Nepal Journal of Science and Technology Vol. 13, No. 1 (2012) 143-155

Water Quality Parameters and Bird Diversity in Jagdishpur Reservoir, Nepal

Jham Bahadur Thapa[1] and Tej Bahadur Saund[2]
[1]*Central Department of Environmental Science*
Tribhuvan University
Kirtipur, Kathmandu
[2]*Pancheswar Multipurpose Project*
Anamnagar, Kathmandu
e-mail: jhamthapa2038@gmail.com

Abstract

Water quality parameters were analyzed seasonally to examine relationships with bird numbers and species richness in Jagdishpur reservoir. This wetland is a Ramsar site and an important bird area (IBA) of Nepal. The trophic status of the reservoir was categorized as eutrophic as assessed by Secchi disk transparency (1.45 ± 0.53 m), total alkalinity (220.94 ± 85.52 mg/l) and total nitrogen (884.19 ± 291.61 µg/l) concentrations. Direct count method detected a total of 77 bird species belonging to 8 orders and 31 families of which 40 species were resident and 37 migrants**.** Species richness ranged from 21(summer) to 74 species (winter). Secchi disk transparency showed a significant positive correlation with bird numbers (($r = 1.00$, $p < 0.01$) whereas significant negative correlation was found between water temperature and species richness ($r = - 0.97$, $p < 0.05$). Absolute positive correlation between species richness and seasons was established ($r = 0.74$). The seasonal distribution pattern showed two peaks of species richness, Shannon diversity, equitability and evenness index, one in winter and the other in autumn. *Fulica atra* (30.53%), *Dendrocygna javanica* (15.88%) and *Anas strepera* (9.58%) were the three most dominant bird species. Fourteen CITES species, 8 globally and 14 nationally threatened species were recorded. Conservation action plan for threatened species that focuses on population monitoring, protecting key habitats and habitat enhancement is urgently needed.

Key words: bird, eutrophic, physico-chemical parameters, trophic status, wetland

Introduction

The national wetland policy of Nepal (2003) defines wetlands as natural or artificially created areas, such as swamp, marsh, riverine floodplain, lake, water storage area and agricultural land containing water from underground water resource or atmospheric precipitation that may be permanent or temporary, static or flowing and freshwater or saline (GoN/MFSC 2003).

Wetlands occupy approximately 5% (743,500 ha) of the total area of Nepal. Out of the total wetland area, 34,455 ha have been designated as Ramsar sites. Nepal has nine Ramsar sites (KoshiTappu, Beeshazar and associated lakes, Ghodaghodi Lake area, Jagadishpur Reservoir, Gokyo and associated lakes, Gosaikunda and associated lakes, Phoksundo Lake, Rara Lake and Mai Pokhari) (Siwakoti & Karki 2009).

Nepal is renowned internationally for its rich diversity of bird species. The high total of 867 bird species has been recorded, over 8% of the world's known birds. An alarming number of 149 bird species (17%) are threatened at the national level. As many as 99 species are thought to be critically endangered or endangered. A total of 40 (27%) nationally threatened species inhabit wetlands. A large percentage of Nepal's wetland birds (29 species, 75%) are considered critically endangered or endangered. Some wetland species have shown precipitous declines over recent years, for example Brahminy Kite *Haliastur indus*, Caspian Tern *Sterna caspia*, Black-bellied Tern *S. acuticauda* and River Tern *S. aurantia*. Birds are good indicators of environmental health because they occur in almost all habitats and are sensitive to environmental change (BCN & DNPWC 2011).

Wetland supports congregation of large number of migratory and resident bird species as it has high nutritional value as well as productivity (Paracuellos 2006). Freshwater wetlands hold more than 40% bird species of the entire world and 12% of all animal species. Birds are most conspicuous and significant component of freshwater wetland ecosystems and their presence or absence may indicate the ecological conditions of the particular areas (Rajpar & Zakaria 2010).

Wetlands being integrated systems are affected by the changes in the key physical as well as chemical parameters of hydrosphere at the catchment scale. These in turn affect the wetland dependent communities as well as the ecosystem attributes such as species richness, its distribution and density (Burkert *et al*. 2004).

The importance of associations among avian species distributions and limnological characteristics of wetlands has been recognized (Hoyer & Canfield 1990). The diversity of birds inhabiting the Vaddekere and Gudavi pond suggests that the physico-chemical and biological parameters of their habitat are the major regulating forces of their population density (Dayananda 2005).

Selection of wetlands by waterfowl is inuenced by a complex of characteristics including water chemistry, aquatic vegetation, invertebrate fauna and physical features (Patra *et al*. 2010). The physical and chemical characteristics of water bodies affect the species composition, abundance, productivity and physiological conditions of aquatic organisms (Bhat *et al*. 2009). Trivedi (1981) has emphasized the importance of species diversity in assessing the water quality and reported that polluted water supports low organism diversity while the clean water supports high diversity.

The study of interactions between biotic and abiotic factors becomes essential to understand the community structure of an ecosystem (Dunson & Travis 1991). Heglund *et al.* (1994) worked out the relationship between limnological characteristics of wetland and waterfowl population. As animals depend directly or indirectly on plants and plants in turn depend on water chemistry, bird's distribution can be expected to change with the change in water chemistry. With respect to water quality, the change in water chemistry has been considered to exert influence in the distribution of many aquatic plant species (Engelhardt & Ritchie 2001). No systematic work has been done in Nepal on the distribution of birds (biotic) in relation to physico-chemical parameters (abiotic) of a water body. This study intended to assess water quality parameters to examine its relationship with bird numbers and species richness. Knowledge on the composition of the bird community in Jagdishpur reservoir facilitates to manage programs aiming at protection and conservation of bird species and their habitats.

Study Area

Jagdishpur reservoir (225 ha), lies in Niglihawa VDC, Kapilvastu district, Lumbini zone; 10 km north of Taulihawa, the district headquarter at geographical coordinates 27°35'N and 83°05'E. The area is characterized by its low elevation (197m above mean sea level) experiencing tropical monsoon climate of hot, rainy summer and cool, dry winter (DNPWC & IUCN 2003).

Jagadishpur reservoir was constructed for irrigation purpose and is harnessed by rock-fill dike. An earthen dike runs north to south from the centre of the reservoir. The eastern part has shallow water body whereas the western part of the reservoir is deeper and completely covered by water. Its depth varies during the summer and winter crop plantation period (2 - 7 m). Jagadishpur reservoir was constructed in the early 1970s over the Jakhira lake and agricultural land for irrigation purposes. A dike was built in the early 1980s. The water is fed from the Banganga lake and river in the Churia catchment. Silts and nutrients coming from the inlet are deposited in the reservoir's mouth which results in reed growth, thus providing habitat for water birds. The diversion of the water from the source of the Banganga river reduces flooding and irrigates the cultivated area. The waterbed recharges the groundwater of the surrounding cultivation. The vegetation is mainly in a submerged succession stage with patches of floating species and reed swamp formations. Marsh meadows and extensive mudflat fringed by marsh lies in the northern part. The terrestrial vegetation is dominated by Sisoo *(Dalbergia sisoo)* and Khair *(Acacia catechu)* along the dike. The wetland vegetation consists of morning glory *(Ipomea carnea* sub sp. *fistulosa)* and Cattail *(Typha angustifolia)*. The aquatic vegetation is represented by extensive coverage of floating leaf species mainly lotus *(Nelumbo nucifera)* followed by wild rice *(Hygrorhiza aristata)* and pondweed *(Potamogeton nodosus)*. The free floating species include water velvet *(Azolla imbricata)* and duckweed *(Lemna spp.)*. The abundant submerged species include water nymph *(Naja minor)*, hydrilla *(Hydrilla verticillata)* and hornwort *(Ceratophyllum demersum)*. The reservoir is surrounded by smaller lakes (e.g., Sagarhawa & Niglihawa) serving as a buffer zone for bird movements of 42 recorded species. The site provides important resident, wintering and stopover habitats for waders, other water-birds, and small passerines (DNPWC & WWF 2005).

The globally threatened smooth-coated otter, *Lutrogale perspicillata* and 25 species of fish were recorded during the July 1997 survey (DNPWC & IUCN 2003). Forty-two fish species belonging to 6 orders, 18 families and 34 genera were recorded from Jagdishpur reservoir, comprising of 38 indigenous and 4 exotic species (Gautam *et al.* 2010).

Bird Life International has identified Jagdishpur as an important bird area (IBA) because of its international importance for threatened species and their habitat conservation (Baral & Inskipp 2005).

The reservoir has been leased for a period of five years for fish stocking at a cost of NRs.7.6 million according to informal estimates provided by officials at the district irrigation office, Butwal (Birdlife International 2012).

Methodology

Water quality analysis

Physico-chemical characteristics of water of Jagdishpur reservoir were studied at seasonal intervals (winter, spring, summer and autumn) in 2007 by choosing four different sampling sites (Site A – sub outlet for agricultural use, Site B – Inlet region where agricultural runoff is likely to enter, Site C – central region of the reservoir and Site D- main outlet which contains stagnant water) representing different regions of the reservoir (Fig.1). Physico-chemical analysis of water was conducted to determine the water quality of the reservoir. Physico-chemical parameters were determined employing methods described in APHA,

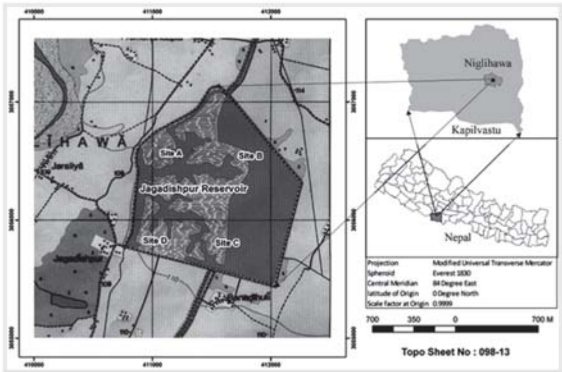

Fig.1. Sampling sites in the study area

AWWA and WPCF (1995) and Trivedy and Goel (1984).

Bird surveys

Bird surveys were carried out at seasonal intervals (winter, spring, summer & autumn) at Jagdishpur reservoir in the year 2007. Direct count of the birds was carried out by using the binoculars. The methodology was followed as described by Bibby *et al.* (2000). The counts were conducted between (0730 & 1130hrs) in the morning. Vantage points (open-water areas, mudflats and short-grass flats) were identified that covered large sections of the reservoir where birds were less disturbed and the chances of visibility was high. Birds were identified with a popular field guide, Helm Field Guide "Nepalka Charaharu" (Grimmett *et al.* 2003). Scientific nomenclature and systematic order of birds follows Bird Conservation Nepal Checklist (2009). The seasonal status of birds follows Inskipp and Inskipp (1991).

Analysis of bird community

For the analysis of bird community, Shannon - Weiner diversity index (Shannon & Wiener 1949), Index of dominance (Simpson 1949), Evenness index (Pielou 1966) and Relative abundance (Rajpar & Jakaria 2011) were employed in the present investigation.

Statistical analysis

The significant difference if any in the mean values of water quality parameters with species richness and bird number was performed by statistical software SPSS (version 16.0). Pearson's correlation coefficients were calculated to evaluate the parametric relationships between the abiotic (i.e., physico-chemical parameters) and biotic factors (i.e., bird) supposedly in interaction. The tests were all two tailed and the correlations were tested at 5% and 1% level of significance.

Results and Discussion

Water quality analysis

The annual mean values of various physico-chemical parameters of Jagdishpur reservoir are presented in Table 1.

Table 1. Physico-chemical parameters of Jagdishpur reservoir in 2007

Physico-chemical parameters	Mean ± S.D
Water temperature (^{0}C)	27.63 ± 3.61
pH	6.91 ± 0.41
Transparency(m)	1.45 ± 0.53
Conductivity(µS/cm)	379.13 ± 29.40
Dissolved oxygen (DO) (mg/l)	7.33 ± 2.00
Free CO_2 (F CO_2) (mg/l)	25.80 ± 2.49
Total alkalinity (mg/l)	220.94 ± 85.52
Chloride (mg/l)	9.65 ± 7.39
Phosphate (PO_4) (mg/l)	0.28 ± 0.17
Total nitrogen (µg/l)	884.19 ± 291.61

The water temperature was maximum in summer (32.75 ± 1.50^{0}C) and minimum in winter (23.5 ± 1.00 ^{0}C). The variations in water temperature may be due to different timings of collection, influence of the season and the effect of atmospheric temperature. Natural bodies of water may exhibit seasonal and diurnal variations, as well as vertical stratification in temperature, which is related with the change in atmospheric temperature (Kundanagar *et al.* 1996). Water temperature was positively correlated with bird numbers (r = 0.1) and significantly negatively correlated with species richness (r = - 0.97, $p < 0.05$). A positive correlation between water temperature and bird numbers may be, at least in part, a response to zooplanktons abundance and thereby influences prey availability. Water temperature is known to influence the life of aquatic organisms. Increasing temperature positively influences the growth and survival of aquatic organisms (Aldridge *et al*. 1995).

The hydrogen ion concentration (pH) was highest in winter (7.25 ± 0.10) and lowest in summer (6.30 ± 0.18). The maximum pH recorded during winter is associated with phytoplankton maxima (Roy 1955). The minimum pH in the summer can be attributed to low photosynthesis due to the formation of carbonic acid (Bais *et al*. 1995). Extremes in pH are stressful and can even be deadly to aquatic organisms. Levels of pH too high (> 9) or too low (< 5) can kill aquatic life (Younos 2007). The hydrogen ion concentration (pH) was negatively correlated with species richness (r = - 0.74) and positively correlated with bird numbers (r = 0.49). A positive correlation between hydrogen ion concentration and bird numbers may be, at least in part, a response to higher macroinvertebrates and thereby attracting more birds. A significant relationship between waders' diversity and pH of the wetland habitats was established by Nagarajan and Thiyagesan (1996).

Transparency of water column was maximum in winter (2.13 ± 0.26 m) and minimum in summer (0.90 ± 0.31 m). High transparency during winter may be related to absence of runoff and gradual settling of suspended particles. The low water transparency during summer may be due to more sand and colloidal particles carried by the rain water. The reservoir can be classified as eutrophic (Forsberg & Ryding 1980) based on transparency. Transparency was negatively correlated with species richness (r = - 0.22). A significant perfect positive correlation was found between Secchi disk transparency and bird numbers ((r = 1.00, $p < 0.01$). A significant positive correlation between transparency and bird numbers may be related to high content of nutrients and low transparency value. The productive nature of the reservoir may yield increased prey densities, which may favor birds to use a large range of water depths for foraging. Productive aquatic ecosystems are able to support a greater number of birds and more specialized species. When a wetland is productive, there is probability enough food for the avifauna (Patra *et al*. 2010). More productive systems (as determined from nutrient concentrations, chlorophyll "A" and/or other water chemistry parameters) may have a larger food base and may support more specialized species of wildlife, resulting in greater species richness (Wright 1983). Alvo *et al*. (1988) identified a positive relationship between waterfowl density and Secchi transparency in the lake of Ontario, Canada.

The highest dissolved oxygen (DO) value of (9.54 ± 0.60 mg/l) was found in winter while the lowest of (5.31 ± 0.88 mg/l) was found in summer. High dissolved oxygen in the winter may be due to low temperature. Low DO in the summer could be the function of higher water temperature and decomposition of organic matter (Badge & Verma 1985). The oxygen deficit during summer is a characteristic feature of a productive wetland (Sreenivasan 1970). DO > 5 mg/l is considered favorable for growth and activity of most aquatic organisms; DO < 3 mg/l is stressful to most aquatic organisms, while DO < 2 mg/l does not support fish life (USEPA 2000). Dissolved oxygen showed negative correlation with species richness (r = - 0.35) and bird number (r = - 0.57). However, dissolved oxygen has a greater impact on invertebrate diversity (insects, fish etc.) showing higher diversity with increasing DO. A positive correlation between abundance of zooplankton and dissolved oxygen was obtained by Yadav (1996). The oxygen concentration regulates the invertebrate distribution, which has an effect on the waterfowl population and distribution since these birds largely feed on a wide range of the invertebrate community and small fishes (Masfiwa *et al.* 2001).

Free CO_2 was highest in summer (27.50 ± 1.66 mg/l) and lowest in winter (23.25 ± 2.22 mg/l). Maximum free carbon dioxide during summer may be due to decomposition of organic matter by microbes in the bottom resulting in the rapid production of free CO_2. During winter, due to slow decomposition of organic matter, CO_2 production is less (Patra *et al.* 2010). Carbon dioxide rarely causes direct toxicity to aquatic organisms. Free CO_2 of water showed negative correlation with species richness (r = - 0.1) and bird number (r = - 0.83).

The total alkalinity was maximum in summer (290 ± 41.03 mg/l) and minimum in autumn (95 ± 46.01 mg/l). High value of alkalinity during summer may be related to concentration of nutrients in water and the presence of excess of free CO_2 product as a result of decomposition process. The low alkalinity during autumn may be due to dilution of water (Trivedy & Goel 1984). The reservoir can be categorized as rich nutrient water body (Spence 1964) and highly productive (Jhingran 1991) based on total alkalinity. A total alkalinity of $\geq$ 20 mg/l is necessary for good community production (Wurts & Durborow 1992). Total alkalinity was positively correlated with species richness (r = 0.65) and bird number (r = 0.49). A positive correlation of total alkalinity with species richness and bird numbers may be related to eutrophic status of the reservoir. Eutrophic conditions may attract elevated number of birds due to their increased biological productivity. Bird number and species richness is increased on eutrophic lakes, perhaps because productive lakes have greater food resources. Nilsson and Nilsson (1978) found positive correlation between nutrient content and waterfowl abundance for most avifaunal species. In two studies of Florida lakes, abundance and species diversity of birds were positively correlated with eutrophic conditions (Hoyer & Canfield 1990, 1994).

Chloride was highest in winter (17.33 ± 1.15 mg/l) and lowest in autumn (0.70 ± 0.13 mg/l). High chloride content in the water during winter may be due to low volume of water in the reservoir. Low chloride concentration in the autumn may be due to dilution of water. The chronic standard of chloride for aquatic life is 230 mg/l (MPCA 2010). Chloride was positively correlated with species richness (r = 0.79) and negatively correlated with bird numbers (r = - 0.76). Absolute positive correlation between chloride and species richness could not be justified in the present study and hence needs further evaluation.

The conductivity in water was maximum in winter (392.75 ± 39.34 µS/cm) and minimum in spring (363.75 ± 23.19 µS/cm). High conductivity during winter may be due to fertilizers runoff from catchment. Similar results were reported by Gautam and Bhattarai (2008). The variation in the level of electrical conductivity is attributed to the dissolved solids in water (Bauder *et al.* 2003). Conductivity was positively correlated with species richness (r = 0.62) and negatively correlated with bird numbers (r = -0.33). Absolute positive correlation between conductivity and species richness may be, at least in part, a response to the favourable saline conditions. However, salinity has a greater impact on invertebrate diversity, with particular taxonomic groups such as the Rotifera and Crustacea showing lower richness with increasing salinity. Species richness of waterbirds from surveys of lake Bryde data was negatively correlated with salinity (as electrical conductivity) over the whole recorded range of 130-79100ìS/cm (Cale 2007).

The maximum concentrations of total nitrogen (1288.75 ± 95.10 µg/l) and phosphate (0.46 ± 0.12 mg/l) in water were observed in summer whereas the minimum value of total nitrogen was observed in winter (594.50 ± 264.71µg/l) and phosphate in autumn (0.05 ± 0.03 mg/l). High concentration of total nitrogen and phosphate during summer may be due to agricultural runoff which carries fertilizers along, increasing the nutrient content in the reservoir (Deshkar *et al*. 2010). The average phosphate content (0.28 ± 0.17) exceeded the normal range (0.1 to 0.2 mg/l, Sreenivasan 1965) for the sustenance of phytoplankton density, which forms food for fish. On the basis of total nitrogen, the reservoir can be classified as eutrophic (Forsberg & Ryding 1980). Total nitrogen was negatively correlated with species richness (r = - 0.57) and bird number (r = - 0.49). Phosphate was positively correlated with species richness (r = 0.19) and bird number (r = 0.53). A positive correlation of phosphate with species richness and bird number may be attributed to increased nutrient content of the water possibly from phosphate rich agricultural runoff and guano of bird. Both high duck density and species richness were associated with high concentration of nutrients such as phosphate (Murphy *et al*. 1984). Aggregations of migratory birds in water body significantly change the water quality by the addition of extra loads of nutrients (Andrikovics *et al*. 2003). The concentration of phosphate decides the amount of alga and the later influences abundance of zooplankton. Nagarajan and Thiyagesan (1996) suggested that level of phosphate influences prey availability, which in turn determine habitat selection by wintering water birds.

As anticipated, the physico-chemical parameters of water varied according to seasonal fluctuations. Pearson's correlation coefficients indicated positive correlation of bird presence with water temperature; hydrogen ion concentration, transparency, total alkalinity, chloride, conductivity and phosphate perhaps reflect the influence of water quality parameters on bird populations. The study findings support our impression that the influence of water quality cannot be rule out as the main factor that explains waterbird distribution directly and indirectly. Water quality influences the availability and accessibility of prey items to various aquatic predators. The water quality is important in waterbird habitat assessment because a host of interacting physical and chemical factors can influence the level of primary productivity in aquatic systems and thus influence the trophic structure and total biomass throughout the aquatic food web (Wetzel 1975). The physico-chemical characteristics of the water largely determine the waterbird community of wetland habitats, primarily by their direct and indirect impact on the availability and abundance of the birds' prey (Nagarajan & Thiyagesan 1996). Murphy *et al*. (1984) stated that physico-chemical characteristics of water bodies regulate the abundance of waterfowl. Todhunter (1995) reported the limnological factors as the key factor of waterfowl aggregation in North American wetlands. However, various factors such as morphological and vegetation characteristics of the reservoir, open water, food availability, surrounding habitat etc. can influence bird assemblages.

Jagdishpur reservoir was found to be polytrophic: eutrophic on the basis of transparency and total nitrogen and hypereutrophic on the basis of phosphate concentration (Gautam & Bhattarai 2008). The reservoir was categorized as hypereutrophic on the basis of Secchi disc and phosphorus content and Oligotrophic based on Chlorophyll "A" (DNPWC & WWF 2005). The reservoir was classified as Oligotrophic by Mc Eachern (1996) on the basis of Total nitrogen and Total phosphorus; mesotrophic by Bhandari (1996) based on nitrogen. However, the present study disclosed the reservoir as eutrophic based on transparency, total nitrogen and total alkalinity that probably had a major role in determining the bird's population in the study area. Selection of reservoir by birds may be influenced by the eutrophic status of the reservoir. A water body's trophic status is a major factor inuencing bird species abundance and richness. Eutrophic standing waters support internationally important bird populations. Lough Neagh and Lough Beg, in particular, hold up to 80,000 wintering waterfowl of some 20 species (Reynolds 1998).

Eutrophication may lead to increase in plant growth and increased plant biomass and resultant detritus after turnover (Kadlec 1995). When algae and plants are in abundance, higher trophic level organisms (e.g., invertebrates, fish, birds, mammals) that feed on these materials also often flourish (Weller 1981). Several small fish species (e.g., Gambusia) were two to three times more abundant in enriched portions of the everglades than in unenriched areas (Rader & Richardson 1994). For many lakes and reservoirs, eutrophication control is a major management objective. Successful eutrophication control programs, however, have resulted in reductions in fish and similar reductions in bird abundance and species richness can be expected (Hoyer & Canfield 1994). Eutrophication abatement programs should be planned with full consideration of the potential trade- off between cleaner water and reduced fish and bird populations.

Bird diversity

A study conducted by DNPWC and IUCN (2003) in Jagdishpur reservoir reported 42 species of birds during the July 1997 survey. Baral (2008) reported 108 species from Jagdishpur reservoir area (within 500 m of the dam), nearly half being either winter visitors or passage migrants. However, a total of 77 bird species representing 8 orders and 31 families were observed during the study period (Table 2). The large number of bird species (77 species) indicates that the reservoir is biologically productive and has the potential to provide habitat for a diversity of birds. Birds play a vital role as indicators of nutrient status of wetland ecosystem (Patra *et al*. 2010). The number of bird species reported in this study seems low as compared to 108. This discrepancy may be due to timing of the study period and the coverage area. An increment in the number of bird species as compared to 42 may be attributed to a number of reasons including improvement in habitat condition. Of 77 bird species, 40 species were resident; 35 winter visitors and 2 summer visitors. Order Ciconiiformes represented the highest species composition (42.85%) while Passeriformes and Anseriformes consisted 23.37% and 16.88% respectively. Similarly, family Anatidae represented the highest species composition (15.58%) followed by Accipitridae, Ardeidae, Passeridae consisting 12.98%, 9.09% and 6.49% respectively. *Fulica atra* was the most dominant species (30.53%) followed by *Dendrocygna javanica* (15.88%), *Anas strepera* (9.58%), *Anas crecca* (6.71%), *Aythya ferina* (3.11%), *Anas penelope* (2.87%) and *Anas acuta* (2.09%).

Table 2. Recorded bird species at Jagdishpur reservoir in 2007

Order	Family	Common Name	Scientific Name	Status
Anseriformes	Anatidae	Eurasian Wigeon	*Anas penelope*	W
		Gadwall	*Anas strepa*	W
		Common Teal	*Anas crecca*	W
		Mallard	*Anas platyrhynchos*	W
		Northern Pintail	*Anas acuta*	W
		Northern Shoveler	*Anas clypeata*	W
		Gargeny	*Anas querquedula*	W
		Cotton Pigmy-goose	*Nettapus coromandelianus*	R
		Common Pochard	*Aythya ferina*	W
		Ferruginous Pochard	*Aythya nyroca*	W
		Tufted Duck	*Aythya fuligula*	W
		Red-crested Pochard	*Rhodonessa rufina*	W
	Dendrocygnidae	Lesser Whistling Duck	*Dendrocygna javanica*	R
Ciconiiformes	Ardeidae	Cattle Egret	*Bubulcus ibis*	R
		Little Egret	*Egretta garzetta*	R
		Intermediate Egret	*Mesophoyx intermedia*	R
		Great Egret	*Casmerodius albus*	R
		Purple Heron	*Ardea purpurea*	R
		Indian Pond Heron	*Ardeola grayii*	R
		Grey Heron	*Ardea cinerea*	W
	Ciconiidae	Asian Openbill	*Anastomus oscitans*	R
		Lesser Adjutant	*Leptoptilos javanicus*	R
	Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	R
		Great Crested Grebe	*Podiceps cristatus*	W
	Phalacrocoracidae	Little Cormorant	*Phalacrocorax niger*	R
		Great Cormorant	*Phalacrocorax carbo*	W
	Jacanidae	Bronze-winged Jacana	*Metopidius indicus*	R
		Pheasant-tailed Jacana	*Hydrophasianus chirugus*	R
	Charadridae	Red-wattled Lapwing	*Vanellus indicus*	R

		Grey-headed Lapwing	*Vanellus cinereus*	W
	Scolopacidae	Green Sandpiper	*Tringa ochropus*	W
		Common Greenshank	*Tringa nebularia*	W
	Accipitridae	Black Kite	*Milvus migrans*	R
		Egyptian Vulture	*Neophron percnopterus*	W
		White-rumped Vulture	*Gyps bengalensis*	R
		Slender-billed Vulture	*Gyps tenuirostris*	R
		Himalayan Griffon	*Gyps himalayensis*	W
		Eurasian Griffon	*Gyps fulvus*	W
		Greater Spotted Eagle	*Aquila clanga*	W
		Pied Harrier	*Circus melanoleucos*	W
		Shikra	*Accipiter badius*	R
		Short-toed Snake Eagle	*Circaetus gallicus*	W
	Falconidae	Peregrine Falcon	*Falco peregrinus*	W
		Common Kestrel	*Falco tinnunculus*	W
	Threskiornithidae	Black Ibis	*Pseudibis papillosa*	R
	Anhingidae	Oriental Darter	*Anhinga melanogaster*	W
Gruiformes	Rallidae	Common Moorhen	*Gallinula chloropus*	W
		Purple Swamphen	*Porphyrio porphyrio*	R
		Common Coot	*Fulica atra*	W
		Brown Crake	*Amaurornis akool*	R
	Gruidae	Sarus Crane	*Grus antigone*	S
Coraciiformes	Dacelonidae	White-throated Kingfisher	*Halcyon smyrnensis*	R
	Alcedinidae	Common Kingfisher	*Alcedo atthis*	R
	Coraciidae	Indian Roller	*Coracias benghalensis*	R
	Cerylidae	Pied Kingfisher	*Ceryle rudis*	R
Passeriformes	Sylviidae	Smoky Warbler	*Phylloscopus fuligiventer*	W
		Hume's Warbler	*Phylloscopus humei*	W
		Greenish Warbler	*Phylloscopus trochiloides*	W
	Alaudidae	Ashy-crowned Sparrow Lark	*Eremopterix grisea*	R
	Passeridae	Paddyfield Pipit	*Anthus rufulus*	R
		Tawny Pipit	*Anthus campestris*	W
		Olive-backed Pipit	*Anthus hodgsoni*	W
		Black-breasted Weaver	*Ploceus benghalensis*	R
		Red Avadavat	*Amandava amandava*	R
	Sturnidae	Common Myna	*Acridotheres tristis*	R
	Muscicapidae	Red-throated Flycatcher	*Ficedula parva*	W
		Bluethroat	*Luscinia svecica*	W
		Pied Bushcat	*Saxicola caprata*	R
	Corvidae	House Crow	*Corvus splendens*	R
		Large-billed Crow	*Corvus macrorhynchos*	R
	Cisticolidae	Ashy Prinia	*Prinia socialis*	R
		Plain Prinia	*Prinia inornata*	R
	Laniidae	Long-tailed Shrike	*Lanius schach*	R
Cuculiformes	Cuculidae	Indian Cuckoo	*Cuculus micropterus*	S
	Centropodidae	Greater Coucal	*Centropus sinensis*	R
Strigiformes	Strigidae	Spotted Owlet	*Athene brama*	R
Columbiformes	Columbidae	Spotted Dove	*Streptopelia chinensis*	R

Seasonal variation

Migrants began to congregate in numbers (204) with a variety of species in autumn. Bird numbers reached a peak in winter (2784) and began to decline as birds left the reservoir in spring (668) and summer (71). The population of birds varies throughout the year depending on the climatic conditions and availability of food (Gunawardena 1999). The low sighting of the birds in summer could partly be attributed to rainy days during the period (Dahal & Bhuju 2008). Bird numbers showed strong negative correlation with seasons (r = - 0.79).

The highest number of species (74 species) was observed in winter followed by 67 species in spring, 43 species in autumn and lowest (21 species) in summer. Fifteen of these were present in all sampled seasons suggesting a relatively low level of residency over the study period. The species richness of birds are expected to be highest during winter when the migratory populations arrive and minimum during summer when the migratory populations leave the area and the resident species are engaged in the nesting activities (Deshkar *et al.* 2010). A positive correlation was found between species richness and seasons (r = 0.74) which may be related to climatic conditions, breeding, food availability and suitable foraging areas. Water birds tend to be highly mobile in winter, moving to other areas in response to factors such as cold weather and changes in water levels and in food resources (Kershaw & Cranswick 2003).

Diversity indices

The highest Shannon -Wiener diversity index was in autumn **(**1.39), whereas the lowest was in summer (1.00). The value of Shannon-Wiener diversity index can theoretically range from zero to infinity. However, values normally range from 0 to 4 (Shannon & Wiener 1949). An increase in diversity index during autumn reflects an increase in the diversity of the community (Yimer & Mengistou 2009). The dominance indices showed a maximum value in winter (0.15) and a minimum value in autumn (0.07). The value of Simpson's dominance index varies between 0 and 1. High dominance value during winter reflects diversified resources in the habitat available for components of the community. Low dominance value during autumn indicates increase by an average species resulting in the lowering of the number of coexisting species in the community (Simpson 1949). An inverse relationship was found between dominance and species diversity of birds. High value of Shannon Weiner diversity indexes a low concentration of dominance (Odum 1996). The evenness indices showed a maximum evenness in autumn (0.85) when the highest Shannon-Wiener diversity index value was noted and minimum evenness in winter (0.61). High index of species evenness in the autumn may be attributed to increase in community diversity (Yimer & Mengistou 2009). The seasonal distribution pattern showed two peaks of species richness, Shannon diversity, dominance, and evenness index, one in winter and the other in autumn (Table 3). A number of reasons including north-south migration, breeding, food availability and vegetation changes could be attributed to this pattern (Harisha & Hosetti 2009).

During the investigation period, 14 Convention on international trade in endangered species of wild fauna and flora (Appendix-I & II) species, 8 globally threatened species and 14 nationally threatened species were recorded (Table 4).

The present study inferred Jagdishpur reservoir as an important feeding ground for migratory and resident

Table 3. Season-wise diversity, dominance and evenness index for birds at Jagdishpur reservoir in 2007

Diversity Indices \ Seasons	Winter	Spring	Summer	Autumn
Species richness (S)	74	67	21	43
Total number of Individuals (N)	2784	668	71	204
Shannon-Wiener diversity index (H2)	1.14	1.25	1	1.39
Simpson's dominance index (c)	0.15	0	0	0.07
Pielou's evenness index (e)	0.61	0.68	0.76	0.85

Note: Winter (December- February); spring (March-May); summer (June-August); autumn (September-November)

Table 4. List of threatened birds recorded at Jagdishpur reservoir

Species	CITES Appendix	Globally threatened species	Nationally threatened species
Nettapus coromandelianus			Vulnerable
Aythya nyroca		Near Threatened	Vulnerable
Anastomus oscitans			Vulnerable
Grus antigone	II	Vulnerable	Endangered
Anhinga melanogaster		Near Threatened	Vulnerable
Hydrophasianus chirurgus			Endangered
Leptoptilos javanicus		Vulnerable	Vulnerable
Accipiter badius	II		
Aquila clanga	II	Vulnerable	Endangered
Circaetus gallicus	II		
Circus melanoleucos	II		Vulnerable
Gyps bengalensis	II	Critical	Critical
Gyps fulvus	II		
Gyps himalayensis	II		Vulnerable
Gyps tenuirostris	II	Critical	Critical
Neophron percnopterus	II	Endangered	Vulnerable
Falco peregrinus	I		
Falco tinnunculus	II		
Athene brama	II		
Milvus migrans	II		
Ploceus benghalensis			Vulnerable

bird species. Various lessons have been learned during the present study. These include:

- Conservation action plan for threatened bird species should be prepared and immediately implemented. Species conservation plan that focuses on population monitoring, protecting key habitats and habitat enhancement is urgently needed. Research activities in relation to safeguarding the habitat and bird fauna should be promoted.
- Conservation education and awareness about the importance of birds and their habitat should be imparted. Integrated conservation and development programmes that benefit the local people and help to maintain the biological diversity of the reservoir through their active involvement at all levels are necessary.
- The influence of morphology, water depth, abiotic changes of the reservoir and food availability in the distribution pattern of birds should be examined. Bird counts should be conducted with a description of individual bird habitat use, habitat preference, nesting locations and feeding activities.
- Commercial fish farming in Jagdishpur reservoir can be detrimental to the ecosystem of the reservoir. Fish introductions can alter the food web affecting the ecological status of the reservoir. Introduction of exotic fish species can have significant impacts on genetic integrity of established native fish populations.

Acknowledgements

We thank Prof. Dr. Umakant Ray Yadav then Head of the Department, Department of Environmental Science, Tribhuvan University for providing necessary guidance, and laboratory facilities for this work. Authors are grateful to Dr. Hem Sagar Baral, Chairman of Nepalese Ornithologist Union for his encouragement, guidance and invaluable suggestions for this research work. We are also thankful to Dinesh Giri of Lumbini Buddha Garden for providing the field assistance.

References

Aldridge, D.W., B.S. Payne and A.C. Miller. 1995. Oxygen consumption, nitrogenous excretion, and filtration rates of *Dreissena polymorpha* at acclimation temperatures between 20 and 32 °C. *Canadian Journal of Fisheries and Aquatic Sciences* **52**: 1761–1767.

Alvo, R.D., J.T. Husse and M. Berrill. 1988. The breeding success of common loons (*Gavia immer*) in relation to alkalinity and other lake characteristics in Ontario. *Can. J. Zool.* **66**: 746-752.

American Public Health Association (APHA), American Water Works Association (AWWA) and Water Pollution Control Federation (WPCF). 1995. *Standard methods for examination of water and waste water*. 19th edition. American Public Health Association, Washington, D.C.

Andrikovics, S., G. Gare, J. Juhasz and G. Lakatos. 2003. Mallard population parameters and their effect on water quality. In: *Proceedings of the 4th conference: Aquatic birds working group of Societas Internationalis Limnologiae (SIL)*, Sackville, Canada. Pp. 15-16.

Badge, U.S. and A.K. Verma. 1985. Limnological studies on J.N.U. lake. New Delhi, India. Bull. Bot. Soc.Sagar **32**:16-23.

Bais, V.S., N.C. Agrawal and A. Tazeen. 1995. Comparative study on seasonal changes in phytoplankton community in the Sagar lake and military engineering lake (M.P.). *J. Freshwater Biol.* **7:** 19-25.

Bauder, T.A., R.M. Waskom and J.G. Davis. 2003. *Irrigation water quality criteria*. Colorado State University Press, USA.

Baral, H.S. 2008. Birds of Jagdishpur reservoir, Nepal. *Forktail* **24**: 115-119.

Baral, H.S. and C. Inskipp. 2005. *Important bird areas in Nepal. Key sites for conservation*. Bird Conservation Nepal and Birdlife International. Kathmandu, Nepal and Cambridge, U.K.

BCN. 2009**.** *Birds of Nepal: An official checklist.* Department of National Parks and Wildlife Conservation and Bird Conservation Nepal, Kathmandu.

BCN and DNPWC. 2011. *The state of Nepal's birds 2010*. Bird Conservation Nepal and Department of National Parks and Wildlife Conservation, Kathmandu.

Bhandari, B. 1996. *An inventory of Nepal's Terai wetlands*. Interim Report. Heritage and Biodiversity Conservation Program, IUCN/Nepal, 309 p.

Bhat, M.M., T. Yazdani, K. Narain, M. Yunus and R.N. Shukla. 2009. Water quality status of some urban ponds of Lucknow, Uttar Pradesh. *Journal of Wetlands Ecology* **2**: 67-73.

Bibby, C.J., N.D. Burgess, D.A. Hill and S.H. Mustoe. 2000. *Bird census techniques.* 2nd edition. Academic Press, London.

BirdLife International. 2012. *Important bird areas factsheet: Jagdishpur reservoir.* www.birdlife.org

Burkert, U., G. Ginzel, H.D. Babenzien and R. Koschel. 2004. The hydrogeology of a catchment area and an artificially divided dystrophic lake- consequences for limnology of lake Fuchskuhle. *Biogeochemistry* **71**:225-246.

Cale, D.J. 2007. *Wetland survey of the lake Bryde natural diversity recovery catchment: Waterbirds, aquatic invertebrates and water chemistry*. Department of Environment and Conservation. Wildlife Research Centre, Western Australia.

CITES and UNEP. 2011. *Convention on international trade in endangered species of wild fauna and flora appendices I, II and III valid from 22 December 2011*. Convention on International Trade in Endangered Species of Wild Fauna and Flora and United Nations Environment Programme, 46 p.

Dahal, B.R. and D.R. Bhuju. 2008. Bird mobility and their habitat at Tribhuvan international airport, Kathmandu. *Nepal Journal of Science and Technology* **9**:119-130.

Dayananda, G.Y. 2005. *Ornitho-ecological studies of Gudavi Bird Sanctuary,* Sorab, *Karnataka*. Ph.D. dissertation. Kuvempu University, Karnataka, India.

Department of National Parks and Wildlife Conservation (DNPWC) and International Union for Conservation of Nature (IUCN). 2003. *Information sheet on Ramsar wetlands (RIS) - Jagdishpur reservoir*. Unpublished report submitted to the Ramsar Convention Bureau.

Department of National Parks and Wildlife Conservation (DNPWC) and World Wildlife Fund (WWF). 2005. *Factsheet Jagadishpur reservoir Kapilbastu*. Kathmandu, Nepal.

Deshkar, S., J. Rathod and G. Padate. 2010. Avifaunal diversity and water quality analysis of an inland wetland. *Journal of Wetlands Ecology* **4**: 1-32

Dunson, W. and J. Travis. 1991. The role of abiotic factors in community organization. *The American Naturalist* **138**:1067-1091.

Engelhardt, K. and M. Ritchie. 2001. Effects of macrophyte species richness on wetland ecosystem functioning and services. *Nature* **411**:687-689.

Forsberg, C. and S.O. Ryding. 1980. Eutrophication parameters and trophic state indices in 30 Swedish waste-receiving lakes. *Arch. Hydrobiol.* **89**(1/2): 189-207.

Gautam, B. and B. Bhattarai. 2008. Seasonal changes in water quality parameters and sediment nutrients in Jagadishpur reservoir, a Ramsar site in Nepal. *Nepal Journal of Science and Technology* **9**: 149-156.

Gautam, D., T.B. Saund and J. Shrestha. 2010. Fish diversity of Jagadishpur reservoir, Kapilbastu district, Nepal- a Ramsar site. *Nepal Journal of Science and Technology* **11**: 229-234.

Government of Nepal (GoN) / Ministry of Forest and Soil Conservation Nepal (MFSC). 2003. *National wetland policy 2003.* GoN/MFSC Kathmandu, Nepal.

Grimmett, R., C. Inskipp, T. Inskipp and H.S. Baral. 2003. *Birds of Nepal* (Nepali Edition). Prakash Books, New Delhi.

Gunawardena, A. 1999. Bird diversity at Kiralakele wetland, Sri Lanka. Oriental Bird Club. *Bulletin* **29**: 12-13.

Harisha, M.N. and B.B. Hosetti. 2009. Diversity and distribution of avifauna of Lakkavalli Range forest, Bhadra Wildlife Sanctuary, Western Ghats, India. *Ecoprint* **16**:21-27.

Heglund, P.J., J.R. Jones, L.H. Frederikson and M.S. Kaiser. 1994. Use of boreal forested wetlands by Pacic loons (*Gaviapacica lawrance*) and horned grebes (*Podicepsauritus L.*): relations with limnological characteristics. *Hydrobiologia* **279/280**: 171-183.

Hoyer, M.V. and Jr. D.F. Canfield. 1994. Bird abundance and species richness on Florida lakes: Inuence of trophic status, lake morphology and aquatic macrophytes. *Hydrobiologia* **297/280**: 107-119.

Hoyer, M.V. and Jr. D.E. Canfield. 1990. Limnological factors inuencing bird abundance and species richness on Florida lakes. *Lake Reservoir. Mgmt.* **6**: 132-141.

Inskipp, C. and T. Inskipp. 1991. *A guide to the birds of Nepal* (2nd Edition). Christopher Helm, London.

Jhingran, V.G. 1991. *Fish and fisheries of India.* (3rd Edition). Hindustan Publication, New Delhi.

Kadlec, R.H. 1995. Overview: Surface flow constructed wetlands. *Water Science and Technology* **32**(3):1-12.

Kershaw, M. and P.A. Cranswick. 2003. Deriving population estimates for wintering wildfowl in Great Britain. *Ornis Hungarica*. **12-13**: 75-87.

Kundangar, M.R.D., S.G. Sarwar and J. Hussain. 1996. Zooplankton population and nutrient dynamics of wetlands of Wular Lake, Kasmir, India. In: *Environment and biodiversity in the context of South Asia* (Eds. P.K. Jha, G.P.S. Ghimire, S.B. Karmacharya, S.R. Baral & P. Lacoul). Ecological Society (ECOS), Nepal. pp. 128-134.

Masifwa, W.F., T. Twongo and P. Denny. 2001. The impact of the water hyacinth, *Eichhornia crassipes* (Mart) Solms on the abundance and diversity of aquatic macroinvertebrates along the shores of northern lake Victoria, Uganda. *Hydrobiologia* **452**: 79-88

Mc Eachern, P. 1996. *Regional and seasonal characteristics of water chemistry, algal biomass and nutrient limitations in lakes of Nepal*. M.Sc. thesis. Faculty of the Graduate School, University of Missouri, Columbia.

Minnesota Pollution Control Agency (MPCA). 2010. *Guideline manual for assessing the quality of Minnesota surface waters for determination of impairment*: *305(b) and 303(d) List*. 2010 Assessment cycle. 520 Lafayette Road North, Saint Paul, 113pp.

Murphy, S.M., B. Kessel and L.J. Vining. 1984. Waterfowl populations and limnological characteristics of Taiga ponds. *J. Wildl. Mgmt*. **48**:1156-1163.

Nagarajan, R. and K. Thiyagesan. 1996. Waterbirds and substrate quality of the Pichavaram wetlands, southern India. *Ibis*. **138**: 710-721.

Nilsson, S.G. and I.N. Nilsson. 1978. Breeding bird community densities and species richness in lakes. *Oikos* **31**: 214-221.

Odum, E.P. 1996. *Fundamentals of ecology.* W. B. Saunders Company, Philadelphia and London, 574 pp.

Paracuellos, M. 2006. How can habitat selection affect the use of a wetland complex by waterbirds? *Biodiversity and Conservation* **15**: 4569-4582.

Patra, A., K.B. Santra and C.K. Manna. 2010. Limnological studies related to physico-chemical characteristics of water of Santragachi and Joypur Jheel, W.B., India. *Our nature* **8**:185-203.

Patra, A., K.B. Santra and C.K. Manna. 2010. Relationship among the abundance of waterbird species diversity, macrophytes, macroinvertebrates and physico-chemical characteristics in Santragachi Jheel, Howrah, W.B, India. *Acta Zoologica Bulgarica* **62** (3):277-300.

Pielou, E.C. 1966. The measurement of diversity on different types of biological collections. *J. Theo. Biol* **13**: 131 - 144.

Rader, R.B. and C.J. Richardson. 1994. Response of macroinvertebrates and small fish to nutrient-enrichment in the Northern Everglades. *Wetlands* **14**:134-146.

Rajpar, M.N. and M. Zakaria. 2011. Effects of water level fluctuation on waterbirds distribution and aquatic vegetation composition at natural wetland reserve, Peninsular Malaysia. *International Scholarly Research Network Ecology* **2011**: 1-13.

Rajpar, M.N. and M. Zakaria. 2010. Density and diversity of water birds and terrestrial birds at Paya Indah Wetland Reserve, Selangor Peninsular Malaysia. *Journal of Biological Sciences* **10** (7): 658-666.

Reynolds, J. 1998**.** Ireland's freshwaters. In: *Societas internationalis limnologiae (SIL) international association of theoretical and applied limnology XXVII Congress* (August 9-14, 1998), Dublin, Ireland. The Marine Institute - Forasna Mara, Dublin.

Roy, H. 1955. Plankton ecology of river Hooghly (West Bengal). *Ecol.* ***36***: 169-744.

Shannon, C. E and W. Wiener. 1949. *The mathematical theory of communication*. University of Illinois Press, Urbana, 117 p.

Simpson, E.H. 1949. Measurement of diversity. *Nature* **163**: 688.

Siwakoti, M. and J.B. Karki. 2009. Conservation status of Ramsar sites of Nepal Terai: an overview. *Botanica Orientalis*: *Journal of Plant Science* **6**: 76-84.

Spence, D.H.N. 1964. The macrophytic vegetation on freshwater lochs, swamps and associated fens. In: *The vegetation of Scotland* (Ed. J.H. Burnett). Oliver and Boyd, Edinburgh. Pp.306-425.

Sreenivasan, A. 1965. Limnology and productivity of tropical upland impoundments in Nilgiris, Madras state India. *Phycos*. **7**(1): 146-160.

Sreenivasan, A. 1970. Limnology of tropical impoundments: A comparative study of the major reservoirs in Madras State (India). *Hydrobiologia **36***: 443-469.

Todhunter, P. 1995. Hydroclimatic perspectives on waterfowl production in the North Dakota Praire Pothole Region. *Great Plains Res* **5** (1): 137-162.

Trivedi, R. C. 1981. Use of diversity Index in evaluation of water quality. In: *Proceedings of the WHO workshop on biological indicators and indices of environmental pollution*. Central Pollution Control Board, New Delhi. Pp. 175 – 188.

Trivedi, R.K. and P.K. Goel. 1984. *Chemical and biological methods for water pollution studies*. (Ist Edition). Environmental Publications, Karad, India, 251 p.

United States Environmental Protection Agency (USEPA). 2000. Aquatic life criteria for dissolved oxygen, Washington, DC.

Weller, M.W. 1981. *Freshwater marshes, ecology and wildlife management*. University of Minnesota Press.

Wetzel, R.G. 1975. *Limnology*. W.B. Saunders Company, Philadelphia.

Wright, D.H. 1983. Species-energy theory: an extension of species-area theory. *Oikos* **41**:496-506.

Wurts, W.A. and R.M. Durborow. 1992. *Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds*. *Southern Regional Aquaculture Centre*. Department of Agriculture, U.S.

Yadav, L.P. 1996. *The effects of physico-chemical parameters on the distribution and abundance of zooplankton in Taudaha lake (a natural) lake*. M.Sc. dissertation. Tribhuvan University,Nepal.

Yimer, H.D. and S. Mengistou. 2009. Water quality parameters and macroinvertebrates index of biotic integrity of the Jimma wetlands, Southwestern Ethiopia. *Journal of Wetland Ecology* **3**: 77-93.

Younos, T. 2007. *Nutrient in lakes and reservoirs-A literature review for use in nutrient criteria development*. Special Report. Virginia Water Resources Research Center, Virginia Tech, 112 p.