 | 6.58 | 6.79 | 0.179 |
| 4 | 6.79 | 5.15 | 0.131 | | 4 | 6.58 | 6.48 | 0.179 |
| 5 | 6.85 | 5.13 | 0.129 | | 5 | 6.62 | 6.49 | 0.183 |
| 6 | 6.77 | 4.89 | 0.129 | | 6 | 6.81 | 6.72 | 0.181 |
| 7 | 6.80 | 4.89 | 0.127 | | 7 | 6.79 | 6.72 | 0.178 |
| 8 | 6.80 | 5.14 | 0.135 | | 8 | 6.79 | 6.69 | 0.180 |

| **East** Above ground biomass (g/m$^2$) (Pre-monsoon) | | | | | **South** Above ground biomass (g/m$^2$) (Pre-monsoon) | | | |
|---|---|---|---|---|---|---|---|---|
| S.N. | Quad. No. | $T_1$ Dry wt. | $T_2$ Dry wt | | S.N. | Quad. No. | $T_1$ Dry wt. | $T_2$ Dry wt |
| 1 | $Q_1$ | 228.28 | 168.28 | | 1 | $Q_1$ | 148.25 | 191.56 |
| 2 | $Q_2$ | 160.25 | 175.37 | | 2 | $Q_2$ | 155.29 | 189.37 |
| 3 | $Q_3$ | 165.72 | 187.11 | | 3 | $Q_3$ | 32.35 | 37.99 |
| 4 | $Q_4$ | 27.25 | 37.13 | | 4 | $Q_4$ | 64.56 | 81.52 |
| 5 | $Q_5$ | 89.38 | 91.89 | | 5 | $Q_5$ | 87.32 | 69.36 |
| 6 | $Q_6$ | 67.36 | 63.91 | | 6 | $Q_6$ | 78..72 | 63.52 |
| 7 | $Q_7$ | 68.45 | 67.21 | | 7 | $Q_7$ | 81.76 | 71.59 |
| 8 | $Q_8$ | 78.91 | 64.29 | | 8 | $Q_8$ | 79.16 | 75.76 |
| 9 | $Q_9$ | 71.45 | 67.30 | | 9 | $Q_9$ | 79.12 | 85.65 |
| 10 | $Q_{10}$ | 68.39 | 69.37 | | 10 | $Q_{10}$ | 71.29 | 69.25 |
| | | | | | | | | |
| | | Biomass in $T_1$ | Post monsoon $T_2$ | | | | Biomass in $T_1$ | Post monsoon $T_2$ |
| 1 | $Q_1$ | 376.96 | 289.15 | | 1 | $Q_1$ | 335.21 | 245.19 |
| 2 | $Q_2$ | 379.52 | 315.77 | | 2 | $Q_2$ | 319.54 | 379.31 |
| 3 | $Q_3$ | 307.89 | 389.25 | | 3 | $Q_3$ | 289.41 | 341.19 |
| 4 | $Q_4$ | 41.23 | 45.24 | | 4 | $Q_4$ | 49.25 | 45.59 |
| 5 | $Q_5$ | 197.25 | 203.72 | | 5 | $Q_5$ | 85.89 | 89.91 |
| 6 | $Q_6$ | 89.21 | 87.71 | | 6 | $Q_6$ | 89.73 | 92.83 |
| 7 | $Q_7$ | 111.37 | 100.29 | | 7 | $Q_7$ | 87.81 | 79.49 |
| 8 | $Q_8$ | 103.71 | 113.25 | | 8 | $Q_8$ | 93.39 | 99.41 |
| 9 | $Q_9$ | 92.17 | 95.57 | | 9 | $Q_9$ | 102.27 | 101.39 |
| 10 | $Q_{10}$ | 121.89 | 119.52 | | 10 | $Q_{10}$ | 99.91 | 83.67 |
| | | | | | | | | |

| Limnological value in pre monsoon sample | | | | | Limnological value in pre monsoon sample | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | 1 | 2 | 3 | | Parameters | 1 | 2 | 3 |
| Water temp | 23.29 | 23.31 | 23.35 | | Water temp | 23.37 | 23.37 | 23.42 |
| pH | 5.51 | 5.47 | 5.53 | | pH | 5.81 | 5.85 | 5.83 |
| DO | 3.93 | 3.95 | 3.97 | | DO | 4.12 | 4.19 | 4.13 |
| TN | 0.177 | 0.183 | 0.185 | | TN | 0.179 | 0.179 | 0.179 |
| Orthophosphate | 0.0045 | 0.0051 | 0.0053 | | Orthophosphate | 0.0051 | 0.0055 | 0.0053 |
| Limnological value in post monsoon sample | | | | | Limnological value in post monsoon sample | | | |
| Parameters | 1 | 2 | 3 | | Parameters | 1 | 2 | 3 |
| Water temp | 22.72 | 22.69 | 22.72 | | Water temp | 22.03 | 21.97 | 22.05 |
| pH | 6.07 | 6.09 | 6.07 | | pH | 6.63 | 6.65 | 6.72 |
| DO | 7.45 | 7.55 | 7.47 | | DO | 7.51 | 7.52 | 7.55 |
| TN | 0.10 | 0.09 | 0.05 | | TN | 0.09 | 0.11 | 0.13 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Orthophosphate | 0.0021 | 0.0023 | 0.0023 | | Orthophosphate | 0.019 | 0.021 | 0.0023 |

| Soil parameters with their respective values (pre-monsoon) | | | | | Soil parameters with their respective values (pre-monsoon) | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | OM (%) | N(%) | | | pH | OM (%) | N(%) |
| 1 | 7.40 | 8.19 | 0.154 | | 1 | 5.22 | 8.63 | 0.32 |
| 2 | 5.62 | 5.24 | 0.28 | | 2 | 5.05 | 8.08 | 0.28 |
| 3 | 5.42 | 5.46 | 0.252 | | 3 | 5.24 | 8.29 | 0.29 |
| 4 | 5.93 | 8.10 | 0.182 | | 4 | 5.29 | 8.63 | 0.28 |
| 5 | 5.65 | 8.19 | 0.154 | | 5 | 5.19 | 8.63 | 0.29 |
| 6 | 5.68 | 8.10 | 0.266 | | 6 | 5.15 | 8.29 | 0.32 |
| 7 | 5.64 | 8.19 | 0.28 | | 7 | 5.21 | 8.63 | 0.29 |
| 8 | 5.65 | 8.10 | 0.266 | | 8 | 5.20 | 8.08 | |

| | Post monsoon | | | | | Post monsoon | | |
|---|---|---|---|---|---|---|---|---|
| | pH | OM (%) | N(%) | | | pH | OM (%) | N(%) |
| 1 | 5.81 | 7.49 | 0.229 | | 1 | 5.23 | 8.62 | 0.31 |
| 2 | 5.83 | 7.51 | 0.221 | | 2 | 5.21 | 8.61 | 0.28 |
| 3 | 5.71 | 7.61 | 0.232 | | 3 | 5.19 | 8.11 | 0.29 |
| 4 | 5.65 | 7.63 | 0.236 | | 4 | 5.15 | 8.13 | 0.29 |
| 5 | 5.71 | 6.99 | 0.237 | | 5 | 5.15 | 8.13 | 0.29 |
| 6 | 5.71 | 7.81 | 0.231 | | 6 | 5.07 | 8.49 | 0.35 |
| 7 | 5.72 | 7.83 | 0.237 | | 7 | 5.15 | 8.62 | 0.32 |
| 8 | 5.65 | 7.83 | 0.232 | | 8 | 5.07 | 8.6. | 0.31 |

| Soil characteristics of west-forest (Pre-monsoon) | | | | | Soil characteristics of west-forest (Post -monsoon) | | | |
|---|---|---|---|---|---|---|---|---|
| | pH | OM (%) | N(%) | | | pH | OM (%) | N(%) |
| 1 | 6.19 | 5.79 | 0.154 | | 1 | 6.11 | 5.79 | 0.177 |
| 2 | 6.18 | 4.92 | 0.182 | | 2 | 6.12 | 5.72 | 0.178 |
| 3 | 6.09 | 5.57 | 0.196 | | 3 | 6.11 | 5.39 | 0.181 |
| 4 | 6.18 | 4.92 | 0.182 | | 4 | 6.09 | 5.37 | 0.169 |
| 5 | 6.21 | 4.92 | 0.168 | | 5 | 6.09 | 5.99 | 0.181 |
| 6 | 6.11 | 5.79 | 0.154 | | 6 | 6.1 | 5.97 | 0.181 |
| 7 | 6.18 | 5.57 | 0.154 | | 7 | 6.02 | 5.79 | 0.178 |
| 8 | 6.19 | 5.57 | 0.182 | | 8 | 6.03 | 5.79 | 0.181 |

| | Post monsoon | | | | | Post monsoon | | |
|---|---|---|---|---|---|---|---|---|
| | pH | OM (%) | N(%) | | | pH | OM (%) | N(%) |
| 1 | 5.81 | 7.49 | 0.229 | | 1 | 5.23 | 8.62 | 0.31 |
| 2 | 5.83 | 7.51 | 0.221 | | 2 | 5.21 | 8.61 | 0.28 |
| 3 | 5.71 | 7.61 | 0.232 | | 3 | 5.19 | 8.11 | 0.29 |
| 4 | 5.65 | 7.63 | 0.236 | | 4 | 5.15 | 8.13 | 0.29 |
| 5 | 5.71 | 6.99 | 0.237 | | 5 | 5.15 | 8.13 | 0.29 |
| 6 | 5.71 | 7.81 | 0.231 | | 6 | 5.07 | 8.49 | 0.35 |
| 7 | 5.72 | 7.83 | 0.237 | | 7 | 5.15 | 8.62 | 0.32 |
| 8 | 5.65 | 7.83 | 0.232 | | 8 | 5.07 | 8.6. | 0.31 |

Diversity index of species in two season at different sides of lake

| Side | Pre-monsoon | Post monsoon |
|---|---|---|
| West | 3.52 | 3.68 |
| North | 3.56 | 3.41 |
| East | 3.84 | 3.78 |
| South | 3.49 | 3.85 |

**Appendix**

**Biomass of aquatic macrophytes in each transect of**

**during pre monsoon period**

| S.N. | Quadrate No. | Biomass (g/$m^2$) | Mean |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

**Biomass of aquatic macrophytes in each transect during**

**post-monsoon period**

| S.N. | Quadrate No. | Biomass (g/$m^2$) | Mean |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## Place, Names and Boundary


Source: Municipality and Field Observation