A STUDY ON WATERFOWL POPULATION AND HUMAN USE OF HOKERSAR AND HYGAM WETLANDS OF KASHMIR VALLEY FOR CONSERVATION PLANNING

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By

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CERTIFICATE

This is to certify that the thesis of **Ms. Foziah Hamid entitled "A Study on Waterfowl Population and Human Use of Hokersar and Hygam Wetlands of Kashmir Valley for Conservation Planning"** is an original piece of work submitted to the Saurashtra University, Rajkot (Gujarat) for the award of the degree of **Doctor of Philosophy in Wildlife Science.**

Ms. Foziah Hamid has put in more than six terms of research work embodied in this thesis under my guidance and supervision. The work presented in this thesis has not been submitted in part or full for any degree of any other University or Institution.

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Contents

Executive Summary

Wetland ecosystems are extremely productive part of the landscape. By virtue of their production functions they form an important component of wildlife habitats. Besides, a range of direct use values on which the sustenance of local communities depends comes from the wetlands in almost all parts of the world. However, extensive loss of wetlands is occurring throughout the world at an alarming rate. It is estimated that 50% of the wetlands that existed by 1990 have been lost with most of the loss accounted from northern countries. Tropical and subtropical wetlands are increasingly being lost or degraded since 1950s through conversion to agricultural use and development activities.

Wetland landscape characterization provides future trends and the risk that is posed by natural and anthropogenic stresses. The waterbird communities form an important component of wetlands with their potential to detect aspects of wetland landscape condition. Individual species differ in their responses to human disturbances and therefore enable a better and more holistic assessment of the effects of such disturbances. Pattern of habitat utilization of a species and its study is essential to understand species biology and consequently, for management and conservation. Detailed descriptions of vegetation community reveal the conservation status of various species and are of major significance in animal ecology and wildlife management. A key challenge to the management of PAs in India is the local people's livelihood vis-à-vis biodiversity conservation. In this context, analyzing linkages between the socio-economic structures of the surrounding people with natural areas is important. For conservation policies to be successful, adequate knowledge on attitudes of local communities regarding environmental issues and their practices of resource use is essential. Decisions affecting wetlands without knowledge of attitudes of local people can make conservation programmes unsuccessful.

The Kashmir valley in Jammu and Kashmir has a large number of wetlands. However, their ecological and socio-economic values were rarely explored. The present study was carried out in Hokersar and Hygam Reserves. Both the wetlands contribute significantly to the livelihoods of local communities. The primary focus of this study was to evaluate the landscape composition and describe the floristic communities; assess the waterbird abundance and its spatio-temporal variation. The study also examined the resource dependence of local communities and their conservation attitudes towards these wetlands.

Keeping in view the above background, following research questions were posed while formulating the present study:

- Are the land use - land cover characteristics of Hokersar and Hygam wetlands different from each other?
- Is there any marked spatio-temporal variation in the density and diversity pattern of waterbirds in Hokersar and Hygam wetlands of Jammu & Kashmir?
- Is there any variation in habitat use pattern by waterbirds in these wetlands considering the fact that the wetlands have different degrees of human impacts?
- What is the extent of resource use by the local people living around these two wetlands and how their perceptions and attitudes can help in the management?

In order to respond to the above mentioned questions, the following objectives were set forth:

- Map the habitat types with respect to water depth and vegetation characteristics of Hokersar and Hygam wetlands of Jammu & Kashmir.
- Derive spatio-temporal variation in the density and diversity pattern of waterbirds in these wetlands.

- Examine the seasonal pattern of use of these two wetlands by migratory and resident waterbirds.
- Examine the extent of use of these wetlands by the local people and their perception and attitude towards these wetlands.

The study design included (i) literature and reconnaissance survey to get acquainted with two study wetlands, (ii) field sampling to collect data on research questions addressed, (iii) data analysis and land use mapping in Geographical Information System (GIS) domain. The field work was done during July to October 2004; mid-winter (December - January, 2004-2005); post-winter/ spring (February - April, 2005); summer (July - August, 2005), from June to October, 2006 and from June to October 2007.

Land use maps of Hokersar and Hygam wetlands in GIS domain were generated using IRS-1C-LISS III data. A False Colour Composite (FCC) of Lambert Conformal Conic Projection was generated with bands 3, 2 and 1 for the two study areas. Extensive ground truthing was done to collect ground control points (GCPs) for different habitat types in the two wetlands using a Global Positioning System receiver from 329 sample locations inside Hokersar wetland and from 53 locations in the peripheral plantation and again from 160 sample locations inside Hygam wetland and 48 locations in peripheral plantation.

Floristic associations were determined by vegetation sampling in 5 m × 5 m sample plots laid in different strata/habitat types. Stratification of two study wetlands was based on vegetation and other physiognomic characteristics. Species observed were recorded and their percentage cover estimated. A total of 53 circular plots in Hokersar wetland and 48 plots in Hygam wetland were sampled to record number of tree and sapling species laid on six transects in Hokersar plantation and on four transects in plantation in Hygam wetland.

Waterbird density and diversity parameters were estimated by visual count method. Scan sampling of flocks was done from 16 sites in mid-winter season and from 15 sites in post-winter season in Hokersar wetland and from seven sites in mid-winter season and eight sites in post-winter in Hygam wetland. Each site was assigned a fixed view point. Sites were selected after stratification of wetlands into vegetation types/habitats. Flocks were scanned with the help of field binoculars and spotting scope and data was collected on flock size and composition. A survey of breeding waterbirds recorded number of nests in each of 20 m × 20 m quadrats at fixed intervals along five line transects laid in Hokersar wetland and three in Hygam wetland. Data was collected on variables of clutch initiation and hatching date, clutch size and nest success.

One-way ANOVA was used to compare differences in mean densities of waterbirds among habitats. Waterbird species diversity and richness was computed by ecological analysis package Biodiversity Professional beta version 2.0. Neu *et al*. analysis technique (1974) was used for analysis of availability - utilization data. This was followed by the construction of Confidence interval (95%) following the Bonferroni approach i.e number of habitats over or under-used than expected frequencies by waterbirds.

Seasonal pattern of habitat utilisation of waterbirds was examined by weekly ground and boat surveys. Number of sampling points in each of the habitat types recorded determined availability of habitat. Each location of waterbirds was assigned to particular habitat type. Data was gathered on other parameters of flock size, composition and activity pattern of waterbirds respectively. Each group of waterbirds was considered as one observation.

Secondary data of all the 30 villages located within a distance of five km from Hokersar wetland and 26 villages from Hygam wetland was collected on 20 socio-economic parameters. Stratified random sampling approach of selection of 10% of households in four study villages around each wetland for intensive questionnaire survey was adopted. A structured questionnaire was designed and employed to obtain information on socio-economic parameters and dependence on wetland resources. Subsequently, an attitudinal and perception survey was conducted by a set of semi-structured, open as well as closed yes/no type questions.

Pearson product moment correlation coefficient and Pearson chi square was used to examine correlation among different Ordinal and Interval/Ratio variables. In the present study variables included household income and income contributed from wetland resources and influence of caste on wetland use intensity. Data analysis was performed using the software package Statistical Package for Social Sciences (SPSS/PC+ 4.0).

The findings of this study indicate a difference in landscape structure between two wetlands. The pattern of land use - land cover between two landscapes shows that the extent of marshy areas was more in Hokersar wetland landscape (35.65%) than Hygam landscape (22.26%). Peatland and submergent vegetation as land cover types existed only in Hokersar landscape while barren land as a major land cover type and hillock were found only in Hygam landscape. The land use types between two areas were found similar. However, the area of land use classes *viz* plantation, crop field and habitation was less in Hokersar wetland landscape than in Hygam.

Aquatic plant community of Hokersar was more diverse in number of species when compared to Hygam. Extent of major aquatic plant communities; emergent vegetation, floating vegetation and submergent vegetation was more in Hokersar (29.34%) than in Hygam (20.81%).

Of the 22 species of waterbirds recorded from Hokersar, 12 (54%) were migratory. Whereas in Hygam of the 16 species of waterbirds recorded, nine (56%) were migratory. The overall density of waterbirds in Hokersar was 680.57 birds ha^{-1} during mid-winter and 30.05 birds ha^{-1} during post-winter. The variation in density was statistically significant in both the seasons. Of the seven habitats recorded in mid-winter, floating vegetation had the highest density of birds of 205.7 birds ha^{-1}, (mean= 9502 birds± 64319). Peatland in this season revealed lowest bird density of 0.44 birds ha^{-1} (mean= 23 birds ±3.2).

Comparison of relative abundance of different species recorded in mid-winter season indicated Gadwall *Anas strepera* with highest mean density of 38.12 birds ha^{-1}. The least abundant Common Snipe *Gallinago gallinago* confined to tall emergents had density of 0.0003 birds $ha^{-1.}$ Comparison of density estimates among eight habitats in post-winter indicated distinct variation. Submerged peatland showed highest mean density of 90.02 birds ha^{-1}. Individual species density showed that Mallard *Anas platyrhynchos* in this season had highest mean density of 86.14 birds ha^{-1}.

Density estimates across habitats and in seasons from Hygam wetland indicated variation of 1.26 birds ha^{-1} as overall mean density in mid-winter and 19.02 birds ha^{-1} in post-winter season. A significant variation in density estimates among habitats was indicated in both seasons. Of the five habitats recorded in mid-winter, floating vegetation showed highest estimate on mean density of 9.1 birds ha^{-1} (mean = 273.18 birds±47.53). Plantation revealed lowest density of 0.57 birds ha^{-1} (mean = 35.8 birds±11.28).

Comparison of estimates of relative abundance of species recorded in mid-winter indicated Common Teal *Anas crecca* with mean density of 31.38 birds $ha^{-1.}$ Comparison of density estimates among six habitats in post-winter indicated distinct variation. Open water supported maximum population of 10.11 birds ha^{-1}. Of all species recorded in this season, Common Teal *Anas crecca* was reported in highest numbers with density estimated as 20.73 birds ha^{-1}.

Four species of waterbirds were reported nesting in Hokersar wetland in three different breeding habitats. An overall nest density for Mallard was 0.002 nests m^{-2} and for Moorhen, nest density was 0.001 nests m^{-2}. Hatching success rate indicated a value of 92.7% for Mallard and 100% for Indian Moorhen. Hygam wetland showed two species of waterbirds breeding from three different nest sites. An overall nest density for Mallard was recorded as 0.001 nests m^{-2} and 0.001 nests m^{-2} for Moorhen *Gallinula chloropus.*

Diversity in waterbird community showed variation between two wetlands and among seasons. The more diverse community during mid-winter season was found in Hygam (Shannon index 1.33 for drawdown meadows) than in Hokersar (Shannon index 0.85 for floating vegetation). However waterbird community of Hokersar showed more diversity (0.94 Shannon index for submerged paddy field) during post-winter season than that of Hygam (Shannon index 0.88 for submerged grassy meadow).

Noticeable differences were detected in habitat preferences by all groups of waterbirds for seven habitats in mid-winter; eight in post-winter and nine in summer season from Hokersar and for 5 habitats in mid-winter; six each in post-winter and summer seasons from Hygam. Anatidae showed marked variation in habitat preferences in three seasons of study in Hokersar. Ardeidae appeared to show consistent preference for drawdown meadows in three seasons and Podicipedidae for floating vegetation in Hokersar. Paddy field was indicated as only habitat avoided in all the three seasons. Anatidae recorded from Hygam showed a marked preference for floating vegetation in mid and post-winter seasons. With the exception of floating vegetation, all habitats from Hygam were avoided in summer.

Type of activities in habitat types showed marked variation by study waterbird groups with change in season from both wetlands. Anatidae showed most of its activities in floating vegetation in mid and post-winter from Hokersar wetland. Floating vegetation was indicated as only habitat from Hokersar which showed performance of all major activities in mid-winter while in Hygam all major activities were performed during summer.

The socio-economics and resource dependency of local communities residing around Hokersar wetland showed that around 82% of the people depended on it for 13 different types of subsistence with a major use of reed harvesting. Of the mean annual family income of Rs 41,643±21,831, around 29% was contributed by the wetland. A sense of positive attitude and responsibility towards conservation was seen among all the respondents, and 93% respondents were to found cooperate for restrictions on resource use. All the respondents (100%) knew about the siltation and nutrient problems and perceived removal of excessive weeds and desiltation as the best option of management.

Hygam wetland showed dependence of 97% of households for 14 different types of subsistence with livestock grazing as a major use. Of the mean annual family income of Rs 38,574 ±30197, 34% was contributed by wetland resources. A sense of positive attitude was seen in surveyed respondents and 92% showed willingness to cooperate for restrictions on resource use.

Based on this study, following measures are suggested to improve the status of waterbirds in these wetlands. Attempts should be made to restore the degraded portion of the wetlands through appropriate mechanism. Management practices directed towards enhancing vegetation - water interspersion in both Hokersar and Hygam wetlands would greatly enhance their value to waterbirds. Such interspersion would increase structural habitat complexity and open up foraging and resting habitats for most waterbird species.

Specific management recommendations include creation of open water patches and increase in areas of floating vegetation in Hokersar and creation of discrete *Typha* stands interspersed with open water patches in Hygam.

Hygam wetland reserve faces severe threat of siltation. A great influx of heavy silt load into Hygam from Balkul and Ningli perennial streams drain directly into this wetland which has resulted in deterioration of wetland quality and has reduced extent of the wetland area in the landscape. Results suggest desiltation of the wetland either through dredging or digging in the wetland. This would increase expanses of open water and other marshy habitats that in turn would increase the potential of the wetland to sustain abundant waterbird communities. Further siltation of Hygam wetland can be prevented by diversion of Balkul and Ningli flood channels to outside of the wetland. Furthermore, the application of proper soil and water conservation practices throughout the watersheds is of major importance.

Existing information (Weller, 1999) suggests that many wetland birds prefer "hemi-marsh conditions". This is an indication of the need for further research to determine marsh-open water ratio for different avian species or guilds, and whether such management would be a feasible option.

Local communities showed widespread support for the protection of Hokersar and Hygam wetlands and the awareness of their ecological significance. Protected areas in context of wetlands of Jammu and Kashmir have not worked against the economic interests of local communities. The integrated land use and wetland map of two areas shows that much of the catchments of two wetlands are located in the agricultural areas. As a result surface run-off carrying pesticides and fertilizers from agricultural fields and discharge of domestic sewage and effluents has resulted in prolific weed growth. Thick reed infestation particularly *Typha angustata* induced by eutrophication and siltation has led to decline in biodiversity of two areas. It is observed from this study that close-intimacy with wetland ecosystems has brought adequate awareness among local people of the problems associated with these wetlands.

The enhancement of conservation education will help local people to become more aware of the ecological importance of wetlands. Local communities particularly the Dars, Bhats, Khans, Chopans, Mirs retain a wealth of traditional knowledge. Management of the two wetlands should incorporate ideas, opinions and knowledge of local people. When decisions affecting wetlands are made with inadequate knowledge of local people conservation programs are unlikely to be successful.

Management of the wetlands in a comprehensive manner by incorporating other neighbouring wetlands, for example Mirgund, Narbal near Hokersar and Asham, Sopore- Numbal and Wular lake near Hygam will not only save the smaller wetlands in Kashmir valley from extinction but also facilitate maintenance of the water balance in both Hokersar and Hygam wetlands.

Hokersar has been listed under National Wetlands Conservation Programme. The wetland has also been internationally designated as Ramsar site. In the light of results of present study, Hygam also fulfils more than one criterion for qualification as a Ramsar site and deserves to be on the national priority list of wetlands of India.

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CHAPTER 1
INTRODUCTION

1.1 Wetlands - bioenergetics approach

Existence of life is the most striking feature of earth, and the most striking feature of life is its diversity (Tilman, 2000). Diversity of life or biodiversity can be defined as variety and variability within and among living organisms and the ecological complexes in which they occur, representing itself at various hierarchical levels of ecosystem diversity; community diversity; species level diversity; genetic diversity and functional level diversity. In the vast mosaic of ecosystem diversity, wetland ecosystems are extremely productive part of the landscape with average annual production above 1000 g cm^{-2} yr^{-1} (Whittaker & Likens, 1973; Gibbs, 1993) and various globally threatened avian species depend on them (Green, 1996). Nevertheless, wetlands are a patched habitat immersed in surrounding terrestrial landscape, where organisms seem to be affected by the natural insularity of the environment (Brown & Dinsmore, 1986; Knutson *et al*., 1999, Rey Benayas *et al*., 1999, Naugle *et al*., 1999; Wettstein & Schmid, 1999; Verboom *et al.*, 2001).

Wetlands are the first major ecosystems to be protected by an international treaty, "Ramsar convention" (1971) which defines them as “areas of marsh, fen, peatland, or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine waters, the depth of which at low tide does not exceed six meters.” Cowardin et al. (1979) based on detailed scientific criteria described wetlands as “lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.” Three attributes, which wetlands must have: (a) at least periodically, the land supports predominantly hydrophytes (b) the substrate is predominantly un-drained hydric soil (c) the substrate is non-soil and is saturated with water at some time during the growing season of the year. However, these ecosystems have always been an enigma to scientists because they are difficult to define precisely, not because of their great geographical extent, but because of the wide variety of hydrologic conditions in which they are found.

The estimate of the wetland extent in the world is difficult and depends on accurate definition. Maltby & Turner (1983), using the work of Russian geographers (Bazilevich *et al.,* 1971) provided an approximation that over 6% or 8.6 million km^2 of the entire land mass of the world is wetland. As part of the methane emission studies, the global extent of natural wetlands was calculated by Mathews & Fung (1987) as 5.3 million km^2. These figures are approximately double than those from earlier global wetland area estimates (Lieth, 1975, Ajtay *et al.*, 1979). This seems largely because two more recent studies used a broader definition of methane-producing wetlands. Mathews *et al.* (1991) estimated 1.5 million km^2 while Aselmann & Crutzen (1989) estimated 1.3 million km^2 of rice paddies. Thus, by including rice fields, aerial extent of wetlands was estimated as 7 to 8 million km^2. Finlayson & Spiers (1999) estimated global wetland cover from 12.75 million km^2 to 12.79 million km^2 .

Wetland ecosystems provide diverse functions and services at global, ecosystem and population levels. Ecosystem functions are primary productivity and decomposition (Mitsch & Gosselink, 1993; Corner, 1994); biogeochemical transformations and community / habitat provide a diversity of services vital for human well-being and poverty alleviation. Wetlands are also important in the global cycling of elements such as nitrogen, sulfur, and carbon (Bayley *et al*., 1986; Bowden 1987; Faulknerer & Richardson, 1989). Inland water systems play two critical but contrasting roles in mitigating the effects of climate change, firstly the regulation of greenhouse gases (especially carbon dioxide) and physical buffering of climate change impacts. Peatlands hold 540 gigatons of carbon, representing about 1.5% of the total estimated global carbon storage. Wetlands deliver a wide array of hydrological services, notably flood attenuation, aquifer recharge, river flow regulation, specifically the augmentation of low flows. They provide significant aesthetic, educational, cultural and spiritual benefits, as well as a vast array of opportunities for recreation and tourism. Wetlands are unique biotic communities that support diverse plants and animals adapted to shallow and often dynamic water regimes. At the population level, the wetland functions as wildlife habitats, maintaining unique species and biodiversity. Schweiger *et al.* (2002) states that it is the high habitat diversity, extent of resources, ecotones and refugia within wetlands that make them to support a high diversity of species (generalized across all taxa) compared to surrounding uplands.

There are increasing evidences of a rapid and continuing decline in many populations of wetland-dependent species. Data on the status and population trends on inland wetland-dependent groups, including mollusks, amphibians, fish, waterbirds and some water dependent mammals show clear declines. An overall index of the trend in vertebrate species populations have been developed and continuous and rapid decline observed in freshwater vertebrate populations since 1970 - a markedly more drastic decline than for terrestrial or marine species.

1.2 Waterbirds - taxonomic and ecological status

The waterbird communities form an important component of wetlands with their potential to detect aspects of wetland conditions, not detected by any other group. Referred as “birds belonging to the groups Gaviiformes, Podicipediformes, Pelecaniformes, Ciconiiformes, Anseriformes, Gruiiformes, Ralliformes and Charadriiformes” (Anonymous, 1996), these groups of birds ecologically dependent on wetlands are susceptible to disturbance, pollution, drainage and development. They also fulfill a very important role as being the main vector in maintaining a biotic connection between catchments for aquatic plants and invertebrates. Gill (1995) classified waterbirds into 14 taxonomic orders and 50 families. This classification system included some taxonomic bird groups less dedicated to water. Obviously, the unique and dominant feature of waterbirds is that these species seem to become better adapted to live in or on water, and long-term adaptations include genetically selected modifications in anatomy, morphology and physiology.

Waterfowl, the most conspicuous group of waterbirds is placed in order Anseriformes and with few exceptions; all species are assigned to Anatidae, the family of ducks, geese and swans. The most closely related birds, and the only other group placed in the same order is Anhimidae- the Screamers, (Johnsgard, 1965 & Kear, 1970), a family of only three species of long-legged, hook-billed birds restricted in distribution to South America (Fig.1.1). Early taxonomists constructed classifications based on superficial comparisons of morphology and limited reference material (Eyton, 1838; Peters, 1931). Important studies by Johnsgard (1961a) significantly increased the knowledge about waterfowl behavior. However, these studies nevertheless remained quite different from the phylogenetic approaches used in modern systematics. Livezey (1986, 1991) was the first to provide a classification based on cladistic analysis of 120 morphological characters to develop a phylogeny of the recent genera within Anseriformes and later used 157 characters to study the phylogeny. DNA studies were undertaken towards the end of 1990s, this probably represented the most useful arrangement of relationships. It was the sequence adopted by Madge & Burn (1988) who hoped that Livezey's review would be a standard for many years to come. Many waterbird populations are migratory in which the entire population or a significant proportion of the population (>1%) cyclically and predictably crosses one or more national borders or jurisdictional migrations between their breeding areas and non-breeding grounds, along several different flyways.

The characteristics of wetlands are being accentuated by human action on a worldwide basis, with a higher fragmentation and loss of area, which negatively affects waterbirds (Owen & Black, 1990; Finlayson *et al.*, 1992). As a result there has been a decline in several waterbird populations and number of species. Of the 1,138-waterbird biogeographic populations whose trends are known, 41% are in decline. Of the 878 species of waterbirds recorded globally in eight orders and 20 taxonomic families (Boere *et al.*, 2007), 173 species and 55 genera belong to waterfowl (Livezey, 1997b). Again, 203 species (21% of total) are extinct or globally threatened. A higher percentage of species dependent on coastal systems are globally threatened than those dependent on inland wetlands. The status of globally threatened birds dependent on freshwater wetlands and coastal waterbirds has deteriorated faster since 1988 than those dependent on other (terrestrial) ecosystems.

Based on the analysis of trends in biogeographic populations of 20 waterbird families, 41% are in decline. Inland and coastal waterbird populations are decreasing significantly especially in Oceania and the Neotropics. In Europe, 39% of populations are declining. The families showing population declines include darters with 71% decline, divers with 67%, skimmers with 60%, storks with 59%, rails and jacanas with 50% each, ibis and spoonbills with 48% and cranes with 47% decline. Only gulls, flamingoes and cormorants appear to have a relatively healthy population status. A similar picture emerges for Africa-Eurasia, although the status of some families in this region is worse than their global status (Millennium Ecosystem Assessment, 2005).

1.3 Wetlands and human values

Human beings are benefited from wetlands through production of renewable resources (Mitsch & Gosselink, 2000). Local communities worldwide depend on wetlands for a range of direct use values of food, fish and fiber that contribute to human well-being and poverty alleviation (Ozesmi, 2002). Some groups of people, particularly those living near wetlands, are highly dependent on these services and are directly harmed by their degradation. Two of the most important wetland ecosystem services affecting human well-being involve fish supply and water availability. Inland fisheries are of particular importance in developing countries, and they are sometimes the primary source of animal protein to which rural communities have access. Wetland related fisheries also make important contributions to local and national economies. Capture fisheries in coastal waters alone contribute $34 billion to gross world product annually. Groundwater, often recharged through wetlands, plays an important role in water supply, with an estimated 1.5 - 3 billion people dependent on it as a source of drinking water. Wetlands are important tourism destinations because of their aesthetic value and the high diversity of the animal and plant life they contain. The declining condition of wetlands has placed their ecosystem services and the people who depend on them at increasing risk. Water scarcity and declining access to fresh water is a globally significant and accelerating problem for 1-2 billion people worldwide, leading to reductions in food production, human health, and economic development.

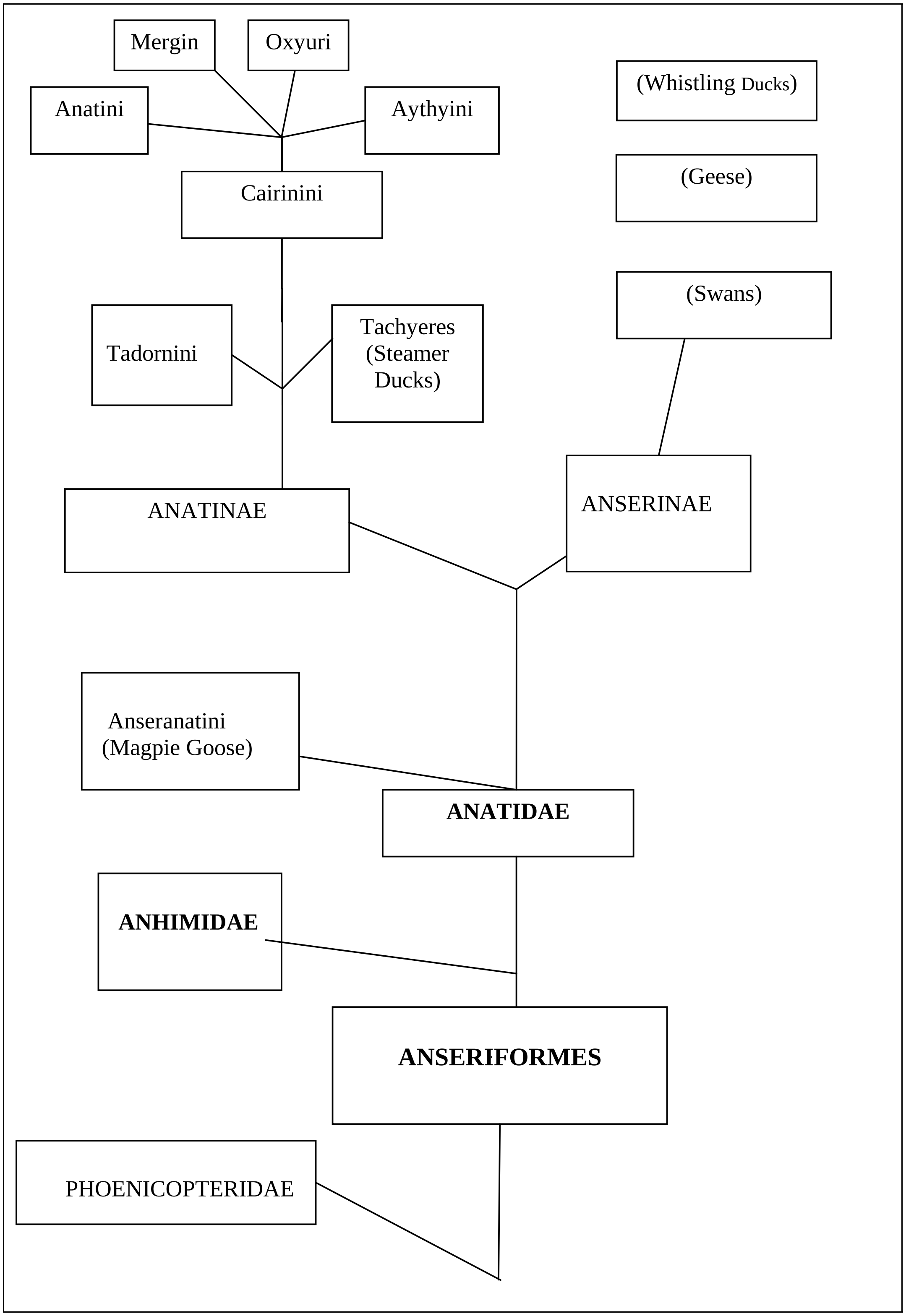

Figure 1.1 Simplified evolutionary tree of waterfowl and their close relatives.

Source: Johnsgard (1965) and Kear (1970).

1.4 Ecological stresses and threats

Wetlands are disappearing throughout the world at an alarming rate. Loss of wetlands worldwide is estimated as 50% of those that existed since 1990 (Dugan, 1993; OECD, 1996) with most of the loss accounted from northern countries. Tropical and sub-tropical wetlands are increasingly being lost or degraded since 1950s through conversion to agriculture use. Agriculture is the principal cause for a total of 26% of wetland loss worldwide. A study of coral reefs (WRI, 1998) indicate that 58% of the world's reefs are at moderate to high risk from human disturbance; 36% are threatened by over-exploitation; 30% by coastal development; 22% by inland pollution and erosion and 12% by marine pollution. Studies (Moser *et al.*, 1996) indicate that 84% of Ramsar-listed wetlands under threat by ecological change. No overall estimate of wetland loss in Asia is available. However, the region experienced wetland loss for thousands of years, with vast wetland areas drained for agriculture or settlement as again indicating wetland loss as total in some countries (Vietnams Red river delta flood plains). Wetlands continue to be degraded or destroyed in Asia; in their overview of the Asian wetland directory, Scott & Poole (1989) reported threats at 85% of the 734 sites.

Given trends in globalization during the past century, and the acceleration of commerce in the past few decades, human populations created enormous pressure on all natural environments including wetlands (Foundation for Environmental Conservation, 2001). Inextricably linked with the rate and extent of wetland loss and degradation worldwide is the issue of water allocation and distribution, which has become extremely important in recent times. Many rivers around the world are being regulated by the construction of dams to satisfy the increasing demand for irrigation and hydropower. Impacts on the rivers and associated natural water bodies, swamps and marshes include increased nutrient load, diminishing of underground water reserves, declining biodiversity and impoverishment of fish stocks due to impeded migration and degraded habitat (Bolen, 1982; Gopal & Wetzel, 1995; Liu, 1984). Ironically, countries are now facing problems with siltation of reservoirs. Taub (1984) reports that water demand in Japan resulted in many large artificial lakes on almost all river systems, but a decrease in water volume of 70 - 80% occurred due to silting over 20-30 years. Growing populations and increased development is also resulting in more domestic and industrial pollutants being discharged into wetlands. Yet there has been little research on pollutants and their effects, especially on fisheries, in many developing countries (Gopal & Wetzel, 1995).

Small lakes and ponds have been drained or filled in to extend arable land, regulated to reduce water-level fluctuations and used as dumps for an array of anthropogenic wastes. Many natural populations of commercially important freshwater species have been over-exploited (Loganathan & Kannan, 1994; Richter *et al*., 1997; Leveque, 2001).

Extinction rates of freshwater species are estimated as high as for tropical rainforest systems (Riccardi & Rasmussen, 1999) considering them as most stressed terrestrial systems on earth. Presently, more than 1100 fresh-water invertebrates are endangered, a number that most certainly is too low as knowledge on smaller, less conspicuous or economically unimportant species is sparse and there is little or no monitoring of freshwater organisms in large parts of the world (Strayer, 2001). Some groups seem to be at higher risk than others. For example, 21 of the 297 North American freshwater clam and mussel species are already extinct and over 120 are threatened, while 30% of North American and 40% of European fish species are threatened. Many anthropogenic factors affect biodiversity in ponds and lakes and often several factors act in concert to cause the extinction of a certain species. For example, the number of threats affecting endangered freshwater species in the USA ranges from one to five per species (average 4.5, Richter *et al*., 1997). Changes in land use, atmospheric Co_2 concentration, nitrogen deposition, acid rain, climatic and biotic exchanges are the most important determinants of biodiversity at the global scale. For lakes, land-use changes and invasion of exotic species will remain major drivers of biodiversity over the next century, whereas climate or deposition of nitrogen or Co_2 was predicted to have a low impact on biodiversity in the future (Sala *et al.*, 2000).

Predictions based on a review by Bronmark *et al.* (2002) to determine future of wetland ecosystems against ecological stress suggest that older, well known threats *viz* eutrophication, acidification and contamination by heavy metals and organochlorines may become less of a problem in developed countries in future. New threats including global warming, ultraviolet radiation, endocrine disruptors and especially invasion by exotic species, transgenic organisms most likely increase in importance (Sala *et al*., 2000), have far-reaching effects on wetland ecosystem functioning and biodiversity.

1.5 Wetlands in Indian context

India, with its annual rainfall of over 130 cm, varied topography and climatic regime supports and sustains diverse and unique wetland habitats. Natural wetlands in India consist of the high-altitude Himalayan lakes, followed by wetlands situated in the flood plains of the 14 major river systems and saline and temporary wetlands of arid and semi-arid regions. Along the entire coast, there are lagoons, estuarine backwaters and extensive mangroves in the deltas and estuaries of numerous rivers. Marine wetlands include coastal beds of marine algae and coral reefs. Infact, with the exception of bogs, fens and typical salt marshes, Indian wetlands cover the whole range of ecosystem types found. In addition to the various types of natural wetlands, a large number of man-made wetlands also contribute to the faunal and floral diversity. It is estimated that freshwater wetlands alone support 20 percent of the known range of biodiversity in India (Deepa & Ram Chandra, 1999). Varying estimates of the total extent of wetland resources exist in India. The Ministry of Environment and Forests, Government of India in 1990 estimated 4.1 million hectare of area under wetlands in India (excluding paddy fields and mangroves) (Anonymous, 1993). This included 67, 429 wetland units in the country. Of this, 1.5 million hectare or 2167 wetlands exist as natural and 2.6 million hectare or 65, 253 wetland units as man-made wetlands. A survey by Space Application Centre (SAC) during 1990s using remote sensing techniques estimated 3.5 million hectare of area under wetlands in India, above 56 hectare in size.

Wetlands in India where 16% of the world's population is contained in only 2.42% of the earths land surface are increasingly facing several anthropogenic pressures. The rapidly growing human populations, large-scale changes in land use- land cover, burgeoning development projects and the improper use of watersheds have all caused a substantial decline of wetland resources of the country (Foote *et al*; 1996). Significant losses in India have resulted from its conversion for industrial, agricultural and various urban developments. These have led to hydrological perturbations, pollution and their effects. Unsustainable levels of grazing and fishing activities have also resulted in degradation of wetlands. Survey of the 140 major sites across various agro-climatic zones identified anthropogenic interference as the main cause of wetland degradation (Anonymous, 1993).

Three quarter of Indian population being rural, places great demands on wetland resources in India. Healthy wetlands are essential in India for sustainable food production and potable water availability for human and livestock. Wetlands are also necessary for the continued existence of India's diverse populations of wild animal and plant species of which a large number of endemic species are wetland dependent.

India is also a winter terminus for several species of migratory waterbirds from Palearctic region in central Asia (Ali & Ripley, 2002). There are 42 species of Anatids of 245 waterbird species that are recorded in India. Most species being migratory in nature undertake annual migrations *via* central Asian-Indian flyway.

In India, the Ministry of Environment and Forests (MoEF) constituted a National Committee on Wetlands, Mangroves and Coral Reefs, to advise the government on appropriate policies and programmes for the conservation of these ecosystems, to suggest specific sites for conservation action, and to identify research and training priorities. Several wetland sites in the country have been selected on a priority basis for conservation and management action, financial support for which is being extended by the Ministry of Environment and Forests (MoEF, 2001). Twenty-six sites from India have been internationally designated as Ramsar sites however; they do not represent even a fraction of the wetland diversity in the country.

Recognizing the value of wetlands and taking cognizance of the fact that there does not yet exist a formal system of wetland regulation, the National Environment Policy (NEP), 2006 as approved by the cabinet in May 2006 seeks to set up a legally enforceable regulatory mechanism for identified valuable wetlands to prevent their degradation and enhance their conservation. It also undertakes to develop an inventory of such wetlands. In pursuance of the policy resolution, a multi disciplinary expert group has held a series of meetings to formulate a regulatory framework for the wetlands. The expert group has prepared its recommendation on the categories of wetlands for regulation, process and procedure for identification, composition of regulatory authority, functions of the authority, and activities to be regulated. A draft notification is proposed to be brought out under the provisions of the Environment Protection Act, 1986.

1.6 Wetlands in Jammu & Kashmir

Stretching between 32^0 17’N to 37^0 6’N latitude and 73^0 26’E to 80^0 30’E longitude, the Himalayan state of Jammu and Kashmir abounds in diversified types of natural freshwater lakes and wetlands. Space Application Centre (1998) estimates 3.97% of the land of the state covered by wetlands, each of size of 56.25 ha and above. Based on above scale, 42 wetlands covering an area of 4,068 km^2 are located in Jammu and Kashmir (Vijayan *et al.*, 2004).

Kashmir valley nestled in northwestern folds of the Himalayas is replete with diverse types of freshwater bodies (Khan, 2000). Zutshi & Khan (1978) in a classic typology recognized three major categories of water bodies based on their origin, altitude and nature of biota; valley lakes (1580-1600 m) of Kashmir valley, forest lakes (2000-2500 m) of Pir Panjal range and glacial or high altitude (3000 m) lakes. Valley lakes located in flood plains of river Jhelum and river Sind show varied hydroedaphic features. The valley wetlands provide over-wintering resort to millions of waterbirds from their breeding grounds in Palearctic region extending from north Europe to Central Asia (Ali, 1979) and breeding ground to a segment of waterbird species (Pandit, 1982).

Pandit & Kaul (1982) reported 198 species of phytoplankton and 147 species of zooplankton from wetlands of Kashmir valley. Zutshi & Gopal (1990) reported the occurrence of about 255 aquatic plant species in Kashmir constituting about 20% of the total Indian species. Various estimates on fish species are available, Hora *et al.*(1955) reported 17 species; Das *et al.(* 1963*)* reported 36 species and Nath *(*1986*)* reported a total of 42 fish species from wetlands of Kashmir valley. Further revised version by Yousuf (1996) shows the presence of only 37 species with some having uncertain taxonomy. Variation in avifauna data of wetlands of Kashmir valley is found, however avifaunal studies yield 90 bird species from the valley (Prasad *et al*., 2004). Wetland dependent globally threatened bird species recorded from Jammu and Kashmir include Marbled Teal *Marmaronetta angustrirostris*, Palla's Fishing Eagle *Haliaeetus leucoryphus*, Greater Spotted Eagle *Aquila clanga*, Sarus Crane *Grus antigone* and Black Necked Crane *Grus nigricollis.*

The major threats to wetlands of Jammu and Kashmir include increased siltation, eutrophication due to run-off from catchments, agricultural conversion, receding open water areas as a result of expanding reed beds, construction of canals, weirs, levees and over-grazing (Bacha, 2002). The recent enactment of the Roshni act by the Jammu and Kashmir Government has very serious consequences on the wetlands, particularly the wetlands of Kashmir valley. The Roshni act has a provision of legalizing all the illegal encroachments, after payment of a token money by the encroachers.

Of the 21 Important Bird Areas in Jammu and Kashmir, 11 fulfill Ramsar criteria (Islam *et al.*, 2008) and four wetlands are designated as Ramsar sites. It includes Wular Lake and Hokersar wetland in Kashmir valley, Tso morari in Ladakh division and Surinsar-mansar lakes in Jammu division of the state. The Ministry of Environment and Forests, Government of India, has identified


Marshy Areas of Wetland Ecosystems


Floating Leafed Vegetation in Wetland Ecosystems


Peatland Habitats in Wetland Ecosystems


Plantation bordering Wetland Ecosystem

Plate 1. Wetland habitat types in Jammu & Kashmir

the following wetlands under the Wetland Conservation Programme: Hokersar, Mansar-Surinsar, Pangong Tsar, Ranjitsagar, Tso Morari, Tisgul Tso and Chushul marshes and Wular Lake.

1.7 Review of literature

Vast bodies of literature pertaining to waterbird communities exist. Waterbird population estimates by Rose & Scott (1994, 1997) and Wetlands International (2002), the only published document on status of world's waterfowl population provide regular updates on their status and estimates of trends in population. Rose & Scott (1994) in a first ever attempt provided an overview of what is known about the status of world's waterfowl populations. Since then a many gaps in knowledge have been filled and some erroneous or out of date piece of information have been corrected.

Effects of habitat diversity on waterbird distribution were studied in detail by Henderson *et al.* (1992) in lake Naivasha, Kenya; Gan *et al*. (2007) in Yangtze river estuary China, Hetmeyer & Vohs (1984) in Oklahoma. Such studies indicate that complexity in wetland habitats contribute to increased species diversity. Meininger *et al*. (2000) attributed salinity gradients in estuarine wetland as a limiting factor in waterbird distribution.

Published literature pertaining to impacts of wetland degradation, climate change and disturbance is available. Duncan et al. (1999) in a long-term study on effects of changes in agricultural practices in Marais Poitevin wetland, France revealed a sharp decline in waterbird number in response to wetland loss. A decrease in waterbird carrying capacity of wetland ecosystems in relation to climate change, human disturbance, dam geomorphology is reported (Atkinson et al., 2004; Burton et al., 2002a, b; Burger et al., 2004, Stevens et al., 1998). Evaluation of bird species richness in lake Agmon, Israel prior to draining and after re- flooding was attempted (Beckerman, Oron & Frankenberg, 1998). Mamikon et al. (2002) compared waterbird diversity of lake Sevan and lake Gilli in Armenia while Zhao et al. (2004) attempted similar study in artificial and natural wetlands. The studies found water regime as the prime deciding factor and artificial wetlands as no alternatives to natural wetlands as bird habitats.

Apart from mid-winter waterbird census in U.K by Wetlands International (Rose & Scott, 1997), annual wetland bird survey (WeBS) provides periodic indices of annual abundance and national population estimates (Cranswick *et al*., 1997).

Detailed studies on effects of landscape fragmentation on waterbird populations are poorly documented (Guadagnin *et al*., 2005, 2007) Nevertheless; the studies show abundance and composition of waterbird assemblages affected by factors of regional pool of species, fragment area, matrix permeability and wetland connectivity (Bellrose, 1972; Longcore & Gibbs, 1988, Owen & Dix 1986; Pirot, *et al*., 1989, Atkinson *et al*; 2006).

Some notable North American breeding waterbird surveys include those of Kantrud and Stewart (1973) in Praire wetlands of North Dakota and Duebbert *et al*. (1983), Lokemoen & Woodward (1992), Krasowski & Nudds (1986) and Klett *et al*. (1988) in Parkland region of southwestern Manitoba.

Long-term monitoring of effects of spring temperature on duck nest success was attempted (Drever & Clark, 2007). Study showed that nesting success is not affected by spring temperature increase. Three long-term data sets (26 years) assembled from literature and unpublished records between 1959 and 1984 (Kaminski & Gluesing, 1987) evaluated Mallard recruitment rate in Mississippi flyways.

A few studies on habitat utilization of dabbling ducks have been attempted. (McKinney et al., 2006; Heitmeyer & vohs, 1984; Hirst & Eastthope, 1981). Kaminski & Prince (1984) examined availability – preferences of dabbling ducks in delta marsh, Manitoba. Study revealed that species pair densities and species diversity are positively correlated to proportional area. Habitat use of migrant Sand hill Cranes (Krapu *et al*., 1984), Mallard (Lagrange &

Dinsmore, 1989), American Black Ducks (Brunswick, 1990) are also reported. Only study conducted on waterfowl habitat use on high altitude wetlands of Uinta Mountains Utah (Peterson & Low, 1977) attributed waterfowl utilization to ice melts. Availability and invertebrate duck preference was studied by Joyner (1980); Mulkin & Kadlec (1986). Information in Asian context is little documented (Quan *et al.*, 2001; Hattori & Mae, 2001).

Interrelations between wetland ecosystems, resource dependence and local economy have been rarely studied. Most of the research has assessed this relation on forest ecosystems. Sah & Heinen (2001) examined resource use and conservation attitude of local people in Ghodaghadi lake area, Nepal. The study indicated that decisions affecting wetlands without knowledge of conservation attitudes and resource use practices of local communities were unsuccessful. A study in North Brazil on relationship between mangrove ecosystem and local communities (Gluser, 2003) attributed subsistence production of mangrove ecosystems to socio-economics of local rural communities.

Drew *et al*., (2005) derived direct use values and other goods and services of a tropical freshwater wetland. Other attempts to quantify free services and amenities wetlands provide for society include Wharton, 1970; Gosselink, Odum & Pope, 1974; Jaworski & Rapheal, 1978; Mumphrey et al., 1978; Mitsch, Hutchinson & Paulson, 1979 and Costanza, 1984.

Satellite remote sensing has been used to map large wetland ecosystems, including Sango Bay on lake Victoria in Uganda, which includes papyrus swamps, tall grass swamps, riverine and swamp forests (Fuller *et al*., 1998). Also, energy fluxes of the internationally important, Esteros del Ibera in Argentina, one of South Americas largest wetlands which consists of a mosaic of marshes, swamps and lagoons (Louiselle *et al*., 2001) were also studied using remote sensing.

Coastal tidal marshes are the type of wetlands that have been most frequently studied using satellite remote sensing. Hardisky *et al*., (1986), Hinson *et* *al*.,(1994), Jensen *et al*., (1993a), Lee & Park (1992) and Ramsey & Laine (1997). Ramsey & Laine (1997) took advantage of multi- temporal data to improve classification. The combination of two dates of imagery allowed separation of emergent and floating vegetation (winter and spring) and flooded emergent vegetation and open water (fall and winter). Mangroves and other coastal wetlands were studied by Butera (1983) in the southern US.

Inland freshwater marshes have been another frequently studied wetland type Ernst & Hoffer (1979), Forgette & Shuey (1997). In the southeastern US, spring imagery was found optimal for wetland discrimination (Jensen *et al*., 1984). Wet meadows were studied by Kindscher *et al*., (1998). Other inland wetlands studied with satellite remote sensing include Prairie Pothole region of the US and Canada (Best & Moore, 1979; Gilmer *et al*., 1980) and Nebraska Sandhills (Goodin, 1995).

Studied areas included forested wetlands, or swamps (Ernst & Hoffer, 1979; Sader *et al*., 1995) including those in the Brazilian Amazon (Mertes *et al*., 1995). Riparian areas in arid regions have been mapped with satellite remote sensing (Hewitt, 1990; Lee & Marsh, 1995). In open water areas, submerged aquatic vegetation was mapped with remotely sensed satellite imagery (Ackleson & Klemas, 1987; Zainal *et al*., 1993).

The knowledge of Indian birds mainly comes from pioneering work of Baker (1929), Whistler (1935) and Ali & Ripley (1968, 1983). Ali & Ripley (1968, 1983) gave information on the distribution and general biology of waterfowl. Information on the status of Indian waterbirds is available since 1987 from mid-winter waterfowl census (ven, 1987, 1988; Scott & Rose, 1989; Mundkur & Li, 2004).

Studies focusing on population estimation of single species in India are available (Jayaraman, 1985; Sridharan, 1989; Ambedkar & Daniel, 1990; Manakadan, 1995; Vijayan *et al*., 1996). However, some studies on waterbird communities are well documented. Hussain & Mohaptra (1984) studied the movement pattern and population structure of avifauna of Chilka Lake while

Ali & Sugathan (1985) studied total Indian avifauna. Vijayan & Bhupathy (1998) did long-term and systematic study on population ecology of migratory waterfowl in Keolodeo National Park. Perennou (1989) and Perennou & Santharaman (1990) assessed the status and species composition of waterfowl in the Coromandel Coast that covers the coastal parts of Tamil Nadu and Andhra Pradesh. Bharadwaj (1997) did assessment of status of aquatic waterbirds in Periyar Lake, Kerala. An extensive and long-term study on shorebirds was carried out by Balachandran (1995) in Marine National Park. Sampath & Krishnamurthy (1989) assessed status of shorebirds of salt ponds at the great Vedaranyam salt swamps, Tamil Nadu. Wintering waterbird communities in a subtropical wetland in Haridwar (Bhatt & Kumar, 2000) and Ropar Punjab (Paliwal & Tak, 2005) were studied. Other detailed account of waterbird communities includes (Venkataraman, 1996 and Bhupathy, 1991). Nagarajan & Thiyagesan (1996) studied substrate quality effect on density and diversity pattern of waterbird communities while Banerjee & Gopakumar (1987) investigated drought effect on wintering cranes. A study on habitat use of waterbirds in artificial wetlands of Saurashtra region was undertaken (Gopakumar, 1980). A Comparative study (Pandey, 1993) on change in avifauna of a Punjab plain zone due to construction of Pong dam. Published works on breeding status of some waterbird species includes (Sridharan, 1989 & Ramachandran *et al*., 1995 from Keolodeo National Park.

In-depth and systematic studies concerning conservation attitude and resource dependence of local communities on wetland ecosystems in Indian context are quite few. Assessment of resource dependence and conservation attitudes of local people towards Kabartal wetland was undertaken (Ambastha *et al*., 2007a). The study revealed various types of subsistence and commercial goods derived from wetland by local communities. Ambastha *et al*. (2007b) evaluated Willingness to Accept (WTA) compensation range by local people around Kabartal wetland as an alternative to resource use. A work on sustainable development and water resources management of Loktak Lake showed that natural resources form the base of existence of the communities living in and around Loktak (Trisal & Manihar, 2004). Badola &

Hussain (2005) did valuation of storm protection function of Bhitarkanika mangrove ecosystem.

A few scientific publications in Indian context on mapping and other characteristics of wetland ecosystems in Geographical Information System (GIS) based domain exist. Chopra *et al*. (2001) studied water turbidity, seasonal water fluctuations and vegetation status of Harike wetland in Punjab by visual analysis of False Color Composite of IRS LISS –II bands 2, 3 and 4. Kushwaha (2000) evaluated ERS- 1 –SAR and 1RS-1B LISS-II data for discrimination of mangrove wetlands in the coastal region of West Bengal.

Ecological studies of aquatic plants in India remained much neglected. Misra (1944b, 1946) made detailed observations on the vegetation of shallow temporary water bodies in and around Varanasi. Subramanayam (1962a, b) published an overview of the more common and important aquatic angiosperms in India. He listed only 117 species covering 32 families. Spence (1982) critically reviewed the literature concerning factors that affect vertical and horizontal zonation of aquatic vegetation. Only some species that are widely distributed geographically occur in a wide range of habitats and those species that cause serious problems in water bodies by their explosive growth, have been intensively investigated. Species studied include; *Phragmites australis* (Rodewald- Rudescu, 1974); *Typha* species (Gopal, 1982; Smith, 1987), *Hydrilla verticillata* (Pieterse, 1981), *Myriophyllum spicatum* and *Potamogeton crispus* (Nichols & Shaw, 1986).

Detailed and long-term scientific investigations on wetlands of Kashmir valley pertaining to their ecological aspects are rare. Published information on some aspects is available. Studies on wetland ecology include plankton dynamics and productivity (Akthar, 1991; Zutshi & Khan, 1980); density estimation, biomass of phytoplankton and zooplankton, benthos and macro fauna (Pandit & Qadri, 1986; Pandit & Kaul, 1982). Mukherji (1926) reported briefly on the vegetation of Dal Lake in Kashmir. Aquatic angiosperms of some parts of Kashmir have been described in some detail during the past few years (Kak, 1982; Handoo, 1978). Study by Khan *et al*. (2004) on the macrophyte community in relation to environmental stresses of Hokersar wetland reserve is probably the only long-term study carried out so far. The study indicates a shift in macrophyte community structure of Hokersar wetland as evidenced by *Nelumbo nucifera* and near disappearance of *Eurayle ferox* and *Acorus calamus.*

The book on Indian birds (Ali, 1979) and an account on birds of Nepal with reference to Kashmir and Sikkim (Fleming *et al*., 1976) carry vivid notes on distribution and various aspects of biology on waterbird communities of Kashmir. Bates & Lowther (1952) in "Breeding birds of Kashmir" provide information on breeding behavior and distribution of waterbirds of Kashmir. Apart from some published reports on waterbird census by Jammu and Kashmir Wildlife Protection Department (Bacha, 1993 & 1994) to provide base-line information on their population status, only a few scientific publications are available. Studies on food of Graylag Geese (Shah *et al*., 1983) and of that of Mallard (Shah, 1988) undertaken in Hokersar wetland supported the herbivory of waterfowl during winter. Pandit (1982) in a detailed study investigated feeding ecology of breeding birds in some selected wetlands of Kashmir valley. A study on feeding of wintering waterbird communities (Pandit, 1989) is also reported. The only ornithological survey in Hygam wetland (Holmes & Parr, 1988) gives a comprehensive account of resident bird species. Nothing in detail is known on patterns of waterbird community structure. Wintering and resident waterbird communities studied (Shah, 1984) dealt precisely with their population status. Khan & Bashir (2003) and Khan (2003) in a one-year study examined population status of resident and non-resident waterbirds in Hokersar wetland.

One and the only study on landscape structure of Hokersar wetland include time series change detection study (Joshi & Hamuyun, 2002) using IRS and LISS III and Land sat – 5 TM satellite imagery data for the year 1992 to 2000. Only one study pertained to socio-economy and ecology of Hanjis of Dal lake ecosystem (Rather, 2003).

From review of literature, it is clear that detailed studies on waterbirds are lacking from wetlands of Kashmir valley. Despite the fact some ecological studies on aquatic plants of Kashmir are reported, studies that capture in totality the aquatic floristic community structure are not available. Virtually nothing is known on dependence of local people on wetland resources and their conservation attitudes. Studies designed to elucidate land use-land cover characteristics of wetland landscapes have been severely neglected. The present study plans to compare the waterbird population and extent of human use in Hokersar and Hygam wetlands in Kashmir valley for conservation planning as a case study.

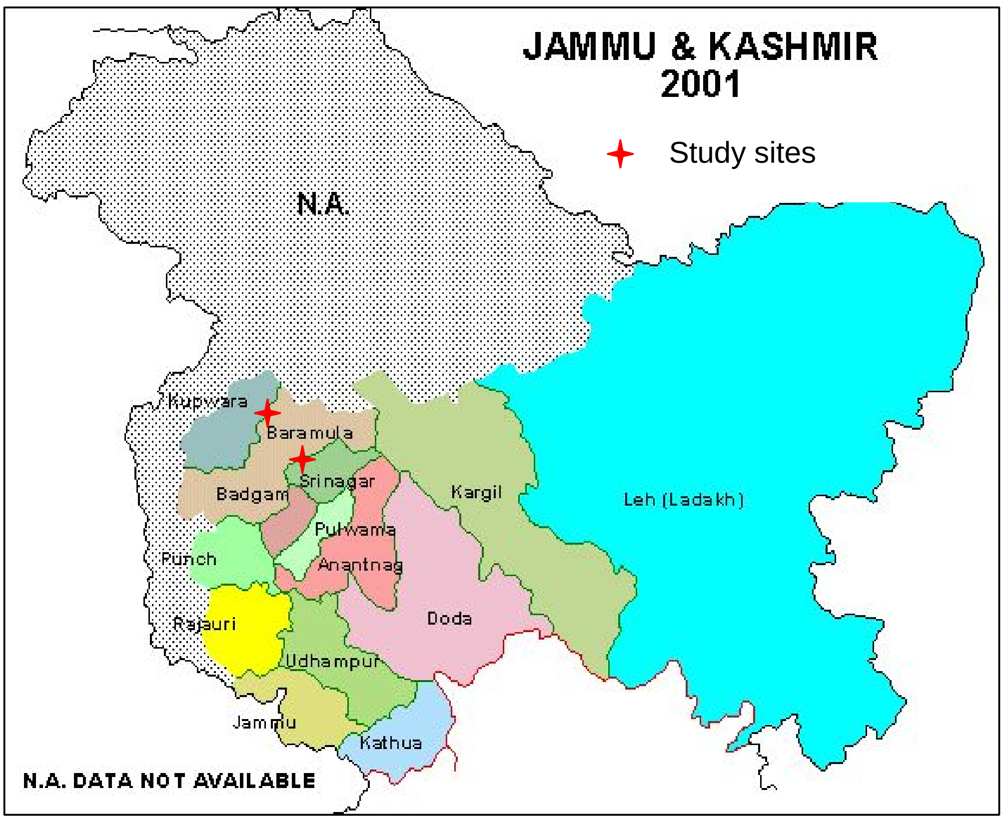

Figure 1.2 Location of the Hokersar and Hygam wetlands in the state of Jammu and Kashmir.

1.8 Justification of study

The waterbird communities represent useful foci for conservation research and action in the light of extensive wetland loss and the surge of interest in conserving diversity. Individual species differ in their responses to human disturbances and therefore enable a better and more holistic assessment of the effects of such disturbances. Pattern of habitat utilization of a species and its study is essential to understand species biology and consequently, for management and conservation. Detailed description of vegetation community reveal the conservation status of various species and are of major significance in animal ecology and wildlife management. A key challenge to the management of PAs in India is the local people's livelihood vis-à-vis biodiversity conservation. In this context, analyzing linkages between the socio-economic structures of the surrounding people with natural areas is important. For conservation policies to be successful adequate knowledge on attitude of local communities regarding environmental issues and their practices of resource use is must. Decisions affecting wetlands without knowledge of attitude of local people make conservation programmes unsuccessful. Characterization of wetland landscapes by land use mapping in Geographical Information System based domain serves as a quick and cost effective database for future landscape change detection studies.

Literature cited shows detailed studies on waterbirds are poorly known from the state of Jammu & Kashmir. There are very little efforts made for assessment of socio-economics of local communities and their dependence on wetland resources in the Jammu & Kashmir State. The present study aim to study the spatio-temporal variation in the density and diversity pattern of waterbirds in Hokersar and Hygam wetlands vis a vis human use for effective conservation planning.

1.9 Research question and objectives

Keeping in view the above background, following research questions were posed while formulating the present study in Hokersar and Hygam wetlands:

- Are the land use - land cover characteristics of Hokersar and Hygam wetlands different from each other?
- Is there any marked spatio-temporal variation in the density and diversity pattern of waterbirds in Hokersar and Hygam wetlands of Jammu & Kashmir?
- Is there any variation in habitat use pattern by waterbirds in these wetlands considering the fact that the wetlands have different degrees of human impacts?
- What is the extent of resource use by the local people living around these two wetlands and how their perception and attitude can help in the management?

In order to achieve the above aim, the following objectives were set forth for the present study:

- Map the habitat types with respect to water depth and vegetation characteristics of Hokersar and Hygam wetlands of Jammu & Kashmir.
- Derive spatio-temporal variation in the density and diversity pattern of waterbirds in these wetlands.
- Examine the seasonal pattern of use of these two wetlands by migratory and resident waterbirds.
- Examine the extent of use of these wetlands by the local people and their perception and attitude towards these wetlands.

1.10 Organization of thesis

The entire effort for the thesis work and its outcomes are synthesized into eight chapter's *viz* (i) Introduction, (ii) Study Areas, (iii) Study design and methods, (iv) Land use mapping and vegetation study, (v) Bird species distribution and abundance, (vi) Habitat utilization, (vii) Socio-economics and resource dependency, (viii) Conservation implications. Chapter I reviews the research subject, enumerates the key questions and outlines the study objectives. Chapter II describes two study areas for this research giving a biogeographic and historical background. A comprehensive introduction to the specific topics of research, along with details of methods and analysis is presented along with each of the succeeding four chapters dealing with the major results of the study. In Chapter III, only cursory methods are mentioned and further details have been adequately elaborated in the relevant technical chapters.

Chapter IV describes land use characteristics and aquatic floristic community structure of two study wetlands and it compares the land use - land cover characteristics of Hokersar and Hygam wetlands. In Chapter V, patterns of waterbird community structure along spatio-temporal gradient are discussed. Chapter VI focuses on seasonal pattern of habitat use by waterbirds. Chapter VII evaluates dependence on wetland resources by local communities and their attitudes towards conservation of these wetlands. Chapter VIII synthesizes and briefly summarizes the broad findings and conclusions, highlight conservation implications, and give pointers for future work. The literature that is referred to and cited in all these chapters is compiled and listed at the end under references.

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CHAPTER 2
STUDY AREA

2.1 Introduction

This study was conducted in Hokersar and Hygam Wetland Conservation Reserves of Jammu & Kashmir state (India). The two wetland reserves hold a unique distinction among the remaining large reed beds of Kashmir valley. They provide an extensive over-wintering resorts, excellent cover and safe roosting and feeding grounds to a large population of migratory waterbirds.

2.2 Hokersar Wetland Reserve

The Hokersar wetland reserve, a renowned waterfowl reserve, lies around 10 km west of Srinagar on Srinagar- Baramulla highway, on the banks of the Jhelum River. The wetland is situated in district Srinagar and Budgam (between $34^0\ 0^{'}$ to $34^0 10^{''}$ N and $74^0 40'$ to $74^0 45^{'}$E) at an altitudinal height of 1584 m asl. (Fig.2.1). The wetland spans an area of 13.75 km^2 in the centre of Kashmir valley and extends from southeast to northwest direction. The wetland is maintained by the Department of Wildlife Protection, Jammu and Kashmir as a Conservation Reserve in accordance with the rules of the Jammu & Kashmir Wildlife Protection Act, 1978. It is approachable by National Highway 1-A leading to Baramulla-Uri sector with snow draped Pir Panchal looming in its backdrop. The wetland is roughly oval in shape and is contiguous with villages of Zainakot, Khushipora and Hajibagh to the east. The wetland is bounded in the north by Srinagar flood-plains of river Jehlum. To the south, it extends upto the human habitation of village Soibugh, while the temporary wetland of Rakh- arth under the control of Lakes and Waterways Development Authority of Jammu and Kashmir state borders the wetland towards south-west direction and to the west, it is bounded by village Gund-Khalil.

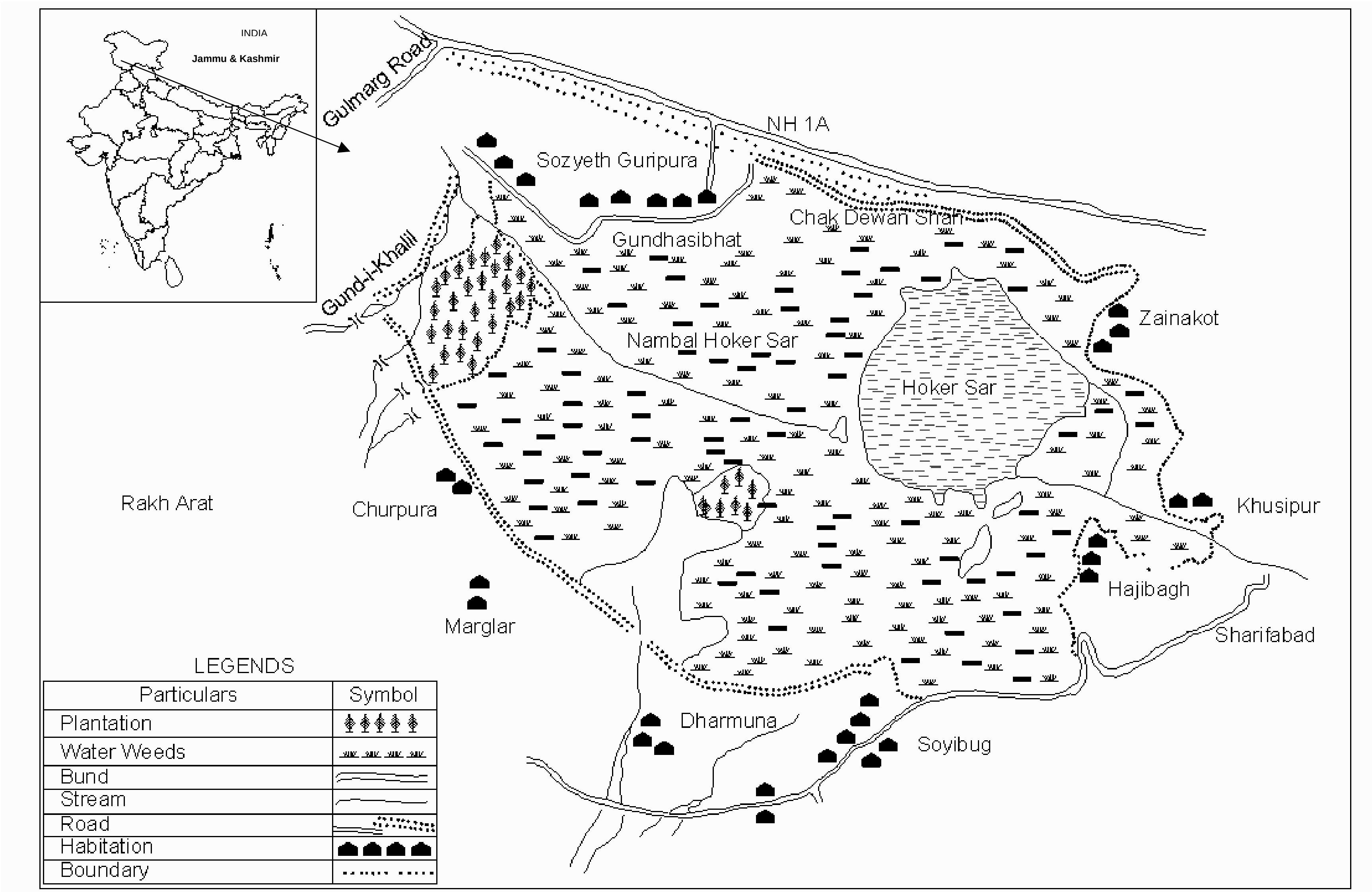

Figure 2.1 Map of Hokersar Wetland Reserve, Jammu & Kashmir

2.2.1 Brief conservation history of the wetland

The wetland has a long history of over a century and was a shooting resort of the then Maharaja Hari Singh of Jammu & Kashmir state. The wetland has successively been under the administration of (1) department of Twaza (Hospitality and Protocol) and Game and Fisheries department till 1947 and it was notified as a state Rakh in the year 1945 (2) Department of Game when Fisheries wing was separated from it till 1973 (3) It was again back to Game and Fisheries department till 1979 (4) Department of Wildlife Protection from 1979 onwards. The wetland has been notified vide cabinet order No: 710/ c of 1945 (G.G) dated July-17-1945 by the then state government. Late Ghulam Ahmed Bakshi, the then Chief Minister of Jammu & Kashmir State, raised the peripheral bund at the time of Maharaja in 1960.

2.2.2 Description of the site

The wetland has been classified as wetland type 14, because of the type of wetland habitat present, i.e. freshwater marshes (Scott, 1989)**.** Given its value in maintaining livelihoods and ecological balance, Hokersar was identified by the National wetland committee as one of the 16 important wetlands in 1987 for drawing up a management action plan and is currently a conservation reserve (Anonymous, 1993). It is also an Important Bird Area (Islam & Rahmani, 2004).The wetland was declared as a Ramsar Site, a wetland of international importance by Ramsar Convention Bureau on November 8, 2005 and the Ramsar Site number accorded to it was 1570.

The wetland is a permanent natural marsh fed by a perennial stream of Doodganga which makes its way into it after passing through the village Hajibagh situated on its southeast. Another stream namely Sukhnag enters into the area near village Narbal located on northwest, which ultimately directly drains into the Doodganga near Sozeith village just behind the existing needle gate. The lake is drained by a channel to the Jehlum river at Sozeith Narbal village.

The water table keeps on fluctuating greatly throughout all seasons in response to the main discharge from the Doodganga channel, where from there is influx of heavy silt load and nutrients. The wetland reaches a maximum depth of 2.5 m in spring with snow-melt water, and a minimum of 0.7 m in autumn. The water is very turbid, with little light penetration. The underlying soils are of a silty-clayey-loam type. The Ph is greatly affected by the high summer temperatures which accelerate the process of decay of organic matter.

2.2.3 Climatic conditions

The climate in the area is sub-Mediterranean with very warm, relatively dry summers (May to August) and cold, wet winters (October to March) with some precipitation in the form of snow. The average annual rainfall is 550 mm, most of which falls between January and March. Average temperatures range from 7.5^0 C in winter to 19.8^0 C in summer.

2.2.4 Floral diversity

The wetland supports a definite type of vegetation ranging from submergent, attached floating, free floating and emergent aquatic vegetation-grasses, herbs, reeds and sedges. Following typical marshy vegetal complexes are exhibited over there which are controlled by factors like water depth, water chemistry etc.

In southern segment and marginal land of shallow water ditches, the dominant plants are *Typha angustata, Typha laximanii, Phragmites communis, Eleocharis palustris, Scirpus* species*, Butomus umbellatus, Frimbistylis squarosa* and those which occur commonly are *Lemna gibba, Lemna minor, Lemna trisulea, Spirodella polyrhiza, Myriophyllum verticilltum, Myriophyllum spicatum, Alisma plantago aquatica* and *Sagittaria sagitifolia.* When these shallow water ditches dry up, the vegetation is replaced by ephemeral species like *Batrachium trichophyllum* etc.

In the region of open water and deeper parts, thick growth of *Trapa natans, Butomus umbellatus, Hydrilla verticillata, Sagittaria sagittifolia, Alisma* species*, Nymphoides peltatum, Nymphoides stellata, Nymphoides candida, Sparganium ramosum, Limnosella aquatica*, *Potamogeton* species, and

Polygonum species, are commonly met in northern and northeast effective lake area. At least 156 species of phytoplankton have been recorded, with Chlorophycea predominating.

In the north- western part of the reserve, large numbers of floating gardens remain invariably inundated and are colonized by hydrophytes like *Myriophyllum spicatum* and *Hydrilla verticillata* during spring months. When in summer the water level recedes, the vegetation of these islands is replaced by *Mentha aquatica*, *Mentha longifolia, Mentha sylvestris, Epilobium parviflorum, Myosotis caespitose, Ranunculus muricatus, Lythrum salicaria, Rorippa sylvestris, Rumex* species and *Rumex patientia.* During late July *Alisma, Sagittaria, Butomus, Sparganium, Scirpus, Eleocharis* and *Carex* genera also come into association. Ephemeral channels which dry up during autumn intercept the floating gardens harbour floating vegetation of *Lemna gibba, Lemna minor, Lemna trisulea, Spirodella polyrhiza, Nymphoides peltatum, Hydrilla verticillta,* while the rooted forms include *Ranunculus sceleratus , Rumex* species etc. A thick belt of Willow *Salix alba* extends along the periphery of the wetland, especially on the west.

2.2.5 Faunal diversity

The wetland is rich in crustacean life forms with the chief contribution from Cladocera, Copepoda and Amphipoda. Among the Cladocera populations *Alona rectangula* is the most dominant and stable form for the most part of the year, except January to March, when *Chydorus sphaericus*, *Graptolaberis testudinaria* and *Pleuroxus* species are met commonly in the area. *Cyclops scutifer*, *Cyclopa vicinis*, *Eucyelops* species, *Macrocyclops albidus* and *Canthe camptus* species are the common forms of *Copepoda*. During spring months *Gammarus* species a representative of Amphipoda is quite commonly seen. The commonly seen insect form include mosquito, water beetles, black swimmers, dragonflies, caddis fly, water boatman, water spiders and water striders. The wetland harbours a rich and diverse fish fauna of *Cyprinus carpio, Crossocheillus* and *Gambusia affinis* besides small sized *Labeo* and *Schizothorax* and their fry and fingerling stages are also found with insignificant and variable populations.

The wetland is important for both resident and migratory waterfowl. The lake is particularly important as a wintering area for migratory ducks and as a breeding area for herons, egrets and rails. Breeding species include Little Grebe *Tachybaptus ruficollis*, Little Bittern *Ixobrychus minutus,* Black-crowned Night Heron *Nycticorax nycticorax,* Little Egret *Egretta garzetta*, Grey Heron *Ardea cinerea*, Water Rail *Rallus aquaticus,* Common Moorhen*, Gallinula chloropus* and Pheasant –tailed Jacana *Hydrophasianus chirurgus*. Pallas fish-eagle *Haliaeetus leucoryphus* is resident in the area, and the Kingfishers *Alcedo atthis, Halcyon smyrnensis* and *Ceryle rudis* are common.

Upto five lakh migratory wintering ducks have been recorded from the wetland, the common species are Eurasion Wigeon *Anas penelope,* Common Teal *Anas crecca,* Northern Pintail *Anus acuta,* Red-crested Pochard *Rhodonessa rufina,* Gadwall*, Anas strepera*, Mallard *Anas platyrhynchos,* Northern Shoveller *Anas clypeata,* White-eyed or Ferruginous Pochard *Aythya nyroca,* Common Pochard *Aythya ferina,* Greylag Geese *Anser anser,* Ruddy Shelduck *Tadorna ferruginea,* Garganey Teal *Anas querquedula* are also reported from the wetland. Rahmani (2008) in his book "Potential and Existing Ramsar sites in India" mentions that Pallas Fish –Eagle *Haliaeetus leucoryphus* among the globally threatened species is resident in the area. The Common Otter *Lutra lutra* is fairly common in the wetland, and other mammals known to occur in the reserve include Red Fox *Vulpes vulpes* and Golden Jackal *Canis aureus*.

2.2.6 Administrative units

The wetland is divided into three administrative units called beats *viz* Zainakot beat, the Gundhassibhat beat and the Sozeith beat with camping ground at Shikarghat (headquarter, Wildlife Warden, Wetlands Division, Jammu & Kashmir state). Beat is considered as jurisdiction of the wetland for which the particular authorities are responsible. One block officer and a fixed number of field staff look after a particular beat.

River Doodganga which entered into the wetland in the year 1975 divided the wetland into two parts, part I and part II. Part II at the back portion of the wetland received less management inputs from the concerned authority. However, for the effective management of the entire wetland, the concerned department in the year 2003 divided the wetland into 17 compartments. Part I towards north of the wetland comprised 10 compartments, while the rest of the compartments lie in part II at the back portion of the wetland. Around a total of 14 villages surrounding the wetland owe the licences given by the Wildlife Department for biomass collection. There are 250 licence holders and the duration of the licence period is for 3 months from June to August with a licence fee of Rs 150 per licence holder.

2.2.7 Economic and social values

The wetland supports a small fishery and a reed-cutting industry and provides a source of water for irrigation**.** The lake is of considerable interest for scientific research, and provides opportunities for nature-oriented outdoor recreation such as bird-watching. For bird watching, there is a tiffenshed made in concrete at the edge of camping ground

2.2.8 Disturbances and threats

The main threats are increased siltation, eutrophication and the encroachment of agricultural land into the peripheral marshes. Some 400 ha of the lake have already been reclaimed for agricultural purposes, and the paucity of cultivable land in the region is likely to lead to further reclamation as population pressure mounts. Fertilisers used on nearby agricultural land enter the lake in run-off and accelerate the rate of eutrophication. The lake receives a heavy load of silt from the Doodganga catchments area, and the expanses of open water are decreasing in size as the lake silts up and the reed-beds expand into the lake. Poaching by influential people still occurs. especially with the connivance of police and high government officials.

2.2.9 Conservation measures taken

The wetland is accorded the protection status of Conservation Reserve by the Department of Wildlife Protection, Jammu & Kashmir as per the provisions of Jammu & Kashmir Wildlife Protection Act (1978). Waterfowl hunting was allowed on a controlled basis in winter till the year 1989. However, due to turmoil in the valley, shooting was permanently banned in the area.

2.2.10 Conservation measures proposed

Various proposals have been made for the management of the lake, including the cutting of weeds, dredging, raising of bunds, diversion of Doodganga flood channel to reduce siltation and erection of a perimeter fence.

2.3 Hygam Wetland Reserve

The Hygam Wetland Conservation Reserve or Hygam Rakh as it is locally called is the largest remaining reed bed in the Kashmir valley, being of major ornithological importance. Hygam is named after a village of the similar name. The wetland is 40 km from Srinagar, the state capital and located in district Baramulla ($34^0 15^{'}$N, $74^0 31'$E) of Jammu & Kashmir state on the flood plains of river Jhelum at an altitudinal height of 1580 m asl. (Fig.2.2). It was notified as a game reserve for duck shooting as far back as 1945. Earlier the area was about 14 km^2 with reed beds of about 4 km^2 (Holmes & Parr, 1988) but now the total reserve has shrunk to 7.25 km^2 . The wetland is maintained by the Department of Wildlife Protection, Jammu & Kashmir and is the only extensive marsh discernible in association with artificial reservoir of lower Jhelum hydro-electric projects at Gantamullah. Buffering the Asia's largest fresh water lake, the Wular Lake, an internationally important wetland in conjunction with other natural sites of Malgam, Ajas, Nowgam, Vijpur, Aharbal, Dalmarg, Kanispora, the wetland is approachable by a motorable road of 5 km from the nearest main town Sopore. The wetland is surrounded all around by villages. Hygam village itself does not border the reserve. An offshoot village, Hanjypora, which is near the edge of the reserve, has the reserve office. The wetland is bounded in the north by Sopore- Sonawari general road. To its south, it is surrounded by villages of Goshbugh and Sukhul. To the east of the wetland is the human habitation of Aakhanpora and to the west it is bounded by village Hanjypora.

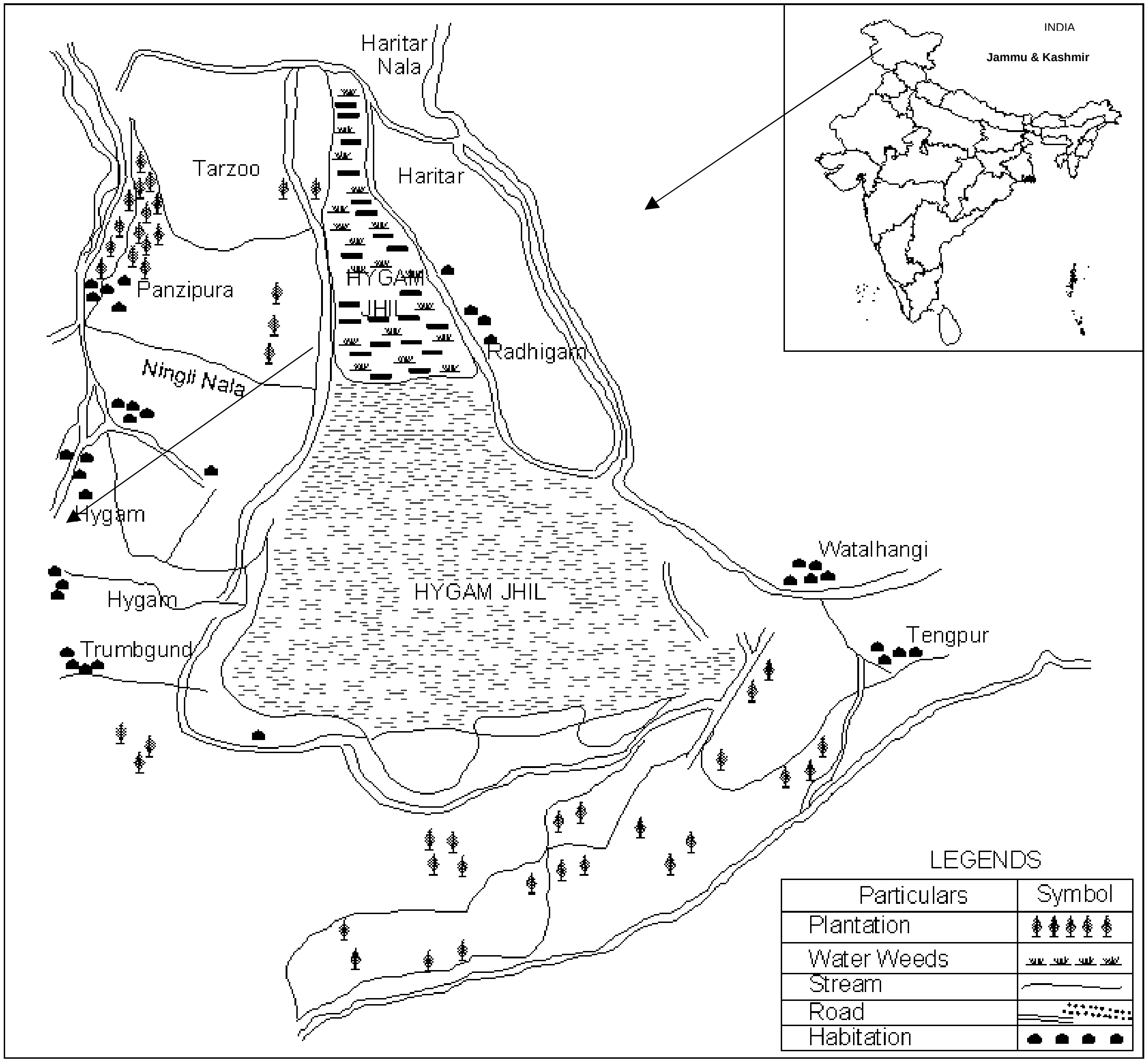

Figure 2.2 Map of Hygam Wetland Reserve, Jammu & Kashmir

2.3.1 Brief conservation history of the wetland

Hygam wetland initially was a vast expanse of open grassland. It used to be a roosting place for the migratory birds of Wular Lake. However, later on it was taken over by Maharaja Hari Singh and it took the shape of a permanent water body when a peripheral bund was constructed around it. The villages at present surrounding the wetland are infact the villages settled by the then Maharaja himself from far flung areas for labour work. These areas were managed by Twaza (Hospitality and Protocol) Directorate to serve as a venue providing sport for themselves and their distinguished guests. Thus an adequate coverage to land and water game birds and animals was provided, with strict enforcement of laws. After 1947, management of these reserves in Kashmir region reverted to Fisheries Directorate till 1954, when Dachigam, Cheshmashahi and Rajparian (Daksum) Rakhs were upgraded as Game sanctuaries in 1951. The administration then passed successively to Forest Department, (1954-60), then Twaza Directorate (1960-64) and back to fisheries Directorate (1972 to ending 1977), during the course many areas were transferred to Forest Department for future forestry management. In 1978 the administration again resettled to Directorate of Game Preservation of Forest Department, which finally emerged as an independent Department of Wildlife Protection in 1982, with the extension of 18 to 43 protected areas both old and new in all the regions, giving a sudden boost of over 15,000 km^2 from 0.20% to 7.5% of total land surface in the state.

2.3.2 Description of the site

The wetland has been classified as wetland type 14, 15 & 19 because of the type of wetland habitat present i.e. freshwater marshes, swamps and rice paddies (Scott, 1989).The wetland is a shallow, permanent, freshwater lake with a maximum water depth 1.25 m. The greater part of lake is dominated by extensive reed-beds. The reed bed is partitioned by a number of boat channels varying in width from 1m to 4m.The wetland is fed by perennial streams of the Balkul and Ningli flood channels and numerous smaller streams. The water table fluctuates seasonally and falls in late summer and reaches its lowest in autumn, then begins to rise again in early winter. Dissolved oxygen reaches very low levels in summer. The underlying soils are of a silty-clayey –loam type. The surrounding land is predominantly rice paddy and natural marsh, with some pastures which flood after heavy rains. The reserve is largely surrounded by a protective bank. Inside this bank, strips of willows have been planted. These act as a silt trap. Outside the bank, and in some places inside, the land is mostly devoted to rice paddy. Slightly further from the bank, at least around Haigam, there are extensive orchards.

2.3.3 Climatic conditions

The climate in the area is sub-Mediterranean type with very warm, relatively dry summers, and cold, wet winters with some precipitation in the form of snow. The average annual rainfall is 900 mm, most of which falls between January and March. There is some rainfall in summer, but no monsoon. Temperatures in summer (May – August) average 25- 30^0 C. Detailed climatic data for Hokersar and Hygam wetland study areas collected from Indian Meteorological department, meteorological centre, Rambagh, Srinagar, Jammu & Kashmir for the years 2004-2005 is shown in Table 2.1 and Table 2.2.

2.3.4 Floral diversity

The Rakh is largely covered by a dense growth of reed and other emergent species. Dominant species include *Typha angustata, Phragmites communis, Phalaris arundinancea, Sparganium erectum, Scirpus* species, *Carex* species and *Eleocharis palustris.* Open water areas have a floating community of water lilies *Nymphaea, Nymphoides* and *Trapa natans,* and beds of *Potamogeton crispus* and *Potamogeton nodosus.* Some 183 species of phytoplankton have been recorded, with Chlorophyceae predominating.

Table 2.1 Average monthly climatic data for Hokersar and Hygam wetlands for the Year 2004.

Month	Mean Maximum Temperature (^0C)	Mean Minimum Temperature (^0C)	Total rainfall (mm)	Mean maximum relative humidity (%)	Mean minimum relative humidity (%)	Mean wind speed (km/hr)	Mean visibility (km)
January	7.1	0.3	79.2	89	70	2.0	< 4.0
February	13.0	1.1	38.1	83	52	3.0	< 10.0
March	21.7	5.6	9.6	64	34	3.0	< 10.0
April	20.7	8.5	145.4	75	56	3.0	< 10.0
May	25.4	10.7	86.6	68	46	3.0	< 10.0
June	27.8	15.0	36.7	70	50	3.0	< 10.0
July	29.4	16.9	68.3	73	51	3.0	< 10.0
August	29.3	17.1	62.3	75	55	3.0	< 10.0
September	29.0	12.6	12.0	71	49	2.0	< 10.0
October	20.6	6.2	61.3	80	63	2.0	< 10.0
November	17.9	1.1	33.2	85	73	2.0	< 4.0
December	9.7	-0.7	12.5	92	74	2.0	< 4.0

(Source: Indian Meteorological department, meteorological centre, Srinagar, Jammu and Kashmir)

Table 2.2 Average monthly climatic data for Hokersar and Hygam wetlands for Year 2005.

Month	**Mean Maximum temperature (^{0}C)**	**Mean Minimum temperature (^{0}C)**	**Total rainfall (mm)**	**Mean maximum relative humidity (%)**	**Mean minimum relative humidity (%)**	**Mean wind speed (km/hr)**	**Mean visibility (km)**
January	7.5	-00.3	85.6	89	67	2.0	< 4.0
February	6.5	0.7	188.5	91	78	2.0	< 4.0
March	14.7	5.3	104.8	81	61	3.0	< 10.0
April	20.7	7.1	48.1	62	41	4.0	< 10.0
May	21.8	9.9	63.6	75	58	3.0	< 10.0
June	29.3	14.4	8.3	64	44	3.0	< 10.0
July	28.9	18.0	115.5	77	60	3.0	< 10.0
August	30.4	16.9	15.6	72	50	2.0	< 10.0
September	29.3	13.7	16.8	74	50	2.0	< 10.0
October	22.7	5.8	18.6	80	56	2.0	< 4.0
November	15.8	-0.2	14.4	82	56	2.0	< 4.0
December	9.9	-3.3	0.0	89	64	2.0	< 4.0

(Source: Indian Meteorological department, meteorological centre, Srinagar, Jammu and Kashmir)

Hokersar wetland, a declared Ramsar site,
Jammu & Kashmir

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Hygam wetland, Conservation Reserve,
Jammu & Kashmir

Plate 2. View of Hokersar and Hygam wetlands

2.3.5 Faunal diversity

The wetland is a major wintering area for migratory ducks particularly Common Teal *Anas crecca,* Mallard *Anas platyrhynchos,* Northern Pintail *Anas acuta,* Gadwall *Anas strepera*, Eurasian Wigeon *Anas Penelope,* Northern Shoveller *Anas clypeata,* Common Pochard *Aythya ferina,* Garganey *Anas querquedula* and Greylag Geese *Anser anser.* The lake is also an important breeding area for a variety of waterfowl notably Little Grebe *Tachybaptus ruficollis,* Little Bittern *Ixobrychus minutus*, Little Egret *Egretta garzetta*, Water Rail *Rallus aquaticus,* Common Moorhen *Gallinula chloropus* and Whiskered Tern *Hydrophasianus chirurgus* and *Chlidonias hybridus.* The kingfishers *Ceryle rudis* and *Alcedo atthis* are common and the warbler *Acrocephalus stentoreus* is particularly abundant in the reed-beds. Palla's fish-eagle *Haliaeetus leucoryphus* is resident in the area.

Holmes and Parr (1988) also found that the very local Swinhoes Reed Warbler *Acrocephalus concinens*, now named the Blunt- winged Warbler breeds in Hygam Rakh in small numbers, often near isolated willow trees. They found about 10 territories, and caught fledged young ones in July-August 1983. Bates and Lowther (1952) have recorded the breeding of the Ferruginous Duck *Aythya nyroca* in the smaller wetlands of Kashmir, particularly at Hygam, but Holmes and Parr (1988) could not find any evidence of breeding. The Pallas Fish –eagle *Haliaeetus leucoryphus* has not been seen in the last 10 years (Rahmani, 2008), although earlier records reported upto five individuals.

Mammals known to occur in the area include Common Otter *Lutra lutra* and Golden Jackal *Canis aureus*; amphibians include *Rana cyanophyctis* and *Bufo viridis*.The wetland supports a rich fish fauna, with large populations of *Cyprinus carpio, Crossocheilus* species*, Puntius conchonius* and *Gambusia affinis*. The invertebrate fauna is also very rich; macro-invertebrates include a variety of Mollusca, Annelida and Arthropoda (mainly Arachnida, Crustacea, and Insecta), and the zooplankton includes at least 51 protozoans, 25 rotiferans, and 40 crustaceans (mainly Cladocera and Rhizopoda).

2.3.6 Economic and social values

The wetland is of major importance to local people as a source of fish, reeds for thatching and mat-making, and fodder for raising live-stock. Many villagers are employed by the department of Wildlife Protection as guards, boatmen and labourers. The wetland is of major interest for conservation education and outdoor recreation.

2.3.7 Disturbances and threats

There are many threats to the Hygam wetland**.** The major problem is the increasing rate of siltation, which has caused a noticeable deterioration in the wetland quality in recent years. Two factors contribute to this problem. First large-scale deforestation in the surrounding mountains has resulted in an increase in the silt load of water coming into the valley. Second, since most of the valley is agricultural land, there are fewer places for this silt to be deposited. Fertilisers enter the lake as run-off, accelerating the rate of eutrophication. Other threats include encroachment as more land is converted to rice paddy, and heavy grazing damages in some parts of the marsh.

2.3.8 Conservation measures taken

The entire wetland is protected as conservation reserve by the Department of Wildlife Protection, Jammu & Kashmir. Active measures have been taken to restrict siltation, to maintain areas of open water, and to prevent further encroachment of rice paddies. The state government of Jammu & Kashmir State has asked the central government to include Haigam Rakh in the National Wetland Conservation Programme.

2.3.9 Conservation measures proposed

Existing management policies will be continued and waterfowl hunting will be maintained at a regulated level. Increasing attention will be given in controlling encroachment, particularly the conversion of marginal areas to rice paddy. Plans include (a) the erection of a barbed wire fence around the lake to prevent further encroachment; (b) the diversion of the Balkul flood channel to minimise the silt load entering the lake; (c) the construction of a sluice gate.

CHAPTER 3
STUDY DESIGN AND METHODS

3.1 Introduction

Wetland ecosystems, the global extent of which is estimated from 7 to 9 million km^2 represent one of the most fertile and productive ecosystems of the world (Mitsch & Gosselink, 2000). Waterbird communities used as bio-indicators form an important component of wetlands with their potential to detect aspects of wetland landscape condition not detected by any other group. Human aspects and their interaction with these ecosystems are crucial so as to maintain the present scenario of community involvement for conservation measures.

The present study was carried out in Hokersar and Hygam wetlands of Kashmir valley; in state of Jammu & Kashmir (India). The primary purpose of this study was to understand patterns of waterbird community structure in these two wetlands. Evaluation of wetland landscape composition and floristic community structure were also part of the study. Assessment of resource dependence was one of the key components. For addressing the above aspects, an inter-disciplinary approach was made for data collection pertaining to the study objectives. An elaborate study design was framed up to achieve the research goals in this context. This chapter provides an overview of the approaches made.

3.2 Study design

The study was attempted at three broad approaches, with each complementing the other either during field sampling or analysis phases, and included specific field sampling protocols. The three approaches are (i) Field sampling in wetland ecosystems to assess populations of waterbirds, to determine floristic associations, to collect ground truthing for land use mapping and to determine bird-habitat association, (ii) Field sampling in peripheral villages to collect information on wetland resource dependency of the user communities in addition to a perception and attitude survey and (iii) A rapid survey for collection of secondary data from concerned government agencies. The fieldwork for this study commenced from July 2004 to September 2007. In this duration, field data collection relevant to different objectives of the study was undertaken for a period of approximately two and half years.

In the initial phase of study, a detailed literature survey was carried out to get an insight of the two study areas and to assess various sampling protocols for their applicability in the field. Based on this, a study design was made. A reconnaissance survey of two study wetlands was undertaken from July to October 2004 to get acquainted with the study areas. The first phase of actual field work started in December 2004 to May 2005 for waterbird population monitoring. This study period was divided into mid-winter (December-January 2004-2005); post-winter/spring (February-May-2005) sampling seasons. Population monitoring of migratory waterbirds was attempted in both seasons to estimate seasonal differences in their density and diversity and also to examine seasonal pattern of their habitat use. Breeding bird survey was initiated in first week of March, 2005 and it lasted up to first week of May, 2005 till completion of breeding season. At the same time, mid-winter period was assumed to be peak season of the congregation of migratory waterbirds. During preliminary survey, base maps of the two study sites were procured from department of Wildlife Protection of Jammu & Kashmir and they were taken to field. The area of each block of two wetlands was collected from official records of concerned agency and scrutinized to estimate area of each habitat type in two study wetlands. The standardized census techniques of line transect and point count was not found appropriate in this study for waterbird density estimation because of congregatory nature of waterbirds and different habitat characteristics of wetland ecosystems than terrestrial habitats where such methods are easily adopted. Point count method was adopted initially but due to unsuitability in the field, it was discarded later. The need to allocate situate points in all habitats in two study wetlands was not found feasible. Some areas were found inaccessible due to non-availability of proper boat channels and disturbance to waterbirds while canvassing from one point to other.

Sampling strategy for waterbirds adopted stratified random sampling approach. The two study wetlands were divided into strata or habitat types based on vegetation type and other habitat characteristics and bird sampling protocols were adopted in these strata (details given in methodology section).Three permanent boat channels and one foot -trail along the wetland boundary served as sampling tracks to examine pattern of waterbird habitat utilization in mid and post-winter seasons in Hokersar wetland. In Hygam wetland sampling tracks included one permanent boat channel and one long wetland boundary trail. Equal sampling effort was made in two study wetlands.

Field study pertaining to pattern of habitat use by resident birds started from July to August, 2005. Similar boat channels and trails as in mid and post-winter season were selected as sampling tracks. Equal sampling effort was made in both wetlands.

To investigate dependency on wetland resources by local user communities and their conservation attitude, field study commenced from June to October, 2006. First stage involved a rapid survey to collect secondary information through perusal of existing documents and official records. Personal visits conducted to offices of 1) Office of Tehsildar, Sopore Tehsil, district Baramulla 2) District Collector's office, district Baramulla 3) Planning and development department, Directorate of Economics and Statistics; district Srinagar 4) Office of District Statistics and Evaluation Officer, district Budgam, to collect requisite information of villages in 5 km radius of two study wetlands.

Vegetation sampling and ground truthing was done from June to October, 2007. Vegetation study included adoption of stratified random sampling for quantification of vegetation in plots in various strata observed in two study wetlands.

In the last stage, analysis of data, synthesis and writing of the thesis was carried out.

3.3 Methods

3.3.1 Land use mapping and vegetation study

Land use maps of Hokersar and Hygam wetlands in GIS domain were generated using IRS-1C-LISS III data. The satellite data was acquired from National Remote Sensing Agency (NRSA). The high spectral resolution of this digital data makes it clear for classification of land use/land cover types in the area. In the present study, the Landsat scenes were much larger than the study area. In such instance, it was found beneficial to reduce the size of the image files to include only the area of interest. This not only eliminated the extraneous data in the files, but it increased the rate of processing due to the smaller amount of data to process. This reduction of data is known as sub setting. This process helped in cutting out the two preferred study areas from image into smaller more manageable files. In the present study, the two images for Hokersar and Hygam wetlands were subsetted. A desired area of interest (AOI) of 120.091 km^2 with Hokersar wetland in mid of area of interest and another 116.91 km^2 with Hygam wetland in its centre was extracted from land sat scenes. A False Color Composite (FCC) of Lambert Conformal Conic Projection was generated with bands 3, 2 and 1 for the two study areas. IRS-1C-LISS -III FCC was taken to field and the reconnaissance survey of entire two areas was made to correlate image characteristics and ground features. The area was visited and extensive ground truthing was done to collect ground control points (GCPs) for different habitat types in the two wetlands using a Global Positioning System (GPS) receiver from 329 sample locations inside Hokersar wetland and from 53 locations in the peripheral plantation and from 160 sample locations inside Hygam wetland and 48 locations in plantations.

Floristic associations of two wetlands was determined by vegetation sampling (Dombois & Ellenberg, 1974) for aquatic macrophytes in 5 m × 5 m sample plots laid systematically in different strata/ habitat type. Stratification of two study wetlands was based on vegetation and other physiognomic characteristics. Vegetation was quantified in each sample plot (n = 329) for Hokersar wetland and (n = 160) for Hygam wetland. Species observed were recorded and their percentage cover was estimated. A total of 53 circular plots in Hokersar wetland and 48 plots in Hygam wetland were sampled to record number of tree and sapling species laid systematically on six transects in Hokersar plantation and on four transects on Hygam plantation.

3.3.2 Bird species distribution and abundance

The waterbird density and diversity was estimated by direct count (Eltringham *et al*., 1961; Sridharan, 1989). Waterbird survey was undertaken on weekly basis in both wetlands. Scan sampling of flocks was done from 16 sites in mid-winter season and 15 sites in post-winter season in Hokersar wetland and from seven sites in mid-winter and eight sites in post-winter in Hygam wetland. Each site was assigned a fixed view point. Sites were selected after stratification of wetland into vegetation types /habitats. Each habitat represented a sampling site. Flocks were scanned with the help of field binoculars and spotting scope and data was collected on flock size and composition. Counts represented a scan sample of birds visible from fixed point. Breeding waterbird survey recorded number of nests in each of 20 × 20 quadrat at fixed intervals along five line transects laid in Hokersar wetland (n = 29) and three transects laid in Hygam wetland (n = 16). Data were collected on variables of clutch initiation and hatching date, clutch size and nest success.

3.3.3 Habitat utilization

To examine seasonal pattern of habitat use of waterbirds, availability of habitat was determined by visual estimation in three seasons of mid-winter, post-winter and summer seasons from two study wetlands. To establish utilization, weekly ground and boat surveys were undertaken. Each location of waterbirds was assigned to particular habitat types (Neu *et al*., 1974, Byers *et al*., 1984). Data were gathered on other parameters of flock size, composition and activity pattern of waterbirds respectively. Each group of waterbirds was considered as one observation.

3.3.4 Socioeconomics and resource dependency

Stratified random sampling approach of selection of 10% of households in four study villages around each wetland for intensive questionnaire survey was adopted. A sample of 190 households in Hokersar wetland and 42 households in Hygam wetland was surveyed. All caste groups were taken into equal proportion. A structured questionnaire was designed and employed to obtain information pertaining to demographics, economic status, wetland dependence, range of direct wetland uses and contribution to family income from the wetland. Subsequently, an attitudinal and perception survey was conducted by a set of semi-structured, open as well as closed yes/no type questions.

3.4 Data analysis

Geo-coding and geo-rectification of two FCCs /images was done and in combination with intensive ground truthing, these were subjected to unsupervised classification scheme. Erdas Imagine 8.7 (computer software) performed the unsupervised classification and maps prepared in Arc View Version 3.1. Estimate S (8.0) (developed by Robert Colwell, 2005) software to quantify plant species diversity was used and hierarchical clustering of vegetation community was done by TWINSPAN, (Hill, 1979) and FORTRAN programs.

A non-parametric one-way ANOVA was used to compare differences in mean densities of waterbirds among habitats. Waterbird species diversity and richness was computed by ecological analysis package Biodiversity Professional Beta version bdpro 2.0.0.0. (McAleece *et al*., 1996). Neu *et al*. analysis technique (1974) was used for analysis of availability –utilization data. This was followed by the construction of Confidence interval (95%) following the Bonferroni approach (Byers *et al*., 1984), i.e. number of habitats over or under-used than expected frequencies by waterbirds.

Pearson product moment correlation coefficient and Pearson chi square was used to examine correlation among different Ordinal and Interval/Ratio variables. In the present study variables included household income and income contributed from wetland resources, influence of caste on wetland use intensity. Data analysis was performed using the software package statistical package for social sciences SPSS/PC+ 4.0 (Norussis, 1984).

3.5 Organization of field work

Fieldwork for the whole study was operated from one base camp (located at village Shikarghat, near headquarters of Hokersar wetland, one of the study wetlands) and from one field station (located at village Hanjipora, near Hygam wetland. On an average, both study wetlands were covered each week during entire study period (mentioned elaborately in section on study design). One local man and one boat man was hired to assist in the field work and to drive the boat during the entire period of study.

3.6 Limitations of field work

Easily disturbed nature of waterbirds on approach of a boat during bird sampling made their proper counting more often difficult and at certain times, total count was an approximation. Standard bird census methods of line transect and point count used for bird communities in terrestrial ecosystems could not be adopted in present study and population estimates derived relied on techniques not vastly known. Sampling was limited by inaccessibility to some sites inside wetlands owing to the fact that sampling was not feasible at various sites and had to solely depend on existing boat channels. Moreover, to draw new boat channels by cutting reeds was not possible due to constraint of time and man-power. Such areas inaccessible by boat could not be reached by foot due to high water depths. Since the two study areas are good wintering waterbird grounds, sometimes fieldwork was not allowed by the concerned authority to avoid disturbance to birds.

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CHAPTER 4
LAND USE – LAND COVER AND VEGETATION STRUCTURE

4.1 Introduction

Natural wetlands are biologically productive ecosystems on earth however; they are among the most threatened. Extensive loss of such wetlands is occurring throughout the world (Mitsch & Gosselink, 1993). Conservation for their biodiversity and for the functions and services they perform emphasizes the need to have better knowledge of their extent, composition and accurate land use distribution along with their adjacent uplands. Current information on the uplands surrounding wetlands is important because land use practices in uplands cause loss of wetland functions, goods, services and values. The principal source of such information has been land use or land cover mapping. Land use maps are needed to characterise the distribution and status of major land surface types for environmental and ecological applications. Accurate land use information plays an important parameter in proper planning and effective management. The land use maps take the guesswork out of managing wildlife habitat, prioritizing conservation areas, and planning open space acquisitions for many agencies, including state, country, municipal and private organisations. The information provides a sound basis for proactive decision making as well as conflict resolution before proposed development, logging or dredging occurs. The landscape maps also provide citizens with the tools to protect rare species habitat at the local level. Geospatial presentation of such habitats using two mutually synergistic technologies of remote sensing and the processing of remotely sensed data through GIS are the two important methods to assess land use distribution in such landscapes. Remote sensing in combination with the GIS hold immense potential in mapping and inventorying of natural resources; generation and management of natural resource database systems; monitoring the process of environmental transformations and formulation of integrated action plans for the sustainable development of natural resources, on time and cost effective basis. Up-dated generation of land use maps in GIS domain is used more effectively in proper planning and better management. Habitat manipulation in absence of updated information regarding land use pattern is ill advised, scientifically non-congenial and counter productive on occasions.

Rossi *et al*. (1992) terms the tools as geostatistical tools to serve for modelling and interpreting ecological data in spatial form (Sanker *et al*., 2000). Remote sensing provides multi-spectral, multi-temporal, multi-sensor and multivariate data of the earth's surface with GIS as a decision support system with capabilities of efficient data storage and convergent analysis of spatial data from diverse sources. They allow the processing and viewing of recorded information on different spatial scales. For ecologists and resource managers, the tools are of tremendous potential value –to address their needs and process their information. Cornett (1994) & Sample (1994b) emphasized that mapping of ecosystems through geospatial approach act as catalyst for effective public involvement in ecosystem management planning, analysis and policy making. The technologies are relatively cheap, rapid for acquiring up-to date information as well as cost effective. Information content available in multi-spectral data form a common database for integrated resource inventories, necessary for the habitat characterization, monitoring and management. The outputs obtained from remotely sensed data along with field information with the help of analysis of these multi-layers is an integral part of the database to serve as a handy tool for the field managers to effectively manage the protected areas.

Spatially and temporally integrated species that retain their individuality in an area forms the plant community and the varying quality and quantity of the community forms its structure (Mueller-Dombois & Ellenberg, 1974; Misra, 1968). Plant communities and their associations characterize the habitats in which transformations, accumulation and flow of energy takes place. It is at this level of community that populations and individuals of a plant species can be identified (Kent & Coker, 1992). Two views regarding the concept of community are the organismic concept of Clements (1982) which states that the whole vegetation can be divided into associations while Gleason's (1926) states that populations independently respond to environmental variables. Information on the patterns of plant species diversity and species composition helps in understanding the ecological nature of any region.

This chapter elucidates land use mapping and vegetation composition of Hokersar and Hygam Wetland Reserves of Jammu & Kashmir state.

4.2 Methods

4.2.1 Land use mapping

Land-use maps of Hokersar and Hygam wetlands in GIS domain were generated using IRS-IC-LISS III data which was acquired on October 15, 2000. The images were procured from National Remote Sensing Agency (NRSA). Digital data received was in two scenes which had Path 092 and Row 046 for the Hokersar wetland and again for the Hygam wetland the Path was 092 and Row was 046 respectively. The high spectral resolution of this digital data makes it clear for classification of land use/ land cover types in the area. Ground resolution for the two images was 23.5 m. IRS-IC-LISS records data in 4 different bandwidths. These bandwidths are broken down into portions of visible (green: 0.52-0.59 µm and red: 0.62-0.68 µm); one in near infrared (NIR-0.77-0.86 µm) and one in short wave infra-red (1.55-1.70 µm). In the present study, the land sat scenes were much larger than the study area. In such instance, it was found beneficial to reduce the size of the image files to include only the area of interest. This not only eliminated the extraneous data in the files, but it increased the rate of processing due to the smaller amount of data to process. This reduction of data is known as sub-setting. This process helped in cutting out the two preferred study areas from image into smaller more manageable files. In this study, the two images for Hokersar and Hygam wetlands were subsetted. Before sub setting, geo-coding and geo-rectification of the image was done with a root mean square error of 0.2 m^2. A desired area of interest (AOI) of 120.091 km^2 with Hokersar wetland in mid of area of interest and another 116.91 km^2 with Hygam wetland in its centre was extracted from land sat scenes. A False Colour Composite (FCC) of Lambert Conformal Conic projection was generated with bands 3, 2 and 1 for the two study areas. IRS-1C-LISS-III FCC was taken to field and the reconnaissance survey of entire two areas was made to get acquainted with general vegetation types and physiography and to correlate image characteristics and ground features. Based on the satellite data, a field work programme was conducted in June-October-2007. The area was visited and extensive ground truthing was done by Global Positioning System (GPS) Garmin model to collect ground control points (GCPs) for different habitat types in two wetlands using Global Positioning System (GPS) receiver from 329 sample locations inside Hokersar wetland and from 160 sample locations inside Hygam wetland. In addition, the peripheral plantation bordering the two wetlands was surveyed and 53 GPS points were taken from Hokersar wetland and 48 points were taken from Hygam wetland respectively. This was done to keep all land cover characteristics into consideration. An initial reconnaissance of the area was done to get acquainted with general vegetation types and physiography. Satellite data details of two study landscapes are given in Table 4.1.

Table 4.1 Details of satellite data for Hokersar and Hygam wetlands.

	Hokersar	**Hygam**
Data used	IRS 1D- LISS III	IRS 1D- LISS III
Path/Row	092, 046	092, 046
Date of Pass	15 October 2000	15 October 2000
Bands Combination	3,2,1	3,2,1
Spatial Resolution	23.5 m^2	23.5 m^2
Projection	Lambert conformal conic	Lambert conformal conic
Geo-rectification	0.2 m^2	0.2 m^2

Colour codes were assigned to land use types for the Hokersar and Hygam wetland landscapes (Table 4.2 ad 4.3) Land use/land cover pattern assessed for the two landscapes showed the following land use/ land cover classes:

Plantation

Plantation was the most dominant land use class in both the study areas and reflects violet tone with a course texture. In Hokersar wetland, the class was mostly intermixed with crop fields and emergent zone in a haphazard manner with the exception of a few large patches. In Hygam wetland, plantation can be seen in association with crop fields and emergent zones in both big geometrical patches and in small scattered units. The category was mostly dominated by Willow *Salix alba* and Popular *Populous deltoids* species.

Emergent Zone

Emergent vegetation appeared greenish on the image. The texture of this category was smooth. In Hokersar wetland, emergent vegetation had a random distribution pattern in the entire area with major proportion restricted to the wetland reserve itself. This can be seen clearly from its only association with the floating vegetation in the reserve. However the class was also observed in dispersed patches along river Jhelum and in small natural water bodies scattered in the area. In Hygam wetland, emergent vegetation exists in a mosaic distribution. Here also, it was primarily restricted to wetland reserve as vast expanses as well as small irregular units outside the wetland.

Crop Fields

Crop fields reflected yellowish tone with a course texture. In Hokersar wetland, the crop fields were seen distributed throughout in small to medium sized patches. The class can be seen in all associations in varying proportions; however, major classes associated were emergent zone and plantation. In Hygam wetland, crop fields can be seen intermixed with plantation and emergent zones. Except a few geometrical patches, the class is seen scattered all along the area. The major cultivated crop was rice paddy.

Peatland

Peatland appeared brownish with a smooth texture on the image. The class had a non-uniform distribution in the area and occurred as small sized patches. Only within the wetland, it was comparatively larger. The partial decomposition of its associate i.e. the emergent zone resulted in the formation of such peat mass. In Hygam wetland no peatland can be seen in the image indicating that peat formation does not take place in the area.

Floating vegetation

Floating vegetation had a scattered distribution in the Hokersar wetland as evident in the image. *Nymphaea odorata* and *Trapa natans* were the dominant species. The class reflected Pinkish tone with a course texture. In Hygam wetland, it occurred in small sized patches and the distribution was sparse. The class was found in association with plantation and crop fields.

Meadows

On thematic map, meadows appeared in fir green tone with a course texture. In both the areas, meadows were seen scattered sparsely in small patches through out the area. The class was associated with floating vegetation and emergent zone and was dominated by *Cynodon dactylon* species only. These were the areas used as grazing lands by the local communities.

Habitation

Habitation reflected red tone on the thematic map and had a course texture. In Hokersar wetland, major proportions were seen in some places of the area whereas the class had a sparse distribution all along. In Hygam wetland, habitation was scattered in the entire area. The class was mainly found in association with plantation and crop fields. A total of 30 villages occur around the Hokersar wetland and the number was 26 for the Hygam wetland (Published records of the department of statistics and planning, district Budgam ,J&K).The settlements were not clearly depicted in the final map.

Water body

Only natural water bodies occurred in the two areas. The class reflected a blue tone with a smooth texture on the final image. In Hokersar wetland, the class was seen to have a localised distribution within the wetland and the river Jhelum flowing through the area. In Hygam wetland, water body was restricted to only one area in the form of Wular Lake and river Jhelum. The class was found in association with plantation and crop fields.

Barren land

Barren land occurred only in Hygam wetland and was not depicted from any where in the Hokersar wetland. The class appeared on the image in a greyish tone and had a course texture. The class was scattered in the entire area. Except a few big patches, it occurred in small sized pockets and was intermixed with plantation and crop fields.

Submergent vegetation

Submergent vegetation reflected a macaw greenish tone and a course texture. The class was restricted to only some portions within the wetland and was associated with emergent vegetation only. Submergent vegetation zone was not seen in Hygam reserve. The reason may be low water level, excessive siltation and intensive expansion of reeds.

Hillock

Hillock was seen as a major landscape unit. At some portions of the image small sized units were also seen. The class was observed in blackish tone with a course texture in the image. The class was found in association with barren land and crop fields.

Dyke

Dyke reflected purple tone with a course texture in the final image. The class was mainly seen along emergent zones as a boundary for the protection to the two wetlands.

Table 4.2 Colour codes assigned to land use/vegetation classes seen on thematic map generated for the Hokersar wetland landscape.

Class name	Assigned colour	Texture	Shape	Association
Water body	Blue	Course	Irregular	Emergent vegetation/Crop field
Emergent vegetation	Green	Smooth	Irregular	Floating vegetation
Peatland	Brown	Smooth	Irregular	Emergent vegetation
Crop field	Yellow	Smooth	Irregular	Emergent vegetation
Willow-popular mixed plantation	Violet	Smooth	Geometrical	Crop field/Floating vegetation
Floating vegetation	Pink	Course	Irregular	Emergent vegetation
Meadow	Fir Green	Course	Irregular	Emergent/Floating vegetation
Habitation	Red	Course	Irregular	Crop field
Submergent vegetation	Macaw green	Course	Irregular	Emergent vegetation
Dyke	Purple	Course	Irregular	Emergent vegetation

Table 4.3 Colour codes assigned to various land use/vegetation classes seen on thematic map for Hygam wetland landscape.

Class name	**Assigned colour**	**Texture**	**Shape**	**Association**
Barren land	Gray	Course	Irregular	Plantation/ Crop field
Crop field	Yellow	Smooth	Geometrical	Emergent vegetation/ Plantation
Dyke	Purple	Smooth	Irregular	Emergent vegetation
Floating vegetation	Pink	Course	Irregular	Emergent vegetation/crop field
Habitation	Red	Course	Irregular	Plantation
Meadow	Fir Green	Smooth	Irregular	Crop field/emergent vegetation
Water body	Blue	Course	Irregular	Plantation/crop field
Willow-popular mixed plantation	Violet	Smooth	Geometrical	Crop field/emergent vegetation
Emergent vegetation	Green	Smooth	Irregular	Crop field

4.2.2 Vegetation composition and structure

Vegetation sampling for aquatic macrophytes was carried out within the two wetland reserves. This was done by stratification of wetland into various habitat types. Sampling plots were laid randomly in each stratum in order to have abundance data of the plant species recorded there. This included a total of 329 quadrats of the size 5 m x 5 m for the Hokersar wetland and 160 quadrats for the Hygam wetland. The vegetation was quantified for each plot. Within the sampled plot, the percentage vegetation cover was estimated and the various species were recorded. For the peripheral plantation surrounding the two wetlands six transects were laid in Hokersar wetland and four transects in Hygam wetland. In each transect, circular plots of 10 m radius were laid at a minimum distance of 100 m. The plots were sampled to record the number of tree and sapling species. This included a total of 53 plots for Hokersar wetland and 48 plots for Hygam wetland respectively. Plant specimens which could not be identified in the field were collected for identification at the Herbarium of Wildlife Institute of India, where voucher specimens are deposited.

4.3 Analysis

4.3.1 Land use mapping

Using computer software, Erdas Imagine 8.7 and Arc View Version 3.1, the satellite data in combination with intensive ground truthing was analysed to classify the two images into various land use categories. The purpose of classification scheme is to provide a framework for organizing and categorizing the information that can be extracted from the data. This categorised data may then be used to produce thematic maps of the land cover present in an image. Normally, multi-spectral data is used to perform the classification and the spectral pattern present within the data for each pixel is used as the numerical basis for categorization. Classifier (Erdas Imagine 8.7 software) performed the unsupervised classification to prepare the land use map. Unsupervised classification is a method which examines a large number of unknown pixels and divides into a number of classes based on natural groupings present in the image value. The basic premise is that values within a given cover type should be close together in the measurement space, whereas data in different classes should be comparatively well separated. The classification scheme included a set of 100 preset target classes for the two images. The analysis was done on the signature files or spectral signatures developed for 100 classes. Grouping of pixels with similar spectral characters was done based on their spectral information. All the pixels in the image were finally assigned to 10 different land use classes or themes. The area was calculated for each class. This was performed by raster attributes in the Erdas Imagine 8.7 software. A classification accuracy assessment was performed by classifier present in the computer software in order to determine the accuracy of the classification process. A set of 30 reference pixels on the two classified images were randomly selected for which the actual ground data was known. Suitable colours were assigned to different classes and a colour-coded map was obtained. After that, proper legending was done and the final classified image was prepared.

4.3.2 Vegetation composition and structure

Data from all the sampling units inside the wetlands was pooled together. This was done separately for two study wetlands. The vegetation classification analysis was carried out using the polythetic divisive clustering technique Twinspan (Hill, 1979). The same procedure was adopted for the peripheral plantation bordering the two wetlands. TWINSPAN is a Fortran based programme for arranging multivariate data in an ordered two-way table by classification of the individuals and the attributes. Five pseudo species cut levels were given according to the frequency of cover scale for both wetlands and for their peripheral plantations. They are 0, 2, 5, 10, and 20 respectively. Minimum group size for division was 5 with maximum number of indicators per division equal to 7. Maximum level of divisions was 6. Total number of species and pseudo species was 25 for Hokersar wetland; 4 for Hokersar plantation; 19 for Hygam wetland and 28 for Hygam plantation. The plant communities were classified and named into individual groups. This involved formation of groups of definite floristic composition and physiognomy. In the present analysis, uniform habitat condition was not taken into consideration.

4.3.3 Species diversity and evenness

Analysis of the species abundance data was done principally with the help of latest and most advanced version Estimate S7+ (developed by Robert Colwell, 2005), a computer software application used to compute non-parametric species richness estimators and Shannon and Simpson diversity indices. Abundance data of 329 sample plots of aquatic macrophytes and 53 sample plots for peripheral plantation in Hokersar wetland and 160 sample plots of aquatic macrophytes and 48 plots in Hygam wetland was pooled together.

Data matrices of the format samples (rows) by species (columns) type were prepared for aquatic macrophytes and peripheral plantation for both the study wetlands. The software programme was run to carry out 1000 randomisations of the sample order. This was done to reduce the effect of sample order by averaging over randomisations, producing relatively smooth estimator curves or diversity index curves and allowing a comparison of richness estimators or diversity indices for the data set that does not depend on the particular order those samples were collected or added to the analysis. A single sample was selected at random; richness estimators and diversity indices were computed based on that sample. This was followed by selection of a second sample; recomputation of the estimators using the pooled data from both samples and so on until all samples in the matrix were included. Samples were added to the analysis in random order, without replacement (each sample was selected exactly once). Samples were accumulated in a different order, in each distinct randomisation with all samples included in each randomisation. The final value for the averaged random-order species accumulation curve, therefore matched precisely, the total number of observed species.

4.4 Results

4.4.1 Land use -Land cover types of Hokersar wetland

The Hokersar wetland landscape comprised a total area of 120.091 km^2 under study. The area constituted a spatial heterogeneous landscape of wetland-plantation complex within a matrix of distributed habitations and extensive agricultural land. Ten different land use types including marshy and non-marshy categories were identified and delineated based on the satellite data of October 2000 and ground validation (Fig.4.1). Land use and vegetation map generated for Hokersar wetland landscape (Fig. 4.2) showed that out of total area, 35.65% was under marshy areas and 64.35% was non-marshy. The landscape composition indicated that 23.25% area was covered by plantation, 18.90% area was under emergent vegetation. Crop fields covered 18.76%, 15.35% was under peatland, 9.78% was floating vegetation, 5.64% was covered by meadows, 3.79% was habitation, 2.90% was covered by dyke, 0.96% was under water bodies while 0.66% area was submergent one (Table 4.4).

4.4.2 Land use -Land cover types of Hygam wetland

Marshy and non-marshy categories of the Hygam landscape included a total of 10 different land use types which were identified and delineated based on the satellite data of October 2000 and ground validation (Fig.4.3). Land use and vegetation map generated (Fig. 4.4) showed the landscape under study comprised a total area of 116.191 km^2 of which 22.26% was marshy habitats and 77.74% formed non-marshy areas. Out of total area, 26.13 % was covered by plantation, 25.94% area was crop field, 16.62% was emergent vegetation, 16.48% area was barren land, 4.19% was floating vegetation, 3.71% area was habitation, 2.64% was under meadows, 2.16% of the area was hillock, 1.45% area was covered by water bodies and 0.85% area was covered by dyke (Table 4.4).

4.4.3 Comparison of the two wetlands

The land use- land cover pattern in two wetland landscapes was compared. The two wetlands represented spatial heterogeneous landscape. The area extent of marshy landscape was more in case of Hokersar wetland than in Hygam wetland. Plantation existed as major land-use class of both landscapes. Peatland existed only in Hokersar landscape and covered 15.35% of the total landscape area. Submergent vegetation represented a small land use class of Hokersar landscape (0.66%) and was not found in

Hygam landscape. Hygam landscape also consisted of a major land cover class as barren land (16.48%) of the total land area while no such land cover was found in Hygam. Hillock was absent in Hokersar and in Hygam wetland it represented 2.16% of the total landscape area.

Table 4.4 Comparison of area extent of Hokersar and Hygam wetland landscapes, Jammu and Kashmir.

S. no.	Land use/Land cover type	Hokersar landscape		Hygam landscape	
		Km^2	%	Km^2	%
1.	Plantation	27.91	23.25	30.31	26.13
2.	Emergent vegetation	22.71	18.90	30.09	16.62
3.	Crop field	22.53	18.76	19.12	25.94
4.	Peatland	18.43	15.35	0	0
5.	Floating vegetation	11.74	9.78	4.85	4.19
6.	Meadow	6.77	5.64	4.30	2.64
7.	Habitation	4.55	3.79	3.06	3.71
8.	Dyke	3.47	2.90	2.50	0.85
9.	Water body	1.161	0.96	1.668	1.45
10.	Submergent vegetation	0.79	0.66	0	0
11.	Barren land	0	0	19.12	16.48
12.	Hillock	0	0	2.50	2.16

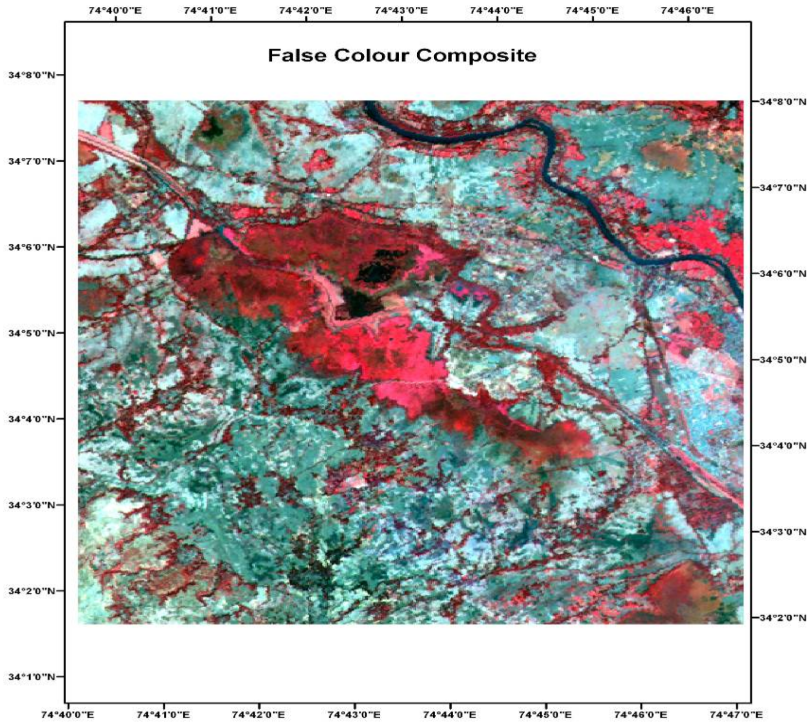

Figure 4.1 False colour composite of Hokersar wetland Landscape

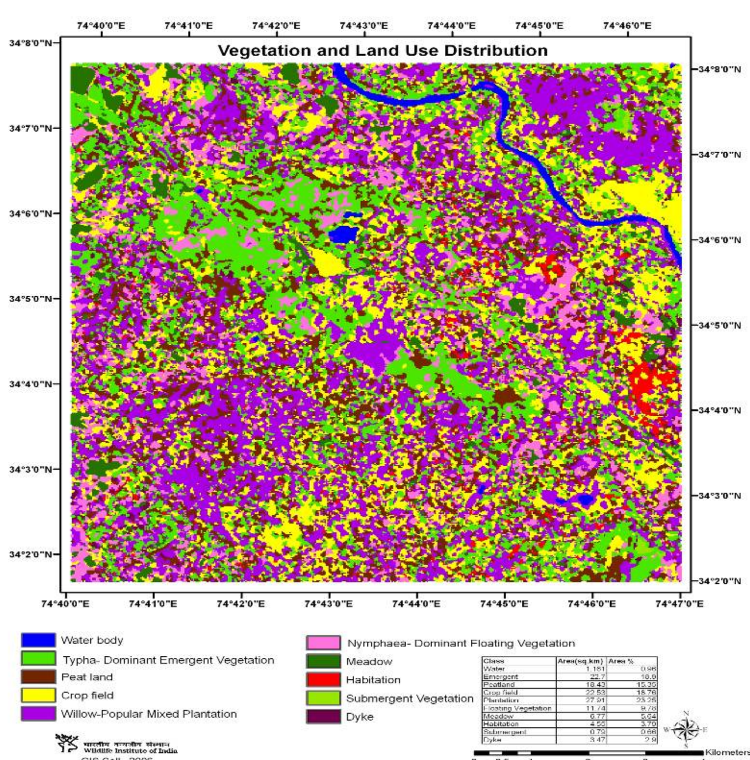

Figure 4.2 Land use and vegetation map of Hokersar wetland Landscape

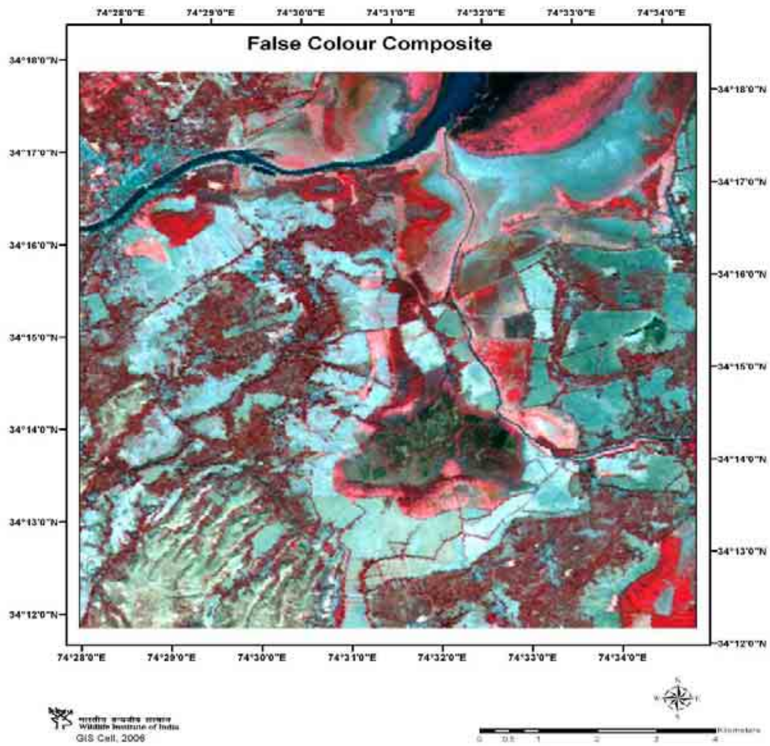

Figure 4.3 False colour composite of Hygam wetland Landscape

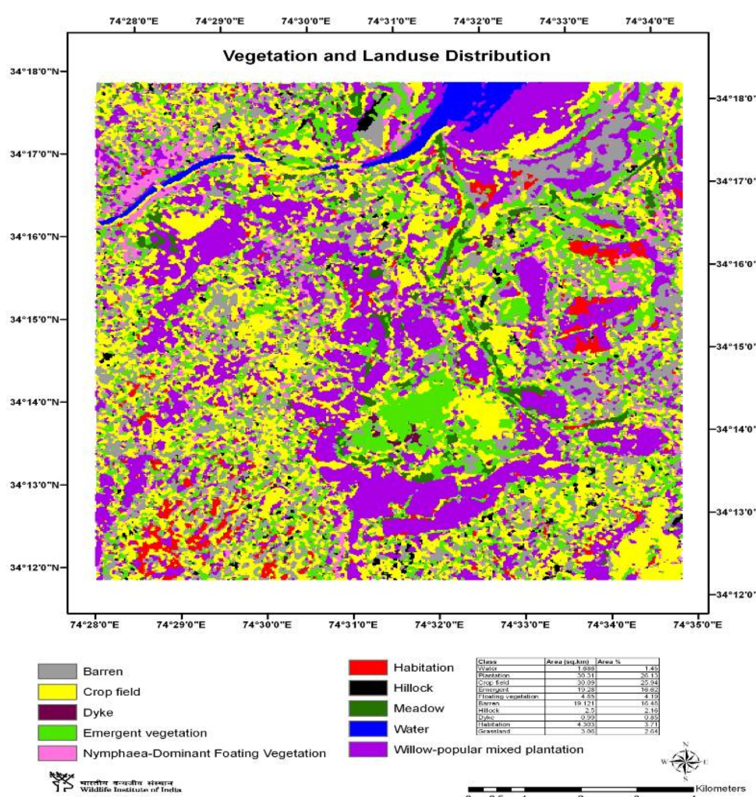

Figure 4.4 Land use and vegetation map of Hygam wetland reserve

4.4.4 Classification Accuracy

The overall classification accuracy of the output map of Hokersar wetland landscape was 90% with Kappa statistics equal to 0.8748. Kappa coefficient of peatland was 0.7101 and 1.0000 for all other classes. Classified image of Hygam landscape showed 93.33% classification accuracy with Kappa statistic equal to 0.9183. Kappa coefficient of barren land and crop field was 0.8370 and for other classes it was 1.00.

4.4.5 Vegetation structure and composition of Hokersar wetland

A total of 26 plant species and 20 families were recorded in various habitats of the Hokersar wetland (Table 4.5). The family with highest number of species was Poaceae with 4 species followed by Typhaceae, Nymphaeaceae and Cyperaceae with 2 species each respectively. Two species belonging to Salicaceae family were recorded in the peripheral plantation bordering the wetland. Classification of aquatic macrophytes followed that of Fassett, N.C. (1957).

The observed species richness of aquatic macrophyte assemblage in Hokersar wetland was 25 (±1.63) species which was exactly equal to true species richness estimated as 25 by Chao 1 estimator with 95% confidence interval. Jack-knife 1 estimator, the most robust one for computing species diversity in assemblage estimated the true species richness of aquatic macrophytes equal to 28 (± 2.99). Jack- knife 2 estimated 31 species as true species richness of aquatic macrophytes. Shannon diversity index computed for the macrophyte assemblage was 2.29 and the estimate of Simpson diversity index was 6.6. In the peripheral plantation bordering the wetland, the observed species richness was only 2 species.

The application of Twinspan technique made it possible to divide the set of 300 sampling plots inside the wetland into 14 clusters at level 6 of the hierarchical classification. These formed 13 vegetation types (Fig.4.5).

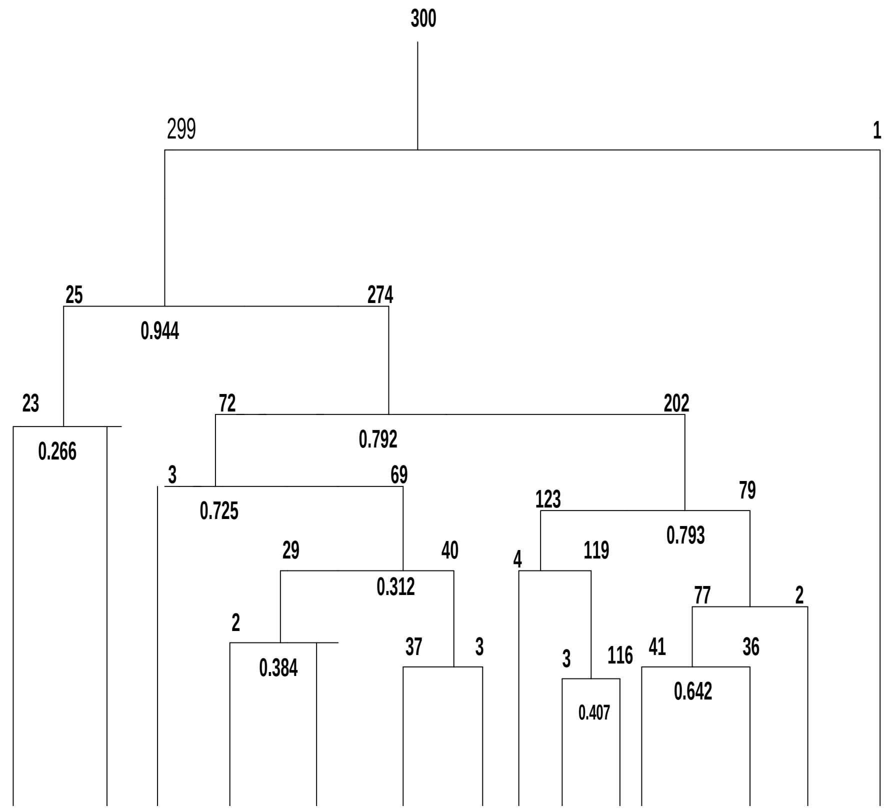

Figure 4.5 Dendrogram showing plant species associations inside Hokersar wetland (number of plots showing associations are given on top, eigen values given between two associations).

The first Twinspan dichotomy of Hierarchical classification separated all the plots into two ecologically distinct main groups based on moisture content. They were wetland group and dry land group. The dry land group located at the right side of the dendrogram was composed of only one vegetation plot whose indicator species were commercially important species *viz Brassica oleracea*, *Allium cepa* and the legume species *Phaseolus vulgaris*. The left side of the dendrogram which formed wetland group was further classified into various vegetation types. The second dichotomy divided the wetland group into monotypic semi-aquatic stands of *Oryza sativa* which occupied the paddy fields in some portions of the wetland and in the adjacent areas. The vegetation type was found at the time when the fields were inundated during growing season till the period of harvesting comprising of 23 plots and two grass plots occupying marshy meadows. A large sub-type of pure aquatic macrophytes comprised of 274 plots which inhabited marshy habitats where submergents, free-floating and emergent life forms dominated. This division was based on level of water and the type of silt or substratum. The marshy vegetation was further classified into various types. Following plant associations were found which are described below:

Group A1 (*Oryza sativa*): The group comprised of only one plant species *Oryza sativa* which occupied the paddy fields in some portions of the wetland and in the adjacent areas. This plant species was found at the time when the fields are inundated during growing season till the period of harvesting. Rice was the staple food of the area and the other land uses of wetland were taken over by the cultivation of this crop.

Group B1 (*Cynodon dactylon*): This group contained patches of grassy meadows inside the wetland and around the fringes of the dyke. *Cynodon dactylon* was the only species found in this group.

Group C1 (*Sagittaria trifolia*): The short emergent *Sagittaria trifolia* was the only plant species of this group. The group occupied the peatlands found within the wetland. Peatlands were formed due to partial decomposition of organic matter.

Group D1 (*Lemna minor –Marsilea minuta):* This plant community was comprised of free-floating *Lemna minor* and rooted-floating *Marsilea minuta*. This community was widespread throughout the open water zones of the wetland.

Group E1 (*Typha elephantia -Nymphaea peltata-Nymphaea odorata*).: The rooted-floating *Nymphaea peltata* and *Nymphaea odorata* and the emergent *Typha elephantia* comprised the most common vegetation type of this group. This group contained the stands of tall reed beds and floating vegetation zones dispersed in vast expanses throughout the wetland.

Group F1 (*Myriophyllum verticillatum–Phragmites communis–Ranunculus sceleratus–Hydrilla verticillatum):* This group was mostly located in the shallow water areas of the wetland. The submergent plant species *Hydrilla verticillata* occupied the base of the wetland. The only tall emergent present in this community was *Phragmites communis* and rest were short emergents comprised of *Myriophyllum verticillatum* and *Ranunculus sceleratus*.

Group G1 (*Marsilea minuta -Scirpus palustris):* This group dominated the submerged siltation zones on the southern side of the wetland and interspersed shallow water areas. The community was characterised by *Scirpus palustris* and *Marsilea minuta* species respectively.

Group H1 (*Eleocharis* species): Tall emergent *Eleocharis* species was the only plant species found in this group. This group dominated the fringes of reed beds and the waterlogged plantation around the periphery of the wetland.

Group I1 (*Salvinia natans – phragmites communis*): This plant community was dominated by *Salvinia natans* restricted to the open water areas of the wetland towards its northern portions and the emergent *Phragmites communis* found dispersed in the reed beds of the wetland.

Group J1 (*Nymphaea peltata- Salvinia natans- Sagittaria sagitifolia*): This group was located on the floating vegetation patches in the interior of the wetland. Rooted floating *Nymphaea peltata* and free floating *Salvinia natans* are the characteristic plant species of this group. Short emergents *Sagittaria sagittifolia* was the other plant species restricted to the shallow water areas of the wetland.

Group K1 (*Trapa natans-Lemna minor*): This plant community was formed of floating species of *Trapa natans* and *Lemna minor.* The type was restricted to the shallow open water areas of the wetland on its northern side*.* The vegetation type is indicative of the high level of transparency in these areas.

Group L1 (*Marsilea minuta-Potamogeton perfoliatus*): Rooted floating *Marsilea* and *Potamogeton* species were the characteristic plant species of this plant community and occupied the open shallow water areas of this wetland.

Group M1 (*Brassica oleracea-Allium cepa- Phaseolus vulgaris*): This plant community was located in the land areas used denoting agro-ecosystem found around the wetland. It comprised vegetation type of the dry land group. Dominant species present in this community were *Brassica oleracea, Allium cepa* and *Phaseolus vulgaris*.

In the peripheral plantation, Twinspan technique divided 54 sample plots into 10 clusters at level 4 of the hierarchical classification to form 8 vegetation groups (Fig.4.6).

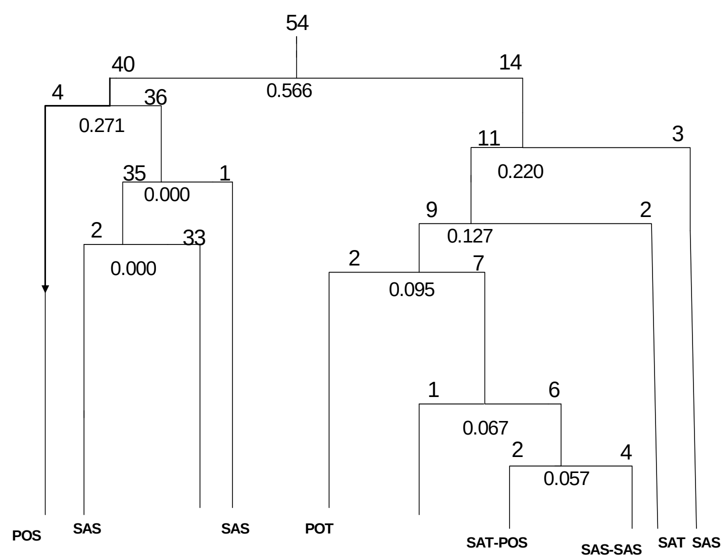

Figure 4.6 Dendrogram showing plant associations in plantation of Hokersar wetland (number of plots showing associations are given on top, eigen values given between two associations).

The classified vegetation groups are described below:

Group A2 (*Populous deltoids* sapling): This group contained the plantation of *Populous deltoids* saplings which had been recently planted in the periphery of the wetland towards its northern side.

Group B2 (*Salix alba* trees): The vegetation type comprised of *Salix alba*, a tree tolerant to water logging conditions. The tree species occurred in groves and bounded the wetland in all directions.

Group C2 (*Salix alba* sapling): The group comprised newly planted *Salix alba* sapling. This occurred as scattered stands along with the willow plantation which bordered the wetland.

Group D2 (*Populous deltoids* trees): All the stands of this vegetation group were found scattered in vast expanses of willow plantation. The habitats are periodically flooded during the time of extreme rains. The only and the characteristic tree species was *Populous deltoids*, a species tolerant to water logging.

Group E2 (*Salix alba* trees-*Populous deltoids* sapling): This particular association was found in places where *Popular* saplings have been planted within the thinly populated willow stands. The group mostly occurred adjacent to the dyke of the wetland.

Group F2 (*Salix alba* sapling - *Populous deltoids* sapling): The plant community consisted of saplings of *Salix alba* and *Populous deltoides.* The vegetation type was found on such areas of periphery where mature trees have been cut and further where they acted as boundary to prevent encroachment of the wetland.

Group G2 *(Salix alba* trees-*Salix alba* saplings): Trees of *Salix alba* and saplings of *Salix alba* were the characteristic species of this vegetation type.

The community was found interspersed within the *Salix alba* groves bordering the wetland in all sides.

4.4.6 Vegetation structure and composition of Hygam wetland

A total of 16 plant species and 11 families were recorded from the wetland (Table 4.5). Three species were recorded from family Poaceae followed by Typhaceae and Nymphaeaceae. In the peripheral plantation Salicaceae comprised 2 species and 1 species belonged to Rosaceae family.

The observed species richness in macrophyte assemblage was equal to 15 The three estimators Chao 1 estimator, Jack-knife 1 estimator and Jack-knife 2 estimator estimated 15 as true species richness of the assemblage which was exactly equal to the observed richness. Shannon index calculated for the diversity was 1.53 and the Simpson index was 2.99 respectively.

Application of Twinspan technique divided the set of 158 sampling plots inside the wetland into 18 clusters at level 6 of the hierarchical classification. These formed 15 vegetation classes. The first Twinspan dichotomy divided 158 plots into aquatic macrophytes comprising 150 plots and semi-aquatic *Oryza sativa* stands which comprised 8 plots (Fig. 4.7).

The marshy vegetation was further classified into various types which are described below:

Group A3 (*Ceratophyllum demersum*): The submergent species *Ceratophyllum demersum* was the only plant species found in this vegetation class. The plant species occupied the deep areas in the middle of the wetland where its roots were embedded in the silty substratum of the wetland.

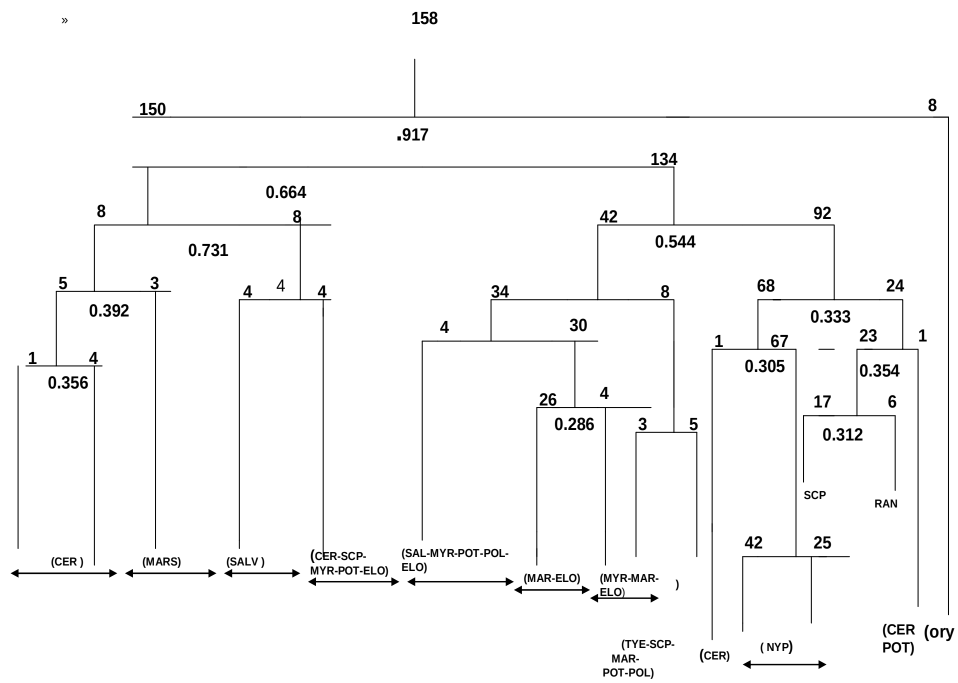

Figure 4.7 Dendrogram showing plant species associations inside Hygam wetland (based on twinspan, number of plots showing associations are given on the top, eigen values given between two associations).

Group B3 (*Marsilea minuta*): *Marsilea* species, a rooted species with floating leaves comprised this vegetation type of the wetland. The vegetation was found in shallow littoral zone between the water bodies and siltation zones towards the southern fringes of the wetland.

Group C 3 (*Salvinia natans*): *Salvinia natans*, free floating species was the only plant species comprising this vegetation type. It dominated the littoral zones towards the boundary of the wetland and also occupied the shallow water zones within the wetland.

Group D3 (*Ceratophyllum demersum-Scirpus* spp.-*Myriophyllum verticillatum - Potamogeton perfoliatus.-Polygonum barbatum- Eleocharis palustris*): This plant community contained submergent, emergent and the floating type plant species. The community was widespread throughout the wetland particularly the middle open water zones and fringes of the emergent reed beds which has had infested a large portion of the wetland. The plant species found in this group were *Ceratophyllum demersum, Scirpus* species, *Myriophyllum verticillatum*, *Potamogeton perfoliatus*, *Polygonum barbatum*, and *Eleocharis palustris*

Group E3 (*Salvinia natans-Myriophyllum verticillatum-Potamogeton perfoliatus-Polygonum barbatum-Eleocharis palustris*): The vegetation type was located on the littoral zone towards the northern side of the wetland. Floating type and the emergents dominated this plant community. The characteristic plant species found in this vegetation class were free floating *Salvinia natans*, rooted floating *Potamogeton* species, short emergents *Myriophyllum verticillatum* and *Polygonum barbatum* and tall emergent *Eleocharis palustris* respectively.

Group F3 (*Marsilea minuta- Ranunculus sceleratus*): This vegetation type occurred on the siltation zones of the wetland, both towards its northern and southern sides. *Ranunculus sceleratus* which is a short emergent occupied the shallow zones near the dyke and *Marsilea* species occur a further ahead towards the centre of the wetland.

Group G3 (*Myriophyllum verticillatum-Marsilea minuta-Eleocharis palustris*) This group was located around the emergent reed beds of the wetland, the light siltation zones towards the southern portions of the wetland and on the fringes of the peatland towards its eastern side. *Myriophyllum verticillatum* was the characteristic species for this vegetation group which is commonly found on the shallow water areas. Among the associates in this community were *Eleocharis palustris*, a short emergent species and *Marsilea* species found in the zones which were shallow due to siltation.

Group H3 (*Scirpus* species - *Nymphaea peltata*- *Potamogeton perfoliatus*): Floating communities in this class comprised of *Nymphaea peltata* and *Potamogeton* species. *Nymphaea peltata*, a rooted with floating leaved species comprised the most common plant species of this vegetation class and occupied the open water areas in the middle of the wetland mostly towards the eastern side. *Potamogeton* was the associate of this species. In addition *Scirpus* species occurred as fragments interspersed in the reed beds.

Group I3 (*Nymphaea peltata* - *Polygonum barbatum-Oryza sativa*): This vegetation community occurred on the southern side of the wetland which was a heavy siltation zone and mostly inundated during most seasons of the year and hence the area was used for the cultivation of paddy. *Nymphaea peltata* was rooted species with floating leaves, *Polygonum barbatum* occurred near places where there was low water level in the same area and *Oryza sativa* was the major plant species found in this group.

Group J3 (*Potamogeton perfoliatus*- *Marsilea minuta*): The floating species of *Marsilea* and *Potamogeton* comprised this vegetation group. The class had a wide distribution throughout the wetland where water level was low due to heavy deposition of silt coming from outside perennial streams.

Group K3 (*Nymphaea peltata*): The floating species *Nymphaea peltata* was the only plant species found in this vegetation class. The class was located inside the wetland forming large floating vegetation zones. The class acted as a conducive resting place for both resident and migratory birds.

Group L3 (*Scirpus* species): *Scirpus* species was the only emergent plant species found in this class. The plant occupied the inner side and fringes of the tall emergent reed beds.

Group M3 (*Ranunculus sceleratus)*: The short emergent *Ranunculus sceleratus* comprised this vegetation class. It mainly dominated the littoral zone adjacent to the dyke of the wetland.

Group N3 (*Ceratophyllum demersum-Potamogeton perfoliatus*): The submergent species, *Ceratophyllum demersum* and floating species, *Potamogeton* constituted this plant community. This vegetation class occurred on the deeper parts of the wetland towards its northern side.

Similar Twinspan technique divided the set of 48 sampling plots of the peripheral plantation into 3 clusters at level 2 of the hierarchical classification. These formed 3 vegetation types labelled as A4 to C4 (Fig.4.8). The first Twinspan dichotomy separated all the tree plots from the sapling plots.

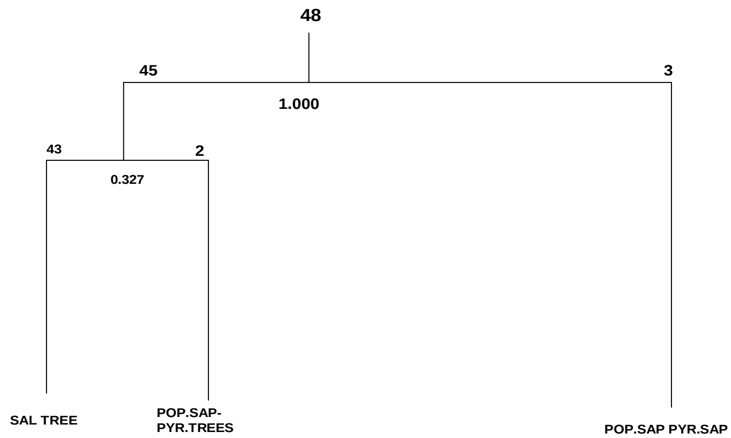

Figure 4.8 Dendrogram showing plant species association in bordering plantation of Hygam wetland (number of plots showing associations are given on top, eigen values given between two associations).

Description of vegetation types is given as below:

Group A4 (*Salix alba* trees): This vegetation type comprised of only one woody tree species i.e. *Salix alba.* This group was widespread throughout the periphery of the wetland as vast groves to act as a fence and as a silt trap.

Group B4 (*Populous deltoids* sapling-*Pyrus malus* trees): The vegetation class was found in such places of the periphery where plantation occurred in association with apple orchards. The group comprised of vast expanses of *Populous deltoids* trees and scattered *Pyrus malus* trees. Mainly located in much drier zones of the peripheral plantation.

Group C4 *(Populous deltoids* sapling-*Pyrus malus* sapling): This plant community was located on the fringes of the bordered plantation towards the western side of the wetland at an elevation slightly higher than the rest of the wetland and with lesser moisture content. Characteristic species were *Populous deltoides* and *Pyrus malus* sapling.

4.4.7 Comparison of vegetation composition and species richness between two study wetlands

A total of 28 species from 20 families was recorded in Hokersar wetland and on the contrary 23 species from 17 families were recorded from Hygam wetland. Plant communities of 13 different categories were found in case of Hokersar wetland and in the peripheral plantation bordering it, 7 communities were found to exist. In case of Hygam wetland, 14 vegetation types were found to exist and in addition, 3 vegetation types were found in case of peripheral plantation (Table 4.5).

The observed species richness of aquatic macrophytes in Hokersar wetland was 25 species and on the contrary it was only 15 species in case of Hygam wetland. Most robust Jack-knife 1 estimator estimated 28 species as the true species richness of macrophyte assemblage for Hokersar wetland whilst the true species richness estimated by the same estimator for macrophytes was 15 in case of Hygam wetland which was exactly equal to the observed species richness. Shannon Index computed for Hokersar wetland was 2.29 whilst in case of Hygam wetland it was 1.53. Similarly the Simpson Index for Hokersar wetland was 6.6 and for the Hygam wetland it was 2.99 respectively indicating highly diverse macrophytic community in Hokersar wetland than Hygam wetland (Table 4.5).

Table 4.5 Comparison of Frequency occurrence of plant species recorded in Hokersar and Hygam wetlands.

		Hokersar		Hygam	
Sl. No.	**Family**	**Frequency of occurrence**	**Plant species**	**Frequency of occurrence**	**Plant species**
1.	Salicaceae	8	*Salix alba* *Populous deltoids*	9	*Salix alba* *Populous deltoids*
2.	Trapaceae	4	*Trapa natans*	0	
3.	Lemnaceae	4	*Lemna minor*	5	*Lemna minor*
4.	Poaceae	12	*Oryza sativa* *Cynodon dactylon* *Phragmites communis* *Agropyron smithii*	14	*Oryza sativa* *Cynodon dactylon* *Phragmites*
5.	Typhaceae	8	*Typha elephantia* *Typha angustifolia*	9	*Typha elephantia* *Typha angustifolia*
6.	Marsileaceae	4	*Marsilea minuta*	5	*Marsilea minuta*
7.	Brasiccacaeae	4	*Brassica oleracea*	0	Nil
8.	Alliaceae	4	*Allium cepa*	0	Nil
9.	Leguminaceae	4	*Phaseolus vulgaris*	5	*Phaseolus vulgaris*

Contd……

Table 4.5 Contd….

10.	Cyperaceae	4	*Scirpus* species *Eleocharis palustris*	9	*Scirpus* species *Eleocharis palustris*
11.	Nymphaeaceae	8	*Nymphaea peltata* *Nymphaea odorata*	9	*Nymphaea peltata* *Nymphaea odorata*
12.	Salviniaceae	4	*Salvinia natans*	5	*Salvinia natans*
13.	Haloragaceae	4	*Myriophyllum verticillatum*	5	*Myriophyllum verticillatum*
14.	Polygonaceae	4	*Polygonum barbatum*	5	*Polygonum barbatum*
15.	Potamogetonaceae	4	*Potamogeton perfoliatus.*	5	*Potamogeton perfoliatus.*
16.	Ranunculaceae	4	*Ranunculus sceleratus*	5	*Ranunculus sceleratus*
17.	Hydrocharitaceae	4	*Hydrilla verticillata*	4	*Hydrilla vertillatum*
18.	Sphagnaceae	4	*Sphagnum cymbifolium*	0	Nil
19.	Alismataceae	4	*Sagittaria sagittifolia* *Sagittaria trifolia*	0	Nil
20.	Rosaceae	0	Nil	5	*Pyrus malus*
21.	Azollaceae	0	Nil	5	*Azolla pinnata*
22.	Cerotophyllaceae	4	*Ceratophyllum demersum*	5	*Ceratophyllum demersum*

Floating vegetation

Tall emergents

Plantations

Trapa beds

Plate 3. Vegetation types in wetlands of Jammu & Kashmir

4.5 Discussion

4.5.1 Spatial pattern of land use of two study landscapes

The findings of this study showed that pattern of spatial heterogeneity and landscape features in both Hokersar and Hygam wetland landscapes represented wetland-plantation complex within a matrix of distributed settlements and extensive agricultural land. A study by Pandit (1991) found the landscapes as patch of marshes with few open water bodies prior to major floods of 1952 and 1959 in the valley of Kashmir, Jammu & Kashmir state. This is in contradiction to findings of the present study which showed landscape comprising of both marshy and non-marshy areas. The marshy landscape was equivalent to permanently saturated zone and non-marshy zone was equivalent to both seasonally saturated and unsaturated zone. Other studies (Rashid & Joshi, 2000) found that factors contributing to this transformation of landscape included fragmentation due to excessive siltation and biotic interferences. Past data not available for Hygam suggested changes in landscape are a consequence of similar factors as that of Hokersar wetland landscape. This may be due to location of both landscapes in same flood plains of river Jhelum, similar geomorphic setting and similar host landforms and subjected to same direct and indirect anthropogenic disturbances. However studies pertinent to spatial pattern of land-uses in temperate landscapes to support this study are essentially lacking. Plantation a dominant land-cover class in both landscapes represented mainly willow *Salix alba* and Popular *Populous deltoids* groves, species tolerant to waterlogged soils besides agricultural land and emergent zone were other major land surface features. Fallow land formed as a result of siltation and its subsequent transformation to woodlands and agricultural land was the result of such landscape composition. Plantation occupied a large area in Hygam landscape than Hokersar. The reason was nearness of the wetland to Asia’s largest freshwater lake, Wular Lake where extremely vast willow plantations occur under the Jurisdiction of government control. In addition, drainage in marshy areas and their subsequent reclamation to paddy cultivation was other factor contributing to increase in percent of agricultural land in both landscapes. Paddy cultivation formed important agricultural practices in two landscapes. This expansion of agricultural land at landscape level was favoured by data (review by Meyer & Turner, 1992) on human population growth and which showed that an increase of 466% of world total cultivated land has occurred from 1700 to year 1986. The herbaceous meadows dominated by *Cynodon dactylon* in both landscapes served as important grazing grounds for pastoral communities inhabiting the surrounding villages. Topographical variation exists in two landscapes. The topography of Hokersar wetland was almost plain while Hygam landscape represented a variety of topographic features such as an undulating terrain bordering it on one side which formed a part of narrow and extensive range of hills stretching across entire Kashmir valley from Qazigund to Baramulla respectively. Barren land was another distinguishing feature of Hygam landscape while no such land-cover feature existed in the Hokersar landscape.

The wetland portion in both landscapes comprised of emergent macrophytes *viz*. *Typha angustifolia, Typha elephantia* and *Phragmites communis* as a result of proliferation of these species in open water bodies. This seemed to be the reason for small areal extent of open water and submergent bodies in both landscapes which decrease at the expense of increase in marshy areas. The reed bed provided a suitable and conducive breeding habitat for a number of waterbirds and as an essential source of food to migratory birds in winter. Diking around wetland was to retain optimum water level in wetland and as a means to confine the actual wetland area. High level of siltation in Hygam wetland in comparison to Hokersar wetland accounted for less area under floating vegetation, open water zones and complete absence of submergent vegetation with less density of *Phragmites communis* species and complete elimination of *Trapa natans* and other edible flora. Integrated wetland and land-use maps prepared (Vijayan *et al*., 2004) for various districts of Jammu & Kashmir state indicate catchments of both study wetlands located in agricultural areas. Hence the general concept of deforestation and resulting soil erosion in catchments could not be the reason associated with major ecological problems of siltation in both wetlands. Influx of heavy load of silt and nutrients by diversion of Doodganga flood spill channel and two seasonal inlets (Soibugh and Dharmuna) into Hokersar wetland and Balkul and Ningli Nallah into Hygam wetland were responsible for concomitant and modification in structure and functioning of two study wetlands. Study by Zutshi (1987) in same state of Jammu & Kashmir showed suspended solids from catchment areas in Dal lake ecosystem from its forested catchment as factors contributing to reduced capacity and shrinkage in water-spread area of the lake. Temporal changes in the wetland cover between 1992-1993 and 2000-2001 worked out for three districts of Ladakh, Baramulla and Jammu (Vijayan *et al*., 2004) showed a substantial loss of 86.98% in Ladakh division, whereas Baramulla had an increase of 6% and Jammu division an increase of 19% of wetlands respectively. Modifications due to channelization and sedimentation are also experienced by some temperate freshwater wetlands; California marshes of North America, Hokkaido marshes of Japan and Montane wetlands of Switzerland. Peatland which is formed when plant production exceeds decomposition, allowing organic matter to accumulate, represented one of the land-cover class in Hokersar landscape. This feature made Hokersar wetland landscape distinct from Hygam wetland landscape where no such peat formation takes place. Peatland found in all continents from tropical to polar zones represent 50-70% of all wetlands of the world and cover more than 4 million km^2 or three percent of the land and freshwater surface of the planet.

Percolation of nutrients from surface run off of agricultural catchments in two wetlands and discharge of waste water from one nearby hospital in Hokersar wetland has resulted in major ecological stress of eutrophication. Proliferation of *Typha angustifolia* and *Salvinia natans* and simultaneous elimination of many commercially important species and subsequent decrease in fish production in both wetlands is a common problem associated with these influxes into wetlands.

Land use classes of two landscapes played an important role in the local economy and livelihoods of people. Local people depended upon Willow and Popular plantations for timber and fuel wood. Emergent and floating vegetation areas served to meet food and fodder requirements of people.

Agricultural land as one of the major land-use class was used for paddy cultivation. Extractions of peat in Hokersar landscape satisfied many essential human needs for fuel, agriculture and other commercial purposes. The herbaceous meadows in both landscapes served as important grazing grounds for pastoral communities inhabiting the surrounding villages.

Management at landscape level by department of Wildlife Protection Jammu & Kashmir was at small to large scale in both sites. The concerned department of Wildlife protection of Jammu and Kashmir state permits on a controlled basis eradication of excessive reeds and floating vegetation from these land-cover classes each year in autumn season. This is done to prevent excessive proliferation and simultaneous enhancement of water spread area for arrival of migratory waterbirds. Peat extraction from peatlands maximise open water areas and during growing stage, floating vegetation zones are seen over these areas. A sluice gate installed in Hokersar wetland has mainly controlled water level. Frequent flooding of other land-uses during excessive rains has been prevented. Land-use dynamics at short time interval is thus not a common phenomenon. Cutting of old dead trees and plantation of new trees is also done on contractual basis in areas bordering the wetland. However proper land-use planning and decision making on scientific basis till date has not been attempted so far.

4.5.2 Vegetation composition and structure

Aquatic plant communities of Hokersar wetland were more diverse in number of species when compared to Hygam wetland. This may be related to high sediment load and more anthropogenic disturbance in Hygam wetland. These results agree with those reported by Shrestha & Janauer (2000) on aquatic macrophytic diversity. Floristic associations are both simple to complex in both study wetlands. Results of twinspan analysis showed 13 aquatic plant species assemblages or vegetation types in Hokersar wetland and 14 types in Hygam wetland. Plant assemblages were seen distributed in both wetland and non-wetland areas of Hokersar study site. The non-wetland areas showed only two assemblages in dry and seasonally inundated habitats characterised by monotypic stands of *Cynodon dactylon* and one association of commercially important crop species forming agro-ecosystems. Wetland areas showed 11 plant assemblages characterised by free-floating and emergent communities. Hygam wetland did not indicate any of the plant community in non-wetland areas. This may be attributed to high sediment load in these zones. Vegetation groups mainly confined to shallow water areas of Hokersar wetland. Hygam wetland represented plant communities in both shallow and deep water areas of wetland. Plant associations represented floating and emergent communities in Hokersar wetland. In contrast in Hygam wetland, submerged community of *Ceratophyllum demersum* was also found. Khan (2000a) reports that in turbid waters of Hokersar wetland, the submerged forms are very sparse although extensive belts of reeds dominated the littorals. *Potamogeton pectinatus*, *Marsilea minuta* and *Nymphaea peltata* represented floating communities and dominant emergent species included *Ranunculus sceleratus*, *Typha angustifolia*, and *Scirpus* species. Pandit & Qadri (1990) reported two macrophytic species *Nymphaea peltata* and *Phragmites communis* as adversely affected during major floods of 1986 and 1987, followed by re-emergence of submerged plants *Ceratophyllum demersum* and *Myriophyllum spicatum*. Casanova & Margaret (2000) also found that duration and frequency of flooding events are important in segregating the plant communities. Zutshi (1975) showed 10 aquatic plant associations in both Hokersar and Hygam study wetlands. A comparative higher number of associations are shown in this study. This may be attributed to weed infestation and invasion of exotic species forming new associations. Macrophytic vegetation form only two monotypic stands of *Sagittaria trifolia* and *Eleocharis* species in Hokersar wetland. Hygam wetland represented more number of monotypic stands of macrophytes. This supports the view that increasing habitat heterogeneity increases species diversity (Nilsson *et al*., 1991). Largest association in Hokersar wetland is seen in group F1 of shallow water areas forming *Myriophyllum verticillatum* - *Phragmites communis*- *Ranunculus sceleratus* - *Hydrilla verticillatum*. Cronk *et al*. (2001) reported distribution of these species in North America and Mediterranean temperate zone. Group D3 located in entire wetland of Hygam study site formed the single large association of *Ceratophyllum demersum* - *Scirpus* species - *Myriophyllum verticillatum* - *Potamogeton perfoliatus*- *Polygonum* *barbatum - Eleocharis palustris.* Khan *et al*. (2004) identified free floating *Salvinia- Lemna* association in Hokersar wetland. The findings of the present study are not consistent with results of this study indicating a shift in macrophyte community structure. Comparable communities are reported in Dal lake ecosystem of Kashmir valley. Khan *et al*. (2004) showed 42 macrophyte species from wetlands of Kashmir valley. Past vegetation studies have shown 29 species in Hygam wetland (Pandit, 1980) and 29 species in Hokersar wetland (Handoo & Kaul, 1982). This study indicated 21 species in Hokersar wetland and 16 species in Hygam wetland. The present findings confirm alteration in species composition and vegetation structure of both study wetlands. Two endemic aquatic plant species *Najas marina* and *Hoppea dichotoma* reported from Jammu & Kashmir (Cook, 1996) are not indicated by this study. Invasion of exotic species in Hygam wetland at the expense of native species may be the reason for decline of this species.

The two study wetlands support a diverse community of aquatic macrophytes. However, alteration in their aquatic habitats through natural and human induced disturbances was responsible for loss of some economically important species. Land cover dynamics of two study wetlands due to siltation and infestation of weeds with subsequent change in hydrological regime is major factor that contribute this change in macrophytic structure. Relevant conservation and management measures to maintain macrophytic diversity include integrated approach of control of sediment and nutrient load and weed infestation at both the wetlands combined with emphasis on sustainable utilisation of aquatic macrophyte resources.

4.6 Summary

Landscape composition of Hokersar and Hygam wetland landscapes was assessed in GIS domain using IRS-1C-LISS III data. Floristic associations of these wetlands were derived by vegetation sampling. Of the total 120 km^2 area of Hokersar wetland landscape, 23.25% area was covered by plantation, 18.90 % area was emergent vegetation, 15.35% was under peatland, 9.78%

was under floating vegetation, 5.64% was covered by meadows, 3.79 % was habitation, 2.9 % was covered by dyke, and 0.96% was under water bodies while 0.66% area was submergent one.

The Hygam wetland landscape under study comprised a total area of 116.191 km^2 of which 26.13% was covered by plantation, 25.94% area was crop field, 16.62% was emergent vegetation, 16.48% area was barren land, 4.19% was covered by floating vegetation, 3.71% area was habitation, 2.64 % was under meadows, 2.16 % of the area was hillock, 1.45 % area was covered by water bodies and 0.85% area was covered by dyke.

Of the 26 plant species recorded in 20 families from Hokersar wetland, the observed species richness of 25 (±1.63) of aquatic macrophyte assemblage was exactly equal to true species richness estimated by Chao 1 estimator with 95% confidence interval. Jack-knife1 estimator estimated true species richness of aquatic macrophytes equal to 28 (±2.99). Jack-knife 2 estimator, estimated 31 species as true species richness of aquatic macrophytes. Shannon diversity index computed for the macrophyte assemblage was 2.29 and the estimate of Simpson diversity index was 6.6.

Hygam wetland recorded a total of 16 species in 11 families. The observed species richness of 15 in macrophyte assemblage was exactly equal to true species as estimated by Chao1, Jack-knife 1 and 2 estimators with 95% confidence interval. Shannon Index calculated for the diversity was 1.53 and Simpson index as 2.99. Twinspan identified 13 different categories of plant associations in Hokersar wetland and 14 categories of plant associations in Hygam wetland.

To summarise, the findings of this study indicated a difference in landscape structure between the two wetlands. The pattern of land use - land cover between two landscapes showed that the extent of marshy areas was more in Hokersar wetland landscape (35.65% of the total landscape) than Hygam landscape (22.26% of the total landscape). The landscape compositions between two landscapes revealed difference in only land cover types.

Peatland and submergent vegetation as land cover types existed only in Hokersar landscape and were absent in Hygam landscape. Barren land as a major land cover type and hillock was found only in Hygam landscape and was absent in Hokersar landscape. The land use types between two areas were found similar. However, the area extent of land use classes *viz.* plantation, crop field and habitation was less in Hokersar wetland landscape than Hygam wetland landscape. Aquatic plant community structure revealed lesser vegetation types of macrophytes (only 13 classes) in Hokersar wetland than in Hygam wetland where 14 vegetation types were found. However macrophytes community of Hokersar wetland was more diverse in number of species in Hokersar wetland (25 species) than in Hygam wetland (15 species). Extent of major aquatic plant communities; emergent vegetation, floating vegetation and submergent vegetation was more in Hokersar wetland (29.34% of total landscape) than in Hygam wetland (20.81% of total landscape). This was mainly attributed to less siltation and other biotic pressures and a less dependency of local people on wetland resources in Hokersar wetland than in Hygam.

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CHAPTER 5
DISTRIBUTION AND ABUNDANCE OF WATERBIRDS

5.1 Introduction

Understanding spatial and temporal patterns of bird species is a pre-requisite for understanding population dynamics and for successful species and habitat conservation. Loss of natural wetlands in recent decades due to intensification of human activities and environmental changes has been a serious threat to waterbird populations (Owen & Black, 1990; Finlayson *et al*., 1992; van Vessem *et al.,* 1997). Population trend of waterbirds is linked to the health or sustainable use of a wetland ecosystem (Siriwardena *et al*., 2001) and many globally threatened avian species depend on them (Green, 1996). Referred to as birds ecologically dependent on wetlands (Ramsar Convention, 1971), waterbirds belong to eight orders and 20 families with 878 species recorded globally; the group has the potential to detect aspects of wetland landscape condition. Millennium Ecosystem Assessment (2005) reports 41% of 1138 global waterbird populations in decline and eight waterbird species as globally threatened (Birdlife International, 2007). Many waterbird populations are migratory, in which the entire population or a significant proportion of the population (>1%) cyclically and predictably crosses one or more national borders or jurisdictional boundaries.

Populations of species vary in time and space. Site tenacity of individuals and spatial turnover of populations over time should be taken into account when protecting habitats of specific species. Bird population parameters such as richness, relative density and diversity of birds frequently provide information on habitat quality (Nilsson & Nilsson, 1978; Weller, 1978; Sampath & Krishnamurthy, 1990). Habitat alteration and changes in biotic interactions (predation, interspecific competition) can cause considerable changes in the distribution of breeding individuals and populations (Wiens, 1989a; Virkkala, 1995; Roos & Part, 2004).

The present study explored waterbird distribution and abundance in Hokersar and Hygam wetlands of Kashmir valley with the objective to explore variation in density, abundances and diversity pattern along spatio-temporal gradient. The chapter in itself was an attempt to answer the following research questions:

- Is there any spatio-temporal variation in the density and diversity pattern of waterbirds in Hokersar and Hygam wetlands of Kashmir valley?
- Are there significant and consistent differences in waterbird population between two wetlands?

5.2 Methods

The survey methodology was designed after referring to the methods used by various authors (Eltringham & Atkinson-Willes, 1961; Roux, 1973; Zewarts, 1976; Alford & Bolen, 1977; Amat, 1984; Sridharan, 1989; and Spindler *et al*., 1981). Waterbird survey data from two wetlands was collected during mid-winter (December-January 2004/2005) and post-winter (February-April, 2005) sampling seasons for estimation of wintering migratory populations. Breeding population survey took place during March-May (2005) in both the wetlands. For estimation of wintering waterbird population, both study wetlands were stratified into visually distinguishable habitat categories. Each habitat type represented a sampling site. Hokersar wetland had seven habitat types in mid-winter and eight in post-winter. Hygam wetland showed five habitat types in mid-winter and seven in post-winter seasons. Each habitat type represented a sampling site. A total of 16 such sites in mid-winter and 15 in post-winter from Hokersar wetland and seven in mid-winter and eight in post-winter from Hygam wetland were sampled for bird populations. Waterbird sampling for each site was done by direct count. Although point count method was adopted in initial stage of the survey, it was later discarded due to its inapplicability in wetland ecosystems. In order to avoid double counting or missing birds, a vantage point was used. Vantage points were selected based on the best visibility of the site. Care was taken that their fields of vision do not overlap. Each site was assigned a fixed view point. From each fixed point, area was scanned for bird flocks. Counting was done with the aid of a 10 x 80 field binoculars and 29x spotting scope. Data was collected by recording the number of individuals of each species (species-wise count). Large flocks were estimated in tens and multiples of ten (10× and 100×). Counts represented a scan sample of birds visible from the fixed point. Birds were identified to species level using available field guides (Grimmett & Inskipp, 1998). Double counting was avoided by recording the birds that flew into and out of the plots during the census. Counts were not made on days with rain, snowfall, and strong wind (Verner, 1985). Weekly observations in each study wetland were made alternately wherein observations were rotated to avoid bias in the number of observations allocated to each point.

Nest searches were conducted from March to mid of May (2005) in nesting sites located in preliminary survey from both study wetlands. The sampling procedure followed that of Thompson (1991) and Bibby *et al*. (1992). Nest sampling recorded number of nests in each of the 20 × 20 m quadrat at fixed intervals along five line transects laid in Hokersar wetland (n=29) and three transects laid in Hygam wetland (n =16). Nests were marked with individual numbers and assigned to its bird species. Data collected on variables of clutch initiation and hatching date, clutch size and nest success was subjected to statistical analysis.

5.3 Analysis

5.3.1 Species composition and structure

The data collected were compiled in MS Excel software. Data of replicates was pooled separately for individual sampling sites to compute estimates of population parameters. This was done separately for the two wintering seasons studied in both wetlands. Average density of waterbirds across each sample site was calculated in each of the season studied from the two wetlands followed by subsequent estimation of individual species density within each site. A non-parametric one-way ANOVA was used on untransformed data to compare the differences in mean densities among habitats following Zar (1974). Significance of inter-group differences was determined by Tukey post-hoc multiple comparison test using the equation given in Siegel & Castellan (1988: 8.6). Data analyses was performed using the software package SPSS/PC + 4.0 (Norussis, 1994).

5.3.2 Species diversity and evenness

Species diversity and richness was computed by ecological analysis package biodiversity pro (Biodiversity professional beta version 2.0.0.0). Data matrices of format, samples in columns and species in rows in bdpro spreadsheet file performed alpha and beta calculations for both mid-winter and post-winter sampling seasons from both the study wetlands. Species richness (S) was derived from rank-abundance plots separately for each sample. Shannon-Wiener, Simpson and Berger-Parker diversity indices were calculated for each sample in both mid-winter and post-winter sampling seasons. Chao 1 estimator and Jackknifing to predict expected species richness with more sampling effort was further done.

Diversity indices were calculated with the following formulas:

The equation for the Shannon Index H' (Shannon & Wiener, 1949), which uses natural logarithms (ln), is

$$H' = \text{€}_{i = l}^{S*} (pi \ ln \ pi)$$

where H' is the average uncertainty per species in a infinite community made up of S species with known proportional abundances p1, p2, p3 … ps; S and pi s are population parameters and, in practice, H' is estimated from a sample as

$$H' = \text{€} \ [(n1/n) \ (n1/n)]$$

Where ni is the number of individuals belonging to the ith of S species in the sample and n is the total number of individuals in the sample.

5.3.3 Nest dispersion

Data from all sampling units (quadrats) was pooled together. This was done separately for each nest site. Total number of nests found and total area sampled was used to calculate average nest density in each site. Again one-way ANOVA was used to compare the differences in mean nest densities among nest sites for each breeding species.

5.4 Results

5.4.1 Status and seasonal species composition

A total of 22 species of waterbirds were recorded from Hokersar wetland during mid-winter (December- January, 2004-05) and post-winter/spring (February-April, 2005). In Hokersar wetland, the species composition belonged to five orders, seven families and 16 genera. In Hygam wetland, 16 species of waterbirds belonging to six orders, seven families and 12 genera were recorded during these periods. About 54% of the waterbird species recorded from Hokersar and 56% from Hygam were migratory. List of bird species found in Hokersar and Hygam wetlands during above-mentioned study period is given in appendix 1.

5.4.2 Density and spatio-temporal distribution of birds in Hokersar

During the intensive study period (mid-winter, 2004-2005; post-winter/spring, 2005) to monitor population status of migratory waterbirds assuming that the study population occupying their wintering grounds during this time and that the estimates during these periods are likely to have less bias, an overall pooled mean waterbird density in mid-winter was recorded as 680.57 individuals ha^{-1}. Post winter density was estimated as 30.35 individuals ha^{-1}. Large variation in population estimates between the two seasons could be attributed to difference in bird congregation between the two seasons assuming mid-winter as peak season and post-winter/spring as season of departure to their Palearctic breeding grounds.

Total waterbird species (cumulative list in two seasons) were17 in mid-winter and 20 species in post-winter. Despite relative variation in percentage composition of major families in mid and post-winter/spring (Table 5.1), Anatidae contributed maximum to bird abundance.

5.4.3 Density and spatio-temporal distribution of birds in Hygam

Results for the Hygam wetland revealed strong temporal gradient of abundance. Estimates of abundance showed 1.26 individuals ha^{-1} as overall mean density in mid-winter (2004-2005) and 19.02 individuals ha^{-1} in post-winter (2005). Out of the total (cumulative in two seasons) waterbird species, 10 were recorded in mid-winter and 12 in post-winter. Despite relative variation in percentage composition of families in mid and post-winter/spring (Table 5.1), Anatidae contributed maximum to bird abundance.

5.4.4 Variation in population across habitats and seasons in Hokersar

Habitat types identified in mid-winter (n=7) revealed floating vegetation; drawdown meadows; siltation zone; plantation; peatland; paddy fields and tall emergents as major habitat elements recorded from the wetland in contrary to post-winter season (n=8) where open water; floating vegetation; peatland; submerged peatland; drawdown meadows; tall emergents; submerged paddy fields and submergent vegetation represented major habitat categories.

Density estimates obtained across habitats during mid-winter indicated a distinct variation in abundance (Table 5.2). Of all the habitats sampled and compared, floating vegetation had highest density with 205.7 individuals ha^{-1} (mean = 9502 birds ±64319) followed by plantation with mean density of 134.52 individuals ha^{-1} (mean = 578.46 birds ±80) and tall emergents with density of 25.9 individuals ha^{-1} (mean = 3501.13 birds ±701.02). Peatland revealed lowest bird density of 0.44 individuals ha $^{-1}$ (mean = 23 birds ±3.2).

Table 5.1 Relative percentages of waterbird families reported from Hokersar and Hygam wetlands in mid and post-winter.

Hokersar wetland				**Hygam wetland**			
Mid-winter		**Post-winter**		**Mid-winter**		**Post-winter**	
Family	**%**	**Family**	**%**	**Family**	**%**	**Family**	**%**
Anatidae	53	Anatidae	34.8	Anatidae	28.6	Anatidae	30.8
Rallidae	11.8	Rallidae	8.7	Rallidae	7.1	Rallidae	0
Ardeidae	11.8	Ardeidae	21.7	Ardeidae	21.4	Ardeidae	15.4
Podicipedidae	6	Podicipedidae	4.34	Podicipedidae	0	Podicipedidae	0
Phalacrocoracidae	0	Phalacrocoracidae	0	Phalacrocoracidae	7.1	Phalacrocoracidae	0
Scolopacidae	0	Scolopacidae	0	Scolopacidae	0	Scolopacidae	7.1

Table 5.2 Comparison of bird density and number among habitats in mid-winter between Hokersar and Hygam wetlands.

Habitat Type	Hokersar			Hygam		
	Habitat area (ha)	**Mean density (Birds ha^{-1})**	**Number of birds**	**Habitat area (ha)**	**Mean density (Birds ha^{-1})**	**Number of birds**
Floating vegetation	46.2	205.7	9502 ± 64319	30	9.1	273.18 ±47.53
Drawdown meadows	42.8	0.65	28 ± 4.51	0	0	0
Siltation zone	25.7	22.3	574 ± 263.08	0	0	0
Plantation	4.3	134.52	578.46 ± 80	62	0.57	35.8 ±11.28
Peatland	29.8	0.44	23 ± 3.2	0	0	0
Paddy fields	90.4	0.55	50 ± 22.18	0	0	0
Short emergents with pools	0	0	0	25	1.22	30.4 ±4.28
Drawdown meadows	0	0	0	0	0	0
Tall emergents	134.9	25.9	3501.13 ± 701.02	0	0	0

Difference in mean densities across habitats were statistically significant (One-way ANOVA $F_{6, 77} = 4.539$, $p = 0.001$, $n = 78$). Using Tukey multiple comparison test (Post-hoc) at 0.05 level of significance for pair wise comparison of mean densities between habitats, significant difference was found between floating vegetation and other habitats except for tall emergents ($p \leq 0.05$) in which it was non-significant. A strong gradient of total bird species richness (cumulative list at each site) and species abundance pattern was seen across habitats.

Of the five waterbird families recorded, Anatidae was the dominant group in regions of floating vegetation, plantation, paddy fields and tall emergents. With the exception of peatland and siltation zone, the birds opted for all other habitats. However, individual species density was relatively higher in floating vegetation than other habitats. Among Anatids Gadwall *Anas strepera* contributed maximum to abundance in floating vegetation (mean density 38.12 individuals ha^{-1}) and paddy fields (mean density 2.65 individuals ha^{-1}). Plantation and tall emergents accommodated Mallard *Anas platyrhynchos* in maximum numbers with mean densities of 20.34 individuals ha^{-1} and 13.5 individuals ha^{-1} in each of them.

Ardeidae (Herons and Egrets) were in higher numbers in drawdown meadows, siltation zone, and peatland. Cattle Egret *Bubulcus ibis* was most abundant in drawdown meadows (mean density 0.6 individuals ha^{-1}); Pond Heron *Ardeola grayii* in siltation zone (mean density 0.03 birds ha^{-1}) and Grey Heron *Ardea cinerea* in peatland (mean density 0.16 birds ha^{-1}). Little Grebe *Tachybaptus ruficollis* was exclusive to floating vegetation while Whiskered Tern *Chlidonias hybridus* to peatland respectively. Least abundant species Common Snipe *Gallinago gallinago* confined to tall emergents had a density of 0.0003 birds ha^{-1}. Common Snipe was the only shorebird species reported in this season. Of all the species Gadwall was reported in higher numbers in this season.

Comparison of density estimates among habitats during post-winter indicated distinct variation with relatively low values of abundance (Table 5.3). With the exception of submerged peatland that estimated a mean density of 90.02 birds ha^{-1}, all other habitats had lower abundance. Open water and submergent vegetation had mean density of 13.7 birds ha^{-1} and 5.7 birds $ha^{-1,}$ respectively. In this season difference in mean densities among habitats was statistically significant (One-way ANOVA, $F_{7, 82} = 6.795$, $P \geq .01$, n= 83).

Tukey multiple comparison test (Post- hoc at 0.05 levels) indicated significant difference in mean density between open water and all other habitats except tall emergents.

Species richness and estimates of relative abundance for each species was quite different among habitats and revealed a total of five waterbird families. Observations indicated submerged peatland as the most densely populated habitat in this season with maximum contribution shown by Anatids. Mallard had highest mean density estimated as 86.14 individuals ha^{-1}; (mean= 2206.28 birds ±1156.68) followed by Northern Pintail *Anas acuta* (mean density 47.6 individuals ha^{-1} (mean = 1219 birds ± 1219). In addition, Anatids (a total of nine species) also occurred commonly in tall emergents where again Mallard reported in higher numbers (mean density 0.08 individuals ha^{-1} and mean= 7.58 birds ±7.58). In open water, Gadwall had the maximum density of 8.95 individuals ha^{-1} (mean = 556.84 birds ±193.73) and in submerged emergents, it was again Mallard with mean density of 4.47 individuals ha^{-1} (mean = 403 birds ± 259.41). The only Anatids recorded exclusively in this season were Red-crested Pochard *Rhodonessa rufina* and Garganey *Anas querquedula*.

Four Ardeid species occurred in all habitats in varying numbers and the only shorebird present in this season was Black-winged Stilt *Himantopus himantopus.* Common Coot *Fulica atra* was the only Rallidae member present in this season. Reported from most of the habitats except submerged paddy fields and drawdown meadows, the species had the highest density of 36.46 individuals ha^{-1} (mean = 933.42 birds ± 520.05) in submerged peatland. Graylag Geese *Anser anser* was exclusive to open water and Black-winged Stilt opted only submerged peatland.

5.4.5 Variation in population across habitats and seasons in Hygam

Observations revealed different micro-habitat diversity between mid-winter (2004-2005) and post-winter (2005).The five habitats recorded in mid-winter included short emergent with pools, drawdown meadows, tall emergents, plantation and floating vegetation. Post-winter season indicated seven habitats *viz* waterlogged plantation, reed bed with floating vegetation, submerged meadows with dry patches, reed bed with open water, submerged meadows as major micro-habitats.

Density estimates obtained across habitats indicated a distinct variation in abundance during mid-winter. Floating vegetation and open water had highest mean density with 9.1 individuals ha^{-1} (mean= 273.18 birds ± 47.53). Plantation showed mean density of 0.577 individuals ha^{-1} (mean number of birds= 35.8). However, waterbirds were absent from tall emergents and drawdown meadows in this season. A statistically significant difference in mean densities was indicated across habitats (One-way ANOVA, $F_{4, 44}$ = 9.860, P ≥ 0.001, n= 48).

The results indicated low population size in this peak period owing to low water depth and reduced water spread area. Tukey multiple comparison tests (Post- hoc) at 0.05 level of significance for pair wise comparison of mean densities between habitats indicated a significant difference between floating vegetation and other habitats except for short emergents with pools.

Total bird species richness (cumulative at each site) and species abundance pattern showed a strong gradient across sites. Of the five waterbird families recorded, Anatids were common in floating vegetation and waterlogged plantation. Common Teal contributed maximum abundance in both the habitats (mean densities as 31.38 individuals ha^{-1} and 27.12 individuals ha^{-1}) respectively.

Ardeids reported from short emergents with pools and floating vegetation had very low abundance. Pond Heron had densities of 0.56 individuals ha^{-1} in short emergents with pools while Night Heron *Nycticorax nycticorax* had mean density of 0.002 individuals ha^{-1} in floating vegetation. Other than Little Cormorant *Phalacrocorax niger,* the only Rallid, Common Coot *Fulica atra* was exclusive to floating vegetation and Black-winged Stilt to waterlogged plantation. Tall emergents and drawdown meadows could not accommodate any of the species. With the exception of open water, all habitats sampled in post-winter had very low waterbird abundance. This habitat supported a maximum population of 10.11 individuals ha^{-1} (Table 5.3). Tukey multiple comparison test (Post-hoc at 0.05 level) indicated significant difference in mean density between submerged meadow with dry patches and other three habitats except reed bed with open water and open water.

Total species richness and their relative abundance showed variation across habitats. Three families recorded revealed Anatidae as the dominant group with relatively very high abundance in reed bed with open water and open water. However, no distinct variation in abundance of individual species could be recorded from any of the habitats. Of the Anatids, Common Teal were in highest number with density as 20.73 individuals ha^{-1} from open water area.

Two Rallid species Common Coot and Indian Moorhen were reported in low numbers. Highest density for Common Coot was estimated as 1.25 individuals ha^{-1} and 1.9 individuals ha^{-1} for Moorhen in open water respectively. Ardeids had low estimated density in their recorded habitats. With the exception of submerged grassy meadows and reed bed with floating vegetation, Anatids opted for all other habitats. Little Bittern *Ixobrychus minutus* was exclusive to reeds with open water type of habitat. Least abundant of all the recorded species Pond Heron *Ardeola grayii* were confined to reed bed with open water and had density of 0.0001 individuals ha^{-1} .The results indicated that over the entire mid-winter sampling season Gadwall and Common Teal showed maximum abundance from the wetland. (mean = 0.07 birds ± 0.0002 and 0.07 birds ± 0.07). Again post-winter/spring season recorded Mallard in maximum abundance (mean = 4.1 birds ± 4.1).

Table 5.3 Comparison of bird density and number among habitats in post-winter between Hokersar and Hygam wetlands.

Habitat Type	**Hokersar**			**Hygam**		
	Habitat area (ha)	**Mean density (Birds ha^{-1})**	**Number of birds**	**Habitat area (ha)**	**Mean density (Birds ha^{-1})**	**Number of birds**
Submerged peatland	99	90.02	2304 ± 479.75	0	0	0
Open water	62.2	13.7	851 ±12.1	60	10.11	6.7.13 ±325.43
Submergent vegetation	90	5.7	513.45 ±163.8	0	0	0
Peatland	25.6	0.74	19.16 ± 6.66	0	0	0
Drawdown meadows	30	0.41	12.4 ±2.42	0	0	0
Floating vegetation	62.2	0.203	12.63 ±3.8	0	0	0
Tall emergents	90	0.13	11.8 ±4.11	0	0	0
Submerged paddy field	99	0.004	0.4 ±0.3	0	0	0
Reed bed with open water	0	0	0	250	1.02	257.1 ±70.26
Reed bed with floating vegetation	0	0	0	25	0.08	2±0.72
Submerged meadow	0	0	0	470	0.006	2.93 ±0.006
Waterlogged plantation	0	0	0	94	0.01	1.23 ±0.18
Submerged meadows with dry patches.	0	0	0	20	0.37	7.45 ±2.39

5.4.6 Seasonal comparison of bird population in Hokersar

Seasonal comparisons indicated a relatively high density in mid-winter. Mid-winter estimated waterbird density as 680.57 individuals ha^{-1} and post-winter as 30.35 individuals ha^{-1}. Large variation in population estimates between the two seasons could be attributed to difference in bird congregation between the two seasons assuming mid-winter as peak season and post-winter as season of departure to Palearctic breeding grounds. Floating vegetation became densely populated habitat in mid-winter contrary to post-winter in which submerged peatland accommodated high populations (Table 5.4). Species exclusive to mid-winter were Common Pochard *Aythya ferina* and Eurasian Wigeon *Anas penelope* while in post-winter they were Red-crested Pochard *Rhodonessa rufina* and Garganey. Further comparison indicated Mallard dominating the waterbird population in mid-winter season (mean density 28.03 individuals ha^{-1}) and Northern Pintail (mean density 4.2 individuals ha^{-1}) in post-winter. The total species richness and their relative abundance showed variations across habitats. Three families showed Anatidae as the dominant group with relatively very high abundance in reed bed with open water and open water. However, no distinct variation in abundance of individual species could be recorded from any of the habitats. Of the Anatids, Common Teal was reported in highest number with estimated density as 20.73 individuals ha^{-1} from open water area.

Two Rallid species, Common Coot and Indian Moorhen were reported in low numbers. Highest density for Common Coot was estimated as 1.25 individuals ha^{-1} in open water and 1.9 individuals ha^{-1} for Indian Moorhen also in open water. Ardeids had low density in their recorded habitats. With the exception of submerged meadows and reed bed with floating vegetation, Anatids opted for all other habitats. Little Bittern was exclusive to reeds with open water type of habitat. Least abundant of all the recorded species, Pond Heron confined to reed bed with open water had density of 0.0001 individuals ha^{-1} respectively. The results indicated that over the entire mid-winter sampling season, Gadwall and Common Teal had maximum mean abundance from the wetland (mean = 0.07 birds ±0.0002 and 0.07 birds ±0.07). Again post-winter/spring season recorded Mallard in maximum mean abundance (4.1 ±4.1). Tukey multiple comparison test (Post-hoc at 0.05 level) indicated significant difference in mean density between submerged meadows with dry patches and other three habitats except reed bed with open water and open water.

5.4.7 Seasonal comparison of bird population in Hygam

Seasonal comparison of mean abundance from the Hygam wetland indicated a very low density of birds in mid-winter of 1.26 individuals ha^{-1} than post-winter of 19.02 individuals ha^{-1} (Table 5.4). Again the difference in habitat diversity between the two seasons confirmed distinct variation in abundance pattern. Species exclusive to mid-winter were Little Cormorant, Night Heron and Black-winged Stilt and in post-winter the exclusive species were Common Snipe, Little Egret and Little Bittern. Over the entire mid-winter, Gadwall and Common Teal showed maximum abundance from the wetland while in post-winter; Mallard was recorded in highest abundance.

5.4.8 Comparison of two wetlands

Population abundance of waterbirds in Hokersar and Hygam wetlands was compared. Average waterbird density in mid-winter (680.57 individuals ha^{-1}) and post-winter (30.35 individual ha^{-1}) was high in Hokersar wetland as compared to Hygam wetland (1.26 individuals ha^{-1} in mid-winter and 19.02 individual ha^{-1} in post-winter). Species exclusive to both mid-winter and post-winter seasons were Anatids in Hokersar wetland and in Hygam wetland, other waterbird species reported as exclusive in both sampling seasons. Mallard dominated the waterbird population in mid-winter and Northern Pintail in post-winter season in Hokersar wetland. In Hygam wetland, Gadwall and Common Teal showed maximum average abundance in mid-winter and Mallard in post-winter.

Table 5.4 Comparison of mean density between habitats in Hokersar and Hygam wetlands during mid-winter and post-winter sampling seasons.

Hokersar wetland						Hygam wetland					
Mid-winter			Post-winter			Mid-winter			Post-winter		
Habitat type	**Habitat area (ha)**	**Density (Birds ha$^{-1)}$**	**Habitat type**	**Habitat area (ha)**	**Density (Birds ha^{-1})**	**Habitat type**	**Habitat area (ha)**	**Density (Birds ha$^{-1)}$**	**Habitat type**	**Habitat area (ha)**	**Density (Birds ha$^{-1)}$**
Floating vegetation	46.2	205.7	Floating vegetation	62.2	0.203	Floating vegetation	30	9.1	Floating vegetation	0	0
Drawdown meadows	42.8	0.65	Drawd0wn meadows	30	0.4	Drawdown meadows	62	0.57	Drawdown meadows	0	0
Siltation zone	25.7	22.3	Siltation zone	0	0	Siltation zone	25	1.22	Siltation zone	0	0
Plantation	4.3	134.52	Plantation	4.3	0	Plantation	200	0	Plantation	200	0
Peatland	29.8	0.44	Peatland	25.6	0.74	Peatland	470	0	Peatland	0	0
Paddy field	90.4	0.55	Paddy field	0	0	Paddy fields	0	0	Paddy field	0	0
Tall Emergents	134.9	25.9	Tall Emergents	90	0.13	Tall Emergents	0	0	Tall Emergents	0	0
Submerged peatland	0	0	Submerged Peatland	99	90.02	Submerged Peatland	0	0	Submerged Peatland	0	0
Open water	0	0	Open water	62.2	13.7	Open water	0	0	Open water	60	10.11
Submergent vegetation	0	0	Submergent vegetation	90	5.7	Submergent vegetation	0	0	Submerged Emergents	0	0
Submerged Paddy field	0	0	Submerged Paddy field	99	0.004	Submerged paddy field	0	0	Submerged Paddy field	0	0

Hokersar wetland						Hygam wetland					
Mid-winter			Post-winter			Mid-winter			Post-winter		
Habitat type	**Habitat area (ha)**	**Density (Birds ha^{-1})**	**Habitat type**	**Habitat area (ha)**	**Density (Birds ha^{-1})**	**Habitat type**	**Habitat area (ha)**	**Density (Birds ha^{-1})**	**Habitat type**	**Habitat area (ha)**	**Density (Birds ha^{-1})**
Short emergents with pools	0	0	Short emergents with pools	0	0	Short emergents with pools	0	0	Short emergents with pools	0	0
Drawdown meadow	0	0	Drawdown meadows	0	0	Drawdown meadow	0	0	Drawdown meadows	0	0
Reed bed with open water	0	0	Reed bed with open water	0	0	Reed bed with open water	0	0	Reed bed with open water	250	1.02
Reed bed with floating vegetation	0	0	Reed bed with floating vegetation	0	0	Reed bed with floating vegetation	0	0	Reed bed with floating vegetation	25	0.08
Submerged meadows	0	0	Submerged meadows	0	0	Submerged meadow	0	0	Submerged meadow	470	0.006
Waterlogged Plantation	0	0	Waterlogged plantation	0	0	Waterlogged Plantation	0	0	Waterlogged Plantation	94	0.01
Submer meadows with dry patches	0	0	Submerged meadows with dry patches	0	0	Submerged meadows with dry patches	0	0	Submerged meadows with dry patches	20	0.37

A mixed flock of waterfowl

Waterbirds swimming in wetland

Nest of Mallard in wetland

Nest of Mallard in wetland

Plate 4. Waterbirds and their nesting in wetlands of Jammu & Kashmir

5.4.9 Spatio-temporal pattern of diversity and richness in Hokersar

Rank abundance plot derived from mid-winter for waterbird assemblage in Hokersar wetland revealed variation in observed species richness (S) across habitats, (n =7). Observed species richness had least value for drawdown meadows (S = 2) which resulted in a comparatively compressed curve to highest value for tall emergents (S =23) (Fig 5.1). Diversity index of Shannon-Wiener (H') computed for waterbird assemblage fluctuated from 0.85 for floating vegetation to 0.0001 for siltation zone in mid-winter in which seven habitats were covered. The observed species richness per plot was as expected except for tall emergents (Chao 1 and Jack-knife 1 estimators) (Table 5.5). None of the waterbird species was unique to any specific habitat types (number of uniques = 0). Number of duplicates, i.e. number of bird species occurring twice in all the habitat types was equal to 22. This in turn reflected a non-unique diversity pattern in mid-winter waterbird assemblage in the given habitat. Species richness plot derived for mid-winter (Fig.5.2) revealed a total of 3000 individuals accumulated as samples pooled in mid-winter season.

Post-winter sampling season showed variation in observed species richness (S) across habitat types (n = 8) in Hokersar wetland as revealed by rank abundance plot (Fig.5.3). Observed species richness was least (S= 2) for submerged paddy fields to (S = 25). Diversity index of Shannon-Wiener (H') computed for waterbird assemblages fluctuated from 0.94 for submerged paddy fields to 0.48 for peatland in post-winter. Two robust diversity estimators of Chao 1 and Jack-knife 1 estimated true species richness of waterbird assemblages as 24 from all habitat types. This expected species richness (more sampling effort) showed variation from the actual species richness derived from Rank-abundance plot (Table 5.6).

The results indicated that none of waterbird species was unique to any of the habitat types. However, further analysis revealed the number of duplicates i.e. number of waterbird species occurring twice in all the habitat types. This in turn reflected a non-unique diversity pattern in post-winter waterbird assemblage in the given habitat. Species richness plot derived for post-winter (Fig.5.4) revealed number of 280 individuals accumulated as samples pooled in post-winter season.

5.4.10 Spatio-temporal pattern of diversity and richness in Hygam

Rank abundance plot derived from mid-winter for waterbird assemblage in Hygam wetland revealed variation in observed species richness (S) across habitat types (n=5). Observed species richness had least value for tall emergents (S =1) to drawdown meadows and floating vegetation (S= 12) where S = number of species (Fig.5.5).

Diversity index of Shannon-Wiener (H’) computed for waterbird assemblage fluctuated from 1.3 for drawdown meadows to 0.4 for short emergents with pools in mid-winter which covered five habitat types in total (Table 5.6). Two robust diversity estimators, Chao 1 and Jack-knife 1 estimated true species richness of waterbird assemblages as 12 from all the habitats sampled. This expected species richness showed variation from the actual species richness derived from rank-abundance plot (Table 5.6).

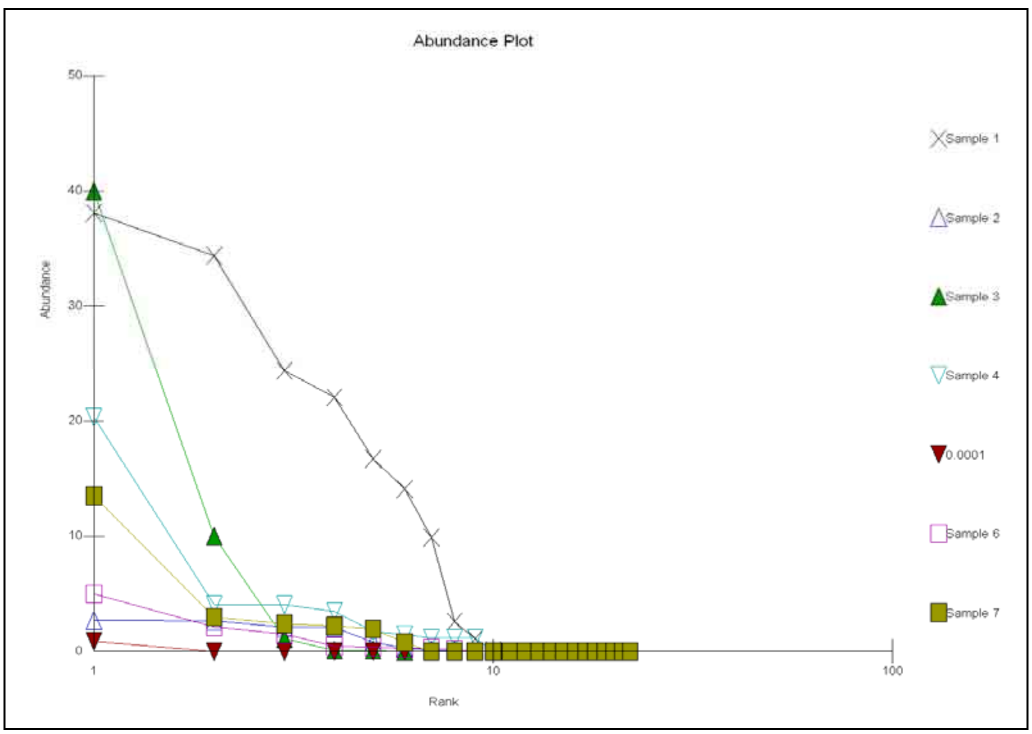

Figure 5.1 Rank abundance plot for mid-winter waterbird assemblage in Hokersar wetland.

* *(sample 1= floating vegetation, sample 2= drawdown meadows, sample 3= paddy field, sample 4= plantation, sample 5= siltation zone, sample 6= peatland, sample 7= tall emergents)*

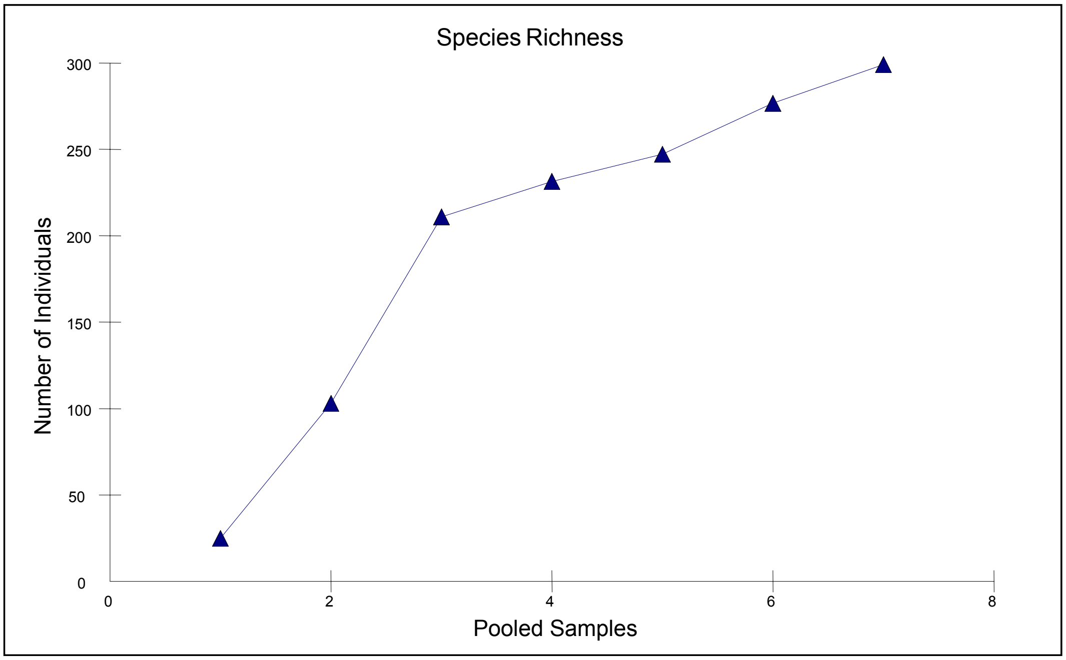

Figure 5.2 Species richness plot of waterbird assemblage for mid-winter season in Hokersar wetland.

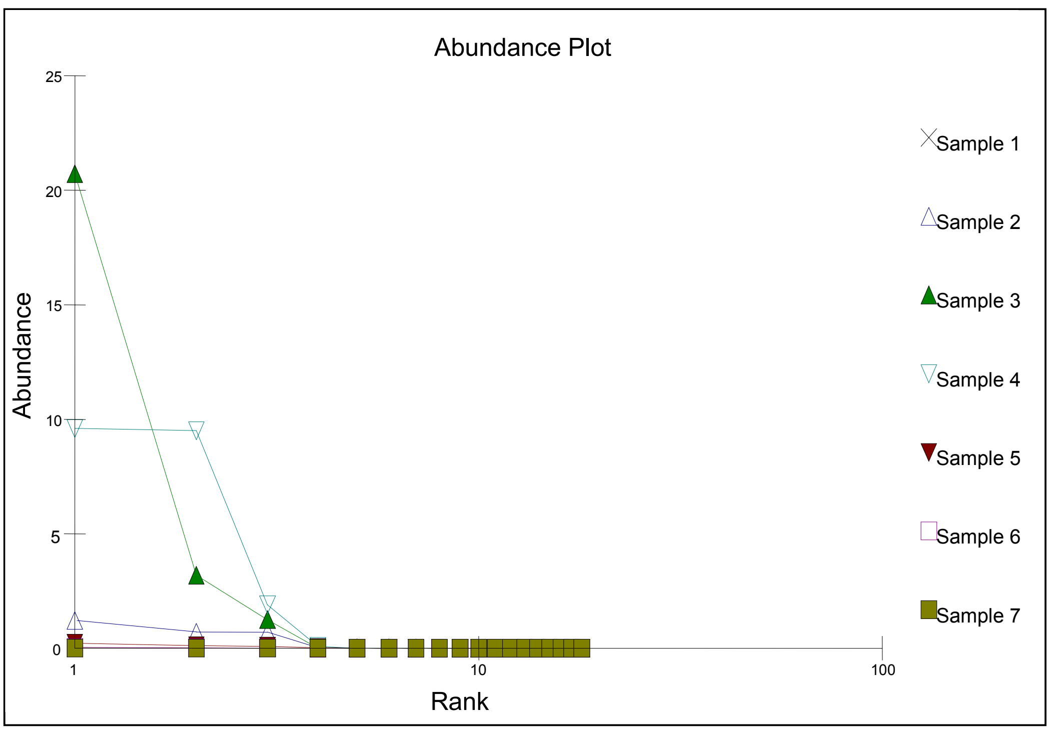

Figure 5.3 Rank abundance plot of waterbird assemblage in post-winter in Hokersar wetland.

* *(sample 1= submerged peatland, sample 2=submerged paddy field, sample 3=tall emergents, sample 4= drawdown meadows, sample 5= peatland, sample 6= floating vegetation, sample 7= open water, sample 8= submergent vegetation).*

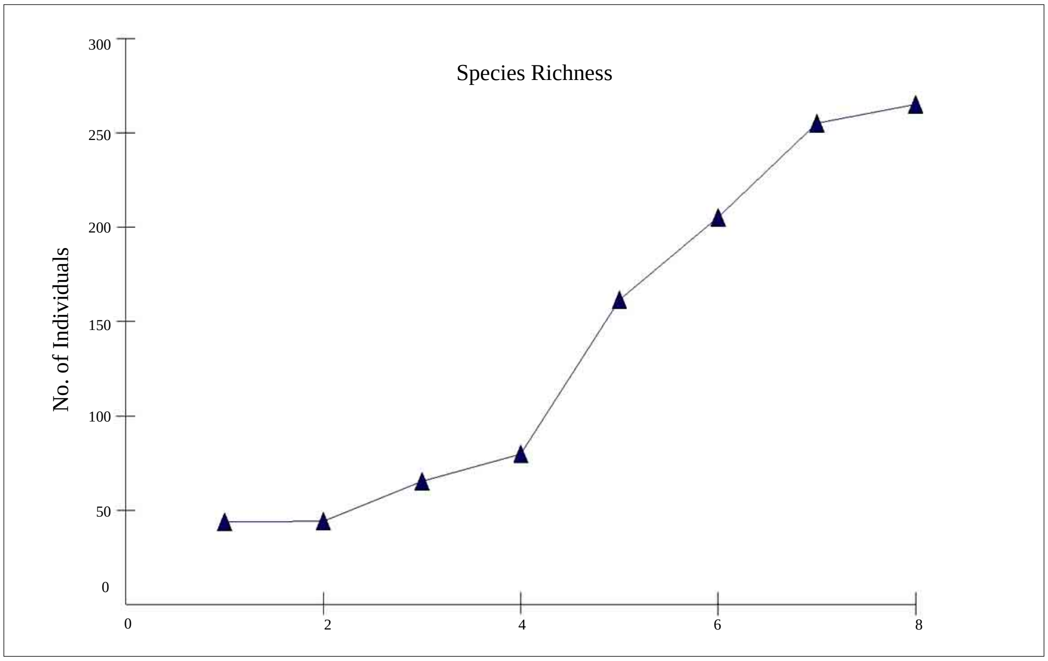

Figure 5.4 Species richness plot of waterbird assemblage for post-winter season in Hokersar wetland.

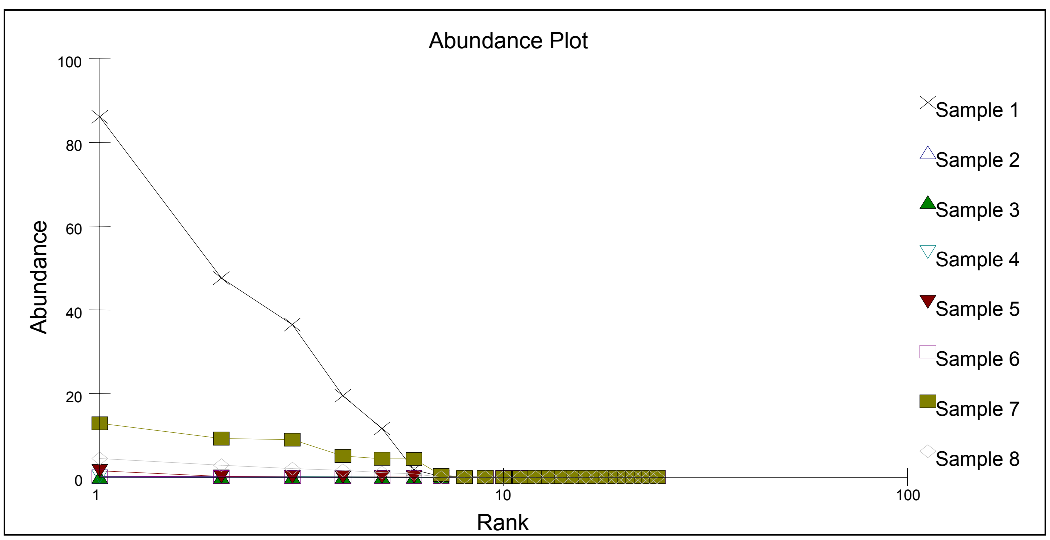

Figure 5.5 Rank abundance plot for mid-winter waterbird assemblage in Hygam wetland.

(sample1=short emergents with pools, sample 2=tall emergents, sample 3= drawdown meadows, sample 4= plantation, sample 5= floating vegetation).*

Table 5.5 Comparison of diversity indices and species richness estimators for waterbird assemblages during mid-winter in Hokersar and Hygam wetlands.

	Hokersar wetland					Hygam wetland				
Habitat	**Shannon index**	**Simpson index**	**Observed species richness**	**Chao-1 estimated richness**	**Jack-knife-1 estimated richness**	**Shannon index**	**Simpson index**	**Observed species richness**	**Chao-1 estimated richness**	**Jack-knife-1 estimated richness**
Floating vegetation	0.85	0.2	9	22	22	0.5	0.9	12	12	12
Drawdown meadows	0.72	0.18	2	22	22	1.3	0.93	12	12	12
Paddy field	0.28	0.65	6	22	22	0	0	0	0	0
Plantation	0.65	0.23	8	22	22	0.6	-0.2	7	12	12
Siltation	0.0001	1.0	6	22	22	0	0	0	0	0
Peatland	0.60	0.2	8	22	22	0	0	0	0	0
Tall emergents	0.58	0.25	23	22	22	1.2	0.94	2	12	12
Short emergents with pools	0	0	0	0	0	0.4	-0.3	0	0	0

None of waterbird species was unique to any of the samples (habitats). (number of uniques = 0). However, further analysis revealed number of duplicates twice in all the pooled samples equal to 19. This in turn reflected a non-unique diversity pattern in mid-winter waterbird assemblage in given habitats. Species richness plot derived for mid-winter (Fig.5.6) revealed a total of 6 waterbird individuals accumulated as samples pooled in mid-winter season.

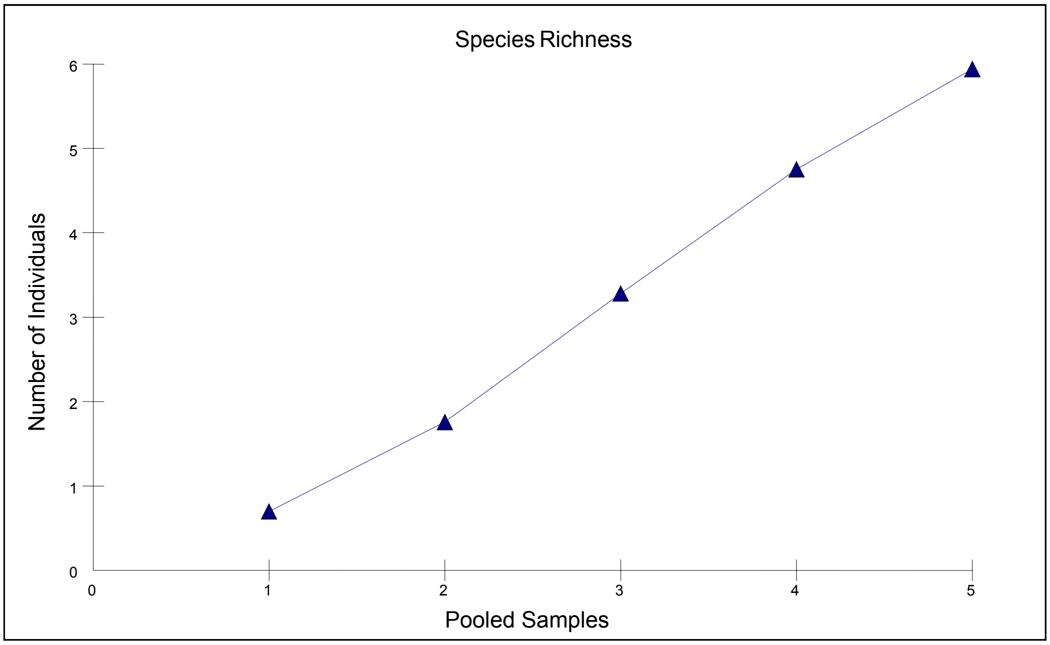

Figure 5.6 Species richness plot of waterbird assemblage for mid-winter season in Hygam wetland.

Species richness and diversity in post-winter sampling season showed variation in observed species richness (S) across habitats (n = 7) in Hygam wetland. Observed species richness was least for submerged meadows and reed beds with floating vegetation (S = 2) and highest for waterlogged plantation (S=19) (Fig.5.7).

Shannon-Wiener diversity index fluctuated from 0.48 for reed beds with floating vegetation to 0.88 for submerged meadows in post-winter which covered seven habitat types. Chao 1 diversity estimator estimated true species richness of waterbird assemblage as 18 from all the samples covered. However, Jack-knife 1 estimator estimated 17 as true species richness from all habitat types with the exception of submerged meadows where it was 16.5 (Table 5.7).

Number of waterbird species unique to any of the habitat types during post winter was 0.4 for submerged meadows. However, further analysis revealed number of duplicates i.e. number of bird species occurring twice in all the pooled samples equal to 18. This in turn reflected a non-unique assemblage in the given habitats. The species richness plot derived for post-winter (Fig. 5.8) revealed a total of 50 waterbirds accumulated as samples pooled in mid-winter season.

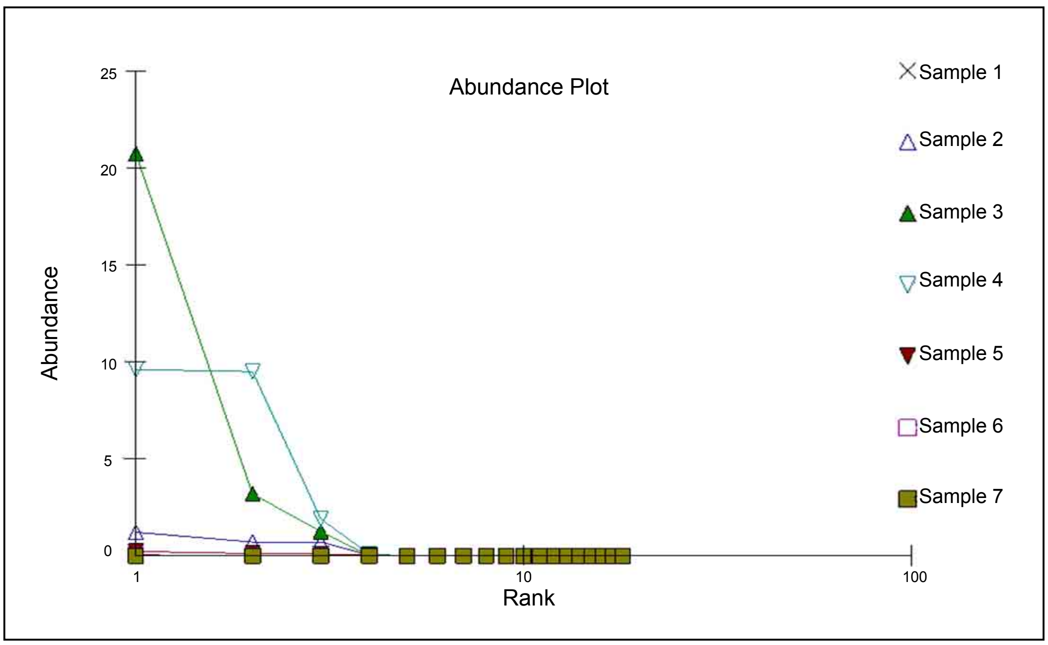

Figure 5.7 Rank abundance plot for post-winter waterbird assemblage in Hygam wetland.

**(sample 1= submerged meadows, sample 2=reedbed with open water, sample 3= floating vegetation, sample 4= open water, sample 5= submerged meadows with dry patches, sample 6=reedbed with floating vegetation, sample 7= waterlogged plantation).*

Table 5.6 Comparison of diversity indices and richness estimators for waterbird assemblage during post-winter in Hokersar and Hygam wetlands.

	Hokersar wetland						Hygam wetland					
Habitat	**Shannon index**	**Simpson index**	**Berger-Parker index**	**Observed species Richness**	**Chao-1 estimated richness**	**Jack-knife-1 estimated richness**	**Shannon Index**	**Simpson index**	**Berger-Parker index**	**Observed species richness**	**Chao-1 estimated richness**	**Jack-knife-1 estimated richness**
Submerged peatland	0.62	0.3	0.41	6	24	24	0	0	0	0	0	0
Submerged paddy field	0.94	0.92	0.45	2	24	24	0	0	0	0	0	0
Tall emergents	0.87	1.3	0.28	7	24	24	0	0	0	0	0	0
Drawdown meadows	0.73	2.2	0.25	5	24	24	0	0	0	0	0	0
Peatland	0.48	0.15	0.71	7	24	24	0	0	0	0	0	0
Floating vegetation	0.7	1.42	0.5	7	24	24	0	0	0	0	0	0
Open water	0.8	0.16	0.3	25	24	24	0	0	0	0	0	0
Submergent vegetation	0.75	0.14	0.3	24	24	24	0	0	0	0	0	0

Contd…

Table 5.6 Contd…

Submerged meadows	0	0	0	0	0	0	0.88	1.0	0.44	4	18	17
Reeds with open water	0	0	0	0	0	0	0.50	-0.45	0.46	4	18	17
Submerged meadows with dry patches	0	0	0	0	0	0	0.52	1.5	0.40	4	18	17
Reeds with floating vegetation	0	0	0	0	0	0	0.48	0.98	0.58	4	18	17
Waterlogged plantation	0	0	0	0	0	0	0.80	0.96	0.44	9	18	17

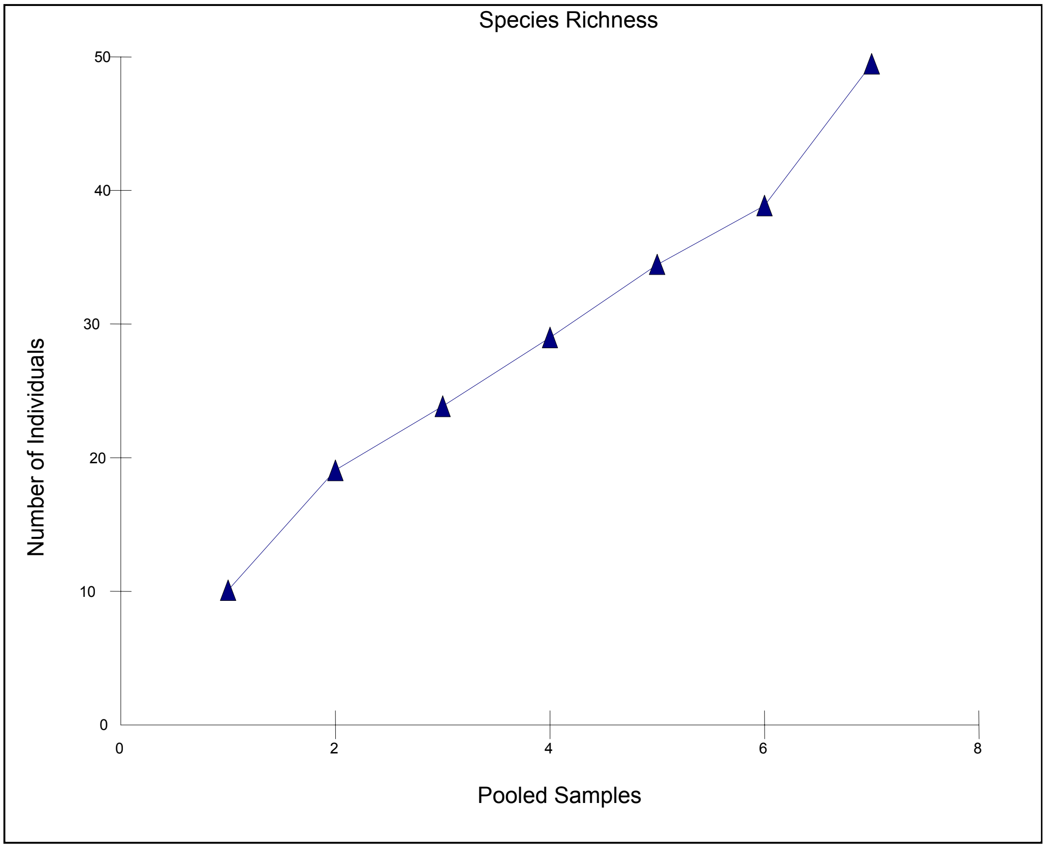

Figure 5.8 Species richness plot for post-winter waterbird assemblage in Hygam wetland.

5.4.11 Comparison of two wetlands

Spatio-temporal pattern of species richness and diversity of two wetlands were compared. Habitat types varied in Hokersar wetland from that of Hygam wetland in both mid-winter and post-winter sampling seasons. Species richness of waterbirds in mid-winter in Hokersar wetland showed highest value of 23 from tall emergents and in Hygam wetland, this was only 12 from drawdown meadows and floating vegetation. Shannon- Wiener index in mid-winter season in Hokersar wetland had a value of 0.85 while in Hygam wetland; it was 1.3 from drawdown meadows indicating a more diverse mid-winter waterbird community in Hygam wetland than in Hokersar wetland. Open water in post-winter season indicated highest species richness of 25 in Hokersar wetland while in Hygam it was 19 was from waterlogged plantation. Submerged paddy field in post-winter season from Hokersar wetland reported highest value of Shannon- Wiener index of 0.94 while in case of Hygam wetland it was 0.88 from submerged grassy meadow.

5.4.12 Status of breeding species and nest density in Hokersar wetland

During the study period, four species of waterbirds nested in Hokersar wetland (spring, 2005). Of all the nest sites Mallard *Anas platyrhynchos*, the only dabbling duck species nesting in this wetland had a nest density of 0.004 nests m^{-2} in peatland from a 3600 m^2 area sampled (n=9). A 4000 m^2 area sampled in plantation of Hokersar (n=10) supported a nesting population of 0.003 nests m^{-2} for Mallard and 0.001 nests m^{-2} for Indian Moorhen. A low nesting density of Mallard estimated as 0.0003 nests m^{-2} occurred in tall emergent (4000 m^2 area sampled, n=10). Indian Moorhen had 0.001 nests m^{-2} in this site. A statistically significant difference in mean nest density for Mallard was found among breeding habitats (One-way ANOVA, $F_{4,\ 14}$ = 18.106, P=0.001, n= 29), while for Indian Moorhen the results were non-significant. An overall nest density for Mallard was estimated as 0.002 nests m^{-2} and for Indian Moorhen the density was recorded as 0.001 nests m^{-2} .

5.4.13 Status of breeding species and nest density in Hygam wetland

Two species of waterbirds were found breeding in Hygam wetland from three different nest sites or breeding habitats (spring- 2006). Of the two nest sites recorded, plantation (4000 m^2 area sampled, n =10) supported a Mallard nesting population of 0.002 nests m^{-2}. Indian Moorhen in this site had a lower nest abundance of 0.0005 nests m^{-2}. The other nest site; tall emergents where 2400 m^2 area was sampled (n= 6) showed Mallard nest density as 0.0004 nests m^{-2} and 0.0008 nests m^{-2} as that of Indian Moorhen. Mean nest density of Mallard between sites showed a statistically significant difference (One-way ANOVA, $F_{2,\ 6}$ = 25.000, P =0.001, n =7) while for Indian Moorhen this was found to be non-significant. The overall nest density for Mallard was 0.001 nests m^{-2} and 0.001 nests m^{-2} for Indian Moorhen.

5.4.14 Clutch size and hatching success in Hokersar wetland

Of the total Mallard nests sampled (n = 25), in 9% nests, egg laying was initiated before mid March, 57% after mid March and 28.6% in the first week of April. Hatching took place after mid of April (38.1%), 23.8% by end of April and first week of May. For Indian Moorhen in 33.3% nests sampled, egg laying was initiated by end of March and 50% by mid of April. By the end of April, 33.3% nests had hatched and 16.7% by first week of May. Mallard clutch size ranged from six to 16 with mean clutch size of 10.47 ± 0.50. Indian Moorhen clutch size ranged from five to six with a mean clutch size of 5.87 ± 0.26.

Of the Mallard nest sample (n =25), 96% hatched and 4% showed human induced hatching failure. A 100% sample of Indian Moorhen nests (n= 9) hatched successfully. Hatching success rate of sampled eggs indicated a value of 92.7% for Mallard (n = 220) and 100% for Indian Moorhen (n = 41). The results indicated a production of a sample of 204 Mallard ducklings in the recruitment of Mallard population and 41 Indian Moorhen chicks in the entire wetland.

5.4.15 Clutch size and hatching success in Hygam wetland

In Hygam egg laying by Mallard was initiated after mid of March and hatched after mid of April. The clutch size varied between 7-14 with a mean clutch size of 10.33 ±0.95 eggs. Of the total Indian Moorhen nests sampled, (n= 4), in 75% nests egg laying was initiated before mid of April and 25% after mid of April. The clutch size for Indian Moorhen ranged between 4-5 with a mean clutch size of 4.75 ±0.25 eggs. A 100% hatching success was recorded for both Mallard (n = 62) and Indian Moorhen (n =19). From these 62 Mallard ducklings and 19 in Indian Moorhen ducklings were produced.

5.4.16 Comparison of two wetlands

Nest density of breeding waterbird species in Hokersar and Hygam wetlands was compared. Four species of waterbirds were found breeding in Hokersar wetland and two in Hygam wetland. Mallard showed a higher nest density in Hokersar than in Hygam wetland. A production of 204 Mallard in the recruitment of its population was seen in Hokersar wetland while in Hygam wetland the recruitment was only 62 ducklings.

5.5 Discussion

Twenty-two species of waterbirds observed in Hokersar wetland and 16 species observed in Hygam wetland over both winter and summer seasons confirmed that the two wetlands sustain diverse waterbird communities and apparently provided functional habitats for a variety of seasonal needs. The low species diversity in Hygam wetland was mainly attributed to more human impact (anthropogenic pressure). Several factors contributed to increase in population trend of waterbirds over the years in two wetlands, mainly reduced disturbance factors on account of stringent protection afforded to waterbird communities and other conservation efforts.

Pattern of abundance and diversity of waterbird communities revealed strong spatio-temporal gradient in Hokersar and Hygam wetland. Variation in waterbird abundance and diversity among habitats in both Hokersar and Hygam wetlands was significant and was attributed to varied habitat composition, morphological and ecological adaptations of different waterbird groups. Pearson (1977) showed waterbird communities were related to floristic structure and habitat composition of wetland ecosystems that was influenced by vegetation changes following a perturbation. The findings in present study indicated high potential of Hokersar wetland to sustain large and diverse migratory waterbird populations particularly waterfowl than Hygam wetland. Several factors other than within-wetland variation in habitat types may be associated with large difference in abundance between two wetlands such as physicochemical conditions, food resources, vegetation cover and interspersion, habitat configuration and various anthropogenic pressures. Various direct threats mainly encroachment in Hygam wetland conservation reserve has led to decline in its area. However the factors associated with low abundance of waterbirds in Hygam wetland deserve attention. Harper & Henderson (1992) correlated abundance of waterbirds in Lake Naivasha with prolific submerged macrophyte growth. Population of migratory waterbirds estimated in mid-winter season was very high in Hokersar wetland (680.57individuals ha^{-1}) and a rather low abundance of waterbird assemblage was seen in post-winter season. This confirmed large seasonal variation in population size. The seasonal pattern corroborated the expected fluctuations due to mid-winter as peak season of arrival of migratory waterbirds from their Palearctic breeding grounds and post-winter as season of their departure. Hygam wetland shows a pattern of abundance opposite to that of Hokersar wetland. Low population estimated in mid-winter (1.26 individuals ha^{-1}) than post-winter (19.02 individuals ha^{-1}) is because of low water depth and subsequent large areas of wetland in drawdown conditions which assume terrestrial characteristics in mid-winter owing to the fact that two water channels feeding the wetland had low water discharge over the years. The major problem in the Hygam wetland was the increasing rate of siltation, which has caused a noticeable deterioration in wetland quality in recent years. The wetland receives a heavy load of silt from these Ningli and Balkul flood spill channels and the expanses of open water are decreasing in size as the wetland silts up. Other threats include encroachment as more land is converted to rice paddy, and heavy grazing damages in some parts of the marsh. Huge wintering aggregations are common place in waterbird communities in temperate regions (Kershaw & Cranswick, 2003; Leopold, 1949). Wetlands of Kashmir valley provide wintering resort to millions of migratory birds particularly the waterfowl (ducks, geese and swans) and conducive breeding grounds to a segment of resident and non-resident summer migrants. The over wintering waterbirds migrate to the wetlands of valley from their breeding grounds in the palearctic region extending from north Europe to central Asia (Ali, 1979) and for some even Ladakh (Jamwal, 1991).

Gradient in abundance across habitats was clear in two seasons in both wetlands. In the present study, floating vegetation revealed highest congregations of waterbirds in both Hokersar and Hygam wetlands in mid-winter season. This was attributed to availability of large food resources in these habitats. The results suggest habitats with floating vegetation as most prioritized feeding and resting habitats in two wetlands which deserve management for conservation of waterbirds. Other habitats mainly willow plantation and open water zones are also important for management to support large concentrations of waterbirds. Previous study (Khan *et al*., 2002) on waterbird population of Hokersar wetland found shallowness of areas in the wetland as positively correlated to waterfowl abundance. Waterfowl mainly dabbling ducks ecologically prefer areas with low water depth to dabble or sieve seeds and invertebrates from shallow water. However, high populations seen in submerged peatland in Hokersar wetland during post-winter reflects the role of growth of new aquatic vegetation as food resources for this pattern.

Anatids contributed maximum to waterbird population in both seasons in Hokersar and Hygam wetlands. Anatids existed as dominant groups in most areas of wetland except in some habitat types where water level was relatively low and drawdown conditions prevailed. This indicates structure of waterbird community as related to diversity in habitats of wetlands. Ardeids and shorebirds existed as dominant groups with relatively low abundance than Anatids in habitats with low-water depths and subsequent drawdown conditions. The results clearly revealed diversity of habitats as the main factor which contributed to diverse populations of waterbird communities.

Diversity pattern showed a gradient across habitats and in seasons in two wetlands. Floating vegetation zone in mid-winter season indicated high diversity (Shannon-Wiener index 0.85) in Hokersar wetland. Submerged paddy fields revealed highest diversity in post-winter season (Shannon-Wiener index 0.94). Drawdown areas showed highest diversity in mid-winter (Shannon-Wiener index 1.3) and floating vegetation in post-winter (Shannon index 0.24) in Hygam wetland. No waterbird species was unique to any of the habitats in mid and post-winter seasons in either of the two wetlands. This reflected a random pattern of distribution in diversity in their mid and post-winter waterbird assemblages.

Hokersar and Hygam wetlands provide conducive breeding habitats to some resident waterbird species in spring season which usually start from month of March to May in the valley of Kashmir. However, breeding populations are quite limited as seen in present study. This is because from large wintering populations of migratory waterbirds, only small numbers of few species remain to breed in wetlands of Kashmir valley. Pattern of nest distribution is perhaps related to habitat requirements mainly nesting cover which needs further research. Spatial variation in nest density among species was seen in two wetlands. Peatland and willow plantation represented important breeding sites in Hokersar wetland while in Hygam wetland willow plantation and tall emergents emerged as suitable breeding habitats. Estimated nest density of Mallard of 0.002 nests/m ^{2} or 0.002 breeding pairs in Hokersar wetland and 0.001 nests/m^2 in Hygam wetland was much lower than found in Miller Lake, North Dakota(Duebbert et al;1986) as 0.03 nests/m^2 or 0.03 breeding pairs. Peatlands were favorable nesting site of Mallard in Hokersar wetland as evident from dense nesting concentrations of the species. Factors contributing may be excellent nesting cover found on peat and reduced risk of nest predation. Duebbert *et al*. (1983) also found high nest density of waterfowl on predator free natural islands. Increased nesting associated with cover and island like characteristics shown by this study is consistent with results from previous studies (Duebbert, 1982; Lokemoen *et al*.,1984).This indicates pattern of nesting by Mallard as colonial in areas of the wetland where this peat exists. Many studies reported elsewhere also confirm this finding for most waterfowl species (Cowardin *et al*., 1985, Duebbert, 1982). Past data to support this study is not available from wetlands of Kashmir valley. Nest density of Indian Moorhen was 0.001 nests/m^2 in Hokersar and Hygam wetland. Plantation and tall emergents in Hokersar wetland and willow plantation in Hygam wetland showed concentrated nesting of the species. Nest density of Little Grebe and Common Coot could not be not estimated in Hokersar wetland due to location of only one nest of each species. Mallard nest success of 96% in Hokersar wetland and 100% in Hygam wetland shown by present study is much higher than the average duck nest success (16%) in recent studies conducted in uplands. Klett *et al*. (1988) reported an average Mayfield nest success rate of 15.2% for five duck species during 1980-1984, and Higgins *et al.* (1992) found 16.3% nest success in Norh Dakota upland habitats. A 100% Indian Moorhen nest success is indicated in both wetlands. This indicates a fair production of young ones to the existing population. However, new recruitment to the population is quite low.

Mallard the only dabbling duck species that breeds in Hokersar & Hygam wetlands is cosmopolitan in distribution. In the Indian sub-continent, the species breeds only in wetlands of Kashmir valley. Earlier Lowther & Bates (1952) reported only one Mallard nest located in Hokersar wetland. This study shows concentrated nesting of Mallard in Hokersar wetland. The findings confirm sharp increase in Mallard nesting in wetlands of Kashmir valley. This clearly highlights the importance of these wetlands as only breeding grounds in Indian sub-continent. However, factors responsible need further research.

5.6 Summary

The density and diversity of waterbirds in Hokersar and Hygam wetlands was estimated by direct count. Of the 22 species of waterbirds recorded from Hokersar wetland 54% were migratory. Whereas in Hygam wetland of the 16 species of waterbirds 56% were migratory. The overall density of waterbirds in Hokersar was 680.57 birds ha^{-1} during mid-winter and 30.05 birds ha^{-1} during post-winter. The variation in density was statistically significant in both the seasons. Of the seven habitats recorded in mid-winter, floating vegetation had highest density of birds of 205.7 birds ha^{-1} (mean= 9502 birds ±64319). Peatland in this season revealed lowest bird density of 0.44 birds ha^{-1} (mean= 23 birds ±3.2).

Comparison of estimates of relative abundance of species recorded in mid-winter season indicated Gadwall in highest number in this season with mean density of 38.12 birds ha^{-1}. Least abundant Common Snipe confined to tall emergents had density of 0.0003 birds ha^{-1}. Comparison of density estimates among 8 habitats in post-winter indicated distinct variation with relatively low values of abundance. Submerged peatland showed highest mean density of 90.02 birds ha^{-1}. Mallard had highest mean density of 86.14 birds ha^{-1} in mid-winter.

Density estimates across habitats and in seasons from Hygam wetland indicated variation of 1.26 birds ha^{-1} as overall mean density in mid-winter and 19.02 birds ha^{-1} in post-winter season. A significant variation in density estimates among habitats was indicated in both seasons. Of the five habitats recorded in mid-winter, floating vegetation had highest estimate of mean density of 9.1 birds ha^{-1} (mean= 273.18 birds ±47.53). Plantations revealed lowest density of 0.57 birds ha^{-1} (mean= 35.8 birds ±11.28).

Comparison of estimates of relative abundance of species recorded in mid-winter season indicated Common Teal with a density of 31.38 birds ha^{-1}. Comparison of density estimates among six habitats in post-winter indicated distinct variation. Open water supported maximum population of 10.11 birds ha^{-1}. Of all species recorded in this season, Common Teal was reported in higher numbers with mean density of 20.73 birds ha^{-1}.

Four species of waterbirds nested in Hokersar wetland in three different breeding habitats. An overall nest density for Mallard was 0.002 nests/m^2 and for Moorhen, it was 0.001 nests/m^2. Hatching success rate of 92.7% for Mallard and 100% for Indian Moorhen. Hygam wetland showed two species of waterbirds breeding from three different nest sites. The nest density for Mallard was 0.001 nests/m^2 and 0.001 nests/m^2 for Moorhen

Variation in observed species richness (S) across habitat types was found in mid-winter season from Hokersar wetland. Observed species richness ranged from two in drawdown meadows to 23 in tall emergents. Shannon-Wiener diversity index computed for waterbirds fluctuated from 0.85 for floating vegetation to 0.0001 for siltation zone in mid-winter season. Observed species richness in post-winter reported least (S=2) in submerged paddy fields to highest (S=25) in open water. Shannon- Weiner diversity index fluctuated from 0.94 for submerged paddy fields to 0.48 for peatland.

Hygam wetland showed variation in species richness across habitats in both seasons with S=1 from tall emergents to S=12 in drawdown meadows in mid-winter season. Diversity index of Shannon-Weiner computed in this season fluctuated from 1.3 for drawdown meadows to 0.4 for short emergents with pools. Post-winter season showed least species richness (S = 2) from submerged meadows and reed bed with floating vegetation to highest (S =

19) from waterlogged plantation. Diversity index of Shannon-Wiener fluctuated from 0.48 for reed bed with floating vegetation to 0.88 for submerged meadows.

Diversity in waterbird community showed variation between two wetlands and among seasons. The more diverse community during mid-winter season was found in Hygam wetland (Shannon index 1.33 for drawdown meadows) than in Hokersar wetland (Shannon index 0.85 for floating vegetation). However waterbird community of Hokersar wetland showed more diversity (0.94 Shannon index for submerged paddy field) during post-winter season than that of Hygam wetland (Shannon index 0.88 for submerged grassy meadow). Four species of waterbirds were found breeding in Hokersar wetland while it was only two in Hygam wetland. Mallard showed a higher nest density in Hokersar than in Hygam wetland. A production of 204 Mallard in its recruitment of its population was seen in Hokersar wetland while in Hygam wetland the recruitment was only 62 ducklings.

To summarize, the results indicated a variation in spatio-temporal pattern of density and diversity between Hokersar and Hygam wetlands. Estimated population of migratory waterbirds in winter season was high in Hokersar wetland when compared to Hygam wetland. Average bird density between Hokersar and Hygam wetlands during both mid and post-winter seasons showed a distinct variation. Floating vegetation supported the maximum population in both wetlands during mid-winter season. However, from the area estimates of floating vegetation that served as potential bird habitat in two wetlands, the extent of this macrophyte community was more in Hokersar wetland than in Hygam wetland. This contributes to the factor for Hokersar wetland to sustain large bird population.

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CHAPTER 6
HABITAT UTILIZATION BY WATERBIRDS

6.1 Introduction

Habitat use is a critical facet in the management of wildlife populations. Understanding habitat utilization pattern gives an idea of how organisms use the area and the reasons for preferring specific habitats. Odum (1975) considers habitat as the address of an organism. Specifically, it refers to the physical and biological environment in which a species is usually found (Morrison et al; 1992). The necessity of determining preference or avoidance of a given habitat in terms of its availability has long been recognized (Glading et al; 1940; Bellrose and Anderson, 1943). Interpreting species preferences to certain habitat features from a human perspective is often ambiguous (Block and Brennan, 1993) and also, describing habitat -animal association is scale dependent. The proximate factors enable the species to motivate settling behavior, while ultimate factors influence the survival and reproductive success of individuals. A clear picture on how the species is related to a given environment becomes essential to understand species biology and consequently for management/conservation. Most of the habitat use studies, in effect, intend to provide initial steps towards understanding the complex issue by identifying and describing habitat correlates.

The interaction of proximate and ultimate factors continues to intrigue ecologists studying avian habitat selection. Habitat selection in birds is seemingly guided by instinctive and experiential influences from the physical and/or social environment (Hilden, 1965). Generally, birds are attracted to habitats by proximate cues that perhaps reflect the presence of certain ultimate elements necessary for survival and/or reproduction (Hilden, 1995). True habitat selection occurs when individuals exercise a choice among available habitats, instead of differentially occupying them as a consequence of extrinsic factors like predation and competition (Klopfer, 1969; Wiens, 1976, 1977).

The present study was an investigation to elucidate habitat utilization pattern of waterbirds in Hokersar and Hygam wetlands of Jammu and Kashmir. Here the study focused on habitat selection and described activity pattern of waterbird families in selected habitats. The questions that were addressed are:

- Is there any variation in habitat use by waterbirds in these wetlands considering the fact that wetlands have different degrees of human impacts?

- Does the activity pattern of waterbirds vary across two wetlands and across seasons?

6.2 Methods

This study was undertaken covering the three seasons *viz*. mid-winter (December 2004 - January 2005); post-winter (February - April, 2005) and summer seasons (July -August 2005) to examine seasonal pattern of habitat use by waterbirds in Hokersar and Hygam wetlands. During the mapping studies, 10 types of land uses each in Hokersar and in Hygam wetlands were found. For the habitat use studies, these major land cover types were divided into micro-habitat types. These micro-habitat types varied between two wetlands and with seasons. Table 6.2 provides details of micro-habitat types found in Hokersar and Hygam wetlands during three seasons.

Fixed observation tracks were set up in the two wetlands. Number of tracks set up and their location depended to cover all areas of the wetland. A total of four tracks were set up and monitored in Hokersar and three tracks set up and monitored in Hygam. Length of observation tracks set up is given in Table 6.1.

Table 6.1 Length of observation tracks set up in Hokersar and Hygam wetlands, Jammu and Kashmir.

Hokersar wetland		Hygam wetland	
Track number	**Track length (km)**	**Track number**	**Track length (km)**
1	1.0	1	1.5
2	1.0	2	1.0
3	0.75	3	0.75
4	1.0	4	0.0

Preliminary survey included identification of micro-habitats along these observation tracks. Type of micro-habitats (habitat units) seen along each track was recorded (Table 6.2). Habitat types were based on the dominant plants as determined from ground observations and from hydrologic characteristics of habitats and from land use types identified during mapping study. Because of inaccessibility of certain areas and physical constraints, availability and utilization sampling in a wetland habitat was difficult to quantify. Hence, in the present study a non-mapping technique (Marcum and Loftsgaarden, 1980) was adopted to quantify the availability of micro-habitats present. This was done separately for two study wetlands. In this study, each sampling point was considered as one micro-habitat on each of the observation tracks laid in two study wetlands. Hence, number of sampling points per track was equal to number of micro-habitats observed along that particular track. Further the total numbers of sampling points were classified into micro-habitat types which they represented. As there were seven micro-habitats or habitat units seen in Hokersar wetland during mid-winter season, a total of 193 points were sampled. A total of 278 points were sampled on eight micro-habitats during post-winter and 264 points were sampled on nine micro-habitats during summer season. In Hygam wetland, a total of 293 points were sampled on five micro-habitats during mid-winter season; 365 points were sampled on six micro-habitats in post-winter season and 222 points sampled on six micro-habitats during summer season. Table 6.3 provides details of waterbird families and their species composition recorded in Hokersar and Hygam wetlands during three seasons.

To establish utilization of micro-habitat types by members of waterbird families recorded from the wetlands, surveys on boat and by foot were undertaken on observation tracks and each location of a waterbird flock was assigned to a particular micro-habitat type. Each flock of waterbirds was considered as one observation. Each flock was observed and data were collected on variables of flock size and composition using 8 x 40 binoculars and a spotting scope. Activity of the flock was recorded for a two-minute duration. The two study sites were surveyed thrice every week on randomly chosen days and time of the day and hence a total of 27 surveys in mid-winter, 36 in post-winter and 24 in summer season were undertaken in two study wetlands.

6.3 Analysis for Habitat Preference

The data collected were compiled in MS Excel software. The data were analyzed in the resource availability and utilization framework proposed by Neu *et al*. (1974) in conjunction with a chi-square goodness of fit test used to determine whether or not there was a significant difference between the expected utilization of different micro-habitats and the observed frequency of their usage. If a statistically significant difference was found between utilization and availability, the data were further investigated by Bonferroni confidence interval following Byers *et al*. (1984) to determine which category of micro-habitat was preferred, avoided or used in proportion to availability. Separate analysis was performed for each family of waterbirds recorded. The following formula for Bonferroni confidence interval was used.

Table 6.2 Definition of micro-habitat types of Hokersar and Hygam wetlands, Jammu and Kashmir.

S. no.	Habitat Type	Explanation	Hokersar			Hygam		
			MW	PW	S	MW	PW	S
1.	Tall emergents	Shallow water areas of variable depth, dominated by tall emergent vegetation mostly *Typha* species.	√	√	√	√	X	√
2.	Floating vegetation	Shallow water areas of variable depth, dominated by free-floating and rooted with floating- leafed vegetation (e.g. water lilies).	√	√	√	√	X	√
3.	Drawdown meadows	Exposed areas of wetland due to water level lowering and dewatering, dominated by *Cynodon dactylon* (grass) species.	√	√	√	√	X	√
4.	Siltation zone	Areas of silty-clayey-loam type underlying soils formed because of heavy silt load by perennial streams.	√	X	X	X	X	X
5.	Plantation	Extensive planted stands of Willow *Salix alba* trees in periphery and inside of wetland with no standing water	√	X	√	√	X	√
6.	Peatland	Areas of partially decayed organic matter in wetlands consisting of marshland vegetation and form thick land-masses over water.	√	√	√	X	X	X
7.	Paddy fields	Areas in wetland cultivated by rice.	√	X	√	X	X	√
8.	Submerged peatland	Peatlands submerged by water.	X	√	X	X	X	X
9.	Open water	Deep-water areas of wetland devoid of any vegetation.	X	√	√	X	√	X
10.	Submergent vegetation	Shallow and deep water areas of submerged vegetation	X	√	X	X	X	X
11.	Waterlogged plantation	Plantation with standing water	X	X	√	X	√	X

Contd…

Table 6.2 Contd…

12.	Trapa bed	Areas in wetland with *Trapa* cultivation sown for waterbirds.	X	X	X	X	X	X
13.	Short emergents with pools	Emergent vegetation areas interspersed with patches of water.	X	X	√	√	X	X
14.	Reed bed with open water	Areas of emergent vegetation interspersed with areas devoid of vegetation.	X	X	X	X	√	X
15.	Reed bed with floating vegetation	Areas of emergent vegetation interspersed with areas of floating vegetation.	X	X	X	X	√	X
16.	Submerged meadows	Permanent drawdown areas submerged with water by flooding.	X	X	X	X	√	X
17.	Submerged meadows with dry patches	Submerged drawdown areas interspersed with dry patches.	X	X	X	X	√	X
18.	Submerged paddy fields	Paddy fields with standing water	X	√	X	X	X	X
19.	Dry zone	Drawdown areas in wetland devoid of any vegetation.	X	X	X	X	X	√
	Total	**19**	**7**	**8**	**9**	**5**	**6**	**6**

* MW= mid-winter, PW= post-winter, S= summer

Table 6.3 The major waterbirds of the Hokersar and Hygam wetlands and their ecological characters.

Family	Species	Character	Hokersar			Hygam		
			MW	PW	S	MW	PW	S
Anatidae	Mallard	A dabbling duck which inhabits wetlands and usually feeds by dabbling for plant food and grazing.	√	√	X	√	√	X
	Gadwall	Ponds and marshes are the preferred habitat of the Gadwall, which is often found in deeper water than many other dabblers. The preferred diet is the invasive, exotic submergent, Eurasian water milfoil	X	X	X	X	X	X
	Northern Shoveler	Northern Shoveler inhabits shallow, marshy ponds and wetlands. The bill of the Shoveler is ideally suited for straining small swimming invertebrates from the water and mud.	X	X	X	X	X	X
	Northern Pintail	Northern Pintail are found around shallow wetlands and exposed mudflats. They forage on land, but find most of their food by dabbling in shallow, muddy water.	X	X	X	X	X	X
	Eurasian Wigeon	The foraging strategies of the Eurasian wigeon include picking food from the surface of shallow water, grazing in upland areas, and foraging on vegetation brought up by Coots and diving ducks.	X	X	X	X	X	X

Contd…

Table 6.3 Contd…

	Greylag Geese	Greylag Geese usually feed by grazing in dry lands. When foraging in water, they reach deep submergent plants.	X	X	X	X	X	X
Rallidae	Common Coot	The species shows a preference for shallow water with adjacent deeper water for diving. It shows considerable variation in its foraging techniques, grazing on land or in the water. In water, it dives in search of food.	√	√	X	√	√	X
	Common Moorhen	The species lives around ponds, lakes and marshes and consume vegetable material and small aquatic creatures by foraging while swimming, sometimes upending to feed, or walking through the marsh.	X	X	X	X	X	X
Ardeidae	Little Egret	The species is a small White- heron which stalks its prey in shallow water, often running with raised wings or shuffling its feet.	√	√	X	√	X	X
	Grey Heron	The largest heron found in wetland marshes, reservoirs, lakes, rivers and estuaries. Usually seen standing silently at the waters edge, it starts its food close to the bank, but may wade out into shallow water.	X	X	X	X	X	X
Podicipedidae	Little Grebe	Little Grebe as an excellent swimmer and diver, pursues its fish and aquatic invertebrate preys under water. It uses the vegetation skillfully as a hiding place.	√	√	X	X	X	X

Contd…

Table 6.3 Contd…

Charadriidae	Black-winged Stilt	The Black-winged Stilt is a widely distributed very long-legged wader in the avocet and stilt family. These birds pick up their food from sand or water. They mainly eat crustaceans.	X	X	X	X	X	X
Phalacrocoracidae	Little Cormorant	The Little Cormorant is a member of the Cormorant family of seabirds. The bird can dive to considerable depths, but usually feeds in shallow water and frequently brings prey mainly fish to the surface.	X	X	X	√	X	X
Scolopacidae	Pintail Snipe	The Pintail Snipe is a small stocky wader. These birds forage in mud or soft soil, probing or picking up food by sight. They mainly eat insects and earthworms, but also some plant material.	X	X	X	X	√	X

$P_i - Z_{\alpha/2k}$ ($\sqrt{P_i (1-P_i)/n} \le P_i \le P_i + Z_{\alpha/2k}$ ($\sqrt{P_i (1-P_i)/n}$, where Pi is the proportion of waterbirds in the i^{th} habitat category and n is the sample size, in this case total number of waterbirds recorded from all habitats. $Z_{\alpha/2K}$ is upper standard normal table value and K= number of category tested. If the lower bound of the interval exceeds the availability proportion, then waterbirds have shown preference for this habitat type. The type of activities performed in micro-habitat types by waterbird families was also computed for all three seasons of the study.

6.4 Results

6.4.1 Seasonal pattern of habitat selection by waterbirds in Hokersar

A total of seven micro-habitats or habitat units were identified in Hokersar wetland during mid-winter season; eight micro-habitats or habitat units were identified in post-winter season and nine in summer season (Table 6.2). The micro-habitat types showed variation between seasons. A total of five families of waterbirds were recorded from Hokersar wetland (Table 6.3).

6.4.2 Habitat selection during mid-winter season

A total of four families of waterbirds recorded from Hokersar wetland during mid-winter season showed preference for certain micro-habitat types. Table 6.4 summarizes the proportional availability of different micro-habitat types and the number and proportion of waterbirds of each individual family observed at each type of micro-habitat, together with the simultaneous confidence intervals using the Bonferroni approach.

The results of the test (Table 6.4) indicated that preference for specific micro-habitats varied greatly among families of waterbirds recorded in this season. Of the four families of waterbirds recorded, members of family Anatidae (mostly dabblers) used floating vegetation significantly more than expected in proportion to its availability and hence showed a preference for this habitat. Further results showed that floating vegetation and tall emergents were the preferred micro-habitats of Rallidae. Ardeidae showed a preference for drawdown meadows while Podicipedidae preferred specifically floating vegetation more than its expected utilization. Siltation zone, plantation, peatland and paddy fields were largely avoided. The results showed that members of the families Anatidae and Rallidae were substantially higher in areas having floating vegetation while Ardeidae (Egrets and Herons) were maximum in peatlands.

6.4.3 Habitat selection during post-winter season

The results indicated a significant habitat selection by four families of waterbirds recorded from the wetland. Preference for specific micro-habitats varied greatly among families. Proportional availability of different micro-habitat types and the number and proportion of waterbirds of each individual family observed at each type of habitat, together with simultaneous confidence intervals using the Bonferroni approach is given in Table 6.5.

Submerged peatland and open water accounted for preferred habitats of Anatidae. Rallidae were found to utilize submerged peatland, open water and submergent vegetation more than their expected utilization. Ardeidae revealed preferences for submerged peatland, peatland and drawdown meadows. Podicipedidae showed preference for open water. Tall emergents and submerged paddy fields were largely avoided in this season studied. The two major families Anatidae and Rallidae had a substantially higher number in submerged peatland.

6.4.4 Habitat selection during summer season

The results indicated that five families of waterbirds showed preference for micro-habitat types found in the wetland and this preference for specific types varied among families. Table 6.6 summarizes the proportional availability of different micro-habitat types and the number and proportion of waterbirds of each individual family observed at each type of habitat, together with the simultaneous confidence intervals using the Bonferroni approach.

Table 6.4 Preference or avoidance of micro-habitat types by individual waterbird families during mid-winter season in Hokersar wetland.

Habitat Type	**Number of sampling points**	**Proportion of total sampling points (p_io)**	**Waterbird Family**	**Number of birds observed**	**Expected [a] number of birds**	**Proportion observed at each sampling point**	**X^2 distribution**	**Bonferonni confidence interval for observed proportions pi- z*sqrt pi(1-pi)/n ≤ pi ≤pi +z*sqrt pi(1-pi)/n**	**Habitat Selection**
Tall emergents	70	0.3605	Anatidae	52332	92837.96	0.2033	17673.07	0.2017 ≤ pi ≤ 0.2048	Avoidance
			Rallidae	4874	4221 .53	0.4103	100.84	0.4074 ≤ pi ≤ 0.4252	Preference
			Ardeidae	16	40.74	0.141	15.03	0.2720 ≤ pi ≤ 0.4491	Avoidance
			Podicipedidae	0	36.05	0	36.05	0 ≤ pi ≤ 0	Avoidance
Paddy fields	47	0.2416	Anatidae	3700	20508.31	0.0143	20508.31	0.0139 ≤ pi ≤ 0.0148	Avoidance
			Rallidae	165	2828.96	0.014	2508.58	0.0119 ≤ pi ≤ 0.016	Avoidance
			Ardeidae	0	27.30	0	27.306	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	0	24.16	0	24.16	0 ≤ pi ≤ 0	Avoidance
Floating vegetation	24	0.1234	Anatidae	196495	31794.76	0.7632	853164.64	0.76157 ≤ pi ≤ 0.76482	Preference
			Rallidae	5475	1445.772	0.553	17494.54	0.54408 ≤ pi ≤ 0.56209	Preference
			Ardeidae	0	13.955	0	13.96	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	100	12.34	1	622.089	1≤ pi ≤ 1	Preference
Drawdown meadows	22	0.1144	Anatidae	21	29454.89	8.15E-05	29412.904	4.6682 E ≤ pi ≤ 0.0001	Avoidance
			Rallidae	0	1339.37	0	1339.37	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	21	12.92	0.1858	5.0398	0.1878 ≤ pi ≤ 0.11440	Preference

Contd…

Table 6.4 Contd…

			Podicipedidae	0	11.44	0	11.44	0 ≤ pi ≤ 0	Avoidance
Peatland	15	0.0797	Anatidae	0	20508.31	0	2043.733	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	932.55	0	932.55	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	57	9.001	0.5044	255.94	0.0297 ≤ pi ≤ 0.1295	Avoidance
			Podicipedidae	0	7.965	0	7.965	0 ≤ pi ≤ 0	Avoidance
Siltation zone	13	0.0686	Anatidae	4407	17686.70	0.0171	9970.79	0.0166 ≤ pi ≤ 0.0176	Avoidance
			Rallidae	120	804.25	0.01	582.154	0.0084 ≤ pi ≤ 0.012	Avoidance
			Ardeidae	9	7.7628	0.079	0.197	0.0220 ≤ pi ≤ 0.1153	Avoidance
			Podicipedidae	0	6.8698	0	6.8698	0 ≤ pi ≤ 0	Avoidance
Plantation	2	0.011	Anatidae	500	2959.25	0.002	2043.733	0.0017 ≤ pi ≤ 0.0021	Avoidance
			Rallidae	73	134.56	0.006	28.165	0.0048 ≤ pi ≤ 0.0076	Avoidance
			Ardeidae	10	1.2988	0.0884	58.29	0.0081 ≤ pi ≤ 0.0312	Avoidance
			Podicipedidae	0	1.1494	0	1.1494	0 ≤ pi ≤ 0	Avoidance

[*a] Calculated by multiplying p_io x total number of waterbirds of individual family observed (Neu *et al*; 1974).

[b] pi represents theoretical proportion of observation of waterbirds of individual family and is compared to corresponding pio to determine if hypothesis of proportional use is accepted or rejected i.e. pi= pio (Neu et al; 1974) at p> 0.05 based on Byers simultaneous confidence interval.

X^2 contribution was derived from the formula $\chi^2 = \Sigma\ (oi- Ei)^2/Ei$ (Byers et al; 1984).

Preference= used more than available, Avoidance= used less than available

Table 6.5 Preference or avoidance of micro-habitat types by individual waterbird families during post-winter season in Hokersar wetland.

Habitat Type	Number of sampling points	Proportion of total sampling points (p_io)	Waterbird Family	Number of birds observed	Expected [a]number of birds	Proportion observed at sampling points	X^2 distribution	Bonferonni confidence interval pi- z*sqrt pi(1-pi)/n ≤ pi ≤ pi +z*sqrt pi (1-pi/)/n	Habitat Selection
Tall emergents	45	0.1612	Anatidae	241	16224.19	0.0024	15745.77	0.0021≤pi≤ 0.0027	Avoidance
			Rallidae	136	3024.516	0.0073	2758.63	0.0060 ≤ pi ≤ 0.0085	Avoidance
			Ardeidae	1	39.354	0.0041	37.3802	0.0040 ≤ pi ≤ 0.0121	Avoidance
			Podicipedidae	0	1.4516	0	1.4516	0 ≤pi≤0	Avoidance
Submerged paddy fields	49	0.176	Anatidae	0	17846.61	0	17846.61	0 ≤ pi ≤ 0	Avoidance
			Rallidae	3	3326.96	0.0001	3320.970	2.10E-05 ≤ pi ≤ 0.00034	Avoidance
			Ardeidae	1	43.290	0.004	41.3134	-0.0039 ≤ pi ≤ 0.0121	Avoidance
			Podicipedidae	0	1.5967	0	1.5967	0 ≤ pi ≤ 0	Avoidance
Floating vegetation	31	0.1115	Anatidae	41	11212.72	0.0004	11130.87	0.0002≤pi≤ 0.0005	Avoidance

Contd…

Table 6.5 Contd…

			Rallidae	316	2090.276	0.0168	1506.048	0.0150≤pi≤ 0.0186	Avoidance
			Ardeidae	316	27.19	0.0041	25.24	0.0039≤pi≤ 0.0121	Avoidance
			Podicipedidae	0	1.0032	0.22	0.99036	0.1112≤p ≤ 0.4938	Preference
Drawdown meadows	15	0.0537	Anatidae	0	5408.064	0	5408.064	0 ≤ pi ≤ 0	Avoidance
			Rallidae	3	1008.172	0.00016	1002.1809	2.104E-0 ≤ pi ≤ 0.0003	Avoidance
			Ardeidae	145	13.118	0.5942	1325.84	0.5426 ≤ pi ≤ 0.6558	Preference
			Podicipedidae	0	0.4838	0	0.4838	0 ≤ pi ≤ 0	Avoidance
Peatland	13	0.0458	Anatidae	23	4614.881	0.00023	4568.996	0.00013 ≤ pi ≤ 0.00032	Avoidance
			Rallidae	134	860.3068	0.0071	613.178	0.0059 ≤ pi ≤ 0.0083	Avoidance
			Ardeidae	15	11.194	0.061	1.2938	0.0479 ≤ pi ≤ 0.0916	Preference
			Podicipedidae	0	0.41290	0	0.41290	0 ≤ pi ≤ 0	Avoidance
Submerged peatland	49	0.1774	Anatidae	52792	17846.612	0.5 24	68426.43	0.5217 ≤ pi ≤ 0.5279	Preference
			Rallidae	7894	3326.967	0.42	6269.31	0.4139 ≤ pi ≤ 0.4280	Preference
			Ardeidae	49	. 290	0.2008	0.7530	0.1784 ≤ pi ≤ 0.2510	Preference
			Podicipedidae	0	1.5967	0	1.5967	0 ≤ pi ≤ 0	Avoidance

Contd…

Table 6.5 Contd…

Open water	31	0.1115	Anatidae	47489	11212.72	0.4721	117363.88	0.4690≤pi≤ 0.4751	Preference
			Rallidae	7177	2090.276	0.3827	12378.63	0.3757≤pi≤ 0.389	Preference
			Ardeidae	0	43.290	0	0.7530	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	7	1.5967	0.78	1.5967	0.5016≤pi≤ 1.049	Preference
Submergent vegetation	45	0.1612	Anatidae	4	16224.193	3.97E-05	16216.19	7.960E-0≤pi≤ 7.873E-0	Avoidance
			Rallidae	3089	3024.516	0.1644	1.3748	0.1634 ≤ pi ≤ 0.1700	Preference
			Ardeidae	32	39.35	0.1311	1.3745	0.0887 ≤ pi ≤ 0.1735	Avoidance
			Podicipedidae	0	1.45161	0	1.45161	0 ≤ pi ≤ 0	Avoidance

[a] Calculated by multiplying pio x total number of waterbirds of individual family observed (Neu *et al*; 1974).

[b] pi represents theoretical proportion of observation of waterbirds of individual family and is compared to corresponding pio to determine if hypothesis of proportional use is accepted or rejected i.e. pi= pio (Neu *et al*; 1974) at p> 0.05 based on Byers simultaneous confidence interval.

X^2 contribution was derived from the formula $\chi^2 = \Sigma$ (oi- Ei)^2 /Ei (Byers *et al*; 1984).

Preference= used more than available, Avoidance= used less than available

Of the five families of waterbirds recorded, open water areas were preferred micro-habitat of Anatidae. Rallidae utilized floating vegetation and waterlogged plantation more than their expected availability. Ardeidae preferred drawdown meadows and floating vegetation. Podicipedidae showed preference for floating vegetation, waterlogged plantation and open water while floating vegetation was preferred habitat of Charadriidae. Further results showed that tall emergents, dry plantation, peatland and paddy fields were largely avoided.

Numbers of most dominant family Rallidae were substantially higher in floating vegetation. Other major family, Anatidae (mostly dabbling ducks) was found in maximum numbers in open water and Ardeidae (Herons and Egrets) were maximum in drawdown meadows.

6.4.5 Seasonal comparison for habitat selection

Seasonal comparison of habitat utilization indicated a variation in pattern of habitat use among three seasons. Microhabitats varied between seasons in both wetlands. The results indicated that preference for specific micro-habitats by families of waterbirds also varied greatly between seasons. Only two waterbird families that preferred specific habitats in all three seasons were Ardeidae and Podicipedidae. Ardeidae preferred drawdown meadows and Podicipedidae showed preference for floating vegetation in all three seasons in addition to their preferences for other micro habitats. Similarly, habitats avoided by families of waterbirds recorded varied between three seasons. However, paddy field was found as only habitat largely avoided in all the three seasons by all families recorded.

Table 6.6 Preference or avoidance of microhabitat types by individual waterbird families during summer season in Hokersar wetland.

Habitat Type	Number of sampling points	Proportion of total sampling points (p_io)	Waterbird Family	Number of birds observed	Expected [a]number of birds	Proportion observed at habitat type (pi)	X^2 distribution	Bonferroni confidence interval pi- Z* sqrt pi(1-pi/)/n ≤ pi ≤ pi + Z*sqrt pi (1-pi/)/n	Habitat Selection
Tall emergents	81	0.3057	Anatidae	0	295.357	0	295.357	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	810.86	0	810.86	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	2	480.949	0.0027	476.95	-0.0005 ≤pi≤ 0.00303	Avoidance
			Podicipedidae	0	5.197	0	5.197	0 ≤ pi ≤ 0	Avoidance
			Charadriidae	0	97.53	0	97.53	0 ≤ pi ≤ 0	Avoidance
Paddy fields	95	0.3579	Anatidae	0	345.74	0	345.749	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	949.201	0	949.201	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	0	563.0068	0	563.0068	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	0	6.0846	0	6.084625	0 ≤ pi ≤ 0	Avoidance
			Charadriidae	0	114.176	0	114.176	0 ≤ pi ≤ 0	Avoidance
Floating vegetation	22	0.0841	Anatidae	66	81.18	0.07	2.841	0.0524 ≤ pi ≤ 0.0842	Avoidance
			Rallidae	2323	222.88	0.8759	19787.67	0.8639 ≤ pi ≤ 0.8884	Preference
			Ardeidae	515	132.204	0.3273	1108.383	0.3042 ≤ pi ≤ 0.3505	Preference
			Podicipididae	15	1.428	0.8823	128.905	0.7291 ≤ pi ≤ 1.0355	Preference
			Charadriidae	300	26.810	0.9404	2783.690	0.9144 ≤ pi ≤ 0.9664	Preference

Contd…

Table 6.6 Contd…

Drawdown meadows	16	0.0620	Anatidae	0	59.91	0	59.91	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	164.47	0	164.47	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	996	97.55	0.6331	8274.08	0.6093 ≤ pi ≤ 0.6570	Preference
			Podicipedidae	0	1.0543	0	1.0543	0 ≤ pi ≤ 0	Avoidance
			Charadriidae	18	19.784	0.0 564	0.1609	0.0311 ≤ pi ≤0.0817	Avoidance
Peatland	16	0.0623	Anatidae	0	60.191	0	60.191	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	165.245	0	165.245	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	2	2.27937	0.0013	0.03424	-0.00048 ≤ pi ≤ 0.0030	Avoidance
			Podicipedidae	0	1.0592	0	1.05926	0 ≤ pi ≤ 0	Avoidance
			Charadriidae	0	19.8768	0	19.8768	0 ≤ pi ≤ 0	Avoidance
Waterlogged plantation	1	0.0049	Anatidae	0	4.619	0	4.619	0 ≤ pi ≤ 0	Avoidance
			Rallidae	20	12.68	0.008	4.223	0.00496 ≤ pi ≤ 0.0108	Preference
			Ardeidae	0	7.5219	0	7.5219	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	1	0.081	0.0588	10.382	0.00578 ≤ pi ≤ 0.0082	Preference
			Charadriidae	1	1.525	0.0031	0.1809	0.00532 ≤ pi ≤ 0.00926	Preference
Dry plantation	1	0.0014	Anatidae	0	1.3997	0	1.3997	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	3.8429	0	3.8429	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	0	2.2793	0	2.2793	0 ≤ pi ≤ 0	Avoidance

Contd…

Table 6.6 Contd…

			Podicipedidae	0	0.02463	0	0.02463	0 ≤ pi ≤ 0	Avoidance
			Charadriidae	0	0.46225	0	0.46225	0 ≤ pi ≤ 0	Avoidance
Open water	18	0.0695	Anatidae	900	67.190	0.93	10322.50	0.9157 ≤ pi ≤ 0.947	Preference
			Rallidae	14	184.46	0.0053	157.522	0.0025 ≤ pi ≤ 0.0080	Preference
			Ardeidae	0	109.410	0	109.410	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	1	1.1824	0.0588	0.02814	-0.0530 ≤ pi ≤ 0.1706	Avoidance
			Charadriidae	0	22.188	0	22.188	0 ≤ pi ≤ 0	Avoidance
Trapa bed	14	0.0521	Anatidae	0	50.392	0	50.288	0 ≤ pi ≤ 0	Avoidance
			Rallidae	295	138.345	0.11123	177.387	0.0993 ≤ pi ≤ 0.1232	Preference
			Ardeidae	58	82.057	0.0368	7.0532	0.0275 ≤ pi ≤ 0.0462	Avoidance
			Podicipedidae	0	0.8868	0	0.8868	0 ≤ pi ≤ 0	Avoidance
			Charadriidae	0	16.641	0	16.641	0 ≤ pi ≤ 0	Avoidance

[a] Calculated by multiplying pio x total number of waterbirds of individual family observed (Neu *et al*; 1974).

[b] pi represents theoretical proportion of observation of waterbirds of individual family and is compared to corresponding pio to determine if hypothesis of proportional use is accepted or rejected i.e. pi= pio (Neu et al; 1974) at p> 0.05 based on Byers simultaneous confidence interval.

X^2 contribution was derived from the formula $\chi^2 = \Sigma\,(oi- Ei)^2 / Ei$ (Byers et al; 1984).

Preference= used more than available, Avoidance= used less than available

6.4.6 Habitat selection during mid-winter season in Hygam

A total of five micro-habitats or habitat units were identified in Hygam wetland during mid-winter; six micro-habitats or habitat units were identified in post-winter and six in summer (Table 6.2). A total of six families of waterbirds were recorded from Hygam wetland during three study seasons.

The results indicated that waterbirds showed preference in mid-winter and this preference for specific micro-habitats varied greatly among families. Proportional availability of different micro-habitat types and the number and proportion of waterbirds of each family observed at each micro- habitat type together with simultaneous confidence intervals using the Bonferroni approach is given in Table 6.7.

Of the four waterbird families recorded in this season, Anatidae and Rallidae preferred floating vegetation and plantations. Ardeidae showed preference for floating vegetation, plantation and short emergents with pools while floating vegetation was preferred habitat of Phalacrocoracidae. Tall emergents and drawdown meadows were largely avoided. Numbers of both Anatidae and Rallidae were substantially higher in floating vegetation.

6.4.7 Habitat selection during post-winter season

Waterbirds showed preference for specific micro-habitats recorded during post-winter season. Proportional availability of different micro-habitat types and the number and proportion of waterbirds of each individual family observed at each type of micro-habitat, together with simultaneous confidence intervals using the Bonferroni approach is given in Table 6.8. As indicated in the results, open water and tall emergents with open water was preferred micro-habitats of Anatidae, Rallidae and Scolopacidae. Ardeidae utilized more of open water and submerged meadows with dry patches. Podicipididae indicated preference for waterlogged plantation. Two dominant families, Anatidae and Rallidae were substantially higher in numbers in reed bed with open water.

6.4.8 Habitat selection during summer season

Table 6.9 summarizes the proportional availability of different habitat types and the number and proportion of waterbirds of each family observed at each type of habitat, together with the simultaneous confidence intervals using the Bonferroni approach. However, as indicated in the results, variation in preference for specific micro-habitats could not be found. Both families recorded in this season showed preference for only one micro-habitat i.e. floating vegetation. Other micro-habitats were largely avoided.

6.4.9 Seasonal comparison for habitat selection

Preferences for specific habitats by waterbirds in Hygam wetland varied among seasons. In mid-winter and summer seasons, floating vegetation was the preferred micro-habitat of all the families of waterbirds. However, absence of this habitat in post-winter could not indicate such pattern. Seasonal comparison of micro-habitats avoided by waterbirds revealed that only two micro-habitats were avoided in mid and post-winter seasons from the wetland in contrary to summer season where only one micro-habitat was utilized more and all other micro-habitats were largely avoided.

Table 6.7 Preference or avoidance of micro-habitat types by individual waterbird families during mid-winter in Hygam wetland.

Habitat Type	Number of sampling points	Proportion of total sampling points (p_io)	Waterbird Family	Number of birds observed	Expected [a]number of birds	Proportion observed at each sampling point (pi)	X^2 distribution	Bonferonni confidence interval pi- z*sqrt pi(1-pi)/n ≤ pi ≤ pi +z*sqrt pi (1-pi/)/n	Habitat Selection
Tall emergents	75	0.254	Anatidae	0	558.068	0	558.068	0 ≤ pi ≤ 0	Avoidance
			Rallidae	21	10.419	0	10.419	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	1	3.303	0	3.303	0 ≤ pi ≤ 0	Avoidance
			Phalacrocoracidae	0	0.5082	0	0.1270	0 ≤ pi ≤ 0	Avoidance
Floating vegetation	11	0.0381	Anatidae	1536	83.710	0.699	25195.771	0.680 ≤ pi ≤ 0.718	Preference
			Rallidae	21	1.5628	0.512	241.73	0.3591 ≤ pi ≤ 0.6651	Preference
			Ardeidae	1	0.49555	0.076	0.5135	0.0679 ≤ pi ≤ 0.2217	Preference
			Phalacrocoracidae	2	0.0762	1	48.54	1 ≤ pi ≤ 1	Preference
Drawdown meadows	175	0.597	Anatidae	0	1311.461	0	1311.461	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	24.485	0	24.485	0 ≤ pi ≤ 0	Avoidance

Contd…

Table 6.7 Contd…

			Ardeidae	0	7.763	0	7.763	0 ≤ pi ≤ 0	Avoidance
			Phalacrocoracidae	0	1.1944	0	1.1944	0 ≤ pi ≤ 0	Avoidance
Plantation	23	0.0787	Anatidae	660	173.0012	0.3005	1370.9018	0.9808 ≤ pi ≤ 0.3197	Preference
			Rallidae	20	3.229	0.4878	87.069	0.3343 ≤ pi ≤ 0.6408	Preference
			Ardeidae	5	1.024	0.3846	15.434	0.2663 ≤ pi ≤ 0.5028	Preference
			Phalacrocoracidae	0	0.1575	0	0.1575	0 ≤ pi ≤ 0	Avoidance
Short emergents with pools	9	0.0317	Anatidae	0	69.758	0	69.758	0 ≤ pi ≤ 0	Avoidance
			Rallidae	0	1.3024		1.3024	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	7	0.4129	0.5384	105.068	0.4360 ≤ pi ≤ 0.6408	Preference
			Phalacrocoracidae	0	0.0635	0	0.0635	0 ≤ pi ≤ 0	Avoidance

[a] Calculated by multiplying pio x total number of waterbirds of individual family observed (Neu *et al*; 1974).

[b] pi represents theoretical proportion of observation of waterbirds of individual family and is compared to corresponding pio to determine if hypothesis of proportional use is accepted or rejected i.e. pi= pio (Neu *et al*; 1974) at p> 0.05 based on Byers simultaneous confidence interval.

X^2 contribution was derived from the formula $\chi^2 = \Sigma (oi- Ei)^2/Ei$ (Byers et al; 1984).

Preference= used more than available, Avoidance= used less than available

Table 6.8 Preference or avoidance of micro-habitat types by individual waterbird families during post-winter in Hygam wetland.

Habitat Type	Number of sampling points	Proportion of total sampling points(p_io)	Waterbird Family	Number of birds observed	Expected [a]number of birds	Proportion observed at each sampling point (pi)	X2 distribution	Bonferroni confidence interval Pi- Z* sqrt pi(1-pi/)/n ≤ pi ≤ Pi + Z*sqrt pi (1-pi/)/n	Habitat Selection
Open water	24	0.0652	Anatidae	12947	2410.968	0.3506	46042.892	0.3457 ≤ pi ≤ 0.3554	Preference
			Rallidae	1128	196.126	0.3754	4427.7033	0.3587 ≤ pi ≤ 0.3922	Preference
			Ardeidae	5	4.8313	0.0675	0.00588	0.1106 ≤ pi ≤0.1240	Preference
			Podicipedidae	0	0.7181	0	0.7181	0 ≤ pi ≤ 0	Avoidance
			Scolopacidae	2	0.9140	0.1428	1.2902	0.0404 ≤ pi ≤ 0 .326	Preference
Reed bed with open water	99	0.272	Anatidae	23941	10045.701	0.65	19220.091	0.6434 ≤ pi ≤ 0.5318	Preference
			Rallidae	1389	817.192	0.4623	400.1060	0.7450 ≤ pi ≤ 0.7796	Preference
			Ardeidae	9	20.130	0.1216	6.1543	0.0471 ≤ pi ≤ 0.1909	Avoidance
			Podicipedidae	4	2.9923	0.3636	0.3392	0.0793 ≤ pi ≤ 0.4790	Preference
			Scolopacidae	12	3.8084	0.8571	17.618	0.8738 ≤ pi ≤ 1.0404	Preference
Reed bed with floating vegetation	10	0.0272	Anatidae	0	1004.5701	0	1004.5701	0 ≤ pi ≤ 0	Avoidance
			Rallidae	2	81.719	0.0066	77.768	0.000253 ≤ pi ≤ 0.00158	Avoidance
			Ardeidae	0	2.0130	0	2.0130	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	3	0.2992	0.2727	24.375	0.0095 ≤ pi ≤ 0.5359	Avoidance
			Scolopacidae	0	0.3808	0	0.3808	0 ≤ pi ≤ 0	Avoidance

Contd…

Table 6.8 Contd…

Submerged meadows	187	0..5114	Anatidae	0	188885..919	0	188885..919	0 ≤ pi ≤ 0	Avoidance
			Rallidae	474	1536..322	0.1577	734.564	0.1451 ≤ pi ≤ 0.1704	Avoidance
			Ardeidae	18	37.845	0.2432	10.406	0.1454 ≤ pi ≤ 0.3409	Avoidance
			Podicipedidae	0	5.6265	0	5.6265	0 ≤ pi ≤ 0	Avoidance
			Scolopacidae	0	7.1599	0	7.15995	0 ≤ pi ≤ 0	Avoidance
Waterlogged plantation	37	0.1022	Anatidae	2	3777.183	5.42E-05	3773.184	-2.089 ≤ pi ≤ 0.00012	Avoidance
			Rallidae	11	307.264	0.0036	285.658	0.0015 ≤ pi ≤ 0.0057	Avoidance
			Ardeidae	2	7.5690	0.027	4.0975	-0.00992 ≤ pi ≤ 0.0639	Avoidance
			Podicipedidae	4	1.1251	0.3636	7.3456	0.1356 ≤ pi ≤ 0.1897	Preference
			Scolopacidae	0	1.43199	0	1.43199	0 ≤ pi ≤ 0	Avoidance
Submerged meadows with dry patches	8	0.0217	Anatidae	38	803.656	0.001	729.4529	0.00070 ≤ pi ≤ 0.00135	Avoidance
			Rallidae	0	65.375	0	65.375	0 ≤ pi ≤ 0	Avoidance
			Ardeidae	40	1.610	0.5405	915.123	0.4299 ≤ pi ≤ 0.6540	Preference
			Podicipedidae	0	0.2393	0	0.2393	0 ≤ pi ≤ 0	Avoidance
			Scolopacidae	0	0.3046	0	0.3046	0 ≤ pi ≤ 0	Avoidance

[a] Calculated by multiplying pio x total number of waterbirds of individual family observed (Neu *et al*; 1974).

[b] pi represents theoretical proportion of observation of waterbirds of individual family and is compared to corresponding pio to determine if hypothesis of proportional use is accepted or rejected i.e. pi= pio (Neu *et al*; 1974) at p> 0.05 based on Byers simultaneous confidence interval.

X^2 contribution was derived from the formula $\chi^2 = \Sigma\ (oi- Ei)^2/Ei$ (Byers et al; 1984).

Preference= used more than available, Avoidance= used less than available

Table 6.9 Preference or avoidance of micro- habitat types by individual waterbird families during summer in Hygam wetland.

Habitat Type	**Number of sampling points**	**Proportion of total sampling points (p_io)**	**Waterbird Family**	**Number of birds observed**	**Expected[a] [a]number of birds**	**Proportion [b]observed at habitat type (pi)**	**X^2 distribution**	**Bonferroni confidence interval Pi- Z* sqrt pi(1-pi/)/n ≤ pi ≤ Pi + Z*sqrt pi (1-pi/)/n**	**Habitat Selection**
Tall emergents	59	0.2674	Rallidae	11	156.481	0.0188	135.2547	0.0078≤ pi ≤ 0.0298	Avoidance
			Podicipedidae	0	2.4074	0	2.4074	0 ≤ pi ≤ 0	Avoidance
Paddy fields	30	0.1337	Rallidae	0	78.24	0	78.24	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	0	1.2037	0	1.2037	0 ≤ pi ≤0	Avoidance
Floating vegetation	7	0.0308	Rallidae	574	18.055	0.9811	17117.957	0.9701≤pi ≤ 0.9922	Preference
			Podicipedidae	9	0.2777	1	273.8777	1≤ pi ≤1	Preference
Drawdown meadows	107	0.4835	Rallidae	0	282.87	0	282.87	0 ≤ pi ≤ 0	Avoidance
			Podicipedidae	0	4.352	0	4.352	0 ≤ pi ≤ 0	Avoidance
Dry zone	5	0.0205	Rallidae	0	12.037	0	12.037	0 ≤ pi ≤0	Avoidance
			Podicipedidae	0	0.1851	0	0.1851	0 ≤ pi ≤0	Avoidance
Plantation	14	0.0637	Rallidae	0	37.314	0	37.314	0 ≤ pi ≤0	Avoidance
			Podicipedidae	0	0.5740	0	0.5740	0 ≤ pi ≤0	Avoidance

[a] Calculated by multiplying pio x total number of waterbirds of individual family observed (Neu *et al*; 1974).

[b] pi represents theoretical proportion of observation of waterbirds of individual family and is compared to corresponding pio to determine if hypothesis of proportional use is accepted or rejected i.e. pi= pio (Neu *et al*; 1974) at p> 0.05 based on Byers simultaneous confidence interval.

X^2 contribution was derived from the formula $\chi^2 = \Sigma (oi- Ei)^2 /Ei$ (Byers et al; 1984).

Preference= used more than available, Avoidance= used less than available

6.4.10 Comparison between two wetlands

Habitat preferences by waterbirds in all the three seasons were statistically significant in both the wetlands. However, variation in micro-habitat types between two wetlands and their proportional availability showed variation in habitat preferences by waterbirds between two wetlands. Ardeidae in Hokersar preferred drawdown meadows in all the seasons. Podicipedidae in Hokersar constantly preferred floating vegetation in all seasons. On the contrary in Hygam, these birds showed variations in habitat preference between post-winter and summer seasons. Paddy fields were mostly avoided by waterbirds in all the seasons in Hokersar, while on the contrary no such microhabitat type was found to occur in Hygam.

6.4.11 Seasonal pattern of waterbird activities in Hokersar

The pattern of activities by waterbirds showed a distinct variation within habitats and among three seasons i.e., mid-winter, post-winter and summer seasons. The results indicated that none of the activities was distinct to a particular micro-habitat type in mid-winter. However, variation in pattern of activities among various micro-habitats recorded during mid-winter season was found (Fig.6.1). The figure depicts that pattern of activities by Anatidae varied among micro-habitats. Foraging, swimming, resting and preening were major activities of Anatidae in floating vegetation with swimming found as the most dominant activity. Drawdown meadows also showed foraging and preening by Antidae. Again three types of activities; foraging, preening and resting were recorded from tall emergents with resting as the most dominant activity. Pattern of activities recorded for Rallidae too showed variation among micro-habitat types. Of the four activity types of foraging, swimming, resting and preening by Rallidae, foraging, swimming and resting occurred in floating vegetation; the most dominant activity being foraging. Results further revealed swimming in siltation zone and preening in peatland by Rallidae in this season. Podicipedidae indicated only foraging and swimming in this season, both activities among floating vegetation and plantation with swimming being dominant activity in both the habitats. Other habitats were largely avoided. Ardeidae showed resting in all micro-habitats in this season. Foraging and preening accounted for activities of Ardeidae in drawdown meadows. Siltation zone and paddy fields also showed foraging activity by this bird group.

6.4.12 Activity pattern during post-winter season in Hokersar

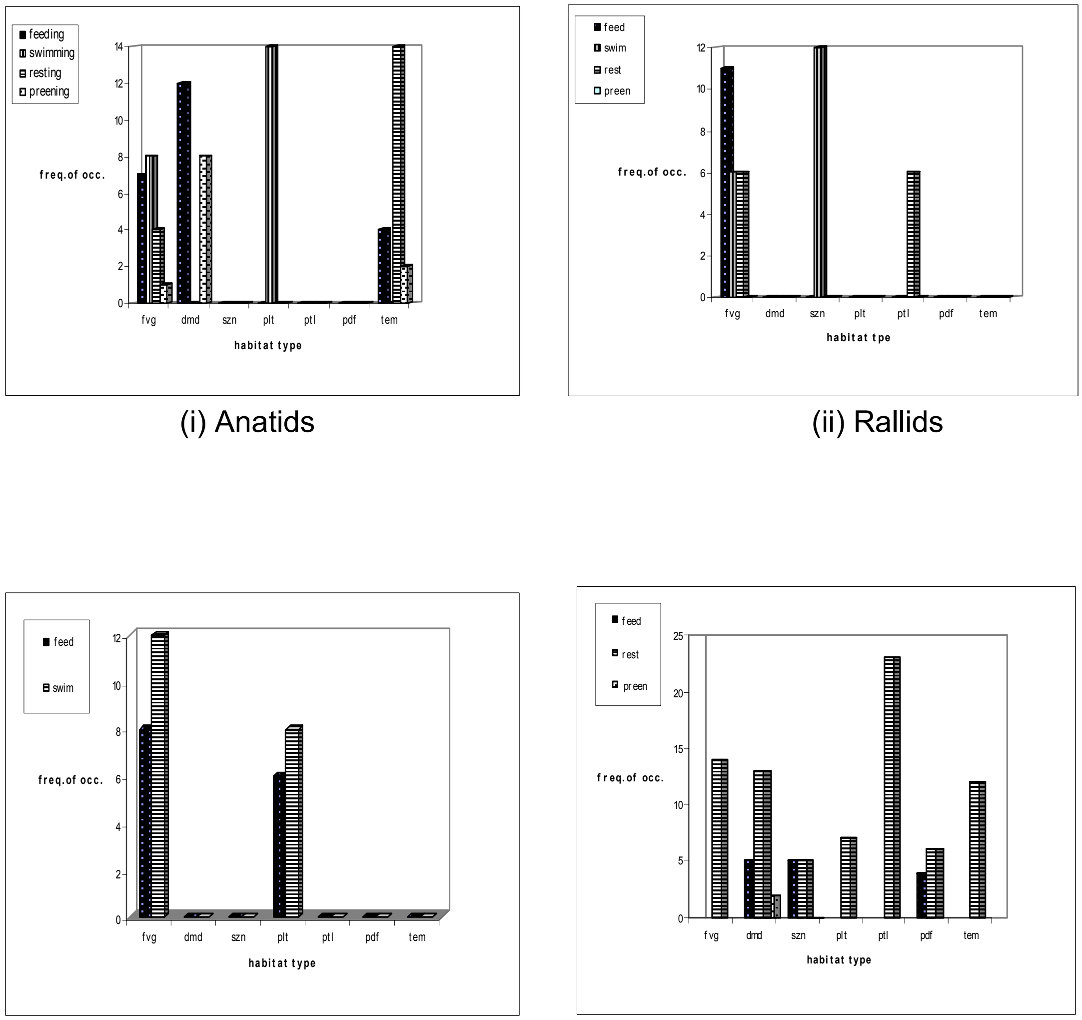
Post-winter season showed considerable differences in activity patterns of waterbird families among habitat types (Fig. 6.2). None of the waterbird family was bound to a particular micro-habitat for any specific activity. There was variation in pattern of activities by Anatidae among various micro- habitats. Figure 6.2 shows three activities i.e. resting, foraging and swimming in submerged peatland, floating vegetation and tall emergents with resting as most dominant activity in submerged peatland and tall emergents and swimming in open water and submergent vegetation. Swimming activity of Rallidae was seen in open water and submergent vegetation, foraging among floating vegetation and resting in tall emergents. Ardeidae showed resting in submerged peatland, peatland, drawdown meadows while that of foraging in drawdown meadows and floating vegetation. Open water showed swimming by Podicipedidae and floating vegetation showed swimming and foraging by this bird group.

6.4.13 Activity pattern during summer season in Hokersar

Five families of waterbirds recorded from this wetland showed variation in activities among micro-habitats in summer season (Fig.6.3). Anatidae showed foraging, resting, swimming and dabbling in floating vegetation. Rallidae showed all its activities of foraging, resting, swimming and dabbling; the most dominant activity as swimming in floating vegetation. This was in addition to some similar activities in other habitats such as swimming in open water; foraging in Trapa beds and resting in tall emergents. Activity pattern of Ardeidae indicated resting in most of the habitats while foraging in only drawdown meadows. Variation in activities of Podicipedidae among micro-habitats was evident from the result. Of the four activities of foraging, swimming, resting and preening in floating vegetation; a few activities were also shown in waterlogged plantation, open water, Trapa beds and tall emergents with none of the activities reported from other habitats by these birds. Charadriidae indicated similar activity of foraging, resting and preening in floating vegetation. However, waterlogged plantation areas were used for foraging by Charadriidae.

6.4.14 Seasonal comparison for activity patterns

Seasonal comparison of activity pattern by individual families of waterbirds showed variation among three seasons. Major activities such as foraging, swimming and resting of most of the birds in mid-winter and summer season were seen among floating vegetation while on the contrary in post-winter season random distribution in activity pattern was seen. Anatidae showed foraging and resting in drawdown meadows in mid-winter season while in post-winter and summer seasons, no activity was seen in this habitat. Dabbling by Anatids in summer season was not seen in mid and post-winter seasons. Podicipedidae showed large number of activities such as in summer season while in mid and post-winter season; only a few activity types were performed.



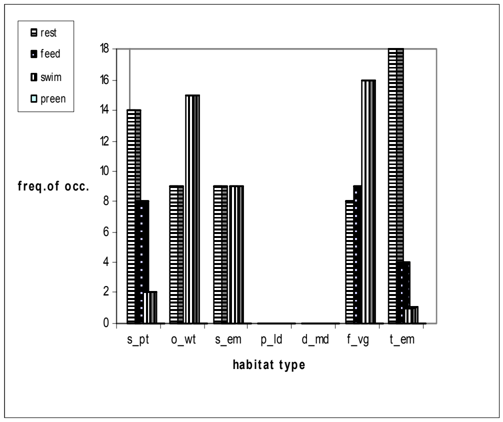
(i) Anatids

(ii) Rallids

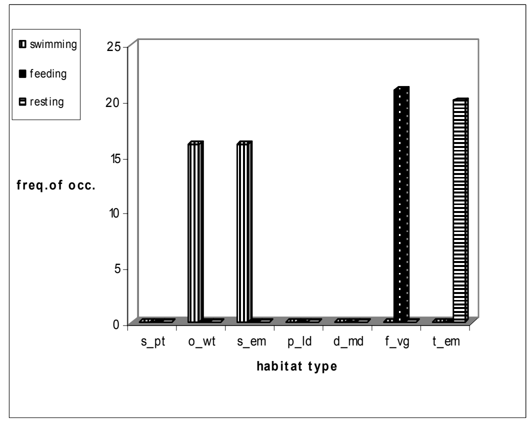
(iii) Podicipeds

(iv) Ardeids

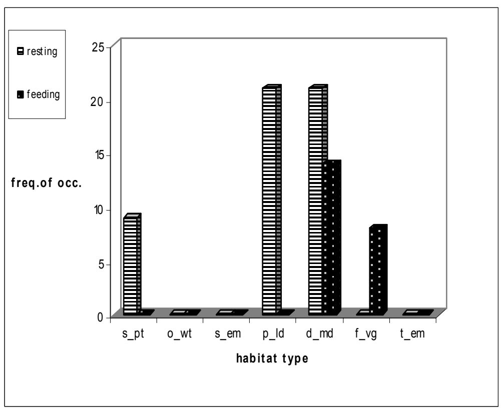
Figure 6.1 Activities of waterbird groups in habitat types in mid-winter season in Hokersar wetland



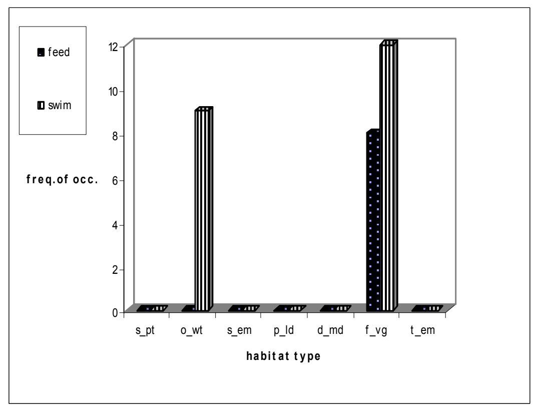
(i) Anatids



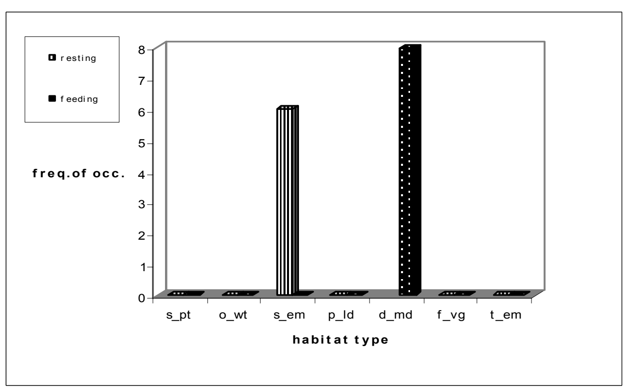
(ii) Rallids



(iii) Ardeids

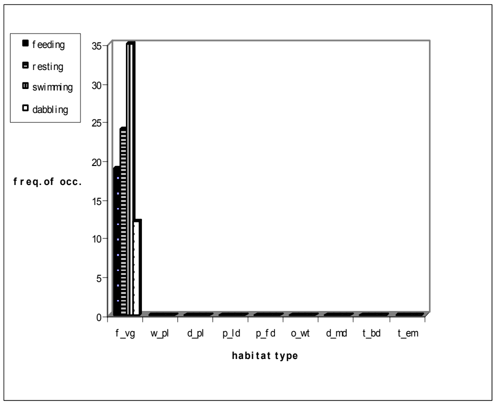


(iv) Podicipeds

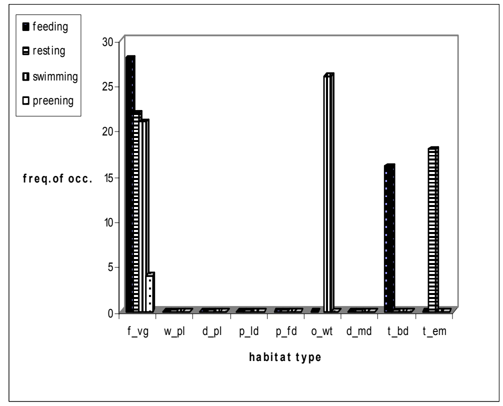


(v) Recurvirostrids

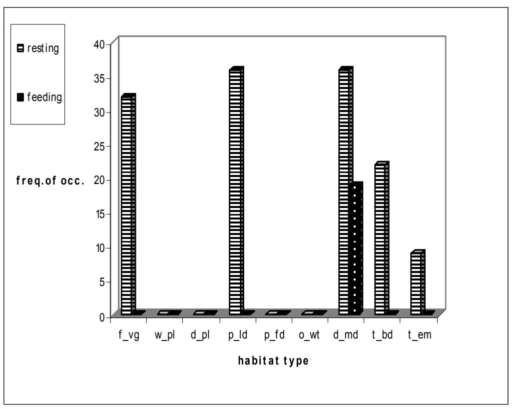
Figure 6.2 Activities of waterbird groups in habitat types during post-winter season in Hokersar wetland.



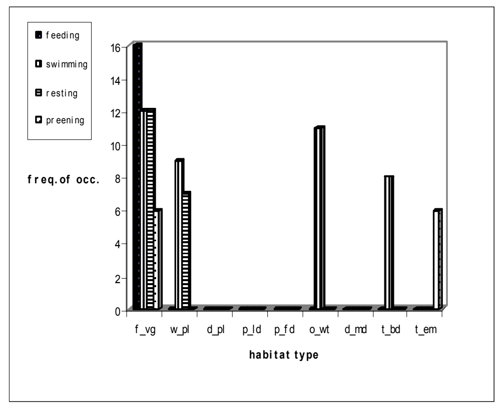
(i) Anatids



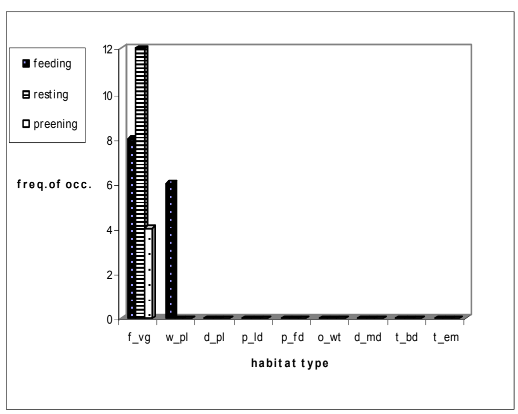
(ii) Rallids



(iii) Ardeids



(iv) Podicipeds



(iv) Charadriids

Figure 6.3 Activities of waterbird groups in habitat types during summer season in Hokersar wetland.

6.4.15 Seasonal pattern of activities by waterbirds in Hygam

The activity pattern showed a distinct variation within habitats and between three seasons i.e. mid-winter, post-winter and summer season. Variation in activity pattern of four waterbird groups were recorded in mid-winter season (Fig. 6.4). The pattern of activities by Anatidae showed variation among habitats. Three activities of foraging, resting and swimming occurred in floating vegetation, the dominant activity being feeding. Results indicated all four activities in floating vegetation; the dominant being foraging activity. Swimming and resting by this group were seen in waterlogged plantation with swimming as dominant activity. Rallidae too indicated activities in only floating vegetation and waterlogged plantation in mid-winter season. Of the three activities of foraging, swimming and resting; all were shown by this bird group in floating vegetation while in waterlogged plantation only swimming and resting were recorded. Ardeidae showed foraging and resting in floating vegetation and resting alone in waterlogged plantation and short emergents with open water. The members of the Phalacrocoracidae rested among floating vegetation. No other activity was seen in any other habitat type by this group.

6.4.16 Activity pattern during post-winter in Hygam

Variation in activity pattern of five waterbird families in different habitats occurred in post-winter season (Fig. 6.5). Results indicated foraging, swimming and resting by Anatidae in open water habitat. Foraging and swimming in reeds with open water and reeds with floating vegetation was found. Rallidae showed foraging and swimming in reeds with floating vegetation and swimming and resting in waterlogged plantation. Only swimming in open water and foraging in reeds with open water was indicated. Resting was the only activity of Ardeidae observed in submerged meadows with dry patches. Podicipediae were foraging in reeds with open water, reeds with floating vegetation and waterlogged plantation. Activities by Scolopacidae indicated both foraging and resting in reeds with open water and resting in reeds with floating vegetation.

6.4.17 Activity pattern during summer season in Hygam

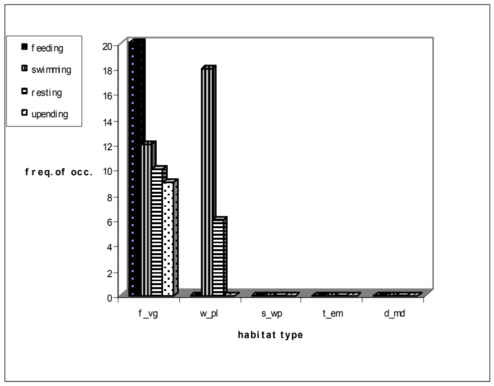
Only two waterbird families recorded in this season showed variation in activity pattern in different habitats (Fig.6.6). Rallidae were found foraging and swimming in floating vegetation and only foraging in tall emergents. Only swimming by Podicipedidae in floating vegetation was indicated in this season.

6.4.18 Seasonal comparison for activity pattern in Hygam

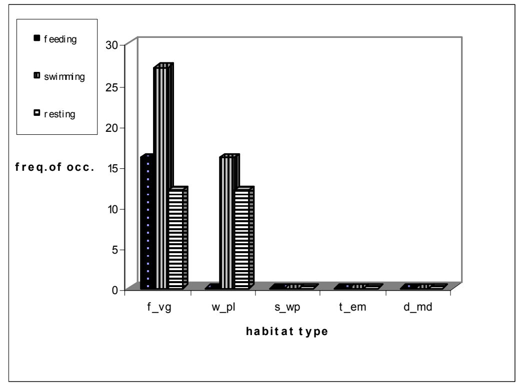
Variation in activity pattern of individual waterbird families among seasons was apparent. Individual waterbird families showed variation in their activity patterns in utilized habitats between three seasons. Seasonal comparison indicated that waterbird families recorded in mid-winter and summer season showed all categories of activities among floating vegetation; however few similar activities here also indicated in other habitats by individual waterbird groups. On the contrary in post-winter season, a random distribution of activities in utilized habitats by waterbird groups was seen (Fig.6.5).

6.4.19 Comparison between two wetlands

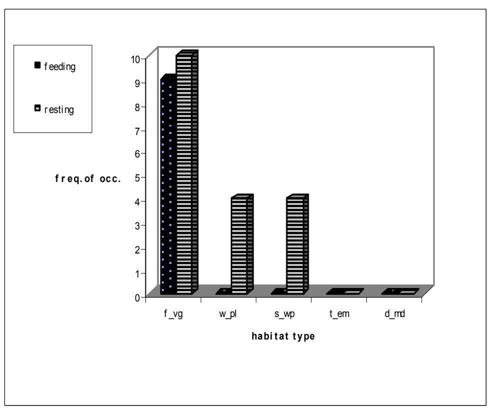
Variation in activity pattern by individual waterbird groups were found among utilized habitats in two wetlands over three seasons. The two wetlands showed variation in habitat types in all the seasons. In mid-winter in Hokersar, Anatidae showed preening activity among floating vegetation with dominant activity being swimming. On the contrary in Hygam, dabbling by Anatidae from floating vegetation was seen with foraging as the dominant activity. Ardeidae showed a variation in their pattern of activities in mid-winter season between two wetlands. All habitat types in Hokersar reported activity by Ardeidae while in Hygam activity was restricted to few habitat types by Ardeidae. Birds were more active in submerged peatland and submerged emergents in Hokersar wetland in post-winter season and on the contrary in Hygam most of the activities by many bird groups were indicated from reeds with open water and reeds with floating vegetation. Anatidae indicated many activities in various habitat types in summer season in Hokersar and in Hygam. Podicipedidae in Hokersar wetland showed many activities in various habitat types in summer season (Fig.6.6). While in Hygam this group indicated only swimming in floating vegetation in this season.



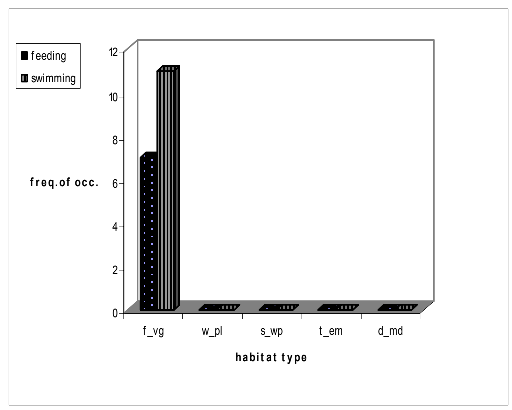
(i) Anatids



(ii) Rallids

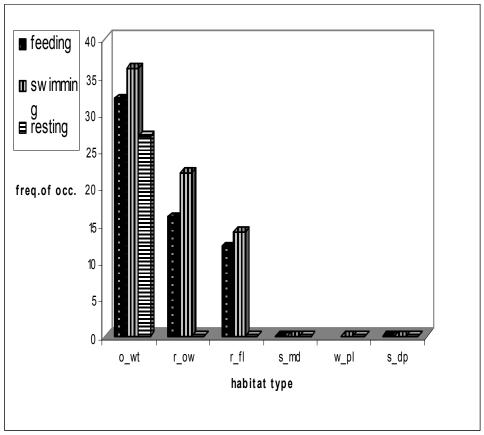


(iii) Ardeids

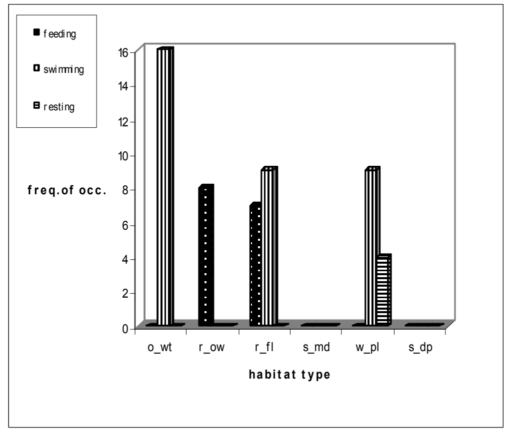


(iv) Phalacrocoracids

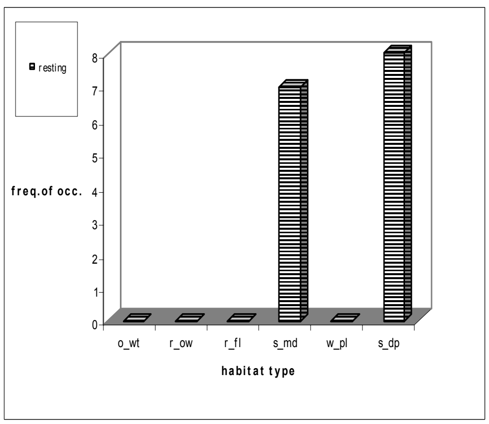
Figure 6.4 Activities of waterbird groups in habitat types during mid-winter season in Hygam wetland



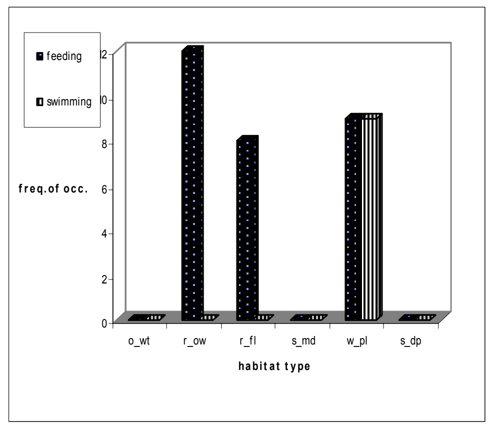
(i) Anatids



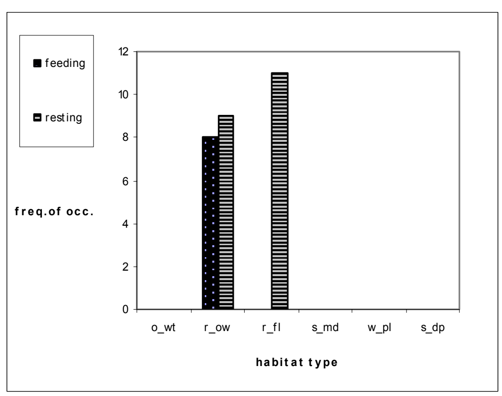
(ii) Rallids



(iii) Ardeids

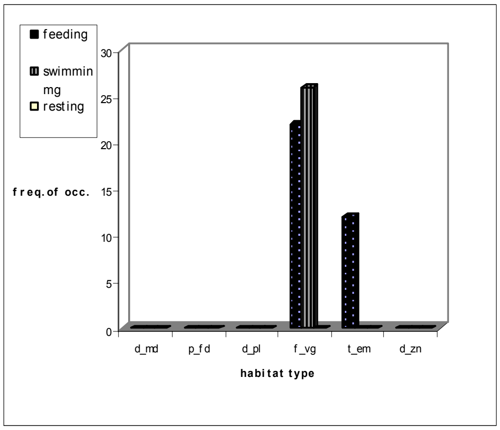


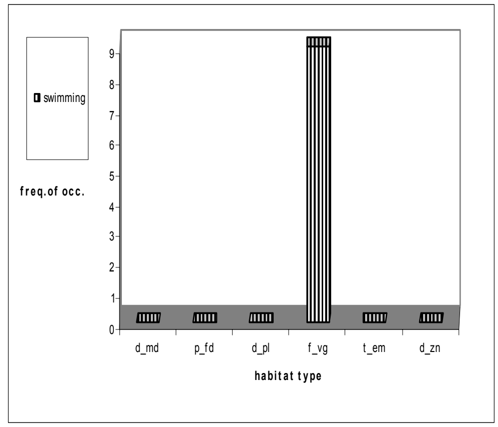
(iv) Podicipeds



(v) Scolopacids

Figure 6.5 Activities of waterbird groups in habitat types in post-winter season in Hygam wetland.





(i) Anatids (ii) Rallids

Figure 6.6 Activities of waterbird groups in habitat types in summer season in Hygam wetland.

6.5 Discussion

Habitat use patterns by wintering populations of migratory waterbirds and summer residents showed marked preference for certain habitats in Hokersar and Hygam wetlands in mid-winter, post-winter and summer seasons. Seasonal variation in habitat preference by different bird families was indicated in the present study. True habitat selection occurs when individuals exercise a choice among available habitats, instead of differentially occupying them as a consequence of extrinsic factors like predation and competition. (Klopfer, 1969; Wiens, 1976; 1977).

Safran et al. (1997, 2000) suggested that water depth strongly influenced food availability among waterbirds. Nagrajan and Thiyagesan (1996) reported that habitat selection by wintering waterbirds is influenced by food availability and accessibility. Our results corroborated their conclusions. Dabbling ducks in present study showed preference/affinity to habitats with physiognomy of openness of water and mainly vegetation as floating leaved types in all three seasons of mid-winter, post-winter and summer. This affinity was found because of presence of larger foraging sites and adequate food resources available in floating vegetation habitat types. This reason perhaps facilitates preference to these habitat types in three study seasons. Dabbling ducks ecologically prefer areas with low water depth to dabble or sieve seeds and invertebrates from shallow water. Aquatic invertebrates are more abundant in emergent herbaceous and floating-leafed vegetation than in ericaceous vegetation (Reinecke 1977: 85; Ringelman, 1980). Consequently, access to benthic invertebrates is a strong selective force shaping the morphology, behavior and distribution of waterbirds. However vegetation type alone does not show much influence, rather it is the habitat structure that appears to determine habitat use by the species. Previous studies (Christiansen and Low, 1970; Sanderson, 1980) suggested that habitat characteristics of presence of adequate food and habitat area influence waterbirds' habitat utilization and are consistent with the findings of present study.

Standing water can increase the availability of heavily used moist-soil plant seeds (LaGrange, 1985), increase the palatability of food items (Shearer et al; 1969), and perhaps increase the security of waterfowl from land predators and disturbance. This pattern of habitat utilization by Anatidae was similar in two wetlands which reflected a similar pattern of heterogeneity in habitats of two wetlands. Anatidae also indicated preference to submerged peatland and open water in post-winter season and open water in summer season in Hokersar wetland. The bird family indicated preference to open water and reed bed with open water in summer season in Hygam wetland. Rallidae on the contrary, did not show specific preference to any of the habitats in three seasons of mid-winter; post-winter and summer in both Hokersar and Hygam. Rallidae showed strong affinity to deeper and open waters (Weller, 1999), which was partly explained by the fact that the birds are equipped with lobate toes effective for diving to feed on both vegetation and invertebrates. The present study indicated preference for open waters by Rallidae in both wetlands during post-winter seasons and not in mid-winter and summer seasons. Absence of such type of habitats in mid-winter and summer seasons is responsible for such pattern of habitat use by members of this family.

Ardeidae showed preference to drawdown areas in Hokersar wetland in all three seasons. In contrast the bird group however did not exhibit any pattern of specific habitat preference in Hygam wetland. The bird group avoided drawdown meadows in mid-winter season in Hygam. Floating vegetation in Hokersar wetland was seen as preferred habitat to Podicipedidae in three seasons. Floating vegetation was selected in summer season by this group in Hygam. Podicipeds preferred reed bed with open water and waterlogged plantation in post-winter season in Hygam. The findings in the present study revealed floating vegetation were used adequately where major waterbirds were seen. Ecological isolation of species enables them to partition resources at spatial scale in such a way that each species is limited by different factors. The same reason is attributed to present case where floating vegetation in Hokersar and Hygam wetlands was seen to meet the resource requirements of all major waterbird groups. This indicated that habitat preference is related to food availability. Interspecific differences in habitat selection are often ascribed to variation in morphology or physiology (Cody 1985, Morse, 1985; Sherry and Holmes, 1985; Martin, 1995). Paddy fields were indicated as only habitats avoided by waterbirds (all groups reported) in all three seasons of study in Hokersar wetland presumably because of lower food supply.

Presence of aquatic habitats which meet the ecological requirements of waterbirds in two study areas appear as the main factor contributing to this pattern seen. However, the birds also seem to avoid these habitats on account of human disturbance from nearby villages. Past study (McKinney et al; 2006) showed landscape setting of a habitat e.g. nearby residential development influence waterfowl habitat utilization in an urban estuary and is consistent with the findings of the present study.

Tall emergents and drawdown meadows were indicated as the only habitat types avoided in mid-winter and summer season in Hygam wetland by all waterbird groups. However, these habitats were absent in post-winter season in Hygam. The findings of the current study supported the widely held view (e.g. Helmers, 1992) that differences among waterbirds in habitat use is largely a function of water depth (Baker, 1979; Poysa, 1983; Colwell and Oring, 1988; Dubowy 1988; Weber and Haig, 1996) and constrained by morphology to use zones of water depth within which they forage at random with respect to invertebrates.

No habitat specific activity was seen in any of the utilized habitats in general by major waterbirds in all three seasons of study in Hokersar and Hygam wetlands. The findings revealed major activities of waterbirds confined to foraging, swimming, resting and preening categories. Results further indicate most of these activities by major waterbird groups in three seasons of study mainly in floating vegetation areas which confirmed floating vegetation habitats in both wetlands as priority for conservation of waterbirds. Other factors contributing to patterns of activities in floating vegetation areas could be foraging behavior of waterbirds and relatively a very low water depth in these habitat types. However, foraging locations of waterfowl in two study wetlands represented a number of habitat types. This indicates invertebrate biomass distributed over a wide range of habitat categories in two study wetlands.

However, waterbirds specific to some seasons indicated specific activities in utilized habitats in both wetlands. Recurvirostridae in Hokersar wetland indicated resting specific to submergent vegetation and foraging to drawdown meadows in post-winter season. Charadriids showed resting and preening in only floating vegetation in summer season. Hygam wetland revealed resting in only floating vegetation in mid-winter season by Phalacrocoracidae and foraging in only reedbed with open water type of habitat in post-winter season by Scolopacidae. Phalacrocoracidae and Scolopacidae were absent from Hokersar wetland.

Existing information suggests that adequate habitats exist in Hokersar and Hygam wetlands to fulfill the critical needs of the over-wintering populations of migratory waterbirds and summer residents. To maximize utilization of these wetlands by waterbird populations, managers need to increase their habitat heterogeneity considering the fact that varied waterbird families show variation in their habitat preferences. Floating vegetation existed as prioritized habitat types to provide maximum resource requirements to waterbirds. The areas provide conducive staging grounds to over-wintering populations of migratory waterbirds and a segment of summer residents. These areas provide security, nutritious food resources and energy demands to both migratory and resident waterbirds in two wetlands. In order to protect waterbird populations in Hokersar and Hygam wetlands floating vegetation areas, waterlogged plantations, open waters and other habitat types should be protected. However, these habitat types are suffering severe destruction by excessive siltation and biotic interferences (Rashid and Joshi, 2000). Prohibition of destruction of these habitats and the production of more extensive patches of floating vegetation should be implemented. Enhancing vegetation- water interspersion is needed as a management effort. Management through legislation, changes in agricultural policy, and/or innovative conservation easement can help the habitats of Hokersar and Hygam wetlands to be protected and the effective use of these ecosystems by waterbird populations.

6.6 Summary

The habitat utilization by waterbirds was studied in Hokersar and Hygam wetland conservation reserves in mid-winter, post-winter and summer seasons. Noticeable differences were detected in habitat preferences by all groups of waterbirds for seven habitats in mid-winter; eight in post-winter and nine in summer season from Hokersar and for five habitats in mid-winter; six each in post-winter and summer seasons from Hygam. Anatidae showed marked variation in habitat preferences in three seasons of study in Hokersar. Ardeidae showed consistent preference for drawdown meadows in three seasons and Podicipedidae for floating vegetation in Hokersar. Paddy field was the only habitat avoided in all the three seasons. Anatidae recorded from Hygam preferred floating vegetation in mid and post-winter seasons. With the exception of floating vegetation, all habitats from Hygam in summer were avoided.

Type of activities in different habitat types showed marked variation by waterbirds with change in seasons from both wetlands. Anatidae showed most of its activities in floating vegetation in mid and post-winter seasons in Hokersar. Floating vegetation was only habitat in Hokersar which showed all activities in mid-winter while this habitat was extensively used for all activities during summer season in Hygam.

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CHAPTER 7

SOCIOECONOMICS, RESOURCE DEPENDENCY AND ATTITUDES OF LOCAL PEOPLE

7.1 Introduction

The thrust of India's wildlife conservation policy has been preservationist, wherein emphasis has been placed on minimizing or eliminating consumptive human uses within areas designated for the protection of wildlife (Mishra, 2000). Despite such an exclusionary official policy, natural resource dependency is a common feature in India where as per the current estimates about 66% of the population is rural and more than 170 million of them are poor. More than 80% of the protected areas have human presence and some level of natural resource use, albeit within state-imposed restrictions (Kothari et al., 1989). Dependency on the natural resource base is the result of lower socio-economic status and lack of infrastructural facilities (Badola, 1997). Use of natural resources has also been the part of traditions and culture of the majority of rural population (Panwar, 1990). The conservationist approach demands local communities to have access to natural resource base in a sustainable way. Restrictions on traditional resource use following the creation of protected areas are responsible for local hostility and absence of local support for conservation efforts (Kothari *et al*., 1989; Saberwal, 1996). In a situation where the ownership and management of these wetland resources is under state controlled formal institutions, the traditional management structures have become marginalized. The existing protected area system in India allows for little involvement of local communities in resource management. The resultant conflict between different social groups and between the state and civil society precludes setting up of sustainable resource management.

Community attitude and perception towards conservation influences the kinds of interactions people have with PAs, and thereby conservation effectiveness.

Local communities in almost all parts of world depend on wetland for fisheries, reed harvesting, grazing etc. (Ozesmi, 2002). High habitat diversity, extent of resources, ecotones and refugia within wetlands make them to typically support a high diversity of species (generalized across all taxa) compared to surrounding uplands (Schweigner, *et. al*., 2002). When decisions affecting wetlands are made with inadequate knowledge of attitudes of local people and practices of resource use, conservation programs are unlikely to be successful (Sah & Heinen, 2001; Pyrovetsi & Daoutopoulos, 1991).

This chapter deals with the resource dependency and attitudes of local communities towards conservation for the Hokersar and Hygam wetland reserves of Jammu & Kashmir state.

7.2 Methods

The data was collected in two stages of sampling between June and October 2006. The first stage of data collection was mainly from secondary sources that covered all the 30 villages located within a distance of five km from Hokersar wetland and other 26 villages from Hygam wetland. Published records maintained at the office of directorate of economics and statistics, department of planning and development, district collector office, Tehsil offices and census of India, 2001 were scrutinised. In total data on 20 parameters of all villages was collected which included information regarding location and distribution with respect to wetland, demographic profile of villages, pattern of land –use, livestock information, information on access to facilities such as PHC's, schools, communication centres, administrative offices, approach to villages, source of drinking water and source of electricity.

In the second stage, four villages in four different directions around two wetlands were selected for intensive study. The representative villages were selected based on proximity to wetlands and various development indicators. These included Zainakot, Sozeith, Aliabad and Soibugh villages for Hokersar wetland and Hanjipora, Aakhanpora, Sukhul and Rengi for Hygam wetland.

Using 10% stratified random sampling approach, an intensive household survey was conducted which included equal proportion from all castes. This formed a resulting sample of 190 households for Hokersar wetland and 42 households for Hygam wetland. Each household represented one sample unit. For determining the socioeconomics and assessment of wetland resource use, a structured questionnaire was designed to obtain information on various parameters viz demographic structure of households i.e. family size, sex, literacy level, occupational structure, livestock holding, land holding, agriculture practices, product, income generating pattern, wetland resource use pattern, income generated from wetland resources and degree of dependency.

An attitudinal survey was taken up in the sample villages to know the perception and attitude of local people towards conservation issues. A set of semi-structured along with a few open type questions were used to interview the selected households regarding their attitude towards conservation, their views regarding various problems confronting the wetlands and opinion on alternative management scenarios. Yes/ No type close-ended questions as well as those having a series of statements were presented. The interviews were carried out after visiting each household.

7.3 Analysis

The data collected were compiled in MS Excel software. The data was statistically analysed following Zar (1974) using computer programme SPSS/PC+4.0 (Norussis, 1994). Correlation among different ordinal and Interval/Ratio (qualitative) variables was examined by working out Pearson's product moment correlation coefficient using bivariate procedure of SPSS/PC+. Pearson Chi square test was performed using CROSSTAB procedure of SPSS/PC+ to determine the correlation between nominal level (quantitative) variables.

7.4 Results

7.4.1 Pattern of distribution of villages around Hokersar and Hygam wetlands

Thirty villages were located within five km radius of the Hokersar wetland. All were revenue villages. Only four villages were located very close (<1 km) to the wetland and the rest were distributed in the range of three to five km (Fig.7.1). Twenty-five villages were found around Hygam wetland. Among these, two villages were located closer (<1km) to the wetland while most of them were distributed in the range of two to five km (Fig.7.2).

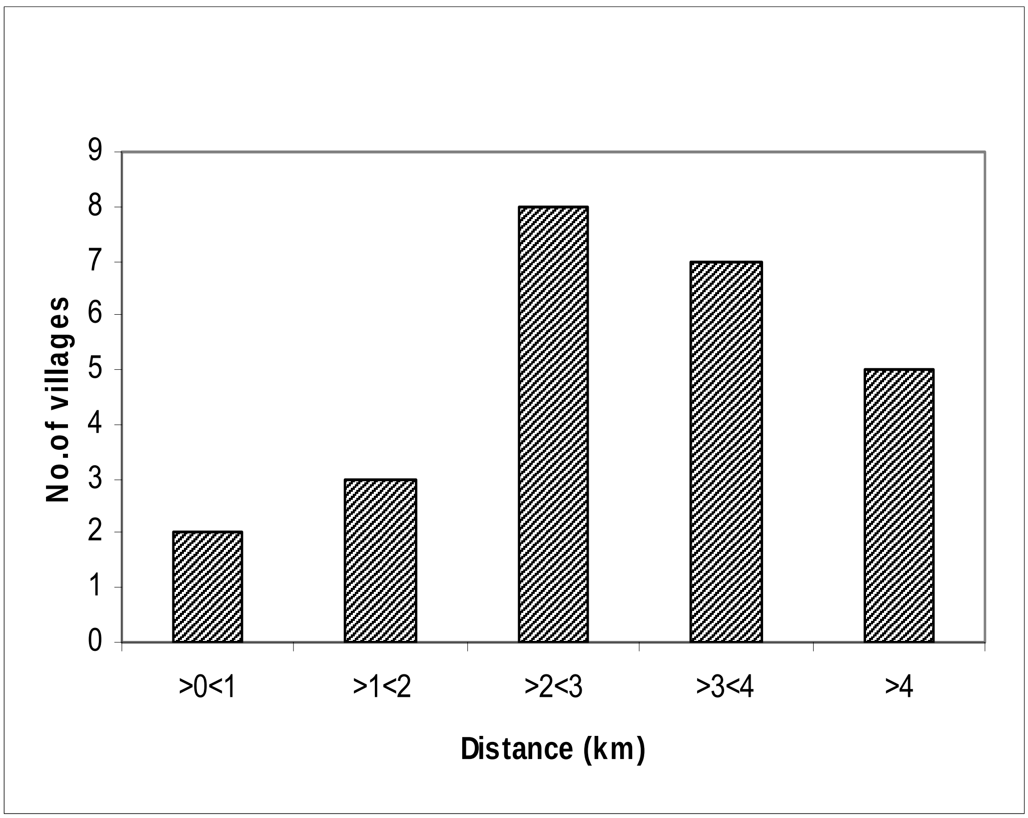

Figure 7.1 Distribution of villages around Hokersar wetland, Jammu & Kashmir.

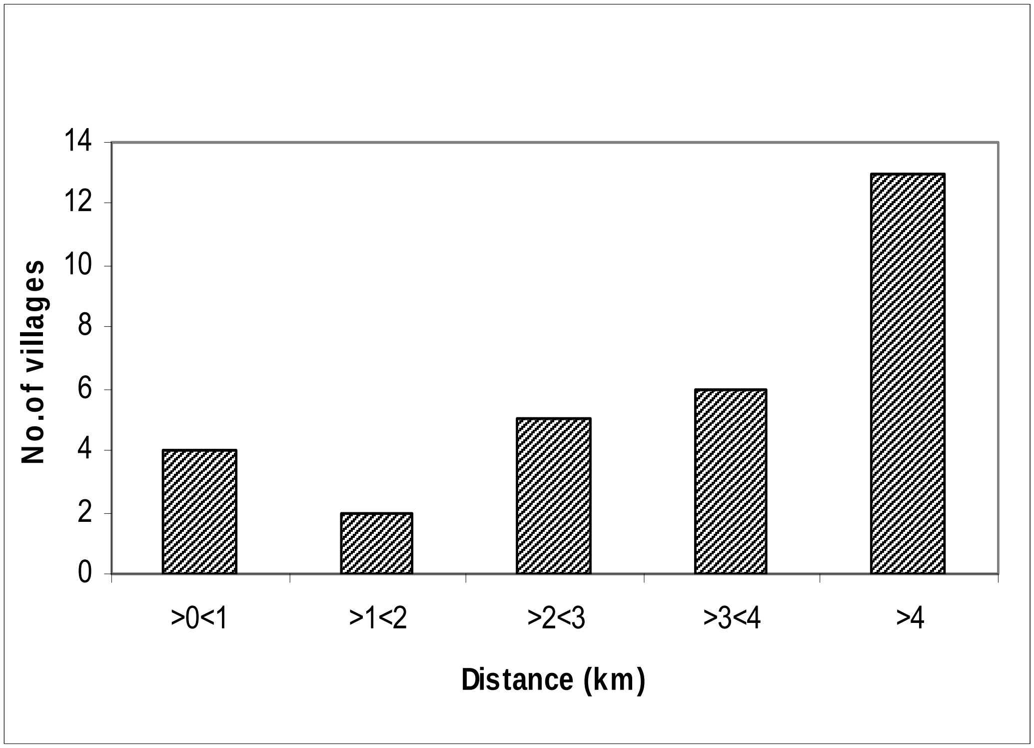

Figure 7.2 Distribution of villages around Hygam wetland, Jammu & Kashmir.

7.4.2 Socio-economic profile of villages

The total human population of 30 villages surrounding Hokersar wetland was 70,310. The entire area was found moderately populated. The results indicated that the average literacy rate of the villages was 18.6% with education being imparted only at secondary level. Male literacy was more (24%) than females (12%). About 80% were found to own cattle and the land owing families constituted around 76.8% of the figure (Table 7.1). Average number of houses in the surrounding villages was 294 having average area as 265 ha. Land use statistics for the study villages indicated lower irrigated land (41.7%) than non-irrigated land (46.3%) (Table 7.2). Basic infrastructure of the surrounding villages was moderate, while administrative facilities were weak (Table 7.3).

Around Hygam wetland, the total human population of the surrounding 25 villages was 1, 13,790. The whole area was found moderately populated. The average literacy rate of the villages was 20%. Male literacy was found to be more (25%) than females (18%). The average number of households in the surrounding villages was 342 (Table 7.1).

Table 7.1 Demographic profile of villages within five km radius of Hokersar and Hygam wetlands, Jammu & Kashmir.

Demographic Parameter	**Hokersar (Mean)**	**Hygam (Mean)**
Population density ha^{-1}	53±188.1	66± 134
Sex ratio	0.8±0.1	0.8± 0.1
Average literacy (%)	18.6±17.8	20.5± 15.3
Male literacy (%)	24.1±18.8	25.5± 17.4
Female literacy (%)	12.3±17.5	18.0± 21.85
Average number of household $village^{-1}$	293.6 ±239	342± 438
Employment level (%)	58±0.1	59.6 ± 22.7
Average cattle population $village^{-1}$	575.3± 469.1	1762± 2079
Cattle owing families (%)	80.1± 39.7	99
Land owing families (%)	76.8± 42	99

The average area of the villages around Hygam wetland was found as 214 ha. The total land area of all the villages was found to be 5288 ha. Out of the total land area, 54.77% was irrigated land and 45.2% was un-irrigated. A small percentage of 12.4 % was uncultivated (Table 7.2). The average literacy level was 18.6% with education imparted at secondary level only. The administrative facilities in villages surrounding Hygam wetland were weak (Table 7.3).

Table 7.2: Land use statistics of villages within five km radius of Hokersar and Hygam wetlands, Jammu & Kashmir.

Land Utilisation (ha)	Hokersar	Hygam
Village area	10070	5348.16
Irrigated land	4198	2896.64
Non-irrigated land	4661	1735.53
Uncultivated or fallow land	1211	655.85

Table 7.3 Access to services in the surrounding villages of Hokersar and Hygam wetlands, Jammu & Kashmir.

Access to service	Number of Villages	
	Hokersar	Hygam
Primary school	27	19
Middle school	21	11
High school	8	6
Primary health centre	15	15
Hospital	2	1
Police station	2	1
Tehsil office	0	1
Post office	10	7
Metalled road	27	16
Electricity	30	25
Piped/Tap water	30	25

The results indicated densely populated area and a more literate population around Hygam wetland than Hokersar. Population was found more employed around Hygam wetland than Hokersar. A high variation was found in cattle population around the two wetlands with villages around Hygam wetland having more number of cattle (44050) than Hokersar wetland (17260). Land use statistics indicated less irrigated area around Hygam wetland than Hokersar.

7.4.3 Socio-economic profile of intensive villages

The villages Zainakot, Aliabad, Sozeith and Soibugh represented four intensive study villages around Hokersar wetland. Human population and area extent of Soibugh was found to be highest. Results indicated Sozeith having lower literacy when compared to other three villages (Table 7.4). The household sampling indicated 18 diverse caste groups around Hokersar wetland. *Dar* was found to be the dominant caste with 12% families. None of the community had schedule caste or schedule tribe status (Table 7.5). Around 92.3% of families were found to own land.

The villages Aakhanpora, Hanjipora, Rengi and Sukhul represented intensive villages around Hygam wetland. Of all villages, Rengi had the highest human population and was largest in terms of area. The overall literacy rate was again higher in this village than other three villages (Table 7.4). Seven caste groups were identified with *Dar* as dominant community (50% families). No schedule tribe and schedule caste communities were found (Table 7.5). The results showed 73.8% of the families owned land.

The results indicated intensive villages around Hokersar wetland more populated and larger in area than villages around Hygam. The literacy rate was higher in villages around Hokersar wetland than around Hygam. A more diverse caste composition existed around Hokersar wetland than around Hygam wetland. *Dar* (fishermen community) as a dominant caste represented only 12% of sampled families around Hokersar wetland while around Hygam wetland, 50% of families were found to belong to this group. A larger population around Hokersar wetland owned land (92.3%) while only 73.8% of the families were found to own land in villages around Hygam wetland.

Table 7.4 Socio-economic characteristics of sample villages around Hokersar and Hygam wetlands, Jammu & Kashmir.

Parameter	**Villages around Hokersar**				**Villages around Hygam**			
	Zainakot	Soibugh	Sozeith	Aliabad	Aakhanpora	Hanjipora	Rengi	Sukhul
Location	West	North-west	North-east	East	East	West	South-west	South
Distance from wetland (km)	0.1	0.3	0.1	0.2	0.3	0.4	1	1.5
Village area (ha)	273.16	604	319	210.77	19	9	140.83	11
Number of households	1000	1000	647	403	80	60	170	29
Total population	8646	10196	4000	3500	820	600	1500	175
Sex ratio	0.95	0.94	0.9	0.98	0.6	0.5	0.7	0.9
Literacy (%)	30	42	13.1	21.7	1.2	6.6	7.3	6.8
Land owing families (%)	99	100	100	100	100	100	100	100
Cattle owing families (%)	99	90	100	100	100	100	100	100

Table 7.5 Caste composition with percent proportion of families around Hokersar and Hygam wetlands, Jammu & Kashmir.

	Hokersar			Hygam		
No.	**Caste**	**Number of Families**	**%**	**Caste**	**Number of Families**	**%**
1.	Ahangar	4	0.02	Ahangar	0	0
2.	Beig	4	0.02	Beig	0	0
3.	Bhagat	7	0.03	Bhagat	0	0
4.	Bhat	21	0.11	Bhat	0	0
5.	Dar	23	0.12	Dar	21	0.5
6.	Ganai	17	0.08	Ganai	7	0.16
7.	Hajam	3	0.01	Hajam	4	0.09
8.	Khan	9	0.04	Khan	0	0
9.	Malik	15	0.07	Malik	0	0
10.	Malla	4	0.02	Malla	2	0.04
11.	Mir	11	0.05	Mir	2	0.04
12.	Parray	16	0.08	Parray	0	0
13.	Kumar	5	0.02	Kumar	0	0
14.	Shah	5	0.02	Shah	0	0
15.	Sheikh	9	0.04	Sheikh	0	0
16.	Sofi	17	0.08	Sofi	0	0
17.	Wagay	6	0.03	Wagay	0	0
18.	Wani	14	0.07	Wani	0	0
19.	Laway	0	0	Laway	1	0.02

7.4.4 Occupational structure

The results indicated surveyed population around Hokersar wetland engaged in 13 occupations. A larger population (77.8%) had agriculture as their main occupation (Fig.7.3). In total, nine occupation categories were identified in the sample population around Hygam wetland with 71.4% of families engaged in agriculture (Fig.7.4).

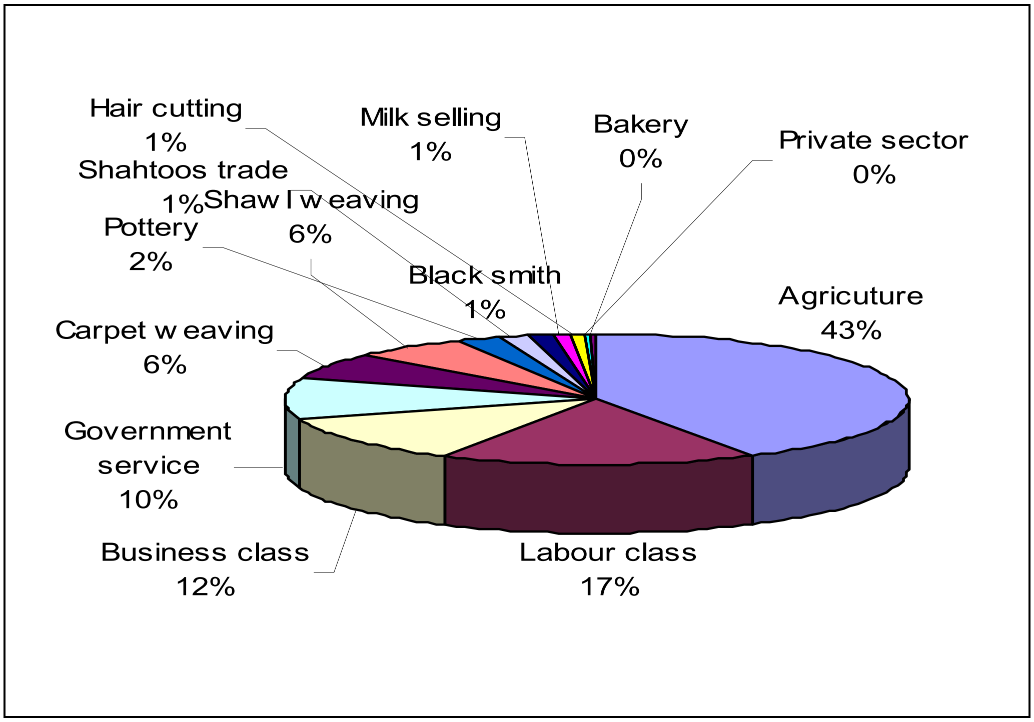

Figure 7.3 Occupational structure of sampled population around Hokersar wetland, Jammu & Kashmir.

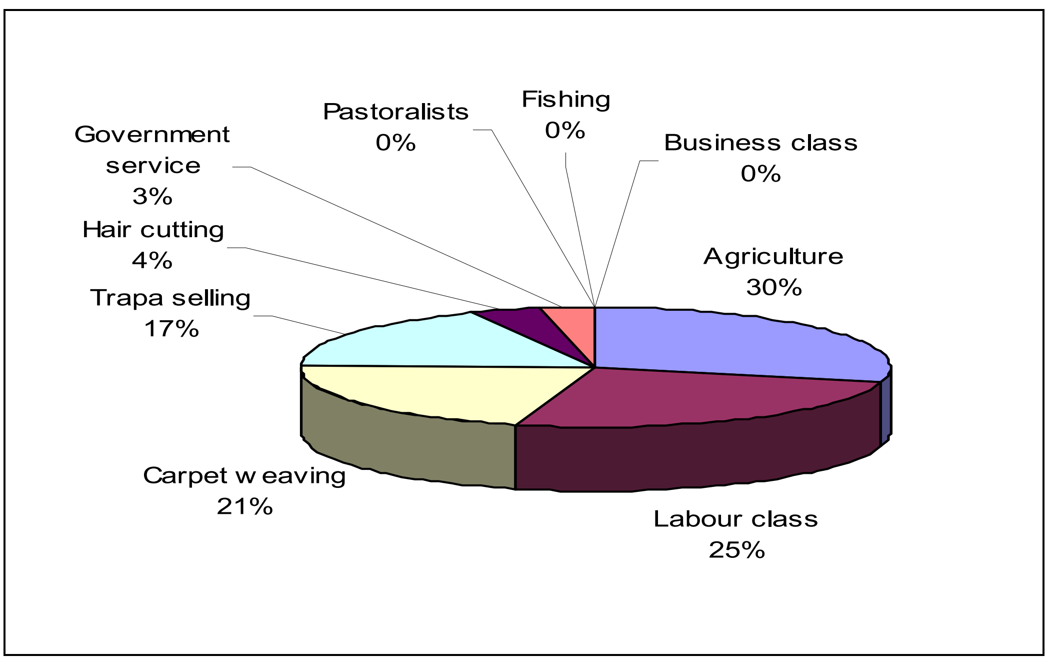

Figure 7.4 Occupational structure of population around Hygam wetland, Jammu & Kashmir.

In both areas occupation was found to be associated with education as evident from families engaged in government service being more educated. The population surveyed around Hokersar wetland was engaged in more occupations than around Hygam. None of the families around Hygam wetland was associated with government jobs and business activities. More families around Hokersar wetland were educated than around Hygam.

7.4.5 Resource use and intensity

A total of 13 consumptive and non-consumptive resource use categories were identified in Hokersar wetland. The results showed 82.3% of families surveyed depended on wetland resources. Consumptive uses included reed harvesting; fuelwood collection; irrigation; paddy cultivation; peat collection; fishing; livestock grazing; clay gathering; cattle fodder and agriculture while the non-consumptive uses included domestic, sewage discharge and solid waste disposal. Harvesting of the reeds was indicated as most intensively used resource (50% of families found to use reeds) (Fig.7.5). Four percent families depended fully for subsistence on wetland resources.

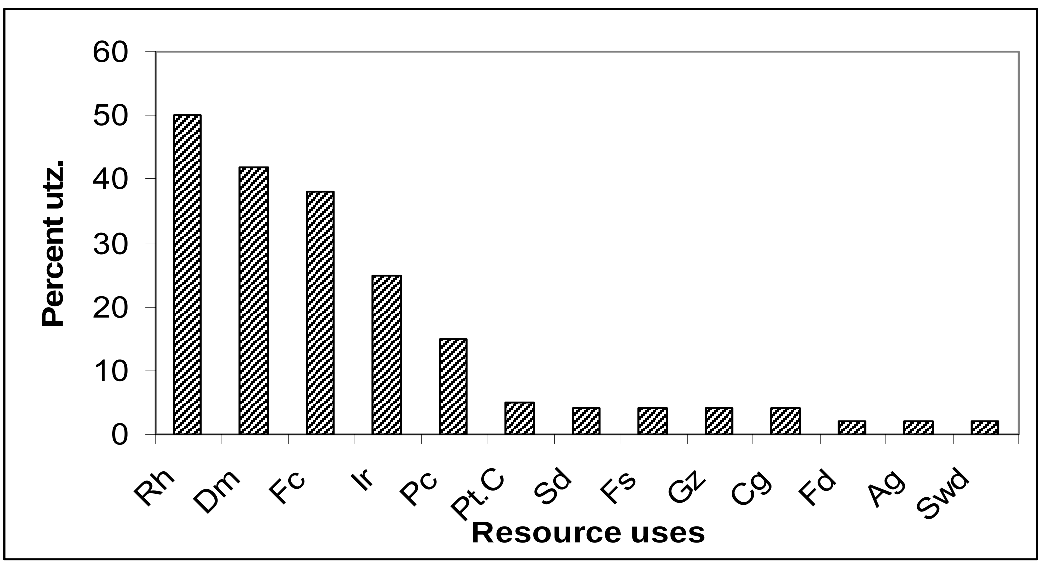

Figure 7.5 Percent utilisation of resource uses around Hokersar wetland, Jammu & Kashmir.

(Rh= reed harvesting; Dm= Domestic; Fc= Fuelwood collection; Ir= Irrigation; Pc= Paddy cultivation; Pt.C= Peat collection; Sd= Sewage discharge; Fs= Fishing; Gz= Grazing; Cg= Clay gathering; Fd= Fodder; Ag= Agriculture; Swd= Solid waste disposal).

A total of 14 consumptive and non-consumptive resource use categories were identified in Hygam wetland. The results showed 97% of families dependent on wetland resources. Livestock grazing was most intensively used resource with 85.8% of families dependent on it (Fig.7.6). High intensity of livestock grazing could be due to the fact that most of the population in the surrounding villages was engaged in pastoral activities.

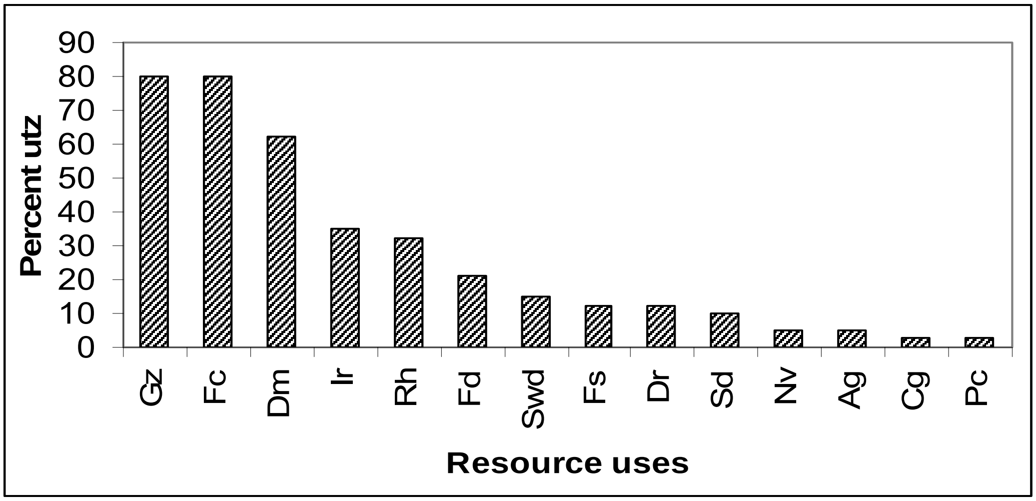

Figure 7.6 Percent utilisation of resource uses around Hygam wetland, Jammu & Kashmir.

(Gz= Grazing; Fc= Fuelwood collection; Dm= Domestic; Ir= Irrigation; Rh= Reed harvesting; Fd= Fodder; Swd= Solid waste disposal; Fs= Fishing; Dr= Drinking; Sd= Sewage discharge; Nv= Navigation; Ag= Agriculture; Cg= Clay gathering; Pc= Paddy cultivation).

A high dependency on wetland resources of Hygam wetland than of Hokersar was observed. Around 82.3% of the families surveyed depended on resources of Hokersar wetland. While for the Hygam wetland, it was 97% of the surveyed families that depended on these wetland resources. Harvesting of reeds was a common resource use in the Hokersar wetland and on the contrary, in Hygam wetland, livestock grazing was a common resource use.

7.4.6 Influence of socioeconomic parameters on resource use

The results indicated that caste was found to influence wetland dependency around Hokersar wetland (Pearson Chi Square= 1968.15; $p = 0.001$) (Table 7.6). Caste was also found to determine the intensity of wetland use (Pearson Chi Square= 180.000; $p < 0.0001$). Results further indicated maximum utilisation of wetland resources by *Malik* community (93% of surveyed families) followed by *Bhat* community (81%) while *Chopan, Malla, Laway* and *Shah* communities were not using wetland resources. A positive correlation (Pearson product- moment correlation coefficient) was found to exist between family size and wetland dependency i.e larger families were found to depend more on wetlands for income (r= 0.254; p= 0.000). A negative correlation (Pearson product -moment correlation coefficient) was found between literacy and wetland use i.e literate families had lower dependency on wetland resources (r= -0.153; p= 0.035). Pearson product-moment correlation coefficient (r= 0.472; p= 0.000) showed livestock population positively correlated with wetland dependency i.e. families with larger livestock were found more dependent on wetland resources especially for fodder.

Results from Pearson Chi Square test showed that the caste of the communities had little influence on wetland dependency of Hygam (no statistically significant association found; Pearson Chi Square= 234.725; p= 0.182). However, caste was found to influence wetland use intensity (Pearson Chi Square= 58.060; p= 0.011) (Table 7.6). Further results indicated maximum utilisation by *Ganai, Hajam* and *Chopan* communities (100%) followed by *Dar* community (95% of surrounding families). Pearson product-moment correlation coefficient (r= 0.079; p= 623) showed no statistically significant relation between family size and wetland dependency. A negative correlation found to exist between literacy and wetland use indicated a decrease in wetland dependency with increase in the level of literacy of surrounding population (r= 0.252; p= 0.112). Livestock population was found positively correlated with wetland dependency (Pearson product-moment correlation coefficient, r = 0.363; p=0.019).

Some communities around Hokersar wetland were independent of wetland resource uses. However, around Hygam wetland, all communities showed utilisation in varying proportions. Larger families around Hokersar wetland showed maximum utilisation of wetland resources. This indicated family size as a factor influencing resource use.

Table 7.6 Chi**-** square test values (cross tabs) for influence of caste on dependency on Hokersar and Hygam wetlands.

Caste versus wetland income								**Caste versus wetland use intensity**							
Hokersar wetland				**Hygam wetland**				**Hokersar wetland**				**Hygam wetland**			
	Value	df	Asymp Sig- (2-sided)		Value	df	Asymp Sig- (2-sided)		Value	df	Asymp Sig- (2-sided)		Value	df	Asymp Sig- (2-sided)
Pearson $\chi2$	1968.15	1768	0.001	Pearson $\chi2$	234.725	216	0.182	Pearson $\chi2$	180.000	119	0.000	Pearson $\chi2$	58.060	36	0.011

Biomass extraction from wetlands

Reed harvesting from wetlands

Water from wetlands used for irrigation

Author interviewing wetland users

Plate 5. Dependency of resources on wetlands of Jammu & Kashmir.

7.4.7 Attitude of local people towards conservation

The results showed a widespread local support for the protection of Hokersar wetland that further confirmed a mutual understanding between local people and park staff. The results further indicated positive attitudes towards conservation among local communities. 92% of the respondents (questionnaire survey) were satisfied with their access to the resources of this wetland. Conversion of the wetland to agriculture was disagreed by majority of population (98% responses). Management of the wetland by park authority was viewed as dissatisfactory by majority (97%) of the population (Table 7.7).

Widespread local support for the protection of wetland existed among local communities around Hygam wetland. Local people had positive attitudes towards conservation. Satisfaction in access to the resources of the wetland was found in 96% of surveyed population. Majority of the respondents (98%) disagreed with conversion of wetland to non-wetland uses. Local people (98%) were dissatisfied with the management of the wetland by concerned authorities. Mutual understanding existed among local communities and reserve staff (Table 7.8).

7.4.8 Views regarding management

The results showed a very high response of local population (78%) around Hokersar wetland for deweeding or removal of excessive weeds in the wetland. Diversion of Doodganga flood channel was favoured by 14% of the survey respondents. Around 18% of the population recommended reduced peatland in the wetland (Table 7.9). A high percentage of the responses (63%) recommended deweeding or the removal of excessive weeds from the Hygam wetland. Diversion of Balkul and Ningli flood channels to outside of the wetland was supported by majority of the population (68% responses).Some 10.5% suggested encroached land be given back to farmers (Table 7.10).

Plantation of more trees, awareness generation, prevention of entry of hospital garbage, breaches in the bund to be plugged off and reduction in the size of peatland were not recommended for the Hygam wetland. On the contrary, encroached land to be given back to farmers, installation of hand pumps and dewatering of wetland by desiltation and removal of weeds were some of the options that could not be suggested for the Hokersar.

Table 7.7 Attitudes of local people towards conservation of Hokersar wetland, Jammu & Kashmir (n= 190).

Attitude/ Awareness	Positive responses (%)	Negative responses (%)	No responses (%)
Are you aware that Hokersar wetland is protected under department of wildlife protection Jammu & Kashmir?	100	0	0
Do you feel any sense of responsibility for the protection of diverse flora and fauna?	95	8	0
Do you think your rights have been violated after its protection?	4	92	4
Are you willing to cooperate with wildlife department?	90	4	38
Do you face any problems because of the wetland?	20	88	0.5
Do you feel that wetland should be drained and used for agricultural and other purposes?	15	98	0
Do you feel that present situation of maintaining the wetland is good?	8	97	4
Would you cooperate for restrictions on resource use?	78	3	23

Table 7.8 Attitudes of local people towards conservation of Hygam wetland, Jammu & Kashmir (n=42).

Attitude/awareness	**Positive responses (%)**	**Negative responses (%)**	**No responses (%)**
Are you aware that Hygam wetland is protected under department of wildlife protection?	100	0	0
Do you feel any sense of responsibility for the protection of diverse flora and fauna?	100	0	0
Do you think your rights have been violated after its protection?	23	76	0
Are you willing to cooperate with wildlife department?	100	0	0
Do you face any problems because of the wetland?	2	99	0
Do you feel that wetland should be drained and used for agricultural and other purposes?	2	99	0
Do you feel that present situation of maintaining the wetland is good?	23	76	0
Would you cooperate for restrictions on resource use?	92	7.6	0

Table 7.9: Views of local people towards management of Hokersar wetland, Jammu & Kashmir.

Management Option	Responses (%)
Excessive weeds in the wetland should be removed	78
Diversion of Doodganga flood channel to outside peripherals of the wetland	14
Desiltation of the wetland either through dredging or through digging in the wetland	44
Erection of more needle gates to maintain a constant water level.	6
Further bund raising around the periphery of the wetland	4
Cutting of the peripheral plantation	4
More plantation of trees for breeding of the birds and as a fence	4
Awareness among people about the benefits of wetland	2
Prevention of hospital garbage entering into wetland and water quality analysis	6
Plugging off the breaches in the peripheral bund	4
Reduction in peatland size with creation of more water pools.	18

Table 7.10 View of local people towards management of Hygam wetland, Jammu & Kashmir.

S.no.	Management Option	Responses (%)
1.	Deweeding or removal of excessive weeds in the wetland	63.15
2.	Diversion of Balkul and Ningli flood channels to outside of the wetland	68.4
3.	Desiltation in the wetland either through dredging or digging	57
4.	Erection of more needle gates to maintain a constant water level	36
5.	Further raising of the peripheral boundary	57
6.	Cutting of the peripheral plantation	21
7.	Plantation of more trees for breeding and as a fence	5
8.	Plugging off the boundary breaches	5
9.	Return of the encroached land to the farmers	10.5
10.	Installation of pump shed to fill in water during shortage	15.7
11.	Dewatering of wetland followed by desiltation, removal of weeds and sowing of Trapa.	10.5

7.4.9 Ecosystem-economy linkage of Hokersar and Hygam wetlands

Results revealed that families around Hokersar wetland had mean annual income of Rs 41,643 ±21,831, around 29% contribution to this income was from wetland resource use. Pearson product-moment coefficient revealed no link between resource use and household income ($r = -0.013$; $p > 0.934$; $n = 189$) indicating no significant ecosystem-economy linkage (Table 7.11).

Mean family income of local communities around Hygam wetland was found to be Rs 38,574 ±30,197. Around 34% contribution to this income was from wetland resource use. Pearson product-moment correlation showed no link between annual income and the income derived from wetland resources ($r = 0.049$; $p > 0.756$; $n=42$) (Table 7.11). Local people around Hygam wetland were more dependent on wetland resource use than Hokersar wetland. This confirmed a more significant impact of wetland resource use on community well-being around Hygam wetland as compared to Hokersar.

Table 7.11 Correlation (Pearson product-moment) between annual income and income derived from wetland resource utilisation in Hokersar and Hygam wetlands**.**

	Hokersar wetland		**Hygam wetland**	
	Annual income	**Income from wetland use**	**Annual income**	**Income from wetland use**
Annual income	1.000 . 41	-0.013 0.934 41	1.000 0.0 42	0.049 0.756 42
Income from wetland use	-0.013 0.934 41	1.000 . 41	0.049 0.756 42	1.000 0.0 42

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

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

7.5 Discussion

The study has resulted in an improved understanding of the society's attitudes towards wetlands, and the factors that affect the conservation status of wetlands. No large urban settlements were in the vicinity of the two study wetlands and the villages around happened to be uniformly distributed. The population density was 5300 persons km^{-2} in surrounding villages of Hokersar wetland and 6600 persons km^{-2} around Hygam wetland. This was markedly higher than the average population density of 99 persons km^{-2} for Jammu & Kashmir (village population- census 2001 records) and of the entire country (324 persons km^{-2}). A highly fertile landscape, plain topography, proximity to water bodies could be attributed to such high estimates. Nearness of Hygam wetland to one major town of the state was the major factor responsible for such a comparatively higher estimate. Net area sown of the 30 villages around Hokersar wetland was 88% of the total area and 87.57% of the total area of 25 villages around Hygam wetland, which was markedly higher than the net area sown of 30% of Jammu &Kashmir and 46.3% of India. A great premium was thus put on land and it was seldom left fallow. Agriculture appeared to be the only basic productive resource in the area and posed a grave danger for the existence of wetlands. Agricultural conversion had been the main reason for the elimination of wetlands (Williams, 1990; Meyer, 1995; Kabii, 1996).The availability of agricultural land was therefore regarded as very important. A large population of 42% in surrounding villages of Hokersar wetland and another 39% around Hygam wetland constituted the unemployed class. However, cattle was an integral part of the local economy. Around 80% of the families in surrounding villages around Hokersar wetland and 99% around Hygam owned cattle.

The basic infrastructure was relatively moderate. Though basic facilities for primary education were available, this was not so for higher education. The literacy rate of 18.6% for Hokersar villages and 20% for Hygam villages faired poorly in comparison to literacy rate of 65.38% of the whole of India (http://gist.ap.nic.in/Cgi).This indicated a low development of the neighbouring society around both study wetlands. Public health facilities were limited to primary health centers that were poorly equipped and badly managed.

The findings indicated complex interaction between local communities and two wetland ecosystems. Both wetlands were located in similar type of agricultural landscapes and same socio-economic and cultural values were associated with them. Social and ecologically sustainable relationship between local inhabitants and wetland ecosystems existed in the form of wetland resource dependence. The majority of population around both study wetlands were engaged in agriculture or agriculture related activities. The availability of agricultural land was therefore regarded as very important. Other occupations mainly as labour work and carpet weaving were seen followed during winter months. Occupation was associated with education as evident from families engaged in government service being more educated. The results could be extrapolated to economy of people surrounding other major wetland ecosystems of Kashmir valley. Resource use pattern in this case indicated a direct dependence of local communities on wetland resources of both Hokersar and Hygam wetlands that in turn reflected an important role in the subsistence economy of this population. Around 82% of local inhabitants depended on 14 different types of consumptive and non-consumptive resources of Hokersar wetland, with reed harvesting being predominant. Harvested reeds mainly *Typha angustifolia*, *Phragmites communis* and *Nymphaea peltoides* were used as food, fodder and as thatching and insulating material and played an important role in social sustainability and livelihoods of local people. Other studies (Ambastha *et al*., 2007; Ozesmi, 1999) also indicated dependence of local communities on wetland resources. Around 97% of local communities depended on wetland resources of Hygam wetland. Livestock grazing a major and common use of this wetland was due to a large population of surrounding villages engaged in pastoral activities, particularly the *Chopans* community. The national parks policy in India is categorical in “banning” livestock grazing. This ban though not presently in force in Hokersar and Hygam wetlands will deprive people of the benefits they are enjoying. Approximately 8% of the people around Hokersar wetland and 3% around Hygam were not dependent on wetlands for any direct use values of fodder, fuel wood, construction materials or other wetland products.

Livestock owned was positively correlated with wetland dependence of local communities around both wetlands. Communities with larger livestock population depended more on wetland resources to meet fodder requirements of their livestock. A similar study in Kabartal reported the same findings in which a positive correlation between livestock owned and quantity of fodder extracted was seen (Ambastha *et al*., 2007). This suggests local communities from different biogeographic zones in India show similar pattern of wetland resources use. Despite ban on consumptive use of resources in areas designated as wildlife reserves, three-fourths of them are grazed by livestock (Kothari *et al*., 1989). However, in the present case the local communities derived direct use benefits of wetlands only for three months in a year on account of the fact that the two wetlands are declared conservation reserves maintained by state wildlife protection department. For rest of the year, they rely on other market commodities *viz*-dry straw and mustard cakes to sustain their livestock and for subsistence needs.

In the present case, low-income level section of the fringe society was not more dependent on direct uses of wetland resources. This was due to other livelihood options preferred by locals mainly various farm tasks, local trade, carpet and shawl weaving industry. However, economic benefits derived showed a substantial contribution of direct wetland resources to average annual income of local communities living around two wetlands. The results do not agree with study by Ozesmi (1999) on sustainable resource use of Kizilirmark wetlands in Turkey that showed more economically marginalized group of local villagers most dependent on wetland resources.

Awareness of Hokersar and Hygam wetlands and their protection status among local communities was high and local people in general recognized the importance of these wetlands. Positive attitude towards conservation was evident among local communities around both wetlands and there was widespread local support for their protection. Affluence in developing countries was believed to be a good indicator of people's attitude (Infield, 1988). No economic, social, ecological or other influential factor was found to govern the attitude of communities around Hokersar and Hygam wetlands. The findings are not consistent with attitude studies of Infield & Namara (2002) and Ambastha *et al*. (2007) which showed attitudes influenced by land ownership and economic interests. Negative attitudes result from colonial approaches to conservation, which alienate communities from wildlife resources, through establishment of exclusive protected areas and punitive policing (Mackenzie, 1987; Hackel, 1999). The present management of two wetlands was perceived as unsatisfactory and people supported better management alternatives. Conservation attitude and willingness to cooperate with co-management initiatives led by Jammu & Kashmir Wildlife Protection Department indicated mutual understanding between local communities and park staff. Attitudinal studies confirmed that lack of interaction between local communities and park staff could create conflict. Community based conservation intended to allow local communities in decision making, planning and implementation was needed for successful conservation efforts.

The two wetlands face similar anthropogenic pressures. Siltation and nutrient load was major threat to both the wetlands. Awareness about problems associated with siltation was high among local communities surrounding two wetlands. Majority perceived siltation as main factor responsible for loss of aerial extent of wetland as well as loss of their ecological functions. This confirmed the long lasting association of local communities with wetland ecosystems. Intervention on part of management to mitigate impacts of siltation on ecology of Hokersar and Hygam wetlands require local traditional knowledge to be incorporated in any process of decision-making. Removal of excessive weeds and desiltation was perceived as the best management option. This study clearly showed its importance in the formulation of management strategies for the conservation of Hokersar and Hygam wetland.

7.6 Summary

The socioeconomics and resource dependency of local communities and their attitudes was studied around Hokersar and Hygam Wetland Conservation Reserves. The areas around these wetlands were densely populated. Majority of the people owned agricultural land and cattle. Agriculture and labour were the main occupations of the people living around the two wetlands. Literacy rates were higher in Hokersar (13-42%) as compared to Hygam (1-7%). Around 82% of the people depended on Hokersar wetland for 13 different types of subsistence with a major use of reed harvesting. Of the mean annual family income of Rs 41,643 ±21,831 around 29% was contributed by the wetlands. Pearson product moment coefficient revealed no link between resource use and household income ($r = -0.1000$; $p > 0.172$; $n = 189$). Positive attitudes and sense of responsibility towards conservation existed among all the respondents with 93% willing to cooperate for restrictions on resource use. All the respondents (100%) knew about the siltation and excessive nutrient load and perceived removal of weeds and desiltation as the best management options.

In Hygam wetland 97% of households depended on the wetland for 14 different types of subsistence uses with livestock grazing as the major use. Of the mean annual family income of Rs. 38,574 ±30,197, 34% was contributed by wetland resource use. Pearson product moment correlation coefficient revealed no relation between annual income and income derived from wetland resources ($r = -0.049$; $p > 0.756$; $n = 42$). Positive attitudes towards wetland conservation were found among respondents and 92% showed willingness to cooperate for restrictions on resource use.

The results showed a variation in resource dependency between Hokersar and Hygam wetlands. There was higher dependency on resources of Hygam wetland when compared with Hokersar. The attitudes of people towards conservation were similar in both wetlands. However, a larger population of surrounding communities around Hygam wetland (96%) seemed to be satisfied with their access to wetland resources as compared to Hokersar (92%). The results indicated cooperation between local people and staff in both wetland reserves.

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CHAPTER 8

GENERAL DISCUSSION AND CONSERVATION IMPLICATION

The Millennium Ecosystem Assessment Report (Millennium Ecosystem Assessment, 2005) highlights that in the last 50 years humans have changed ecosystems more rapidly and extensively than in any other period. This was done largely to meet growing demands for food, freshwater, timber, fiber and fuel. This resulted in a substantial and largely irreversible loss in diversity of life on earth, with 10-30% of the mammal, bird, and amphibian species currently threatened with extinction. The Living Planet Index, created by the World Wide Fund for Nature and the UNEP- World Conservation Monitoring Centre which provides a measure of the trends in more than 3,000 populations of 1,145 vertebrate species around the world showed that freshwater populations have declined consistently with an average decline of 50% between 1970 and 2000 (Loh *et al*; 2005).

Although limited in global extent when compared with marine and terrestrial ecosystems, many freshwater wetlands are relatively species rich. It is well established that many wetland-dependent bird species are globally threatened, and their status continues to deteriorate faster than that of bird species in other habitats. Of the 964 bird species that are predominantly wetland dependent, 203 are extinct or globally threatened (21% of total). Higher percentages of species dependent on coastal systems are globally threatened as compared to inland wetlands. This status has deteriorated faster since 1988. The degradation and loss of inland wetlands and species has been driven by infrastructural development (such as dams, dikes and levees), land conversion, water withdraws, pollution, over-harvesting and the introduction of invasive alien species. Conversion (clearing or transformation) or drainage for agricultural development has been the principal cause of inland wetland loss worldwide. Land use change and habitat loss, along with the deterioration and degradation of both breeding and non-breeding wetland habitats, are widely recognized as being the major causes of the widespread pattern of declining waterbird populations and species.

Wetlands in India, as elsewhere are increasingly facing several anthropogenic pressures. Thus, the rapidly growing human population, large-scale changes in land use- land cover, burgeoning development projects and the improper use of watersheds has all caused a substantial decline of wetland resources of the country. Significant losses have resulted from its conversion for industrial, agricultural and various urban developments. These have led to hydrological perturbations, pollution and their effects (Vijayan *et al*; 2004). Unsustainable levels of grazing and fishing activities have also resulted in degradation of wetlands. India has 78 threatened (including critical, endangered, vulnerable, data deficient and conservation dependent) and 52 near threatened species of birds (Bird Life International, 2001). Among them wetland birds accounted for 37 threatened and 18 near threatened species.

The findings of the present study indicate that landscape composition of Hokersar and Hygam wetlands has been modified by human intervention. Between the two landscapes, much of this human intervention has occurred in Hygam landscape when compared to Hokersar. Only 22.26% of the Hygam landscape has remained marshy, which represents natural wetland habitat while the rest has been converted to non-wetland areas (man-made ecosystems) either through plantation, conversion to agriculture and human habitation. However, the study shows that a great influx of heavy silt load into Hygam wetland from Balkul and Ningli perennial Nallahs (streams) drains directly into the wetland. This heavy silt load has contributed to loss in the area of aquatic habitats of this landscape; 16.48% of area has become barren due to receding water level or drawdown conditions and 2.64% turned into meadows by sediments entering into the wetland through two perennial feeding channels which have decreased expanses of open water in the wetland. However, about 35.65% of Hokersar landscape has remained marshy where no intervention by humans has occurred and rest of the landscape has become non-marshy and non-wetland type which has been put to different land use types by local communities and concerned authorities.

Again, some natural processes e.g. siltation has converted the wetland area into non-wetland land use types e.g. meadows in the landscape have been formed by filling of shallow water areas by sedimentation through feeder channels of wetland and through receding of water level. This seems to be reason that Hokersar wetland still serves as a potential waterbird habitat and sustains a larger waterbird community because the extent of major aquatic plant communities; emergent vegetation, floating vegetation and submergent vegetation is more in Hokersar wetland (29.34%) than in Hygam wetland (20.8%).

The two wetlands represent typical examples of temperate freshwater wetlands where diversity of aquatic plant communities is very low and their structure is relatively simple as compared to tropical freshwater wetlands. However, between the two wetlands, Hokersar wetland is relatively species-rich in aquatic macrophytes and the number of floristic associations or plant communities present is more in comparison to Hygam wetland. Due to excessive siltation in Hygam wetland, submergent vegetation has completely disappeared from the area. Absence of submergent vegetation could be attributed to a very heavy biotic pressure and more dependency of local people on wetland resources in Hygam wetland than in Hokersar wetland.

Further, the findings indicate that Hokersar wetland serves as an important and potential bird habitat of over-wintering populations of migratory waterbirds and summer residents in Kashmir valley when compared to Hygam wetland. However, on the contrary Hygam wetland sustains a relatively small population of migratory waterbirds. Existing information suggests that it is the habitat diversity in Hokersar wetland during winter season, in particular the areas of floating vegetation that satisfy critical needs of the present over-wintering populations of migratory waterbirds. From the area estimates of floating vegetation that serve as potential bird habitats in two wetlands, the extent of this macrophyte community is more in Hokersar wetland than in Hygam wetland. This contributes to the factor that Hokersar wetland sustains a large waterbird population. Hygam wetland reserve faces severe threat of siltation, a high biotic pressure and a heavy dependency of local communities on its resources. This could be the reason that population of migratory waterbirds is low in Hygam wetland. Furthermore, a large number of habitat types exist in Hokersar and Hygam wetlands and this factor seems to be responsible for diversity in waterbird communities of two wetlands. Waterbird associations of major families mainly waterfowl with floating – leafed vegetation, willow plantation and open patches of water in winter season in Hokersar wetland indicate that these habitat types play an important role in this wetland to support major winter concentration of migratory waterbirds. In Hygam wetland, waterbird associations with tall emergents, open water and floating-leafed vegetation emphasize that these habitat elements should be managed to improve waterbird habitat in Hygam wetland. Breeding data of present study shows that some species of waterbirds have started breeding in these wetlands that confirms the role of these wetlands in providing conducive breeding habitats to some species in spring season. It is observed that peatland present in Hokersar wetland serves as an important breeding habitat particularly for Mallard *Anas platyrhynchos,* the only dabbling duck that breeds in the area. However, peatland does not occur in Hygam wetland where willow plantation and tall emergent areas of the wetland serve the purpose.

The habitat utilization of waterbirds in these wetlands was confined only to discrete habitat types. In general, members of family Anatidae (mostly dabblers) used floating vegetation (a microhabitat type) significantly more than expected in two wetlands. Floating vegetation and tall emergents appeared as the preferred habitats by Rallidae. Ardeidae showed preference for drawdown meadows while Podicipedidae preferred specifically floating vegetation in two wetlands. The study further shows that some areas of Hokersar wetland such as paddy fields in and around the wetland were avoided by waterbirds. In general, habitat types that lacked aquatic vegetation did not receive any waterbird use. Plant community of floating vegetation was preferred foraging and resting habitats for most waterbird species in both wetlands. Loss of such habitats will have severe impact on bird distribution affecting habitat use.

Attempts should be made to restore the degraded portion of the wetlands through appropriate mechanisms. Management practices directed towards enhancing vegetation- water interspersion in both Hokersar and Hygam wetlands would greatly enhance their value to waterbirds. Such interspersion would increase structural habitat complexity and open up preferred foraging and resting habitats for most waterbird species.

Specific management recommendations should include creation of open water patches and increasing amounts of floating vegetation in Hokersar wetland and creation of discrete *Typha* stands interspersed with open water patches in Hygam wetland.

Hygam wetland reserve faces severe threat of siltation. A great influx of heavy silt load into Hygam wetland from Balkul and Ningli perennial Nallahs (streams) drains directly into this wetland which has resulted in deterioration of wetland quality mainly reduced extent of the wetland area in the landscape. Results suggest desiltation of the wetland through either dredging or digging in the wetland. This would consequently increase expanses of open water and other marshy habitats that would increase the potential of the wetland to sustain abundant waterbird communities. Further siltation of Hygam wetland can be prevented by diversion of Balkul and Ningli flood channels to outside of the wetland. Furthermore, the application of proper soil and water conservation practices throughout the watersheds is of major importance.

Existing information (Weller, 1999) suggests that many wetland birds prefer “hemi-marsh conditions”. This is an indication of the need for further research to determine marsh-open water ratio for different avian species or guilds, and whether such management would be a feasible option.

The study on breeding habits of waterbirds indicates that Hokersar and Hygam wetlands provide conducive breeding habitats to some resident waterbird species in spring season, which usually starts from month of March to May in the Kashmir valley. Peatland and Willow *Salix alba* plantation represent important breeding habitats in Hokersar wetland. Management should consider protection of these habitats in spring season. The findings reveal tall emergent *Agropyron smithii* patches found in discrete stands over large peat masses in Hokersar wetland as suitable nesting cover for Mallard *Anas platyrhynchos*. Management should include fencing of breeding habitats to exclude damage by predators and human disturbance. Furthermore, there should be establishment of waterfowl food plants near nests.

In Hygam wetland, it is essential to maintain discrete patches of tall emergent as nesting cover for breeding waterbirds, especially of Mallard *Anas platyrhynchos* which breeds only in wetlands of Kashmir in the entire Indian sub-continent.

The study has revealed that there are complex interactions between wetlands and the fringe society. A range of direct – use values on which the sustenance of local people surrounding Hokersar and Hygam wetlands depends comes from these two wetlands. Local economy of these two areas has benefited by wetland resource uses. The local populations have the right to access to resources of these wetlands and this access exists only for a period of three months in a year.

Larger families, less education and families with a large livestock population showed more wetland resource dependence. Harvesting of reeds was a common resource use in Hokersar wetland and livestock grazing in Hygam wetland. The continued exploitation of these wetland resources will consequently have an adverse effect on their long-term sustainability. Due to the fact that a large population surrounding these wetlands is uneducated and unemployed, cattle is an integral part of their economy. These are the reasons that these wetlands are being used especially to meet fodder requirements of livestock. Because the social and ecological sustainability of local communities and their well-being is linked to availability of wetland resources, other livelihood options like eco-tourism can be a good means of generating alternative employment opportunities and reducing pressure on wetlands. Further, increase in the level of education among locals, reduced family sizes and alternative fodder requirements for livestock of local people could help achieve sustainable and wise use of two wetland reserves. The peripherals of wetlands can be managed as grazing pastures and for cultivation of forage species for livestock and this can largely reduce the pressure on wetland resources.

Local communities showed widespread support for the protection of Hokersar and Hygam wetlands and the awareness of their ecological significance. There was no unrest or discord seen among different user groups and conflicts with management were not issues faced by the authorities. Protected areas in context of wetlands of Jammu and Kashmir have not worked against the economic interests of local communities. The integrated land use and wetland map of two areas (Chapter 4) shows that much of the catchments of two wetlands are located in the agricultural areas. As a result surface run-off carrying pesticides and fertilizers from agricultural fields and discharge of domestic sewage and effluents has resulted in prolific weed growth. Thick reed infestation particularly *Typha angustata* induced by eutrophication and siltation has led to decline in biodiversity of two areas. It is observed from this study that close-intimacy with wetland ecosystems has brought adequate awareness among local people of the problems associated with these wetlands.

The enhancement of conservation education will help to make local people more aware of the ecological importance of wetlands. Local communities particularly the Dars, Bhats, Khans, Chopans, Mirs retain a wealth of traditional knowledge. Management of the two wetlands should incorporate ideas and opinions of local people. When decisions affecting wetlands are made with inadequate knowledge of local people conservation programs are unlikely to be successful.

Management of the wetland in a comprehensive manner by incorporating other neighboring wetlands, for example Mirgund, Narbal near Hokersar wetland and Asham, Sopore Numbal and Wular lake near Hygam wetland will not only save the smaller wetlands in Kashmir valley from extinction but also facilitate maintenance of the water balance in both Hokersar and Hygam wetlands. The advantages and ecological impacts of a sluice-cum-regulator system may well be analyzed in this regard.

Hokersar wetland has been listed under National Wetlands Conservation Programme (Islam and Rahmani, 2008). The wetland has also been internationally designated as Ramsar site. In the light of results of present study, Hygam wetland also fulfills more than one criterion for qualification as a Ramsar site and deserves to be on the national priority list of wetlands of India.

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Ackleson, S.G and Klemas, V. (1987) Remote sensing of submerged aquatic vegetation in Lower Chesapeake Bay: a comparison of Land sat MSS to TM imagery. *International Journal of Remote Sensing* **22**: 235-248.

Ajtay, G.L; Ketne, P and Duvigneaud, P. (1979) Terrestrial primary productivity and phytomass. In: Bolen, B; Degens, E.T; Kempe, S and Ketner, P (Eds). *The Global Carbon Cycle*. Scope 13, Wiley, Chichester, New York, Brisbane, Toronto, 129-181.

Akthar, P. (1991) Community structure of zooplankton in polluted water with particular reference to Khuhalsar and Gilsar Lake. M. Phil. Thesis. University of Kashmir. J&K, India.

Alford, J.R and Bolen, E.G. (1977) Influence of winter temperatures on Pintail sex ratios in Texas. *Southwest Naturalist* **21**(4): 554-556.

Alfred, J.R.B. (1999) Biodiversity and Ecology: In Indian context. *Bionotes* **1**(4): 73-75.

Ali, S and Ripley, S.D. (1968) Handbook of the Birds of India and Pakistan together with those of Nepal, Sikkim, Bhutan and Ceylon (Volume I).

Ali, S. (1979) The Book of Indian Birds, 11th edition, The Bombay Natural History Society, India.

Ali, S and Ripley, S.D. (1983) Handbook of the birds of India and Pakistan. Compact Edition, Oxford University Press, Delhi.

Ali, S and Sugathan, R. (1985) Studies on the movement and population structure of Indian Avifauna. Annual Report 1984- 85, Bombay Natural History Society, Bombay.

Ali, S and Ripley, D. (2002) Handbook of the Birds of India and Pakistan, 10 vols. (2nd Eds). Oxford University Press.

Amat, J.A. (1984) Ecological segregation between Red- crested Pochard *Netta rufina* and Pochard *Aythya ferina* in a fluctuating environment. *Ardea* **72**: 229-233.

Ambedkar, V.C and Daniel, J.C. (1990) A study of the migration of Common Teal *Anas crecca crecca* Linnaeus based on ring recoveries in India and U.S.S.R. *Journal of the Bombay Natural History Society* **87**(3): 405-420.

Ambastha, K; Hussain, S.A and Badola, R. (2007a) Resource dependence and attitudes of local people towards conservation of Kabartal wetland: a case study from the Indo-Gangetic plains. *Wetlands Ecology and Management* **15** (4): 287-302.

Ambastha, K; Hussain, S.A and Badola, R. (2007b) Social and economic considerations in conserving wetlands of Indo-Gangetic plains: A case study of Kabartal wetland, India. *Environmentalist* **27**: 261-273.

Anonymous. (1991) A Reference Annual. Research and Reference Division, Ministry of Information and Broadcasting, Government of India, Delhi.

Anonymous. (1993) Directory of Indian Wetlands. WWF INDIA, New Delhi and AWB, Kaulalumpur, xvi, 264pp, 32 map.

Anonymous. (1994) World Development Report. World Bank Development Report.

Anonymous. (1996) Asia- Pacific Migratory Waterbird Conservation Strategy. Migratory Waterbirds. http://www.jawp.org/anet/str 1996.htm# 2.3% 20 Migratory%.20 waterbirds (Accessed October, 2008).

Anderson, S.H. (1979) Habitat assessment for breeding bird populations. Translation North American Wildlife and Natural Resources Conference. **44**: 431-445.

Anderson, J.E and Perry, J.E. (1996) Characterization of wetland plant stress using leaf spectral reflectance: implications for wetland remote sensing. *Wetlands* **16**: 477-487.

Aselmann and Crutzen, P.J. (1989) Global distribution of natural freshwater wetlands and rice paddies, their net primary productivity, seasonality and possible methane emissions. *Journal of Atmospheric Chemistry* **8**: 307-358.

Atkinson, P.W; Austin, G.E; Rehfisch, M.M; Baker, H; Cranswik, P; Kershaw, M; Robinson, J; Langston, R.W.H; Stroud, D.A; Turnout, C.V; MacLean, I.M.D. (2006) Identifying declines in waterbirds: The effects of missing data, population variability and count period on the interpretation of long-term survey data. *Biological Conservation* **130**: 549-559.

Bacha, M.S. (1993) Waterfowl Census in Kashmir wetlands. Report KND No.4, Department of Wildlife Protection, Jammu and Kashmir Government.

Bacha, M.S. (1994) Waterfowl Census in Kashmir wetlands. Report KND No.5, Department of Wildlife Protection, Jammu and Kashmir Government.

Bacha, M.S. (2002) Central Assistance for Hokera Critical Wetland: 2002-2003. Report. Department of Wildlife Protection, Jammu and Kashmir Government, Srinagar.

Badola, R. (1997) Economic assessment of human-forest interrelationship in the forest corridor linking the Rajaji and Corbett National parks. Ph.D. Thesis. Jiwaji University, Gwalior. 220 pp.

Badola, R. (1998) Attitudes of local people towards conservation and alternatives to forest resources: A case study from the lower Himalayas. *Biodiversity and Conservation* **7**: 1245-1259.

Badola, R and Hussain, S.A. (2005) Valuing ecosystem functions: an empirical study on the storm protection function of Bhitarkanika mangrove ecosystem, India. *Environmental Conservation* **32**(1): 85-92.

Baker, E.C. (1929) The Fauna of British India, including Ceylon and Burma. Birds Vol VI. Taylor and Francis, London.

Baker, M.C. (1979) Morphological correlates of habitat selection in a community of shorebirds (Charadriiformes). *Oikos* **33**: 121-126.

Balian, L.V; Mamikon, G.G; Martin, S.A; Daniel, K.J. (2002) Changes in the waterbird community of the lake Sevan- Lake Gilli area, Republic of Armenia: a case for restoration. *Biological Conservation* **106**: 157-163.

Bates, R.S.P and Lowther, E.H.N. (1952) Breeding Birds of Kashmir. Oxford University Press, London, pp: 367.

Bartlett, D and Klemas, V. (1980) Quantitative assessment of tidal wetlands using remote sensing. *Environmental Management* **4**: 337-345.

Bayley, S.E; Behr, R.S and Kelly, C.A. (1986) Retention and release of S from a fresh water wetland. *Water, Air and Soil Pollution* **31**:101-114.

Bazilevich, N.I; Lye, Rodin and Rozov, N. N. (1971) Geophysical aspects of biological productivity. *Soviet Geography Review Translation* **12**: 293-317.

Beckerman, S; Shy, E; Oron, T and Frankenberg, E. (1998) Repopulation and colonization by birds in the Agmon wetland, Israel. *Wetlands Ecology and Management* **6**: 159-167.

Beecher, W.J. (1942) Nesting birds and the vegetation substrate. Chicago Ornithological Society. Chicago. III 69 pp.

Bellrose, F.C and Anderson, H.G. (1943) Preferential ratings of duck food plants. *Illinois Natural History Survey Bulletin* **22**(5): 417-433.

Bellrose, F.C. (1972) Mallard migration corridors as revealed by distribution, banding and radar. Population Ecology of Migratory Birds- A Symposium, Wildlife research report-2. United States Department of the Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Washington, D.C.

Best, R.G and Moore, D.G. (1979) Land sat interpretation of Prairie lakes and wetlands of eastern South Dakota. In: Deutsch M; Wiesnet, D.R and Rango, A.(Eds), *Fifth Annual William T. ECORA Memorial Symposium on Remote Sensing 1979*. American Water Resources Association, Souix Falls, South Dakota, USA, pp: 499-506.

Bibby, C.J; Burgess, N.D and Hill, D.A. (1992) Bird Census Techniques. Academic Press, London.

BirdLife International. (2007) Threatened birds of the world. Lynx Edicions, Barcelona, Spain and BirdLife International, Cambridge, U.K.

Bisht, K.S; Sokhl, B.S and Talagi, R.C.S. (1995) Studying town morphology through remote sensing. *Journal of the Indian Society of Remote sensing* **23** (1): 13-22.

Bhupathy, S. (1991) Population and Resource utilization of waterfowl in Keoladeo National Park, Bharatpur. Ph.D. Thesis. University of Rajasthan.

Bhupathy, S; Vijayan, V.S and Mathur, R. (1998) Population ecology of migratory waterfowl in Keoladeo National Park, Bharatpur. *Journal of Bombay Natural History Society* **95** (2): 287-294.

Block, W.M and Brennan, L.A. (1993) The habitat concept in ornithology: theory and applications. In: Power, O.M. (Eds), 1993. *Current Ornithology*. Vol.11.Plenum Press, New York.

Boere, G.C; Galbraith, C.A and Stroud, D.A. (Eds) (2007) Waterbirds around the world. TSO Scotland Ltd; Edinburgh, UK.940 pp.

Bolen, E.G. (1982) Playa wetlands of the US southern high plains: Their wildlife values and challenges for management. In: Gopal, B; Turner, R.E; Wetzel, R.G and Whigham, D.F (Eds). *Wetlands Ecology and Management*. Proceedings of the first International wetland conference, New Delhi, India, 10-17 September 1980. National Institute of Ecology and International Scientific Publications, India.

Boonazaier E. (1996) Local responses to conservation in the Richtersveld National Park, South Africa. *Biodiversity and Conservation* **5**: 207-314.

Bowden, W.B. (1987) The biogeochemistry of nitrogen in freshwater wetlands. *Biogeochemistry* **4**: 313-348.

Bradter, U; Gombobaetar, S.D; Uuganbayar, C.B; Grazia, T.E and Exo, K.M. (2007) Time budgets and habitat use of White-naped Cranes *Grus* *vipio* in the ulz river valley, north- eastern Mongolia during the breeding season. *Bird Conservation International* **17**: 259-271.

Bronmark, C and Hansson, L.A. (2002) Environmental issues in lakes and ponds: current state a perspective. *Environmental Conservation* **29** (3): 290-306.

Brown, M and Dinsmore, J.J. (1986) Implications of marsh size and isolation for marsh bird management. *Journal of Wildlife Management* **50**: 392-397.

Bryant, E.H. (1973) Habitat selection in a variable environment. *Journal of Theor.Biology* **41**: 421-429.

Burger, J. (1985) Habitat selection in temperate marsh- nesting birds. Pages: 253-281. In: Cody, M.L (Eds). *Habitat selection in birds*. Academic Press. Toronto, Ontario, Canada.

Burger, J; Jeitner, C; Clark, K and Niles, L.J. (2004) The effect of human activities on migrant shorebirds: successful adaptive management. *Environmental Conservation* **31** (4): 283-288.

Burton, N.H.K; Armitage, M.J.S; Musgrove, A.J and Rehfisch, M.M. (2002a) Impacts of man-made landscape features on numbers of estuarine waterbirds at low tide. *Environmental Management* **30**: 857-864.

Burton, N.H.K; Rehfisch, M.M and Clark, N.A. (2002b) Impacts of disturbance from construction work on the densities and feeding behavior of waterbirds using the intertidal mudflats of Cardiff Bay, UK. *Environmental Management* **30**: 865-871.

Butera, M.K. (1983) Remote sensing of wetlands. IEEE Transactions on Geoscience and Remote Sensing. GE-21: 383-392.

Byers, C.R and R.K. Steinhorst. (1984) Clarification of a technique for analysis of utilization-availability data. *Journal of Wildlife Management* **48**: 1050-1053.

Casanova, M.T. and Margaret, A.B. (2000) How do depth duration and frequency of flooding influence the establishment of wetland plant communities? *Plant Ecology* **147**: 237-250.

Chabreck, R.H. (1979) Winter habitat dabbling ducks- physical, chemical and biological aspects. Pages 133-142. In: Bookhout, T.A (Eds).*Waterfowl and wetlands- an integrated review*. The Wildlife Society, Madison, Wisconsin.

Champion, S.H; and Seth, S.K. (1968) .*A revised survey of the Forest types of India*. Manager of publications. New Delhi. pp. 404.

Christiansen, J.E and Low, J.B. (1970) Water requirements of waterfowl marshlands in northern Utah, Utah Division of Fish and Game Publication. 69 pp: 108.

Chopra, R; Verma, V.K; and Sharma, P.K. (2001) Mapping, monitoring and conservation of Harike wetland ecosystem, Punjab, India, through remote sensing. *International Journal of Remote Sensing* **22**: 89-98.

Cody, M. (1985) Habitat selection in birds. Academic Press, London. 557pp.

Colwell, R.K. (2005) Estimate S: Statistical estimation of species richness and shared species from samples. Version 7.5.

Colwell, M.A; Oring, L.W. (1988) Habitat use by breeding and migratory shorebirds in south central Saskatchewan. *Wilson Bulletin* **100**: 554-566.

Cook C.D.K. (1996) Aquatic and wetland plants of India. Oxford University Press, Delhi.

Cornett R and Zane J. (1994) GIS as a catalyst for effective public involvement in ecosystem management decision making. In: Ed.V.Alaric Sample (Eds). *Remote Sensing and GIS in ecosystem management*. Island Press, Washington DC.369 pp.

Corner, W.H. (1994) Effects of forest management practices on southern forested wetland productivity. *Wetlands* **14**: 27-40.

Costanza, R; d'Arge, R; deGroot, R ; Farber, S; Grasso, M; Hannon,B; Limburg, K Naeem, S; O'Neill, R.V ; Paruelo, J; Raskin, Sutton, P and van den Belt, M. (1997) The value of the world's ecosystem services and natural capital. *Nature* **387:** 253-260.

Costanza, R; Faber, C and Maxwell, J. (1989) Valuation and Management of wetland ecosystems. *Ecological Economics* **1**: 335-361.

Courcelles, R and Bedard, J. (1979) Habitat selection by dabbling ducks in the Baie Noire marsh, southwestern Quebec. *Canadian Journal of Zoology* **57**: 2230-2238.

Cowardin, L.M; Carter, V; Golet, F.C and La Roe, E.T. (1979) Classification of wetlands and deepwater habitats in the United States. U.S. Deptt. Interior, Fish and Wildlife Service, FWS/ UBS- 79/31.

Cowardin, L.M; Gilmer, D.S and Shaiffer, C.W. (1985) Mallard recruitment in the agricultural environment of North Dakota. *Wildlife Monographs* **92**. Wildlife Society, Washington, D.C.

Cranswick, P.A; Kirby, J.S; Salmon, D.G; Atkinson-Willes, G.L; Pollitt, M.S; Owen, M. (1997) A history of wildfowl counts by the Wildfowl and Wetlands Trust. *Wildfowl* **47**:216-229.

Crook, J.H. (1979) Social Behavior in Birds and Mammals. (Eds) London, Academic Press.

Cronk, J.K and M.S. Fennessy (2001) Wetland plants: biology and ecology. Lewis publishers.

De Boer, W.F and Baquete, D.S. (1998) Natural resource use, crop damage and attitudes of rural people in the vicinity of the Maputo Elephant Reserve, Mozambique. *Environmental Conservation* **25**(3): 208-218.

Deepa, R.S; and Ramachandra, T.V. (1999) Impact of urbanization in the interconnectivity of wetlands. Paper presented at the National Symposium on Remote Sensing Applications for Natural Resources: Retrospective and Perspective (xix-xxi 1999), Indian Society of Remote Sensing, Bangalore.

Dombois, D.M. and H. Ellenberg. (1974) Aims and Methods of Vegetation Ecology. (Eds.). John Wiley and Sons.

Drew, W.M; Ewel, K.C; Naylor, R.L and Sigrah, A. (2005) A tropical freshwater wetland: III. Direct use values and other goods and services. *Wetlands Ecology and Management* **13**: 685-693.

Drever, M.C and Clark, R.G. (2007) Spring temperature, clutch initiation date and duck nest success: a test of the mismatch hypothesis. *Journal of Animal Ecology* **76**: 139-148.

Duebbert, H.F; Lokemoen, J.T; Sharp, D.E. (1983) Concentrated nesting of Mallards and Gadwalls on Miller Lake Island, North Dakota. *Journal of Wildlife Management* **47** (3): 729-740.

Dugan, P. (1993) Wetlands in Danger- A World Conservation Atlas (eds).Oxford University Press, New York, United States of America.

Duncan, P; Hewison, A.J.M; Houte, S; Rosoux, R; Tournebize, T; Dubs, F; Burel, F and Bretagnolle. (1999) Long-term changes in agricultural practices and wildfowling in an internationally important wetland, and their effects on the guild of wintering ducks. *Journal of Applied Ecology* **36**:11-23.

Dwyer, T.J; Krapu, G.L and Janke, D.M. (1979) Use of Prairie pothole habitat by breeding Mallards. *Journal of Wildlife Management* **43**: 526-531.

Eltringham, S.K and Atkinson - Willes. (1961) Recent population changes in British ducks.12th Annual Report, *The Wildfowl Trust*, pp: 40:57.

Eltringham, S.K. (1973) Fluctuations in the number of wildfowl on an equatorial hippo wallow. *Wildfowl* **24**: 81-87.

Eric, V; Roche, P; Bonnet, V and Tatoni, T. (2001) Nest- density distribution patterns in a Yellow-legged gull archipelago colony. *Acta Oecologica* **22** (5): 245-251.

Ernst, C.L and Hoffer, R.M. (1979) Digital processing of remotely sensed data for mapping wetland communities. LARS Technical Report 122079. Laboratory for Applications of Remote Sensing. Purdue University, West Lafayette, 119 pp.

Eyton, T.C. (1838) A monograph on the Anatidae, or duck tribe, including the geese and swans. Longmans, London.

Fassett, N.C. (1957) A manual of aquatic plants. Edn. 2. University of Wisconsin Press, Madisen, Wisconsin.

Faulkner, S.P. and Richardson, C.J. (1989) Physical and chemical characteristics of fresh water wetland, soils. pp. 41-72. In: Hammer, D.A (Eds). *Constructed wetland for waste water treatment municipal Industrial and agricultural.* Lewis publishers Inc. Chelsea*, MI,* USA.

Fiallo, E.A. and Jacobson S.K. (1995) Local communities and protected areas: attitudes of rural residents towards conservation and Machalilla national park, Ecuador. *Environmental Conservation* **22** (3)**:** 241-249.

Finlayson, C.M; Hollis, G.E and Davis, T.J. (1992) Managing Mediterranean Wetlands and their Birds. IWRB Special Publication 20. IWRB, Slimbridge.

Finlayson, C,M; Van Dam, R.A and Humphrey, C.L. (1999) Wetland risk assessment In: Finlayson, C.M and Spiers, A.G; eds, Techniques for Enhanced Wetland Inventory and Monitoring. Supervising Scientist Report, Supervising Scientist, Canberra, ACT. In Press [?].

Fleming, Sr. R.L; Fleming, Jr. R.L and Bangdel, L.S. (1976) Birds of Nepal listed, Arun K.Mehta and Vakil and Sons.

Foote, L.A; Pandey. S. and Krogman, N.T. (1996) Processes of wetland loss in India. *Environmental conservation* **23** (1): 45-54.

Forgette, T.A and Shuey, J.A. (1997) A comparison of wetland mapping using SPOT satellite imagery and national wetland inventory for a watershed in northern Michigan. In: Trettin, C.C. (Eds), *Northern Forested Wetlands*; *Ecology and Management*. CRC Lewis Publishers, Boca Raton, Florida, USA, pp.61-70.

Foundation for Environmental Conservation. (2000) An introduction to long-term environmental trends. http:// www.ncl.ac.uk/icef (Accessed June, 2008).

Fredrickson, L.H and Drobney, R.D. (1979) Habitat utilization of post breeding waterfowl. Pages 119- 131.In: Bookhout, T.A (Eds).*Waterfowl* *and wetlands- an integrated review*. Northcent Sect; The Wildlife Society; Madison, Wisconsin.

Fretwell, S.D and Lucas, H.L. (1969) On territorial behavior and other factors influencing distribution in birds. I. Theoretical Development. *Acta Biotheor* **19**: 16-36.

Fuller, R.M; Groom, G.B; Mugisha, S; Ipulet, P; Pomeroy, D; Katende, A. (1998) The integration of field and remote sensing for biodiversity assessment: a case study in the tropical forests and wetlands of Sango Bay, Uganda. *Biological Conservation* **86**: 379-391.

Gadgil, M. (1992) Conserving Biodiversity as if people matter: A case study from India. *Ambio* **21**: 266-270.

Gautam, N.C. and Narayanan, L.R.A. (1983) Land sat MSS data for land use /land cover inventory and mapping: A Case of Andhra Pradesh. *Journal of Indian Society of Remote sensing* **11** (3): 15-28.

Ghosh, S; Sen, K.K; Rana U; Rao, K.S and Saxena, K.G. (1996) Application of GIS for land use /land cover change analysis in a mountainous terrain. *Journal of the Indian Society of Remote Sensing* **24** (3): 193-202.

Gibbs, J.P. (1993) Importance of small wetlands for the persistence of local populations of wetland-associated animals. *Wetlands* **13**: 25-31.

Gilmer, D.S; Work, E.A.Jr, Colwell, J.E and Rebel, D.L (1980) Enumeration of prairie wetlands with Landsat and aircraft data. *Photogrammetric Engineering and Remote Sensing* **46**: 631-634.

Gill, F.B. (1995) Ornithology, 2^{nd} edition. New York: W.H. Freeman.

Glading, B; Biswell, H.H and Smith, C.F. (1940) Studies on the food of the California Quail in 1937. *Journal of Wildlife Management* **4** (2): 128-144.

Glaser, M. (2003) Interrelations between mangrove ecosystem, local economy and social sustainability in Caete Estuary, North Brazil. *Wetlands Ecology and Management* **11**: 265-272.

Goodin, D.G. (1995) Mapping the surface radiation budget and net radiation in a sand Hills wetland using a combined modeling/ remote sensing method and Land sat thematic mapper imagery. *Geocarto International* **10**: 19-29.

Gopakumar, G. (1980) Habitat utilization pattern of waterbirds in artificial wetlands of an arid to semi-arid region. *Indian Journal of Forestry* **13**(2): 85-91.

Gopal, B. (1982) Ecology of *Typha* species in India. Proc. 6th EWRS International Symposium. Aquatic Weeds, *Novi* Sad, pp 20-28.

Gopal, B. and Sah, M. (1993) Conservation and management of rivers in India: Case study of the river Yamuna. *Environmental Conservation* **20**: 243-54.

Gopal, B. and Sah, M. (1995) Inventory and classifications of wetlands in India. *Vegetatio* **118**: 39-85.

Gopal, B and Wetzel, R.G. (1995) Limnology in developing countries (volume 1).SIL- International Association for Limnology, New Delhi, India.

Gopal, B. (1997) Biodiversity in inland aquatic ecosystems in India: an overview. *International Journal of Ecology and Environmental Science* **23**: 305-313.

Green, A.J. (1996) Analysis of globally threatened Anatidae in relation to threats, distribution, migration patterns and habitat use. *Conservation Biology* **10**: 1435-1445.

Grimmett, R; Inskipp, C and Inskipp, T. (1999) Birds of India. Princeton University Press, New Jersey.

Guadagnin, D.L; Peter, A.S; Perello, F.C; Maltchick, L. (2005) Spatial and temporal patterns of waterbird assemblage in Fragmented wetlands of Southern Brazil. *Waterbirds* **28** (3): 261-272.

Guadagnin, D.L; Maltchick, L. (2007) Habitat and landscape factors associated with Neotropical waterbird occurrence and richness in wetland fragments. *Biodiversity* and *Conservation* **16** (4): 1231.

Hackel, J.D. (1999) Community conservation in the future of Africa's Wildlife. *Conservation Biology* **13**: 726-734.

Handoo, J.K. (1978) Ecological and production studies of some typical wetlands of Kashmir. Ph.D. Thesis. University of Kashmir, J&K. India.

Handoo, J.K. and Koul, V. (1982) Phytosociological and standing crop studies in wetlands of Kashmir. Pages 187-195. In: Gopal, B, Turner, R.E Wetzel, R.G. and Whigham, D.F (editors). *Wetlands Ecology and Management*, International Scientific publications, Jaipur.

Hardisky, M.A; Gross, M.F and Klemas, V. (1986) Remote Sensing of coastal wetlands. *Bioscience* **36**: 453-460.

Hattori, A and Mae, S. (2001) Habitat use and diversity of waterbirds in a coastal lagoon around lake Biwa, Japan. *Ecological Research* **16**(3): 543-553.

Heitmeyer, M.E and Vohs, P.A.Jr. (1984) Distribution and habitat use of waterfowl wintering in Oklahoma. *Journal of Wildlife Management* **48** (1): 51-62.

Helmers, D.L. (1992) Shorebird Management Manual Western Hemisphere. Shorebird Reserve Network, Manomet, MA.

Henderson, I.G and Harper, D.M. (1992) Bird distribution and habitat structure on lake Naivasha, Kenya. *African Journal of Ecology* **30**: 223-232.

Hilden, O. (1965) Habitat selection in birds. *Ann.Zool.Fenn*. **2**: 53-75.

Hill, M.O. (1979) TWINSPAN. A FORTRAN Program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Ecology and Systematic. Cornell University Ithaca, New York.

Hinson, J.M; German, C.D and Pulich, W.Jr. (1994) Accuracy assessment and validation of classified satellite imagery of Texas coastal wetlands. *Marine Technology Society Journal* **28**: 4-9.

Holmes, P. (1978) Oxford Ornithological Expedition to Kashmir, 1978- Report, 63 pp. P.Holmes, 17 College Drive, Ruislip, Middx; UK.

Holmes, P.R and Parr, A.J. (1988) A checklist of the Birds of Haigam Rakh, Kashmir. *Journal of the Bombay Natural History Society* **85**(3): 465-473.

Hora, S.L; Malik, G.M and Khajuria, H. (1995) Some interesting features of the aquatic fauna of Kashmir valley. *Journal of Bombay Natural History Society* **53**: 140-143.

Houlahan, J.E; Findlay, C.S; Schmidt, B.R; Mayer, A.H and Kuzmin, S.L (2000). Quantitative evidence for global amphibian population decline. *Nature* **404**: 752-755.

Hussain, S.A; Mohaptra, K.K and Ali, S. (1984) Avifaunal profile of Chilka lake, a case for conservation. Technical Report No. 4, Avifauna, Bombay Natural History Society, Bombay.

Infield, M. (1988) Attitudes of a rural community towards conservation and local conservation area in Natal, S. Africa. *Biological Conservation* **45**: 21-46.

Infield, M and Namara, A. (2001) Community attitudes and behavior towards conservation: an assessment of a community conservation programme around lake Mburo National Park, Uganda. *Oryx* **35** (1): 48-60.

Islam, Z.A and Rahmani, A.R. (2004) Important Bird Areas in India*:* Key sites of conservation*.* Indian Bird Conservation Network, Bombay Natural History Society and Birdlife International, Mumbai and UK.

Islam, Z.A. and Rahmani, A.R. (2008) Potential and Existing Ramsar Sites in India. Indian Bird Conservation Network: Bombay Natural History Society, Birdlife International and Royal Society for the Protection of Birds. Oxford University Press. pp.592.

Jafer, P; Bhardwaj, A.K; Peeyuskulty, K.J; Zacharias, V.J. (1997) Studies on the aquatic birds in Periyar Lake, Kerala. *Indian Forester* **123** (10): 929-934.

Jain, S.K. (1992) Land use mapping of Tawi catchment using satellite data. Report No.cs-72, National Institute of Hydrology, Roorkee, 52 pp.

Jaiswal, R.K; Saxena, R. and Mukherji, S. (1999) Application of remote sensing technology for land use/land cover change analysis. *Journal of Indian Society of remote sensing* **27** (2): 123-128.

Jamwal, K.S. (1991) Wetlands Kashmir. *Sanctuary (Asia)* **11**(2): 26-33.

Jayaraman, S. (1985) Wintering Ecology of Coots *Fulica atra atra* (Linn) from January to March 1985 in Keoladeo National Park, Bharatpur, Rajasthan. M.Sc. Dissertation, Bharathidasan University, Tiruchirapalli.

Jensen, J.R; Cowen, D; Althausen, J; Narumalani, S; and Weatherbee, O. (1993a) An evaluation of the Coast Watch Change detection protocol in South Carolina. *Photogrammetric Engineering and Remote Sensing* **59***:* 1039-1046.

Jensen, J.R; Cowen, Christensen, E.J and Sharitz, R. (1984) Nontidal wetland mapping in South Carolina using airborne multi-spectral scanner data. *Remote Sensing of Environment* **16**: 1-12.

Johnsgard, P.A. (1965) Handbook of Waterfowl Behaviour. Ithaca, New York, Cornell University Press.

Johnsgard, P.A. (1961a). The Taxonomy of the Anatidae- A behavioral analysis. *Ibis* **103**: 71-85.

Johnson, D.H. (1980) The comparison of usage and availability measurements for evaluating resource preference. *Ecology* **61**: 65-71.

Jorde, D.G; Krapu, G.L; Crawford, R.D; Day, M.A. (1984) Effects of weather on habitat selection and behaviour of Mallards wintering in Nebraska. *Condor* **86**: 258-265.

Joshi, P.K; Hamayun, R and Roy, P.S. (2002) Landscape Dynamics in Hokersar wetland, Jammu and Kashmir- An Application of Geospatial

Approach. *Journal of the Indian Society of Remote Sensing* **30** (1&2):1-5.

Joshi, P. K; Rawat, G.S; Padaliya, H. and P.S.Roy. (2005) Land use /land cover identification in an alpine and arid region (Nubra valley, Ladakh), Using satellite Remote Sensing. *Journal of the Indian Society of Remote sensing* **33** (3): 371-380.

Joyner, D.E. (1980) Influence of invertebrates on pond selection by ducks in Ontario. *Journal of Wildlife Management* **44**: 700-705.

Kabii, T. (1996) An overview of African wetlands. In: Hails, A.J (Eds).Wetlands, Biodiversity and the Ramsar Convention, Ramsar Convention Bureau.

Kak, A.M. (1982) Aquatic and wetland flora of the northwest Himalayas. XVII. Family Butomaceae in Kashmir Himalayas. *Biol*. *Bull*. *India* **4**: 197-198.

Kaminski, R.M and Prince, H.H. (1981) Dabbling duck activity and foraging responses to aquatic macro invertebrates. *Auk* **98**: 115- 126.

Kaminski, R.M and Gluesing, E.A. (1987) Density – and habitat- related recruitment in Mallards. *Journal of Wildlife Management* **51**(1): 141-148.

Kear, J. (1970) The adaptive radiation of parental care in waterfowl. pp.357-392.

Kershaw, M and Cranswick, P.A. (2003) Numbers of wintering waterbirds in Great Britain, 1994/ 95- 1998/99. I. Wildfowl and selected waterbirds. *Biological Conservation* **111**: 91-104.

Khan, M.A. (2000a) Wetland Biodiversity in the Kashmir Himalaya: Assessment and Conservation Strategies. In: Khan, M.A. (Eds).

Environment, *Biodiversity and Conservation* A.P.H.Publ.Corp.New Delhi.

Khan, M.A. (2003) Kashmir Himalayan Waterfowl habitat, Hokersar: Species composition and threat perceptions. *Indian Journal of Environment and Ecoplanning* **7**(3): 525-528.

Khan, M.A and Bashir, S. (2003) Habitat complexity and avifaunal diversity of Hokersar wetland in the Kashmir Himalaya. *Indian Journal of Environmental Sciences* **7** (1): 85-88.

Khan, M.A; Shah, M.A; Mir, S.S and Bashir, S. (2004) The environmental status of a Kashmir Himalayan wetland game reserve: Aquatic plant communities and eco-restoration measures. *Lakes and Reservoirs: Research and management* **9** (2): 125 -132.

Kindscher, K; Fraser, A; Jakubauskas, M.E and Debinski, D.M.(1998) Identifying wetland meadows in Grand Teton National Park using remote sensing and average wetland values. *Wetlands Ecology and Management* **5**: 265-273.

Klett, A.T; Shaffer, T.L and Johnson, D.H. (1988) Duck nest success in the Prairie Pothole region. *Journal of Wildlife Management* **52**: 431-440.

Knick, S.T and Rotenberry, J.T. (1999) Spatial distribution of breeding Passerine bird habitats in a shrub steppe region of southeastern Idaho. Studies in Avian Biology.No.9: 104-111.

Knutson, M.G; Saurer, J.R; Olsen, D.A; Massman, M.J; Hemesath, C.M and Lannoo, M.J. (1999) Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, U.S.A. *Conservation Biology* **13**: 1437-1446.

Kothari, A. and Singh, S. (1989) Management of National Parks and Sanctuaries in India: A Status report. Environmental studies Division, IIPA, New Delhi. pp 29-30.

Krapu, D.L; Facey, A.E; Fritzell, A.K and Johnson, K.H. (1984) Habitat use by Migrant Sandhill Cranes in Nebraska. *Journal of Wildlife Management* **48** (2): 407-417.

Krasowski, T.P; and Nudds, T.D. (1986) Microhabitat structure of nest sites and nest success of diving ducks. *Journal of Wildlife Management* **50***:* 203-208.

Kumar, A. and Bhatt, D. (2000) Status of migratory avifauna of a subtropical wetland in the Ganga valley, Haridwar, India. *Annals of Forestry* **8** (1): 17-24.

Kushwaha, S.P.S; Dwivedi, R. S and Rao, B.R.M. (2000) Evaluation of various digital image processing techniques for detection of coastal wetlands using ERS-1SAR data. *International Journal of Remote Sensing* **21**: 565-579.

LaGrange, T.G. (1985) Habitat use and nutrient reserves dynamics of spring migratory Mallards in Central Iowa. M.Sc. Thesis. Iowa State University, Ames, 81pp.

LaGrange, T.G and Dinsmore, J.J. (1989) Habitat use by Mallards during spring Migration through central Iowa. *The Journal of Wildlife Management* **53**(4): 1076-1081.

Lee, J.K and Park, R.A. (1992) Application of geoprocessing and simulation modeling to estimate impacts of sea level rise on the northeast coast of Florida. *Photogrammetric Engineering and Remote Sensing* **58**: 1579-1586.

Leemans, R; Lodge, D.M; Mooney, H.A; Oesterheld, M; Poff, N.L; Sykes, M.T; Walker, B.H; Walker, M. and Wall, D.H. (2000) Global biodiversity scenarios for the year 2100. *Science* **287**: 1770-1774.

Leith, H. (1975) Primary productivity of the major vegetation units in the world. In: H. Leith and R.H. Whittaker (Eds). *Primary productivity of the biosphere* (Springer Verlag, Berlin) 203-216.

Leveque, C. (2001) Lake and Pond ecosystems. *Encyclopedia of Biodiversity* **3**: 633-644.

Li, Z.W.D and Mundkur, T. (2004) Numbers and distribution of waterbirds and wetlands in the Asia- Pacific region. Results of the Asian waterbird census: 1997-2001. Wetlands International, Kuala Lumpur, Malaysia.

Liu, J.K. (1984) Lakes of the middle and lower basins of the Chang Jiang (China). In: F.B.Taub (Eds).*Ecosystems of the world 23*: *Lakes and Reservoirs*, Elsevier Science Publishing Company, Amsterdam, The Netherlands, 331-355.

Livezey, B.C. (1986) A Phylogenetic analysis of recent Anseriform genera using morphological characters. *Auk* **103**: 737-54.

Livezey, B.C. (1997) A phylogenetic classification of waterfowl (Aves: Anseriformes), including selected fossil species. *Annals of Carnegie Museum*. **66**: 457-496.

Loh, J; Green, R.E; Rickelts, T; Lamoreux, J; Jenkins, M; Kapos, V; and Randers, J (2005).The Living Planet Index: using species population time series to track trends in biodiversity. Phil. Trans.R.Soc.B.360: 289-295.

Loganathan, B.G and Kannan, K. (1994) Global organochlorine contamination trends: an overview. *Ambio* **23**: 187-191.

Lokemoen, J.T; Duebbert, H.F and Sharp, D.E. (1984) Nest spacing, habitat selection, and behaviour of waterfowl on Miller lake Island, North Dakota. *Journal of Wildlife Management* **48** (2): 309-321.

Lokemoen, J.T; Woodward, R.O. (1992) Nesting waterfowl and waterbirds on natural islands in the Dakotas and Montana. *Wildlife Society Bulletin* **20**: 163-171.

Longcore, J.R and Gibbs, J.P. (1988) Distribution and numbers of American Black Ducks along the Maine coast during the severe winter of 1980-1981. In: Weller, M.W (Eds).*Waterfowl in winter*. University of Minnesota Press, Minneapolis.

Louiselle, S; Bracchini, L; Bonechi, C and Rossi, C. (2001) Modeling energy fluxes in remote wetland ecosystems with the help of remote sensing. *Ecological Modelling* **145**: 243-261.

Ma, Z; Li, B; Zhao, B; Jing, K; Tang, S; Jiakuan, C. (2004) Are artificial wetlands good alternatives to natural wetlands for waterbirds? A case study on Chongming Island, China. *Biodiversity and Conservation* **13**: 333-350.

Ma, Z; Gan, X; Chai, C; Jing, K; Tang, S; Li, B and Chen, J. (2007) Wintering bird communities in newly- formed wetland in the Yangtze river estuary. *Ecological Restoration* **22**: 115- 124.

MacArthur, R.H and Levins, R. (1964) Competition, habitat selection, and character displacement in a patchy environment. *Proc.Natl.Acad.Sci*. **51**: 1207-1210.

Mackenzie, J.M. (1987) Chivalry, social Darwinism and ritualized killing: the hunting ethos in Central Africa upto 1914. In: Anderson, D and Grove, R (Eds). *Conservation in Africa*; *People*, *Policies and Practice*. Cambridge University Press, Cambridge.

Madge, S and Burn, H. (1988) Waterfowl, an identification guide to the Ducks, Geese and Swans of the world. Boston, MA: Houghton. Mifflin.

Madsen, J. (1998) Experimental refuges for migratory waterfowl in Danish wetlands. I. Baseline assessment of the disturbance effects on recreational activities. *Journal of Applied* Ecology **35** (3): 386-397.

Maltby, E and Turner, R.E. (1983) Wetlands of the world. *Geography Magazine*; **55**: 12-17.

Mathews, E and Fung, I. (1987) Methane emission from natural wetlands: global distribution, area and environmental characteristics of sources. *Global Biogeochemical Cycles* **1**: 61-86.

Mathews, E; Fung, I and Lerner, J. (1991) Methane emission from rice cultivation: geographic and seasonal distribution of cultivated areas and emissions. *Global Biogeochemical Cycles* **5**: 3-24.

Mc Aleece, N; Lambshed, P.J.D; Paterson, G.L.J; Gage, J.D. (1996) Biodiversity Pro. A programme for analyzing ecological data.

McKinney, R.A; McWilliams, S.R; Charpenter, M.A. (2006) Waterfowl- habitat associations during winter in an urban North Atlantic estuary. *Biological Conservation* **132** (2): 239-249.

Meyer, W.B and Turner, B.L. (1992) Human population growth and global land-use/cover change. *Annual review of Ecology and Systematics*, vol. **23**, pp: 39-61. http://www.jstor.org/stable/2097281 (Accessed: May, 2008).

Middleton, B. A. (1989) Succession and goose herbivory in monsoonal wetlands of the Keoladeo National Park, Bharatpur, India. Ph. D. Thesis. Iowa State University Ames, Iowa. 140 pp.

Millennium Ecosystem Assessment. (2005) Ecosystems and Human well-being: Wetlands and Water *synthesis*.
http://www.millenniumassessment.org/documents/document.358.aspx.pdf (Accessed October, 2008).

Minakshi; Chaurasia R. and Sharma, P.K. (1999) Land use/land cover mapping and change detection using satellite data, a case study of Dehlon Block. District, Ludhiana, Punjab. *Journal of Indian Society of Remote sensing* **27** (2): 115-121.

Misra, R. (1944b) The vegetation of Rajghat ravines. *Journal of Indian Botanical Society* **23**: 44-57.

Mishra, C. (2000) Socio-economic transition and wildlife conservation in the Indian transhimalaya. *Journal of Bombay Natural History Society* **97** (1): 25-32.

Mitch, W.J. and Gosselink, J.G. (1993) Wetlands 2nd edition. New York: Van Nostrand Academy Press.

Mitch, W.J. and Gosselink, J.G. (2000) Wetlands 3rd edition. New York: Van Nostrand Academy Press.

Ministry of Environment and Forests. (2001) Conservation of natural resources including Forestry and Wildlife.
http:// envfor.nic.in/report/0102/chap 03: html (Accessed June, 2008).

Mohanty, R.R. (1994) Analysis of urban land use change using sequential area photographs and SPOT data. An example of north Bhubaneshwar, Orissa. *Journal of Society of Remote sensing* **22** (5): 225-235.

Moisan, G; Smith, R.I and Martinsen, R.K. (1967). The Green-winged Teal. Its distribution, migration and population dynamics. United States Department of the Interior. Fish and Wildlife Service. Special Scientific Report- Wildlife No.100.

Morrison, M.L; Marcot, B.G and Mannan, R.W. (1992) Wildlife habitat relationships; concept and application. University of Wisonsin Press, Madison.

Moser, M; Prentice, C and Frazier, S. (1996) A global overview of wetland loss and degradation. In Papers, Technical Session B, Vol.10/12B, proceedings of the 6th meeting of the conference of contracting parties, Brisbane, Australia, 19-27 March 1996, Ramsar Convention Bureau, Gland, Switzerland, 21-31.

Moss B. (2000) Biodiversity in fresh waters: an issue of species preservation or ecosystem functioning? *Environmental Conservation* **27**:1-4.

Mouney, H.A; Oesterheld, M; Poff, N.L; Sykes, M.T; Walker, B.H; Walker, M and Wall, D.H. (2000) Global biodiversity scenarios for the year 2100. *Science* **287**: 1770-1774.

Mukherji, S.K. (1926) Aquatic and marsh vegetation of the Dal lake of Kashmir. Proc. Linn. Soc. London 73B:55-56.

Munyati, C. (2000) Wetland change detection on the Kafue Flats, Zambia, by classification of a multi –temporal remote sensing image dataset. *International Journal of Remote Sensing* **21**: 1787-1806.

Murkin, H.R and Kadlec, J.A. (1986) Relationships between waterfowl and macro invertebrate densities in a Northern Praire marsh. *Journal of Wildlife Management* **50** (2): 212-217.

Nagarajan, R and Thiyagesan, K. (1996) Waterbirds and substrate quality of the Pichavaram wetlands, Southern India. *Ibis* **138** (4): 710-721.

Naugle, D.E; Higgins, K.F; Nusser, S.M and Johnson, W.C. (1999) Scale-dependent habitat use in three species of Prairie wetland birds. *Landscape Ecology* **14**: 267-276.

Negi, S. (2001) Water yield and water quality of some Aquifers in the Himalaya. *International Journal of Ecology and Environmental Sciences* **27** (1): 55-59.

Neu, C. W; Byers, C.R and Peek, J.M. (1974) A technique for analysis of utilization-availability data. *Journal of Wildlife Management* **38**: 54-58.

Nichols, S.A and Shaw, B.H. (1986) Ecological life histories of the three aquatic nuisance plants, *Myriophyllum spicatum*, *Potamnogeton crispus* and Elodea Canadensis. *Hydrobiologia* **131**: 3-21.

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

Nilsson, C; Ekblad, A; Cardfjell, M.and Calberg, B. (1991) Long-term effects of river regulation on river margin vegetation. *Journal of Applied Ecology* **28**: 965-987.

Norris, K; Atkinson, P.W; Gill, J.A. (2004) Climate change and coastal waterbird populations- past declines and future impacts. *Ibis* **146** (Suppl.1), 82-89.

Norussis, M.J. (1994) SPSS professional statistics Version 8.0, SPSS Inc; Chicago, Illinois.

Nudds, T.D and Ankney, C.D. (1982) Ecological correlates of territory and home range size in North American dabbling ducks. *Wildfowl* **33**: 58-62.

Odum, E.P. (1975) Ecology. Oxford and IBH Publishing Co. New Delhi. pp 244.

OECD. (1996) Guidelines for aid agencies for improved conservation and sustainable use of tropical and subtropical wetlands. Organization for Economic co-operation and development, Paris, France.

Owen, M and Dix, M. (1986) Sex ratios in some common British wintering ducks. *Wildfowl* **37**: 104-112.

Owen, M and Black, J.M. (1990) Waterfowl Ecology. Blackie and Son Ltd; Glasgow, London.

Ozesmi, V. (1999) Conservation Strategies for Sustainable Resource Use in the Kizilirmak Delta, Turkey. Ph.D.Thesis. University of Minnesota.

Ozesmi, S.L and Bauer, M.E. (2002) Satellite remote sensing of wetlands. *Wetlands ecology and management* **10** (5): 381-402.

Palaniyandi, M. and Nagarahinam, V.(1997) Land use /land cover mapping and change detection using space borne data. *Journal of Indian Society of Remote sensing* **25** (10): 27-33.

Pandey, S. (1993) Changes in waterbird diversity due to the construction of Pong Dam Reservoir, H.P, India. *Biological Conservation* ***66***: 125-130.

Pandit, A.K. (1980) Biotic factor and food chain structure in some typical wetlands of Kashmir. Ph.D. Thesis. University of Kashmir, Srinagar, India.

Pandit, A.K. (1982) Feeding ecology of breeding birds in five wetlands of Kashmir. *Indian Journal of Ecology* **9** (2): 181-190.

Pandit, A.K.and Kaul, V. (1982) Trophic structure of some typical wetlands. In: Gopal, B; Turner, R.E; Wetzel, R.G and Whigam, D.F (Eds).*Wetlands Ecology and Management*. 1-10, International Scientific Publications.

Pandit, A.K. and Qadri, M.Y. (1986) Nutritive values of some aquatic life forms of Kashmir. *Environmental Conservation* **13**: 260-262.

Pandit, A.K. (1989) Feeding Ecology of Wild Ducks and Geese over wintering in wetlands of Kashmir Himalaya. *Indian Journal of Ecology* **16**(2): 199-202.

Pandit, A.K. and Qadri, S.S. (1990) Floods threatening Kashmir wetlands. *Journal of environmental management* **31**: 299-311.

Pandit, A.K. (1991) Conservation of wildlife resources in wetland ecosystems of Kashmir, India. *Journal of Environmental Management* **33**: 143- 154.

Panwar, H.S. (1990) Status of management of Protected Areas in India: problems and prospects. Presented at the regional expert consultation on the management of Protected Areas in the Asia-Pacific region organized by FAO regional office for Asia and the Pacific, Bangkok. December: 10-14 pp.

Paracuellos, M and Telleria, J.L (2004) Factors affecting the distribution of a waterbird community: the role of habitat configuration and bird abundance. *Waterbirds* **3**: 3-13.

Parry, D and Campbell, B. (1992) Attitudes of rural communities to animals, wildlife and its utilization in Chobe Enclave and Mababe Depression, Botswana. *Environmental Conservation* **19** (3): 245-252.

Pearson, R. (1977) A pantropical comparison of bird community structures on six lowland forest sites. *The Condor* **79**: 232-244.

Perennou, C. (1989) Waterfowl surveys along the Coromandel Coast. *Blackbuck* **5** (4): 3-12.

Perennou, C and Santharam V. (1990) An ornithological survey of some wetlands in south east India. *Wetlands and Waterfowl*, *Newsletter* **2**: 26-31.

Peters, J.L. (1931) Check-list of birds of the world, volume1. Harvard University Press, Cambridge, Massachusetts.

Peterson, S.R and Low, J.B. (1977) Waterfowl use of Uinta Mountain wetlands in Utah. *The Journal of Wildlife Management* **41** (1): 112-117.

Pieterse, A.H. (1981) *Hydrilla verticillata*- a review. Abstracts. *Trop*. *Agric*. **7**(6): 9-34.

Pimbert, M.P and Pretty, J.N. (1995) Parks, people and professionals: putting 'participation' into Protected Area Management, 297-330. In: Ghimire, K.P and Pimbert, M.P. (Eds). *Social change and conservation*. Earthscan, London.

Pimbert, M.P. and Gujja, B. (1997) Village voices challenging wetland management policies: experiences in participatory rural appraisal from India and Pakistan. *Nature & Resources* **33** (1): 34-42.

Pirot, J.Y; Laursen, K; Madsen, J and Manvel, J.Y. (1989) Population estimates of Swans, Geese, Ducks and Eurasian Coot *Fulica atra* in the western Palearctic and Sahelian Africa. In: Boyd, H and Pirot, J.Y. (Eds). *Flyways and reserve networks for waterbirds*. IWRB. Special Publication No.9, Slimbridge.

Pringle, C.M. (2001) Hydrologic connectivity and the management of biological reserves global perspective*.* *Ecological Applications* **11** (4): 981-998.

Pyrovesti, M. and Daoutopoulos, G.A. (1989) Conservation – related attitudes of lake fishermen in Greece. *Environmental Education* **16**: 245-250.

Quan, R.C; Wen, X; Yang, X; Peng, G.H; Huang, T.F. (2001) Habitat use by wintering Ruddy Shelduck at Lashihai Lake, Lijiang, China. *Waterbirds* **24** (3): 402-406.

Quan, R.C; Wen, X and Yang, X. (2002) Effects of human activities on migratory waterbirds at Lashihai lake, China. *Biological Conservation* **108**: 273-279.

Ramsar. (1971) Convention on wetlands of international importance .In: Carp, E. (Eds).International Waterfowl Research Bureau, Ramsar, Iran.

Ramsey, E.W. III; Chappell, D.K and Baldwin, D.G. (1997) AVHRR imagery used to identify hurricane damage in a forested wetland of Louisiana. *Photogrammetric Engineering and Remote Sensing* **63**: 293-297.

Rashid, H and Joshi, P.K. (2000) Evaluation of waterfowl habitat in Hokersar wetland reserve, Jammu and Kashmir. A Geospatial Approach, Report, IIRS, Dehradun.

Rather, A. (2003) Hanjis of Dal Lake: A study of the ecology, economy and society. http:// jmi.nic.in/Research/ab2003_geography_javeedah (Accessed February, 2007).

Reimold, R.J; Gallagher, J.L and Thompson, D.E (1973) Remote sensing of tidal marsh. *Photogrammetric Engineering and Remote Sensing* **4**(1): 477-488.

Reinecke, K.J. (1977) The importance of fresh water invertebrates and female energy reserves for black ducks breeding in Maine. Ph.D. Thesis. University of Maine, Orono.113pp.

Rey, Benayas J.M; Colomer, M.G.S and Levassor, C. (1999) Effects of area, environmental status and environmental variation on species richness per unit area in Mediterranean Wetlands. *Journal of Vegetation Science* **10**: 275-280.

Riccardi, A and Rasmussen, J.B. (1999) Extinction rates of North American freshwater fauna. *Conservation Biology* **13**: 1220-1222.

Richardson, C.J. (1994) Ecological Functions and human values in wetlands: A Framework for Assessing Forestry Impacts. *Wetlands* **14** (1): 1-9.

Richter, I.D; Braun, D.P; Mendelson, M.A and Master, L.L (1997) Threats to imperiled freshwater fauna. *Conservation Biology* **11**: 1081-1093.

Ringelman, J.K. (1980) The breeding ecology of the black duck in south-central Maine. Ph.D.Thesis. University of Maine. Orono. 88pp.

Ritchie, M.E and Olff, H. (1999) Spatial scaling laws yield a synthetic theory of biodiversity. *Nature* Vol. **500**: 557-560.

Rodewald- Rudescu, L. (1974) Das Schilfrohr. E. Schweizerbart'sche Verlag, Stittgart.

Roos, S and Part, T. (2004) Nest predators affect spatial dynamics of breeding Red-backed Shrikes (*Lanius collurio*). *Journal of Animal Ecology* **73**: 117-127.

Rosenweig, M.L (1974) On the evolution of habitat selection. *Proc.Int.Congr.Ecol* **1**: 401-404.

Rossi, Richard, E; David, J; Mulla, Andre, Ournel and Elden, H. Franz. (1992) Geospatial tools for modeling and interpreting ecological spatial dependence. *Ecological Monograph* **62** (2): 277-314.

Rose, P.M and Scott, D.A. (1994) Waterfowl Population Estimates. IWRB Publication No.29.Slimbridge, UK.

Rose, P.M and Scott, D.A (1997) Waterfowl Population Estimates- Second Edition. Wetlands International Publication No.44, Wageningen, The Netherlands.

Roux, F. (1973) Censuses of Anatidae in the central delta of the Niger and the Senegal delta- January 1972. *Wildfowl* **24**: 63-80.

Rural Poverty Portal. (2007) Rural Poverty in India. http:// www.ruralpovertyportal.org/english/regions/asia/ind/index.htm (Accessed 8.12.2007).

Rutchey, K and Vilhek, L. (1999) Air photo interpretation and satellite imagery analysis techniques for mapping cattail coverage in a northern Everglades impoundment. *Photogrammetric Engineering and Remote Sensing* **65***:* 185-191.

Saberwal, V.K.and Kothari, A. (1996) The human dimension in conservation biology curricula in developing countries. *Conservation Biology* **10** (5):1328-1331.

Saberwal, V.K. (1996). Pastoral politics: gaddi grazing, degradation and biodiversity conservation in Himachal Pradesh, India. *Conservation Biology*.**10**: 741-749.

Safran, R.J; Isola, C.R; Colwell, M.A and Williams, O.E. (1997) Benthic invertebrates at foraging locations of nine water bird species in managed wetlands of the northern San Joaquin Valley, California. *Wetlands* **17**: 407-415.

Sah, J.P and Heinen, J.T. (2001) Wetland resource use and conservation attitudes among indigenous and migrant people in Ghodaghadi Lake area, Nepal. *Environmental Conservation* **28** (4): 345-356.

Sala, O.E; Chapin III F.S; Armesto, J.J; Berlow, E .Bloomfield, J;Dirzo, R; Huber-Sanwald, E; Huenneke, L.F; Jackson, R.B; Kinzig, A; Leemans, R; Lodge,D.M; Mouney, H.A; Oesterheld, M; Poff,N.L; Sykes, M.T; Walker, B.H; Walker, M and Wall,D.H.(2000) Global biodiversity scenarios for the year 2100. *Science*. **287**: 1770-1774.

Sampath, K and Krishnamurthy, K. (1990) Shorebirds (Charadriiformes) of the Pichavaram mangroves, Tamil Nadu, India. *Wader Study Group Bulletin*. **58**: 24-27.

Sample, V. Alaric. (1994b). Realizing the potential of remote sensing and GIS in ecosystem management planning, analysis and policy making. In: Ed.V.Alaric Sample. *Remote sensing and GIS in ecosystem management*. Island Press. Washington, D.C.369 pp.

Sankar; Qamar Qureshi, V.B, Mathur; S.K, Mukherjee, G.Arendran, M.K.S.Pasha, Rajesh Thapa and Panna Lal. (2000) Mapping of the protected areas (PA) and surrounding areas in Pench Tiger Reserve, Madhya Pradesh. A consultancy task assignment report under the India-Ecodevelopment project for Pench Tiger Reserve, Madhya Pradesh. Final Report, Wildlife Institute of India, Dehradun 31pp.

Sarkar, S. (1996) Ecological theory and anuran declines. *Bioscience* **46**: 199-207.

Schweiger, E.W; Scott, G.L; Jeffrey, B.H; Foster, W.E and Downing, M.C. (2002) Synoptic Assessment of wetland functions: a planning tool for protection of wetland species biodiversity. *Biodiversity Conservation* **11** (3): 379-406.

Scott, D.A. and Poole, C.M. (1989) A status overview of Asian Wetlands (comp.) Asian Wetland Bureau, Malaysia.

Scott, D.A. (1989) A directory of Asian wetlands, IUCN, Gland, Switzerland, and Cambridge, U.K.

Shah, G.M; Qadri, M.Y and Ullah, I. (1983) Food of the Graylag Goose, *Anser anser* Linnaeus (Anseriformes: Anatidae). *Journal of Indian Institute of Science* **64** (c): 179-187.

Shah, G.M. (1984) Birds of Hokersar: Food, feeding and breeding of some resident and non-resident birds. Ph.D.Thesis. University of Kashmir, Srinagar.

Sharma, K.P; Jain, S.C and Garg D.K. (1984) Monitoring land use and land cover changes using landsat images. *Journal of Indian Society of Remote sensing* **12** (2): 115-121.

Shearer, L.A; John, B.J and Lenz, L. (1969) Deterioration of duck foods when flooded. *Journal of Wildlife Management* **33**: 1012-1015.

Shrestha, P. (2000) Species diversity of aquatic macrophytes in Lake Phewa and lake Rupa of Pokhara valley, Nepal. *International Journal of Ecology and Environmental Sciences* **26**: 269-280.

Shy E; Beckerman, S; Oron, T and Frankenberg, E. (1998) Repopulation and colonization by birds in the Agmon wetland, Israel. *Wetlands Ecology and Management* **6**: 159-167.

Siegel, S and Castellan, N.J.Jr. (1988) Non-parametric statistics for the behavioral sciences. McGraw-Hill, New York.

Smith, S.G. (1987) *Typha*: its taxonomy and the ecological significance of hybrids. *Arh*.*Hydrobiol*; *Beih*. *Ergebn*.*Limnol*; **27**: 129-138.

Southwood**,** T.R.E. (1977) Habitat. The Template for Ecological Strategies**?** The *Journal of Animal Ecology* **46** (2)**:** 336**-**365.

Spence, D.H.N. (1982) The zonation of plants in freshwater lakes. *Advanced Ecological Research* **12**: 37-125.

Spindler, M.A; Murphy, S.M; Kessel, B. (1981) Ground Census of Waterbird Population in the upper Tanana Valley. In: Miller, F.L; Gunn, A. (Eds.), Symp. On Census and inventory methods for population and habitats. Northwest section of wildlife society, Banff.Alerta pp: 133-148.

Sridharan, U. (1989) Comparative ecology of resident ducks in Keoladeo National Park, Bharatpur. Ph.D.Thesis, Department of Field Ornithology. Bombay Natural History Society, Bombay.

Stevens, H.T; Samuel, B and Larson, J.S. (1995) Public attitudes and economic values for wetland conservation in New England, *Wetlands* **15**: 226-231.

Stevens, L.E; Buck, K.A; Bryan, T, Brown; Kline, N.C (1998). Dam and geomorphological influences on Colorado river waterbird distribution, Grand Canyon, Arizona, USA. *Regulated Rivers*: *Research and Management* **13** (2): 151-169.

Stewart, R.E and Kantrud, H.A. (1973) Ecological distribution of breeding waterfowl population in North Dakota. *Journal of Wildlife Management* **47**(3):729-740.

Strayer, D. (2001) Endangered freshwater invertebrates. *Encyclopedia of Biodiversity* **2**: 425-439.

Subramanyam, K. (1962a) Aquatic Angiosperms. Botanical Monograph 3: Council of Scientific and Industrial Research, New Delhi, 190 pp.

Subramanyam, K. (1962b) Aquatic angiosperms of India. *Bull.Bot.Surv.India* **4**: 261-272.

Svardson, G. (1949) Competitive and habitat selection in birds. *Oikos* **1**(2): 157-154.

Taub, F.B. (1984) Ecosystems of the world 23: Lakes and Reservoirs. Elsevier Science Publishing Company, Amsterdam, The Netherlands.

The Ramsar Convention on wetlands. Resolution VIII on waterbird population estimates. (2002) http:// www.wetlands.org/1wi/WPE note. htm (Accessed 4-06-2008).

Thomas, G. (1976) Habitat usage of wintering ducks at the Ouse Washes, England. *Wildfowl*. **27**: 148-152.

Thompson, K.R and Rothery, P. (1991) A Census of Black-browed Albatross Diomeda melanophrys population on Steeple Jarson Island, Falkland Islands. *Biological Conservation* **56**: 39-48.

Tidsell, C. (1994) Conservation, protected areas and the global economic system: How debt, trade, exchange rates, inflation and micro economic policy affect biological diversity. *Biodiversity and Conservation* **3**: 419-436.

Tillman, D. (2000) Causes, consequences and ethics of biodiversity. *Nature* **405**: 208-211.

Trakolis, D. (2001) Local people's perception of planning and management issues in Prespes Lakes National Park, Greece. *Journal of Environmental Management* **61**:227-241.

Trisal, C.L and Manihar, Th. (2004) The Atlas of Loktak. Wetlands International and Loktak Development Authority: 5pp.

Van der ven, J. (1987) Asian waterfowl 1987. Midwinter bird observations in most Asian countries IWRB, Slimbridge.

Van der ven, J. (1988) Asian waterfowl 1988. Midwinter bird observations in most Asian countries. IWRB, Slimbridge.

Venkataraman, C. (1996) Studies on the Colonial waterbirds and the characteristics of the lake of the Vedanthangal Bird Sanctuary. Ph.D. Thesis. University of Madras.

Verboom, J; Foppen, R; Chardon, P; Opdam, P and Luttikhuizen, P. (2001) Introducing the key patch approach for habitat networks with persistent populations: an example of marshland birds. *Biological Conservation* **100**: 89-101.

Verner, J. (1985) Assessment of counting techniques. Pp 247- 302.In: Johnson, R. F (Eds) 1985. *Current Ornithology* **2**: 247-302.

Vessem, V; Hecher, J.N and Tucher, G.M. (1997) Inland wetlands. Pages 125- 158.In: Tucher, G.M and Evans, I.M (comp.). Habitats for birds in Europe: A Conservation Strategy for the wider environment. Birdlife Conservation Series 6.BirdLife International, Cambridge.

Vijayan, L and Vijayan, V.S. (1996) Ecology of the Siberian crane *Grus leucogeranus* in Keoladeo National Park, Bharatpur, India, during the winter of 1992-1993. In: Rahmani, A.R and Gayatri, U (Eds). Birds of wetlands and grasslands. Proc. Salim Ali centenary seminar, BNHS, Mumbai, pp: 45-51.

Vijayan, V.S; Prasad, S.N; Vijayan, L. and Muralidharan, S. (2004) Inland Wetlands of India- Conservation Priorities. Salim Ali Centre for Ornithology and Natural History, Coimbatore. Pp.xxiv +532.

Virkkala, R. (1995) Bird communities. In: Nierenberg, W.A (Eds).Encyclopedia of Environmental Biology. Academic Press, San Diego, CA, USA, pp: 335- 344.

Walker, J; Lindberg, M.S; Maccluskie, M.C ; Petrula, M.C and Sedinger, J.S. (2005) Nest survival of Scaup and other ducks in the Boreal forest of Alaska. *Journal of Wildlife Management* **69** (2): 582-591.

Wallander, J; Isaksson, D and Lenberg, T. (2006) Wader nest distribution and predation in relation to man-made structures on coastal pastures. *Biological Conservation* **132**: 343- 350.

Weber, L.M and Haig, S.M. (1996) Shorebird use of south Carolina managed and natural coastal wetlands. *Journal of Wildlife Management* **60**: 73-82.

Weller, M.W and Spatchet. (1965) Role of habitat in the distribution and abundance of marsh birds. Special Report No. 43.Agricultural and home economics experiment station, Iowa State University of Science and Technology, Iowa.

Weller, M.W and Fredrickson, L.H. (1973) Avian Ecology of a managed glacial marsh. *Living Birds* **12**: 269-291.

Weller, M.W. (1978) Management of freshwater marshes for wildlife. In: Good, R.E; Whigham, D.F and Simpson, R.L (Eds). *Freshwater wetlands*: *ecological processes and management potential*. Academic Press, New York.

Weller, M.W. (1999) Wetland Birds: Habitat Resources and Conservation Implications. Cambridge University Press, Cambridge.

Wells, M and K. Brandon. (1992) People and parks. Report to World Bank/ World Wildlife Fund/ United States Agency for International Development, World Bank, Washington, USA,99 pp.

Wells, M.P. (1992) Biodiversity Conservation, Affluence and Poverty: Mismatched costs and efforts to remedy them. *Ambio* **21**(3): 237-243.

Wetlands International. (2002) Waterbird Population Estimates- Third Edition. Wetlands International Global Series No.12, Wageningen, The Netherlands.

Wettstein, W and Schmid, B. (1999) Conservation of arthropod diversity in montane wetlands: effect of attitude, habitat quality and habitat fragmentation on butterflies and grasshoppers. *Journal of Applied Ecology* **36**: 363-373.

Wiens, J.A. (1989) The ecology of bird communities, Vol. I. Cambridge University Press, Cambridge, U.K.

Whistler, S. (1985) Wintering Ecology of Coots *Fulica atra atra* (Linn.) from January to March 1985 in Keoladeo National Park, Bharatpur, Rajasthan. M.Sc. Dissertation, Bharathidasan University, Tiruchirapuli.

Whittaker, R.H and G.E. Likens. (1973) Carbon in the biota. In: Woodwell, G.M and E.R. Pecan. (Eds). *Carbon and the biosphere*. USAEC Symp. Series no. 30, Washington, DC, pp. 281-300.

Wiens, J.A. (1976) Population responses to patchy environments. *Annual Review Ecology and Systematics* **7**: 81-120.

Wiens, J.A. (1977) On Competition and variable environments. *American Scientist* **65**: 590-597.

Wiens, J.A and Rotenberry, J.F. (1981a) Censusing and the evaluation of avian habitat occupancy. Pages 522-532 In: Ralph, C.J and Scott, J.M (Eds). Estimating numbers of terrestrial birds. *Study Avian Biology* **6**.

Wilkinson G and Shepherd, I. (1995) Testing the water, monitoring and modeling wetlands use integrated GIS and RS techniques. *GIS Europe* **4**: 38-40.

William, M. (1990) Wetlands: A threatened landscape. The Institute of British Geographers. pp: 1-42.

World Resources Institute. (1998) Reefs at risk. http://www.wri.org./biodiv/marihome.html (Accessed October, 2008).

Yousuf, A.R. (1996) Fishery resources of Kashmir. Page 87-105. In: Khan, A.H and Pandit, A.K. (Eds). *Ecology, Environment and Energy.* Department of Distance Education, University of Kashmir, Srinagar, India.

Ysebaert, T; Meininger, P.L; Meire, P; Devos, K; Berrevoets, C.M; Strucker, RCW; Kuijken, E. (2000) Waterbird communities along the estuarine salinity gradient of the Schelde estuary, NW- Europe. *Biodiversity and Conservation* **9**: 1275-1296.

Zar, J.H. (1974) Biostatistical Analysis. Prentice Hall, New Jersey, U.S.A.

Zewarts, L. (1976) Density related processes in feeding dispersion and feeding activity of Teal (*Anas crecca*). *Ardea* **64**: 192- 209.

Zutshi, D.P. (1975) Association of macrophytic vegetation in Kashmir lakes. *Vegetatio* **30**: 61-65.

Zutshi, D.P and Khan, M.A. (1978) On lake typology of Kashmir. Environment Physiology and Ecology of Plants. pp: 465-472.

Zutshi, D.P; Subla, B.A; Khan, M.A and A. Wangoo. (1980) Comparative limnology of nine lakes of Jammu and Kashmir Himalayas-*Hydrobiologia*: 101-112.

Zutshi, D.P and Gopal, B. (1990) Structure and dynamics of plant communities. In: Gopal, B. (Eds).*Ecology and Management of aquatic vegetation in the Indian subcontinent*. Kluwer Academic Publishers.

Zutshi, D.P. (1996) Quantification of suspended solids in Dal Lake, Srinagar using Remote Sensing technology. *Journal of the Indian Society of remote sensing* **24**(2): 18-24.

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Appendix 1

Birds recorded in Hokersar and Hygam wetlands of Jammu and Kashmir during mid-winter (December-January, 2004-2005) and post-winter/spring (February- April, 2005).

Family	**Bird species recorded**			
	Hokersar wetland		**Hygam wetland**	
	Common Name	Scientific Name	Common Name	Scientific Name
Anatidae	Mallard	*Anas platyrhynchos*	Mallard	*Anas platyrhynchos*
	Gadwall	*Anas strepera*	Gadwall	*Anas strepera*
	Northern Shoveler	*Anas clypeata*	Northern Shoveler	*Anas clypeata*
	Northern Pintail	*Anas acuta*	Northern Pintail	*Anas acuta*
	Eurasian Wigeon	*Anas Penelope*	Eurasian Wigeon	*Anas Penelope*
	Greylag Geese	*Anser anser*	Greylag Geese	*Anser anser*
	Common Teal	*Anas crecca*	Common Teal	*Anas crecca*
	Red -crested Pochard	*Rhodonessa rufina*		
	Common Pochard	*Aythya ferina*		
	Ruddy Shelduck	*Tadorna ferruginea*		
	Garganey	*Anas querquedula*		

Contd....

Appendix 1 contd....

Rallidae	Common Coot	*Fulica atra*	Common Coot	*Fulica atra*
	Common Moorhen	*Gallinula chloropus*	Common Moorhen	*Gallinula chloropus*
Ardeidae	Little Egret	*Tachybaptus ruficollis*	Little Egret	*Tachybaptus ruficollis*
	Cattle Egret	*Bubulcus ibis*	Cattle Egret	*Bubulcus ibis*
	Grey Heron	*Ardea cinerea*	Grey Heron	*Ardea cinerea*
	Indian Pond Heron	*Ardeola grayii*	Indian Pond Heron	*Ardeola grayii*
Podicipedidae	Little Grebe	*Tachybaptus ruficollis*	Little Grebe	*Tachybaptus ruficollis*
Phalacrocoracidae			Little Cormorant	*Phalacrocorax pygmeus*
Scolopacidae	Common Snipe	*Gallinago gallinago*	Common Snipe	*Gallinago gallinago*
Recurvirostridae	Black-winged Stilt	*Himantopus himantopus*		
Charadriidae	Little Ringed Plover	*Charadrius dubius*		
	Common Sandpiper	*Actitis hypoleucos*		