Comparison of bird species diversity with respect to different habitat types, in Pelwatta sugar plantation area

By

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DECLARATION

The work described in this thesis was carried out by me at the Faculty of Applied Sciences under the supervision of Prof. S.W.Kotagama and Ms. Enoka P. Kudawidanage. A report on this has not been submitted to any other University for another degree.

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Affectionately Dedicated

To

My Ever Loving

Parents

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ABSTRACT

The study of Avifaunal diversity was conducted within the sugar plantation area of PSI and its vicinity from November 01, 2003 to February 28, 2004. PSI is located about 3 km from Burutha junction on the A-4 main road (Colombo-Batticaloa) and the study site (section 2 and section 3) is 15 km away from the PSI factory. Line transects, block counts, point counts and opportunistic observations were conducted in four different habitat types to identify bird species diversity. The habitat types studied were, old, man-made water body (re-established in1990), a new, man-made water body (re-established in 2002), a hillock with rocks and shrubs and a stretch of the river boundary of Manik ganga. All nesting habitats in canopy level were identified and counted separately in all four habitat types.

A total of 103 bird species from 46 families and 15 orders were observed in all four habitat types. 92 of them were resident species, 10 migrants and 1 endemic to Sri Lanka. The species richness indicator values were 84, 61, 75, and 56 in the IPW (old water body), PMW (new water body), MGR (riverine) and hillock respectively.

There was a marked difference in species composition and diversity between old and new water bodies. Also it shows different species richness and abundance between four habitat types. Some endangered, vulnerable and rare species like Red-faced Malkoha, Blue-eared kingfisher; Spot billed Pelican categorized under international conservation status were present in the study area. It is pertinent that that protection and conservation programs for the area should be based on the presence of these species.

The rich diversity suggests the ecological importance of the area in terms of bird habitats and the economical importance in term of eco tourism. Also legislation should set the stage for legalizing these habitat areas using under a series of management control.

CONTENTS

ABBREVIATIONS

PSI	:	Pelwatta Sugar Industry
AGA	:	Assistant Government Agent divisions
ICBP	:	International Council for Bird Preservation
GPS	:	Global Positioning Systems
IPW	:	Indigaha Pellassa Wewa
PMW	:	Pahala Menik Wewa
MGR	:	Menik Ganga River
VC	:	Very Commom
C	:	Common
R	:	Rare
VR	:	Very Rare
M	:	Migrant
BrR	:	Breeding Resident

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CHAPTER 1

Introduction and Objectives

1.1 Introduction

Agricultural land is the most important of all habitats for mankind. On the other hand it is not a natural habitat; but a man-made and every one of the 14 million square kilometers of cultivated land exists at the expense of some natural habitat (Diamond et al, 1987). So, agricultural lands are second-class habitats for fauna including birds.

Although it occupies over nine per cent of the land area of the earth, farmland contributes to less than eight per cent of world primary production and well under one per cent of plant biomass. In spite of the enormous investments of time, money, machinery and chemicals that go in to growing food, agricultural land competing poorly with many natural ecosystems. Agricultural ecosystems differ from natural ones in several respects that are important to birds and other wildlife. In most cases the biggest yields are obtained by growing a single crop in large fields, dressed abundantly with chemical fertilizers and pesticides. Intensive agriculture typically depends on such monocultures (Diamond et al, 1987).

One good example is the sugar cane cultivation. Among the sugar producing plants, sugar cane is responsible for about 60 per cent of world's sugar production, the remaining 40 per cent coming from sugar beet, a temperate zone crop (Alexander, 1973).

In the case of sugar cane cultivation, there are lots of changes in the land use. As for every other country this is common to Sri Lanka too.

Land use conflicts and changes (with relation to sugar cane) in use patterns have been most visibly demonstrated in Moneragala district, Sri Lanka with respect to the advent of large sugar cane companies and the vast expansion of monocroping systems. The introduction of sugar industry also poses some environmental concerns, largely because of its scale of operation and multiple impacts in the region (CEA, 1992). Thus sugar cane plantation system has created the path to the further deforestation, soil erosion and displacement of wildlife.

Pelwatta area in Moneragala district is one of the regions, which undergoes large-scale sugar cane cultivation.

In Pelwatta area, the traditional land use pattern namely rain fed highland (chena), changed to a commercial agriculture with the plantation of sugar cane, introduced by the Government in recent years. This transformed most of the traditional chena areas patches of dry mixed evergreen forest and scrub jungles in to sugar cane estates and out grower's plots.

Instead of the sugar cane cultivation, there are some natural habitats in the area are; savanna grassland patches, intermediate forests patches and water bodies. Most of these are secondary habitats. The species composition of secondary habitats is different from primary habitats, and composition further change with time of establish of the habitat.

Also, the Pelwatta sugar plantation area provides secondary niches for the both aquatic and terrestrial avifaunal species, which preferred dry and intermediate climate conditions. The area of Pelwatta inhabited by a diverse avifauna of dry and intermediate zone. The number of bird species, the population size, their dispersal and other population parameters vary with the quality of habitats

1.2 Scope of the study

Establishment of Pelwatta Sugar Industry in 1981(PSI) resulted in the conversion of existing vegetation and wildlife habitats in the area to a monoculture thus affecting animal diversity. Other than sugar cane cultivation, within the PSI area presently there are number of different habitat types, forest patches, grasslands and water holes, some recently constructed and some left unchanged. Wildlife, in this case avifauna still occurs in varied diversities in these locations. The study investigates the different diversity patches of avifauna observed, had different habitat quality conditions.

1.3 Prior Studies

There has been no study; on the species diversity of birds in sugar plantation areas, only few studies of similar nature in Sri Lanka exist on Intermediate zone. According to the prior studies in the Intermediate zone to which the study area belongs, the species richness of birds is very high. Therefore it is very important to carry out this study for the identification of the effect of large-scale plantation (sugar cane) and habitat changes on the diversity of birds. There were two case studies done in Sri Lanka, which are similar to this study and methodology. They were carried out in Maduruoya National Park by S.R.B.Dissanayake and Riversten and Pitawalapathana by W.M.Sriyani.

1.4 Objectives

Identification of the relationship between the species richness of birds and quality of habitats in the Pelwatta Sugar plantation area

Determination of the habitat needs of birds

Map Interpretation of the habitat types

CHAPTER 2

Effects of habitat change on Bird diversity

2.1 Introduction

Birds among all animals offer the most favorable combination of attributes for scientific study. They are numerous, abundantly diversified in form, and easily observed. They are highly organized and responsive with sensory capacities similar to man's and therefore understandable. Pleasing in colours and movements, they also, with few exceptions, inoffensive in their habits and incapable of physically harming the investigator. Many adapt readily to experimentation. Little wander that ornithology, the science of birds, boasts so many practitioners, and in turn contributes so significantly to modern concepts of evolution, speciation, behavior, and ecology (Pettingill, 1985).

Since birds like men, are largely diurnal creatures and share with us the familiar day time world of colour and sound our association with them is not surprisingly, a long and intimate one (Benson, 1960).

2.1.1 Characteristic features of Birds

Birds are unique among all animals in being feathered. Like mammals, they too are warm-blooded, or homoiothermous, capable of regulating there body temperature. And like most of there vertebrate associates, excepting most mammals and few others, they lay eggs (Pettingill, 1985). To assist in maintain an even temperature, the body of a bird is covered with non-conducting feathers, which is the chief characteristic of bird (Ali, 1996).

Animals move from place to place by running, hopping, walking, crawling, swimming, gliding, and flying. Among birds, flight is the principal means of locomotion, even though some forms-for example,. ostriches, kiwis, and penguins-in the course of evolution have lost their ability to fly. Therefore, one recognizes birds as birds because they are formed to fly (Pettingill, 1985).

The modern bird, like an airplane, is structurally and functionally efficient. A bird must be able to take flight, to stay aloft, and to reach its destination under the most adverse conditions (Pettingill, 1985).

2.1.2 Classification of birds

As common to all the other animals birds too are classified in to orders, families, genera and species. Each genus consists of a number of species, which are obviously closely related. The first of a bird two or three Latin names is that of its genus and the second described the species, while a third is used for sub species. A species is a population of birds with distinct identity, which does not interbreed, with other bird's populations. Where there is a constant variation in a species, it is called sub species (Grewal, 1995).

Birds are classified into number of orders and families. Some of Orders are, Anseriformes, Apodiformes, Caprimulgiformes, Charadriiformes, Ciconiiformes, Columbiformes, Coraciiformes, Cuculiformes, Passeriformes, Pelecaniformes, Piciformes, Podicipediformes, Psittaciformes Falconiformes, Galliformes, and Gruiformes (Harrison, 1999). Generally Birds are refined in two main categories as Aquatic and Terrestrial.

2.2 Bird species diversity in the world

There are thought to be between 8600 and 9016 bird species in the world. A precise figure could never be given for new species. New species continue to be discovered in remote or little known areas while the others is very vague, some times bordering on extinction. If sub species or geographical races are taken in to account the figure would rise to nearly 30,000 (Ali, 1996).

The Philippines, another biodiversity hotspot, has lost 97 percent of its original vegetation and has more Critically Endangered birds than any other country. Threatened birds are concentrated in tropical Central and South America, and Southeast Asia. Indonesia has the most threatened birds (115), followed by Brazil

with 113 species. Colombia, China, Peru and India follow, with 78, 76, 75 and 74 species respectively. The overall results are similar to those for 1996 with all the same countries appearing prominent except for Papua New Guinea (32 species), which is now replaced by Tanzania (33 species). New Zealand and the Philippines have by far the highest percentage of threatened species with 42 percent and 35 percent respectively (IUCN, 2003).

Bird Life International's distribution map of all threatened birds shows that globally they are unevenly distributed. They occur on more than 20 percent of the Earth's land surface but less than 5 percent of the land holds almost 75 percent of all threatened birds (IUCN, 2003).

2.3 Birds species diversity in the Indian sub-continent

As the Indian sub continent has a very dense human population, birds, which get on well with man flourish. These are not limited to house sparrows, crows and House martins (Grewal, 1995).

The vast Indian sub-continent with its extensive coastline affords suitable living conditions to a great variety of feathered inhabitants. "Fauna of British India" series of birds enumerated some 2400 forms (species and sub species). The latest check list, "A synopsis of the Birds of India and Pakistan lists 2061 forms of which over 300 are winter visitors, chiefly from the palaearctic region of the north. The Indian sub-continent as a whole falls in to the zoogeographical division of the Earth known as the Oriental region. For the sake of convenience it has been split up in to 5 primary sub divisions as given below (Ali, 1996).

1. The Indo-Gangetic plain
2. Peninsular India
3. Sri Lanka
4. The Himalayas
5. Assam

While many common species are spread over large areas of the oriental realm, others are limited not just to a region but also to habitat. Some birds of a conifer forest of high hills will be found only there, while grassland birds may be restricted to that habitat (Grewal, 1995).

2.4 Birds species diversity in Sri Lanka

Sri Lanka is a remarkable area for bird life. Although far from large, the country has a wide range of climate and habitat, which support some 400 species and sub species of birds (Grewal, 1995).

2.4.1 Geology, Climate and Vegetation distribution of Sri Lanka

Sri Lanka is the tropical island about 430km long and 230km across at its widest point lying approximately between 6° and 9° north of the equator. It is almost joined to the coast of southeast India by a series of islands, sand banks and shoals less than 100 Km long called Adam's Bridge. The coastal areas are mainly low lying with many lagoons and wet lands areas. The northern half of the island is mostly flat intersected by rivers with a number of reservoirs known locally as tanks. The center of the island is mountainous with the highest point mount Piduruthalagala reaching 2524m.The hill country also has a number of tanks, some very large (Harrison, 1999).

On the basis of the lithology, structure and age, the precambrian rocks in Sri Lanka, have been sub divided in to four major groups (Cooray, 1984) as below.

1. Highland Complex (HC)
2. Vijayan Complex (VC)
3. Wanni Complex (WC)
4. Kadugannawa Complex (KC)

There are two seasons in Sri Lanka. From May to September the southwest monsoon brings rain to the southwest and to the hills facing wind (the wet zone) leaving the rest of the country fairly day. During the other months the northeast monsoon blows bringing rain to the north and less so, to the east and southeast (the dry zone), also to the hills and the southwest, with most of the rain falling between November and February (Harrison, 1999).

The annual rain fall in the wet zone rangers between about 5000mm and 2000mm. In the dry zone it is around 1875mm in the north falling to 625mm in the southeast. Midday temperatures at sea level average 27°C and in the higher hills ma cool and often damp 16°C (Harrison, 1999).

As one would expect from the rainfall pattern the vegetation in the in the wet zone is lush while that in the dry is sparse. The needs of agriculture and forestry have modified the original coves over much of the land but some virgin rain forest survives in the Sinharaja forest reserve near Ratnapura. The forest of the dry zone have also suffered centuries of shifting agriculture a much of what remains is secondary forest and scrub (Harrison, 1999).

2.4.2 Avifaunal diversity

The avifauna of the Western Ghats and Sri Lanka is diverse but endemism is not exceptional. There are 528 known bird species from the hotspot; 40 of these are endemic. Twenty-three species are endemic to Sri Lanka, mostly from the lowland rainforests and montane forests of the island's southwestern region. Six endemic species are threatened in the hotspot, all closed-canopy species from Sri Lanka. These include the Green-billed coucal (*Centropus chlororhynchos*), Sri Lanka Whistling thrush (*Myiophonus blighi*), Spot-billed Pelican (*Pelecanus philippensis*) and the Lesser adjutant (*Leptoptilos javanicus*). A third threatened species, the Kashmir flycatcher (*Ficedula subrubra*), breeds in the Himalayas and winters in the Western Ghats and in Sri Lanka (Kumar et al, 1999).

Sri Lanka avifauna is one of the richest in the whole of Asia. It contains 435 species comprising 331 regular species found within the land boundary of the country including the 23 confirmed endemic species 68 irregular species recorded over years and 36 oceanic species (Kotagama and Wijayasinghe, 1998).

Many of the island's birds are identical to those found in India, although for some reason vultures have not been able to cross the palk strait. Sri Lanka can be divided in to 3 zones, the dry plains of the north, the mountainous central region and the humid wet zone around the capital Colombo (Grewal, 1995).

2.4.2.1 Endemism of birds in Sri Lanka

Endemic taxa are forms that have evolved their uniqueness in, and are restricted to, a particular region. Endemism can exist at any taxonomic level from subspecies to phylum. An additional aspect of biodiversity is therefore the degree of endemism in the biota of a particular region. Geographical areas that have been isolated for a long period of evolutionary time often show high level of plant and animal endemism (Cox, 1997).

Sri Lanka has number of endemic plants and animal including 23 species of birds like the Red faced Malkoha, Ceylon Blue Magpie, Sri Lanka Grey Hornbill and others. Also Sri Lanka has other 3 birds species, which are named as the endemic species, but not confirm yet.

Thank to its large range extending in to dry zone forests, the Grey Hornbill is not considered threatened at present (Kotagama, 2000). But Malkoha (Red Faced) and other most species of endemic birds considered as the threatened species.

Malkohas are today entirely confined to undisturbed, tall forest patches in the wet zone, scattered tall forest and riverine vegetation of the dry zone (Kotagama, 2000).

2.5 Bird species diversity in the Intermediate zone of Sri Lanka.

The map of Bio climatic zones of Sri Lanka shows Moneragala district belongs to the hot dry lowland tropical and hot moist lowland tropical (Fernando and Fernando, 1968).

The area is inhabited by a diverse Avifauna of dry and intermediate zone including endangered species and rare species like the Red faced Malkoha, Painted partridge, Blue eared Kingfisher and southern yellow-legged green pigeon. A majority of the 251 resident bird species found in Sri Lanka are also found and during the winter months at least 75 other bird species migrate from Europe and other Northern countries (CEA, 1992).

2.6 Relationship between Birds and habitats

Birds make up a trivial proportion of species on earth. Yet they are extremely important, simply because they are so few species of birds and we know so much about so many of them. Birds are closely related to the habitat conditions. Each species rarely occurs in only one type of habitat. Birds are completely depend on their habitat, its cover, structural and floristic diversity and rich food resources. Habitat type, size of the area, plant community structure and landscape pattern can have a great effect on bird community structure in a given habitat (Vithanage, 1999). Also the species composition of birds vary with Habitat type (Vattala and Kotagama, 1990).

Although the relationship of birds to local habitats and larger-scale landscape variables have been the focus of many studies, surprisingly few investigations have focused on wetland ecosystems. (Sekercioglu, 2002 b). In Sri Lanka, owing to the abundance of wetlands, considerably more attention should be paid to wetland birds.

2.6.1 Ecological distribution

The natural arrangement of organism with relation to environment is called "ecological distribution". Whereas geographical distribution deals with organisms in areas, ecological distribution deals with organisms in habitats on ecosystems; ecological distribution has to do with organisms in environments. The environment that a species normally occupies in its "habitat" (Pettingill, 1985).

2.7 Threats to Avifaunal habitats

At present, some harmful threats have been recorded for the Avifaunal habitats. These threats can be summarized as follow.

2.7.1 Fragmentation and habitat loss

Habitats in the world, especially in the tropics are being fragmented at a rapid rate, causing a tremendous loss of biodiversity. For example 12 per cent of the approximately 10,000 bird species are threatened with extinction in the next 10 to 100 and another 8 per cent are near threatened. This loss of species is likely to result in the collapse of significant ecosystem processes and free ecosystem services to people, such as pest control by insectivorous birds (Sekercioglu, 2002 a).

Conservationists have expressed great concern that as landscapes are fragmented more and more songbirds end up nesting in edge environments where they are subject to unnaturally high levels of predation (Leopold, 1933).

Humans believe that we own and have the right to dominate, every square inch of the earth. That besides being and absurd idea is the basic reason why we are losing, world wide, about 100 species per day. Habitat loss is at the top of every list of primary reasons why species have become extinct or are becoming extinct (Vandeman, 1997).

Outright destruction of habitat (for example paving it or turning it in to farms, golf courses, housing developments or parks) is not the only way that an area can become

useless as habitat. Anything that makes it unattractive or unavailable to a given species causes habitat loss (Vandeman, 1997).

About two-thirds of the species recognized as endangered are threatened by the loss of their habitat. (This figure does not take in to account the long term threat posed by the loss of most of the world's tropical rain forests, which puts at risk up to 2000 species that are not currently classified as endangered.) Loss of habitat is as fatal to a species as killing all the individuals or preventing them from breeding. Unlike people, birds cannot simply find a new patch of habitat because that is already full, nor can they adapt overnight to a new kind of habitat because that will be occupied by other species already adapt to it (Diamond et al 1987).

2.7.2 Immediate effects of Habitat disturbances

Many rare bird species are highly sensitive to disturbance and are threatened (Bird Life, 2000). Five different effects of human disturbance have been identified (Major, 1989).

1. Some birds desert their nests after human interference (Major, 1989)
2. Predators may take eggs from nests under guarded after the parents have been flushed (Major, 1989)
3. Chicks of colonial species, which have been chased in to neighboring territories, may be killed (Robert and Ralph, 1975)
4. Parts may damage their eggs when disturbed (Robert and Ralph, 1975) and
5. There is speculation that humans might be attract predators to nests (Major, 1989)

Also the habitat disturbance may be caused by bird watching. The high expectations of many bird watchers are not always beneficial and the excessive zeal of some bird watchers to see or photograph certain species may have harmful consequences (Boyle and Samson, 1985). Even though most of these may be due to photography rather than bird watching. Here, "disturbance" mainly refers to intrusion and excludes habitat modification (Sekercioglu, 2002 c).

Impacts of disturbance are complex, with responses differing between individuals of the some species and even between different periods for the some individuals (Sekercioglu, 2002 c).

Human presence around bird nests increase nest abandonment and egg loss due to nest predators (Sekercioglu, 2002 c).

However determining the impacts of forest disturbance and fragmentation on tropical biotas is a central goal of conservation biology. Among tropical forest birds, understory insectivores are particularly sensitive to habitat disturbance and fragmentation, despite their relatively small sizes and freedom from hunting pressure (Sekercioglu et al, 2001).

These changes in vegetation also modify the forest microclimate by altering temperature, humidity, light and wind levels (Sekercioglu, 2002 b). Dispersal, crucial in the colonization of habitat islands may be the key mechanisms that make it more likely that small and short lived bird species will go extinct as a result of habitat fragmentation compared with large and long-lived species (Sekercioglu et al, 2001).

2.7.3 Problems related with agricultural land uses

Relatively few kind of bird can thrive in these monoculture conditions, tree-nesting species have nowhere to nest and ground-feeding and ground-nesting birds are vulnerable to the heavy machinery used to plant, manage and harvested the crop (Diamond et al, 1987).

As more and more land is brought in to cultivation of some sort, birds that can adopt to agricultural land must increase at the expense of those that cannot, but in the long term the greatest effect of agricultural land on bird-life will be through the loss of the habitats that are destroyed (Diamond et al, 1987). Application of agro-chemicals to control pests and diseases and weeds may have unfavorable side effects and necessitate rethinking on the methodologies to be practiced (Babu, 1979).

2.8 Conservation of Birds and their habitats

Birds contribute to natural regeneration in numerous ways. Varieties of trees, shrubs and grasses, it follows that the activities of birds are essential for the health of all our ecosystems. Habitat loss and degradation of natural ecosystems are the most serious threats to bird life (Verghese et al, 1995).

ICBP gets results by harnessing the human and financial resources of its most powerful member organizations to the cause of international conservation. Their main task is to spread the conservation word to developing countries in the tropics and on islands where conservation is almost unknown. That is where 75 per cent of the world's threatened birds are found. In such countries, the efforts of a handful of people are all that stand between many forms of wildlife and extinction (Diamond et al, 1987).

Also analogue forestry, which mimics the multi-tiered mixed vegetation of natural forests, is an important method for bird's conservation (Verghese et al, 1995). Minimizing bird disturbance and flushing will also improve the quality of bird watching and may increase bird abundance and species richness. Because birds are highly sensitive to noise and the number of people (Sekercioglu, 2002c).

We treat grassland, scrub and heaths together because they frequently grade in to each other. Their bird life has much in common and they share similar problems (Diamond et al, 1987). However future conservation measures will have to take a metapopulation approach along with eco-regional planning (Cullen et al, 2001).

2.9 Census of Avifaunal diversity and abundance

Birds are perhaps the easiest of animals to census. They are often brightly coloured, relatively easy to see and highly vocal. They are also very popular to study, with the result that there are high- quality field guides available and many professionals and amateurs with a high level of identification skills. Because of this popularity, they are undoubtedly the most frequently censured of all taxa. Though some may argue that

birds receive more than their fair share of the monitoring. Take, the widespread involvement of volunteers in many schemes makes bird census and monitoring an extremely cost- effective way of monitoring an extremely the overall health of the environment (Furness and Greenwood, 1993).

2.9.1 Species Richness

The number of species of organisms present in area is called species richness. This is an important component of biodiversity. If species are weighted by some measure of their importance, such as their abundance, productively or size, we speak of species diversity. The most frequently used indices of diversity are the Shannon-Wiener index and the Simpson index (Meffe and Carroll, 1994).

Shannon-Wiener index is calculated using the following equation,

$$H^1 = -\sum (P_i \log P_i)$$

Where, P_i =Proportional frequency of the i^{th} species.

2.9.2 Study techniques for Avifaunal census

Species diversity and abundance is important for avifaunal conservation. In tropical forest it is very difficult to locate birds, due to the structure of the habitats which has high dense under growth (Bibby et al, 1992). Therefore many researchers on avifaunal studies have selected reliable and safe methods from among a number of different complimentary methods (Sriyani, 2000).

In this study four methods, line transects, block counts, point counts and opportunistic observations were used for data collection.

2.9.2.1 Line transects

The idea of walking about and counting all the birds detected has the appeal of simplicity. One would expect to count more individuals of a species in its favored habit than elsewhere and more in a year of high than low population density. By keeping moving, it is possible to cover more ground in fixed time than by any more elaborated efficiently. Long transect can be divided in to small sections whose habitats can be measured (Bibby et al, 1992).

Line transects are undertaken by observers moving along a fixed route and recording the birds they see on either side of the route. Transects can be worked (or driven) on land, sailed on the sea, or flown in the air. Because the observer needs to be able to more freely though the land, sea or air, transects are most suitable for large areas of continues, open habitat (Southerland, 1996).

A transect route could even be square or rectangular allowing the observer to end up at the stating point. Where maps are insufficient to plan a route, precisely, it is a good idea to walk along compass bearings (Koskimies and Vaisanen, 1991).

2.9.2.1.1 Advantages of Line transect method

Transects can be under taken at any time of year, on land, on sea, or in the air. They are suited to large areas of homogeneous habitat, and are particularly useful where bird populations occur at low density. Estimates of density can be calculated. The area sampled by a line transect increases linearly away from the transect line, thus errors in detecting birds close to the observer and distance estimate are less likely to bias density estimation than in point counts (Southerland, 1996).

2.9.2.2 Block counts

This method was done on the wetland birds. In this study this was done for the 2 man made water bodies.

When counting maximum accuracy should be aimed for, sometimes this is best achieved by counting each bird individually (direct counts or census); or sometimes by estimating their numbers. Bird by bird counts are usually made if the numbers are small, when there is limited movements of bird and if birds are scattered in a small and open area such as a mudflat (Kotagama, 2003).

Estimates (indirect counts) are usually carried out if the number of birds if fairly high (>3000) or continually in flight or if they are tightly packed together so that identification of individual birds because a difficult task (Kotagama, 2003).

2.9.2.3 Point counts (Spot counts)

If you stand at one place, it is possible to count all the birds seen & heard. As its simple, such a method repeated over several places will assemble a list of species, present in an area. With some assumptions on detectability of birds varies with distance, this can be made in to a powerful method of measuring relative abundance rather efficiently. It has some effective variants if the habit is also measured in a circle around the census point. Inferences can then be drawn about habit selection and preferences of individual bird spears or communities (Bibby et al, 1992).

Point count stations (the position from which the count is made) should be lay out within the study plot either in systematic manner (for example, on a grid) or in a random manner, stratified or not. The stations should not be too close together, as some individuals would be counted at more than one counting station, which could spuriously inflate the sample size and influence the precision of the results. A sensible minimum distance is 200m. If the distance between points is too great, however too much time will be wasted traveling between the counting stations (Bibby et al, 1998).

As a reasonable large of point counts (more than 20) will be needed from each study plot, point counting is not a suitable technique for small study areas. Twenty counts can readily be made in a morning stating soon after dawn (Southerland et al, 1996).

2.9.2.3.1 Advantages of point count

Counting stations are relatively easy to allocate randomly, which is not always the case for territory- mapping plots or transects. Point counts are more suitable than transects where habit is patchy, though much less so in open habitats where birds likely to flee from the observer. Point counts are unsuitable for species, which are easily disturbed. They are, however, very efficient for gathering large amounts of data quickly. Point counts can be used outside the breeding season (Southerland et al, 1996).

2.9.2.4 Opportunistic Observations

Opportunistic Observations was done irrespective of habitats, locations species and number of species when traveling along the plot (Sriyani, 2000).

CHAPTER 3

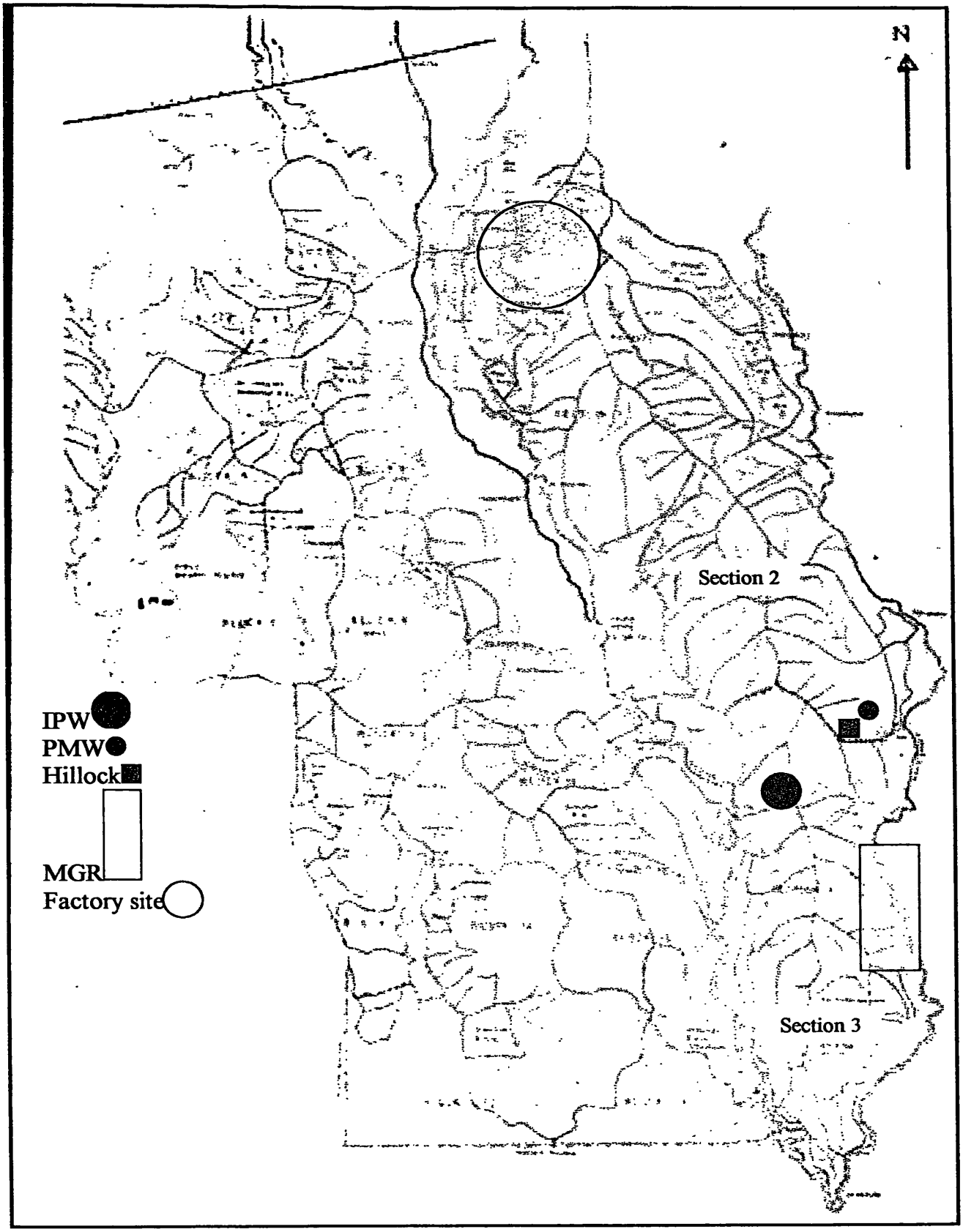
Materials and Methodology

3.1 Study Area

The study of bird species diversity and abundance was carried out at the PSI's sugar plantation area in the Moneragala district. PSI has both private and public investment holdings; though its operations are wholly private. The research was conducted for fifteen weeks from November 01, 2003 to February 28, 2004. The study area of the research lies inside section 2 and section 3 of the sugar plantation area of the PSI. It is about three kilometers away from the Burutha junction on the right side of the Colombo – Pothuvil main road (A4) and in-between Buttala and Wellawaya AGA divisions in Moneragala district in the Uva province of Sri Lanka. The section 2 and section 3 are situated fifteen kilometers far away from the PSI factory site. Those section covers an area including sugar cultivation, roads, grassland patches, bare lands with rocks, man made water bodies, and a hillock. The Kuda Oya and Menik ganga marks two boundaries of section 2 and 3. Another boundary is located between section 2 and section 3 (Figure 3.1). The Plates of the studied habitats are shows structures of the habitats.

3.1.1 Geography of study area

Moneragala district is located between the northern latitudes 6° 17" and 7° 2 ' 8" and between eastern longitudes 80° 50" and 81° 35"(CEA, 1992). The study area was situated within the low and mid country Intermediate zone of Sri Lanka as showed as Figure 3.2 .



Source: PSI.AG/ENG-Survey Scale : uncontrolled reduction of 1:20,000 map

Figure 3.1 Map of the Pelwatta Sugar Plantation area (Study area)

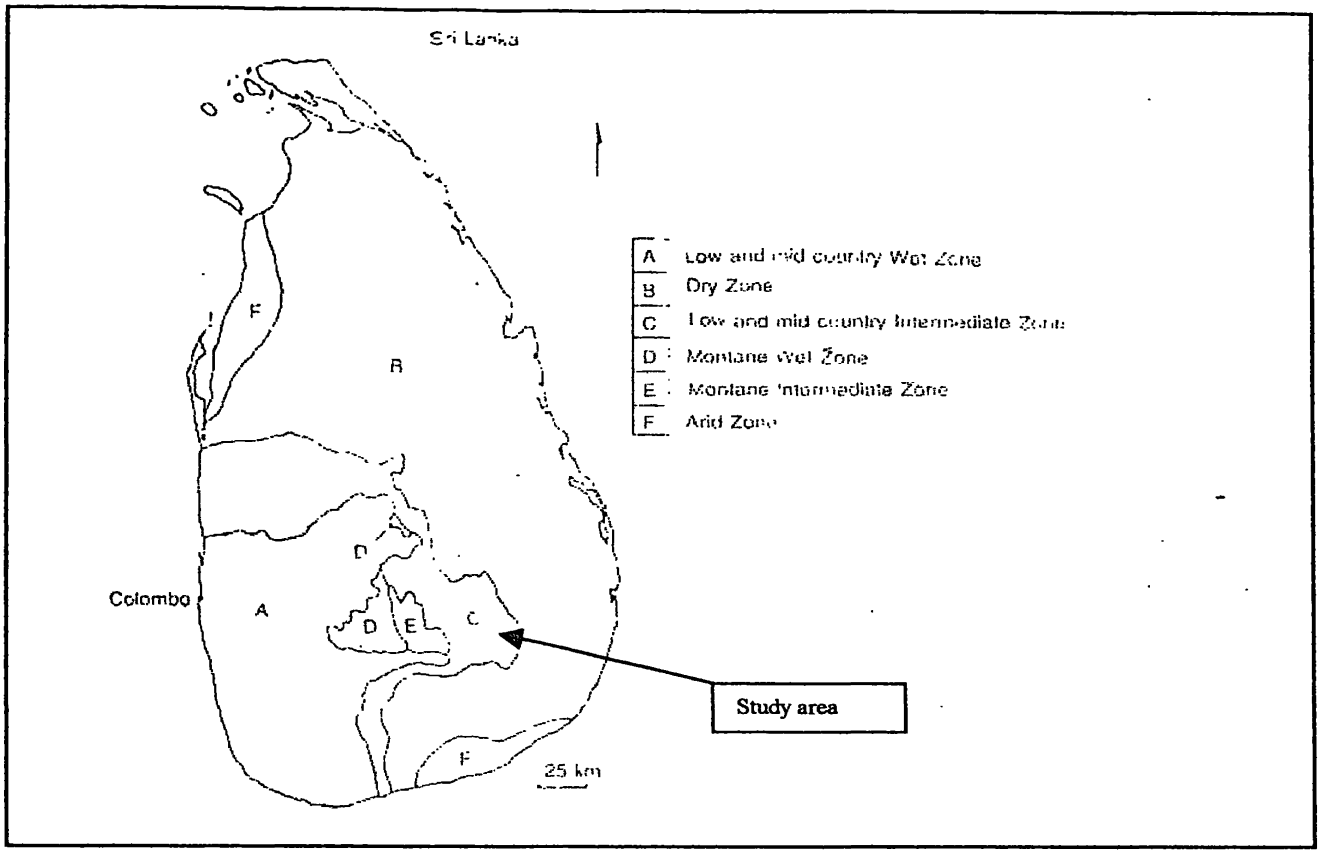


Figure 3.2 Bio climatic zones of the Sri Lanka (Cooray et al, 2000)

3.1.2 Geological setting of the study area

Geologically the study area lies within the Vijayan Complex (VC), according to the geological map of Sri Lanka (Cooray, 1984). The area is in a transitional zone from Central highland to flat lowland (CEA, 1992).

3.1.3 Climate of the study area

There are two rainy seasons namely "Maha"(main) rain season and "Yala" (minor) rain season. The two rainy seasons extend from early October to late January and from late March to late May respectively and corresponding to these long and short rainy seasons there is also a long and short dry seasons (June to September and February to March). Total rainfall in the area ranges 1328mm to 1821mm, in a year. Mean daily temperature of the district vary little over the year as the altitude within

the vast low country of the district does not exceed 91m. The temperature varies only from 26°C in January to 29°C in June (CEA, 1992).

3.1.4 Vegetation distribution of the area

Most of the dry and intermediate zone of Sri Lanka is covered by secondary forests and open grass or scrublands. But in the study area is mostly covered by sugar cane. Because PSI was established in 1981, by cutting the one of dry mixed evergreen forest and by changed traditional chena areas. According to the Fernando and Wirasinghe(1974),Moneragala district has suitable climate for irrigated sugar cane cultivation. Today major proportion of Palwatta is covered with sugar cane, but there are some primary and secondary habitat patches are left in the forms of forests, grasslands, shrub forest and riverine vegetation.

3.1.5 Sampling sites

Four sampling locations were selected to conduct the study. Namely an old, man made lake, A newly established water body, a hillock and a strip of riverine vegetation.

The old, man made lake is colonized with vegetation and is least disturbed. The new water body is still in the regeneration stage with sparse vegetation. The hillock is more or less bare covered to some extent with grass and bushed. The riverine vegetation is the least disturbed and thickly forested.

Plate 3.1 Old, man-made water body (IPW)

Plate 3.2 New, man-made water body (PMW)

Plate 3.3 Riverine habitat (MGR)

Plate 3.4 Hillock

3.2 Methodology

Field observation were made during a period of November, 2003 to February, 2004 in section 2 and section 3 sugar plantation area in between 06.00h to 18.00h. Data was collected in clear sunny days. Only very few days with showers were encounted within the study period. Several preliminary field observations were done prior to the detailed study to get the basic information about the area to design the study. Observations on birds and vegetation were done in the morning between 06.00h to 09.00h, midday 11.00h to 14.00h and evening 16.00h to 18.00h.

3.2.1 Bird species diversity and abundance

Data on birds were obtained using four methods, namely line transects, block counts, point (spot) counts and opportunistic observations. Methods for sampling were selected, according to the habitat type.

Line transects, point counts, while opportunistic observations were made for the hillock and along the river boundary (MGR). Block counts, point counts and also opportunistic observations were made for the two man made water bodies namely Indigahapellassa(IPW) and Pahala Menik Wewa(PMW).

3.2.1.1 Line transects

Line transects were done in some selected routes in the hillock and along the river boundary. The routes were selected around the hillock and along the river and traversed at fixed time at a fixed speed. All birds seen and heard were recorded within a strip of 25m either side of the route. The length of area covered for sampling was 250m area in the hillock and 1km area in riverine.

Simple indices of the number of birds recorded per unit length of transect can be obtained by counting birds either up to an unlimited distance (a fix strip transect), on either side of the transect. Approximate densities can be calculate from the fixed strip transect but rely on the assumption that all birds are detected, which is unlikely to be

the case for all but the narrowest strips and the most detectable of species (Southerland, 1996).

A pair of binoculars (7*50) was used to identify birds at a distance. The 250m line transect (around the hillock) was covered in 30 minutes while the 1km transect (along the river boundary) in 75minutes. The observation were done from 06.00h to 09.00h in the morning, 11.00h to 14.00h in the midday and 16.00h to 18.00h in the evening and also line transects were done on twenty randomly selected days per November, 2003 to February, 2004 time period. But these records were not simultaneously taken in both sites.

3.2.1.2 Block counts

Block counts were done for the two water bodies. A sketch map of water body was drawn and blocks were selected using the compass. The counts were made by a single observer at several times, until the entire wetland was covered. The counts were repeated to the ensure the precision of the counts on several consecutive days. So that pooled data would be a better and more accurate representation of the true population size of the particular species under study. Standard deviation and the confidence limits were calculated.

3.2.1.3 Point counts

Point counts were done in some selected spots around the two water bodies and along the river using spot scope (22*W.A.), pair of binoculars (7*50), and naked eye.

Calculations were based on the simple method of recording how many birds are detected within a fixed distance (Southerland, 1996).

3.2.1.4 Opportunistic observations

Opportunistic observation was done for the all four types of habitats. It was done irrespective of habitats, location, species and number of species when traveling along the plot.

3.3 Vegetational survey

A Vegetational survey was conducted within the habitat types to determine the habitat quality. The distributions of vegetation in the four habitat types were observed. The plant species distribution of four habitat types were recorded. Also the vegetational survey was done for the nesting habitats. The number of nesting habitats was counted observe the habitat needs of birds.

3.4 Map interpretation

The study area was mapped using GPS technique and using a base map of the PSI plan and section 3 map as guidelines.

3.5 Equipment used

1. Pair of binoculars (7*50)

   Audio LABS USA night vision, Multicoated Optics 123m/1000m.
2. Spot scope (22* W.A.)

   Bushnell, space master – Japan
3. GPS 12

   12 channel GARMIN s/n 84641813, USA
4. Camera (kb 10)

   Kodak 35, USA
5. Compass

   PRL100, Japan
6. Tape (2m)

CHAPTER 4

Results and Discussion

The four habitats were selected with reasons. Out of the two water bodies, one is old and one is new. Therefore a comparison can be made as how diversity change with time. The riverine is a different habitat and comparatively less disturbed. The hillock on the other end has minimum requirement for birds and was used as the control.

Given bellow are the analyzed results of the data collected from four habitat types in the section 2 and section3 in the Pelwatta sugar plantation area. Two man made water bodies named as Indigaha Pelassa Wewa(IPW) and Pahala Menik Wewa(PMW), a strip along the Menik Ganga river(MGR) and a hillock were the four habitat types. Table 4.1 is gives information of the geographical features, present from the study.

Table 4.1. Geographical features of the study sites

Parameters	IPW	PMW	MGR	Hillock
Latitude	6° 38' 600" 6° 39'	6° 39' 180" 6° 39' 400"	6° 38' 300" 6° 38' 700"	6° 39' 100" 6° 39' 250"
Longitude	81° 14' 600"- 81° 15'	81° 15' 200" 81° 15' 310"	81° 15' 50" 81° 15' 150"	81° 15' 81° 15' 100"
Altitude max:	138m	140m	141m	145m
min:	137m	139m	139m	140m

4.1 Avifaunal study

The Avifaunal study was conducted on the four habitat types as mentioned earlier. The data obtained from line transects, block counts, point counts and opportunistic observations were analyzed to provide the following information.

4.1.1 Graphical representation of species discovery

A graphical plot of "Cumulative number of species" Vs "Cumulative number of observation days" was done for all the four habitat types (Figure 4.1).

The steepness of the resulting discovery curves shows species richness of the habitat type. PMW, MGR and Hillock showed a low gradient and plateau for the observations. IPW showed relatively high gradient and two plateaus. It shows a tendency to asymptote around 4-6 days in PMW, MGR and Hillock and around 8 days in IPW. The time taken by IPW to reach the plateau higher than the other sites. This difference between IPW and other habitat types showed IPW used by many species than others.

The calculated diversity indices for Species richness are 84, 61, 75, and 56 in the IPW, PMW, MGR and hillock respectively. The discovery curves for the four habitat types show some differences in the species richness. Further analysis from 8th day, confirmed that new species would be increasingly difficult to find. Also obtaining a plateau indicated that the species were adequately sampled in during the study.

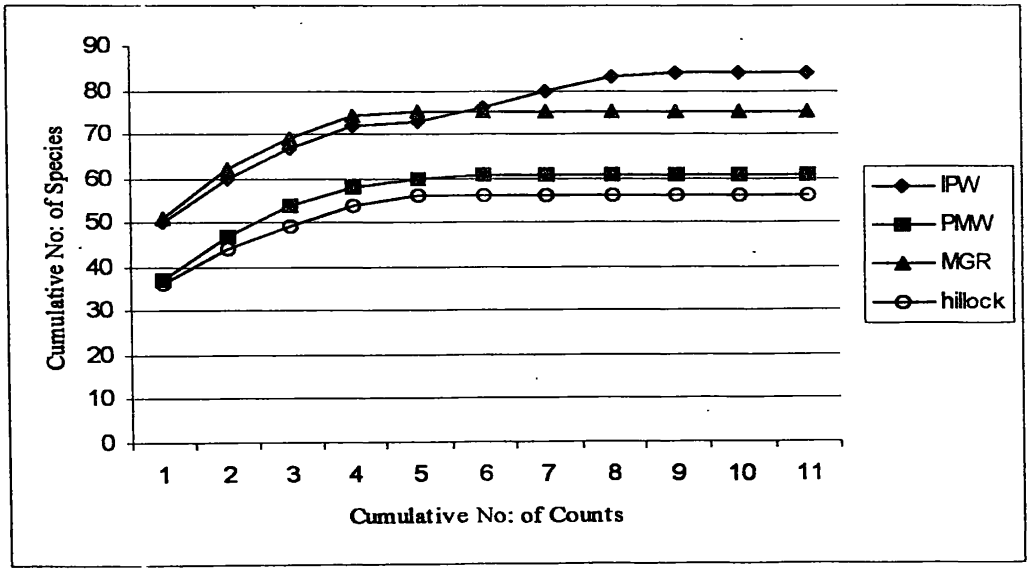


Figure 4.1 Species discovery curve for the four habitat types

4.1.2 Distribution of Avifauna

Of the 435 total avifauna in Sri Lanka, 103 species (23.68 %) were recorded in the 4 habitat types. The species richness found in the study area compared to the records of Sri Lanka and also to each habitat types is given in Table 4.2.

Table 4.2 Avifaunal species found in the study site in relation to the Island avifauna and each habitat type

	Endemic	Resident	Migrants	Total
Sri Lanka	23	227	109	435
Study site	01	92	10	103
% in study site relation to the Sri Lanka	4.35	40.53	9.17	23.68
IPW	-	75	9	84
% in IPW relation to the study site	00	81.52	90	81.55
PMW	-	55	6	61
% in PMW relation to the study site	00	59.78	60	59.22
MGR	1	68	6	75
% in MGR relation to the study site	100	73.91	60	72.82
Hillock	-	53	3	56
% in MGR relation to the study site	00	57.61	30	54.37

46 Families of 15 Orders are represented by the 103 species.92 of them were resident species, 10 migrant species and 1 endemic to Sri Lanka. Appendix I is shows the Families and Orders with the checklist of bird species.

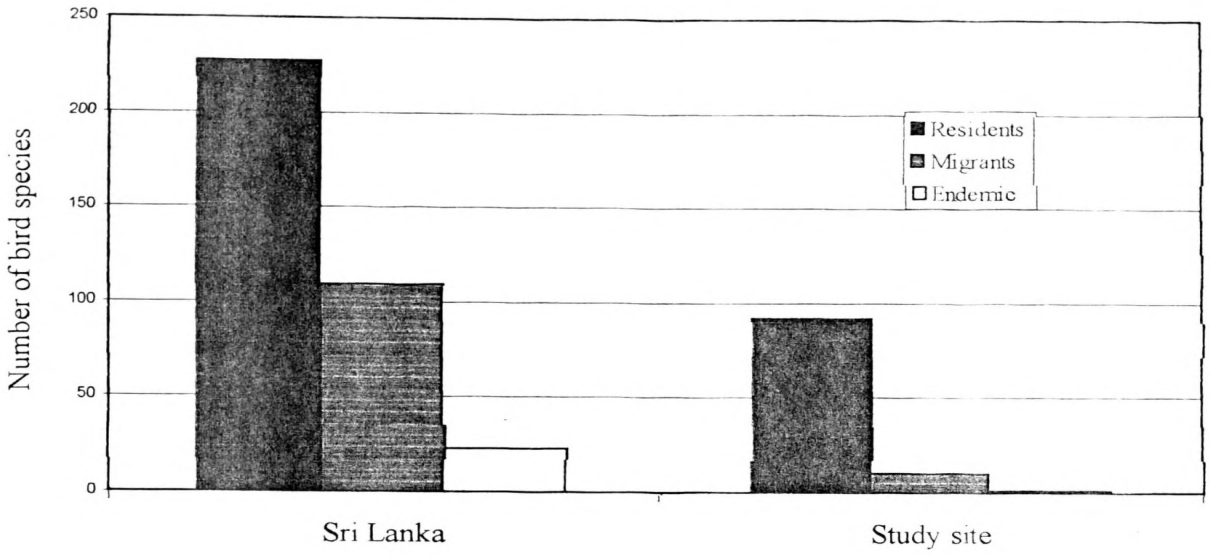


Figure 4.2 Recorded cumulative numbers of Avifaunal species during the study period

Avifaunal species in four habitat types recorded from four methods as given in Table 4.3. In IPW and PMW most species were recorded from the block counts. In MGR and Hillock most species were recorded from line transects. Opportunistic observations were made at all times and at all places in the study area. Also point counts were made at suitable spots in the study area. This data was used for identifying the total number of species in the four habitat types.

The data can be used to identify the best sampling method for each habitat. According to the records, block counts are ideal for the water bodies and line transect method is ideal for the riverine habitat and hillock

Table 4.3 Recorded Avifaunal species from four methods

Method / Habitat type	LT	BC	PC	OO
IPW		63	13	8
PMW		48	9	4
MGR	57		11	7
Hillock	47		7	2

4.1.3 Avifaunal species richness and abundance within the four habitats.

Avifaunal species richness and abundance is compared independently. Table 4.4 shows the difference of the species richness and abundance of Avifauna in habitat types. In IPW and MGR the number of species are higher than other habitats. But individuals per line (100m) low in the MGR. It shows that, MGR is a uniform habitat.

Table 4.4 Difference of the species richness and abundance in four habitats

Habitat type	Total NO: of Species recorded	Mean tot: no: of Spp: per day	Mean tot: no: of Spp: per line (100m) /block	Mean tot: no: of individuals per day	Mean tot: no: of individuals per line(100m) /block
IPW	84	54.30± 3.21346	17.35±1.4162	206.44±4.6	53.8±1.72
IMW	61	38.55±3.06894	12.58±1.0422	94.14±3.68	29.5±1.118
MGR	75	54.25±3.19333	5.26±0.38699	156.83±3.8	14.42±2.86
Hillock	56	36.25±1.94327	13.92± 1.1723	84.5±2.87	27.84±1.02

A graphical plot of "Cumulative number of species" Vs "Cumulative time" was done for all the four habitat types (Figure 4.3).

The species discovery curves per day are showed that, IPW took more time to come to the plateau. It confirmed IPW has the highest species richness. All other became constant in 25 minutes indicating the optimum time for observstions. Also the species difference between old and new water bodies are illustrated in Figure 4.4.

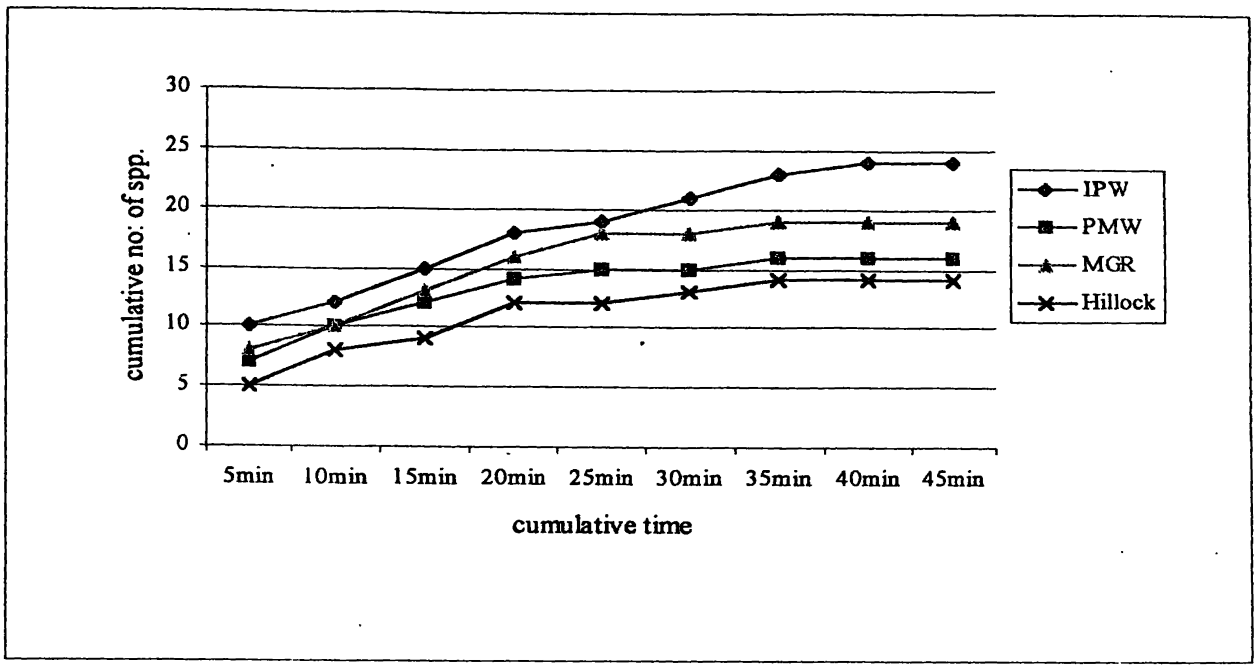


Figure 4.3 Species discovery curve for the four habitat types per day

51 species out of 103 recorded in the four habitat types were very common, 43 species were common, 7 species were rare and 2 species were very rare.

In IPW one very rare species was recorded. In MGR endemic endangered one species was recorded. Others are distributed as indicate in the Table 4.5.

Table 4.5 Distribution of very rare, rare, common, and most common species

Habitat type	VC	C	R	VR	Total
IPW	46	32	5	1	84
IMW	42	27	5	0	61
MGR	42	16	3	1	75
Hillock	33	20	3	0	56

39 species out of 103 recorded in the study area were common to the four habitat types. 16, 2, 6, 1 species were recorded only in the IPW, PMW, MGR and hillock respectively. Figure 4.4 showed how to distributed other species.

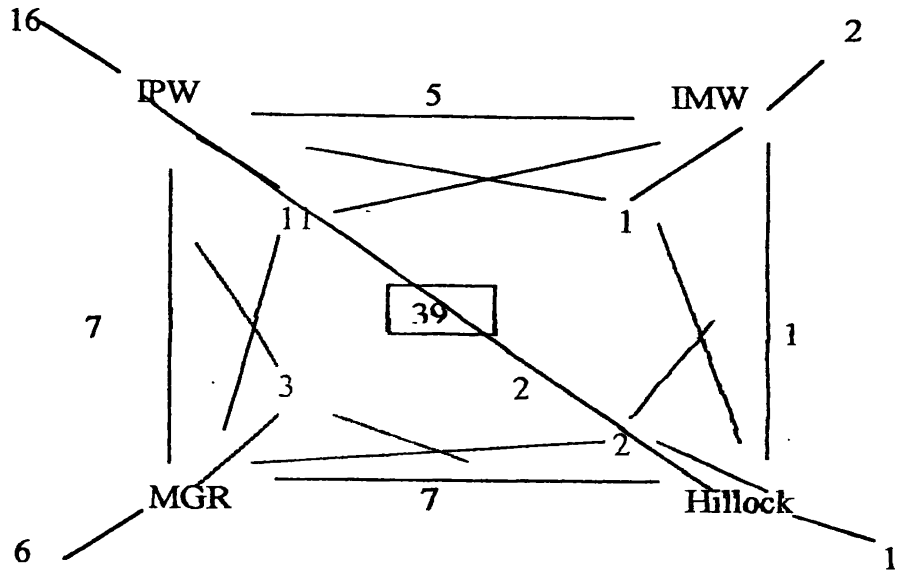


Figure 4.4 Species richness in each habitat types

4.1.4 Comparison of Bird species diversity in the habitat types

One of the objectives of the study was to compare the bird species diversity with respect to different habitat types in the Pelwatta sugar plantation area. The relationships with regards to species in four habitat types of the Avifauna were compared through the statistical analysis of ANOVA.

Appendix III data were analyzed using MINITAB statistical package under the null hypothesis, the bird diversity of all habitats are same and under alternative hypothesis at least one habitat is different from others. The analysis was done at 5% level of significance.

Statistical analysis showed a significant different at IPW with PMW and hillock, but not significant different with MGR. Also it showed a significant different at MGR

with hillock and PMW. But there were no significant different between PMW and hillock. If ,P>0.05 there is no significant difference.

Table 4.5 The significant differences of each habitat (ANOVA)

	IPW	PMW	MGR	Hillock
IPW	-	P=0.000 SD	P=0.9999 NSD	P=0.0000 SD
PMW		-	P=0.0000 SD	P=0.0672 NSD
MGR			-	P=0.0000 SD
Hillock				-

SD-There is a significant difference NSD- There is no significant difference

4.1.5 Species diversity in the study site

The species diversity is represented by various functions as species richness and abundance. The combination of species richness and abundance were calculated using the Shannon-Weiner index. The indices illustrated in Table 4.6.

According to the abundance and species richness calculated based on Shannon Weiner function it did not show much of a difference.

On the base of species richness, maximum diversity was present in the IPW. The lowest value was for the hillock.

According to the results of vegetational survey, it shows IPW is well structured and stabilized. It was reestablished in 1990. But PMW was reestablished in 2002. Therefore it can assumed that after about 10 years PMW will be stabilized as IPW if the habitats exist. The riverine area shows most uniform habitat since the diversity variation along the line is low.

Table 4.6 Shannon Weiner diversity index for the four habitat types

Habitat type	Shannon-Wiener diversity index
IPW	1.3773 Highest diversity
PMW	1.3404
MGR	1.3150
Hillock	1.2604 Lowest Diversity

4.1.6 Diurnal change of Avifauna

In the study period, it is generally observed that the activity is highest in the morning and evening. The diurnal change of Avifaunal activities can be discussed under change of individual number (species abundance) and the change of species number (species richness) for different habitat types. The Figure 4.5 clearly shows how the Avifaunal activities differ during a day.

The overall number of species and individuals were higher at IPW and MGR than other two sites. The total number of individuals was higher in the morning than in the evening or mid day. The variations of environmental factors are the reasons for these changes. Food abundance, climatic conditions affect the birds activities.

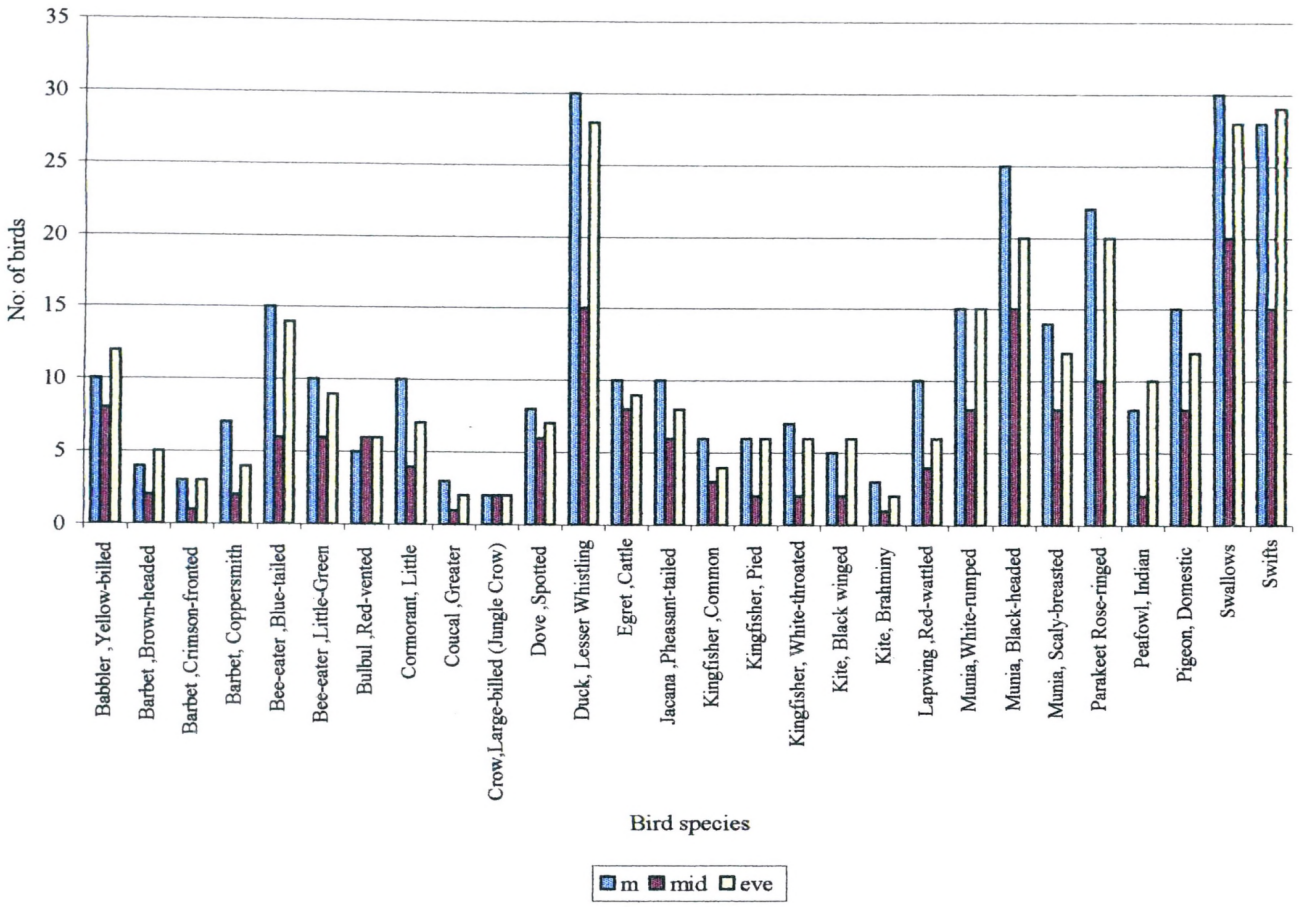


Figure 4.5 Diurnal distributions of most common species in the IPW

4.1.7 Most common species in various locations of the four habitats

The different locations in the four habitat types are used by different species. Table 4.7 shows who are the most common species in the various locations.

Deep water used by water birds such as little grebe, darter, cormorants, and terns. Other places of water bodies used by various bird species. However in the study site every locations used by various bird species indicating a high birding potential.

Table 4.7 Most common species in the various locations in four habitat types

Location / **Habitat**	**Deep water**	**Shallow water with grasses**	**Marshy land**	**Nesting trees**	**Sugar cane bushes**
IPW	Little grebe Darter L.W.duck W. Tern Swallows Swifts L.Cormorant	P.T. Jacana P.Swamphen Y .Bittern I.P. Heron Com.Kingfisher L.Cormorant	Weavers W.B.Water hen Y .Bittern I.P. Heron	L.W.duck D.pigeon R.R.parakeet B.kite W.tern Swifts C.kingfisher P. Kingfisher B.W.Kite	Spot.Dove Weavers Swifts P.Prnia G.bee-eater B.H.Munia I.M.Egret C.Myna
PMW	W.Tern Swifts L.Cormorant	C. Egret I.M.Egret L.Egret P.Kingfisher	LBee-eater	R.V.bulbul B.Robin	Munias Spot.Dove
Location / **Habitat**	**Deep water**	**Flowing water**	**River band**	**Big trees with highly branched**	**Grass lands and bushes**
MGR	WT.kingfisher C.kingfisher L.Cormorant	C.kingfisher WT kingfisher L.Egret IM.Egret C.Egret L.Cormorant	IP Heron WB.waterhen Sand piper RW.Lapwing	Woodpeckers WR.Shama BW.Kite Br.Kite CH.bee-eater	R.F.Malkoha L.bee-eater B.bee-eater In.Pitta J.Prinia P.Prinia RV.bulbul Lark Black robin
Location / **Habitat**	**Trees**	**Sugar cane**	**Grass land**	**Rocky area**	**Bushes and shrubs**
Hillock	Spot. Dove PG.Pigeon	RV bulbul P Prinia YB Babbler	YB Babbler RV bulbul P Prinia	B.Robin OM.Robin	Sun birds Flower peckers

4.2 Vegetational Survey

The main vegetation type in the Pelwatta sugar plantation area was dry mixed evergreen forest. But now a major proportion of the land is covered by sugar cane. The vegetation survey of the study indicates the presence of a large percentage of the monocultural (sugar cane) vegetation an in addition there were patches of natural habitat such as IPW, PMW, MGR, and the hillock. Accordingly with the variation of the site, this four habitat types were selected for the detailed study. There is a prominent variation among the habitats in terms of structure and prominent species composition. The vegetational analysis was important in this study because of direct interaction of birds with the habitats for their activities such as feeding and nesting.

The IPW and MGR habitats are well structured. But around the habitats, there was a dense plantation of cultivated sugar cane making them isolated. The riverine habitat retained much of the vertical structure. It has variety of tree species highly branched. These trees are used by many bird species like Grey headed fish eagle, Black winged kite, Pompadour green pigeon, Flower peckers, Woodpeckers, Bee-eaters as there nesting habitats.

IPW habitat contains a large number of nesting sites. These were seen to attract many bird species, like Rose ringed parakeet, Lesser whistling ducks, Domestic pigeon, Brahminy Kite, Indian Roller, Baya weaver, Streaked weaver, Fan tailor, Sparrows, Black Robins. Also many fruiting trees are there.

PMW and the hillock did not show a well-structured form as seen in other two habitats. In PMW there were limited number of nesting trees in comparison to IPW Since the location is new. So it is used by the very few of bird species, for the nesting sites like Black robins, Red vented bul bul, Fan tails, Sun birds, Flower peckers and Large billed crow. All these birds are those found in domestic areas.. But PMW habitat are also used by many bird species, especially water birds, for their feeding activities.

At the hillock there are no nesting tree or shrubs in the period of study. There were no highly branched big trees either.

Figure 4.7 shows the tree species used by number of bird species as there nesting habitats. Also Figure 4.8 shows the tree species used by most of the bird species.

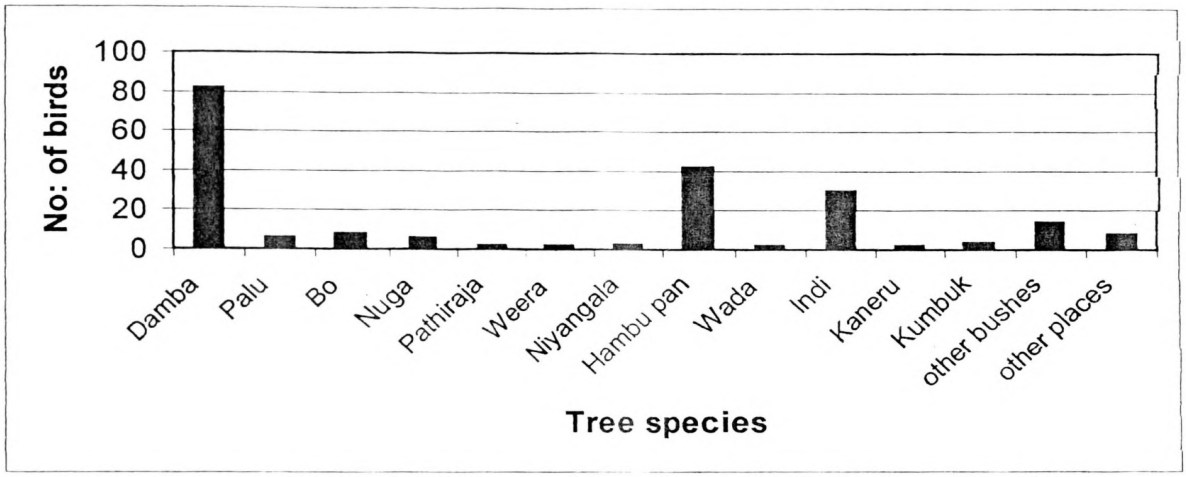


Figure 4.6 Tree species used by number of birds

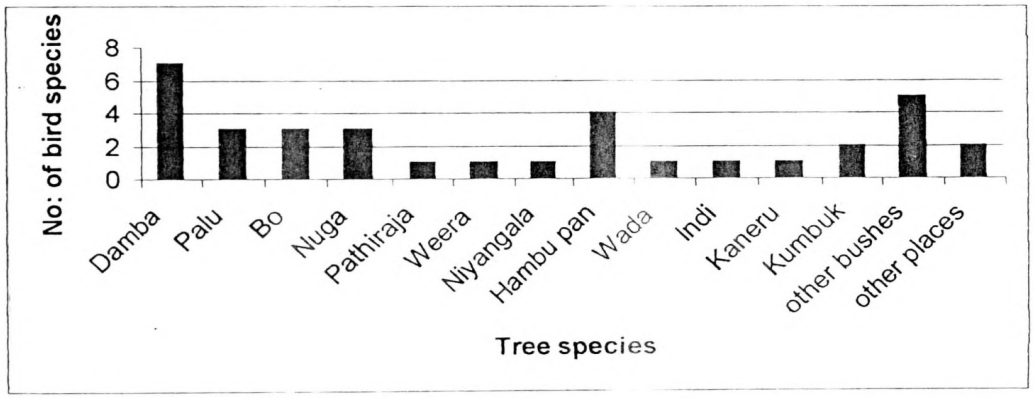


Figure 4.7 Tree species used by most of bird species.

Table 4.8 Most common tree species in the four habitas

Local name	Species Family	Habit	Presence of habitat types			
			IPW	PMW	MGR	H:
Damba	*Syzygium assimile*	Nesting	*		*	
Nuga	*Ficus benjamina*	trees	*		*	
Palu	*Manilkara hexandra*		*		*	
Bo	*Ficus religiosa*		*		*	
Ehala	*Casia fistula*		*	*		*
Indi	*Phoenix farinifera*		*	*	*	
Kumbuk	*Terminalia arjuna*				*	
Palu	*Manilkara hexandra*	Fruiting	*		*	
Bo	*Ficus religiosa*	trees	*		*	
Nuga	*Ficus benjamina*	and	*	*	*	
Kon	*Schleichera oleosa*	Big trees	*	*	*	
Karanda	*Humboldtia launifolia*	with	*	*	*	
Attikka	*Ficus racemosa*	highly	*		*	
Thimbiri	*Diospyros malabarica*	branched	*		*	
Weera	*Drpetes sepiaria*				*	
Lollu	*Cordia curassavica*				*	
Kumbuk	*Terminalia arjuna*				*	
Mee	*Madhuca longifolia*				*	
Godapara	*Dillenia retusa*				*	
Kotadimbula	*Ficus hispida*				*	
Dell	*Artocarpus altilis*				*	
Gammalu	*Pterocarpus marsupiam*				*	
Siyambala	*Terminalia indica*				*	
Kos	*Artocarrus heterophyllus*			*	*	
Wada	*Hibiscus rosa*	Bushes	*	*		*
Sugarcane	*Sachcharum officinarum*		*		*	*
Kalu wella	*Diospyros racemosa*		*		*	
Andara	*Dichrostachys cinerea*		*		*	
Kesel	*Musa*		*		*	*
Kekatiya	*Pittosporum ceylanicum*			*	*	
Wetakeyya	*Pandanus kaida*				*	

4.3 Map Interpretation of the four habitat types

The four habitat types were mapped using GPS technique, base maps of section 3 and PSI plan. Figure 4.8, 4.9, 4.10 are shows the resulted maps of each habitat type.

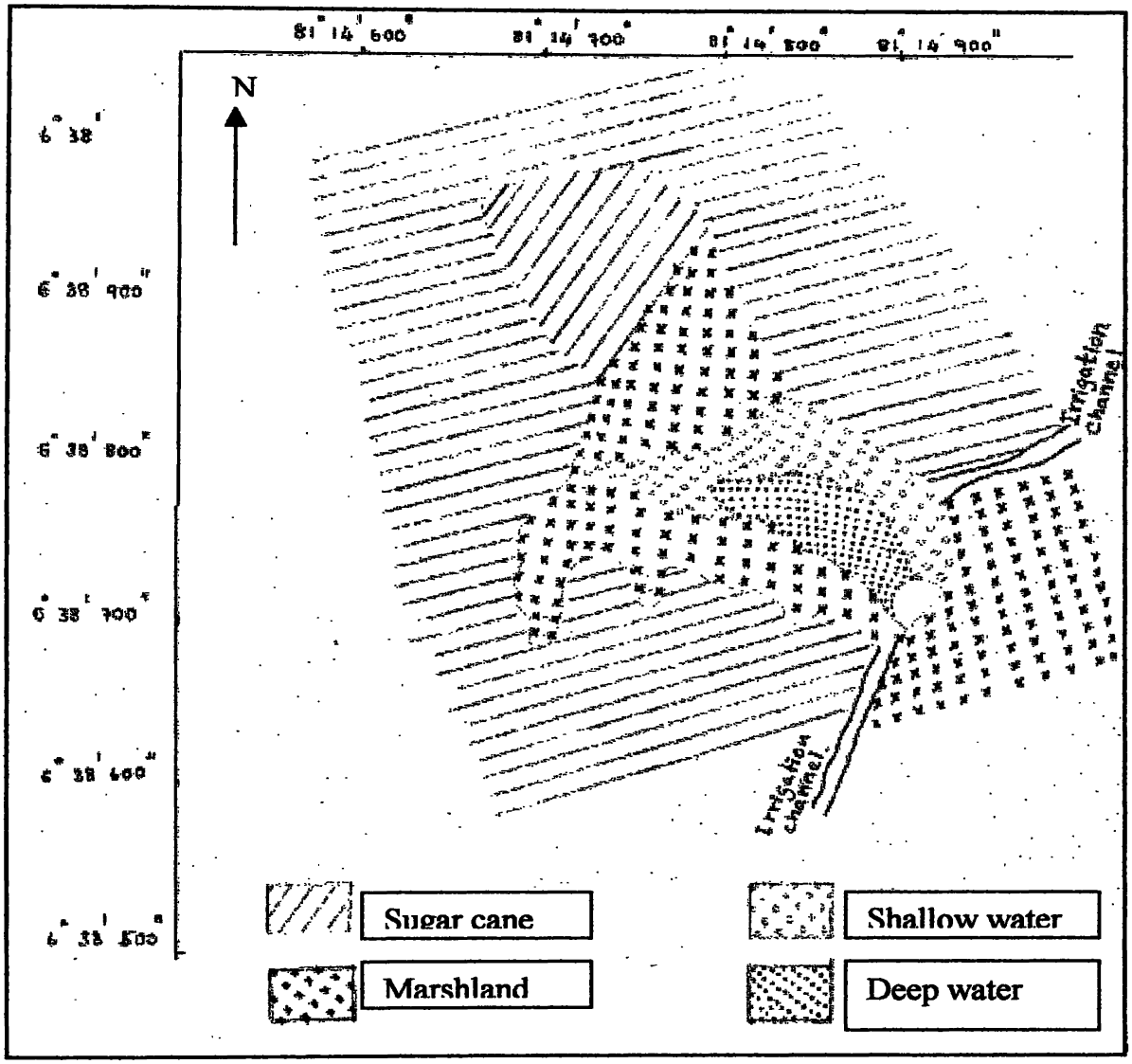


Figure 4.8 Map Interpretation of the IPW water body

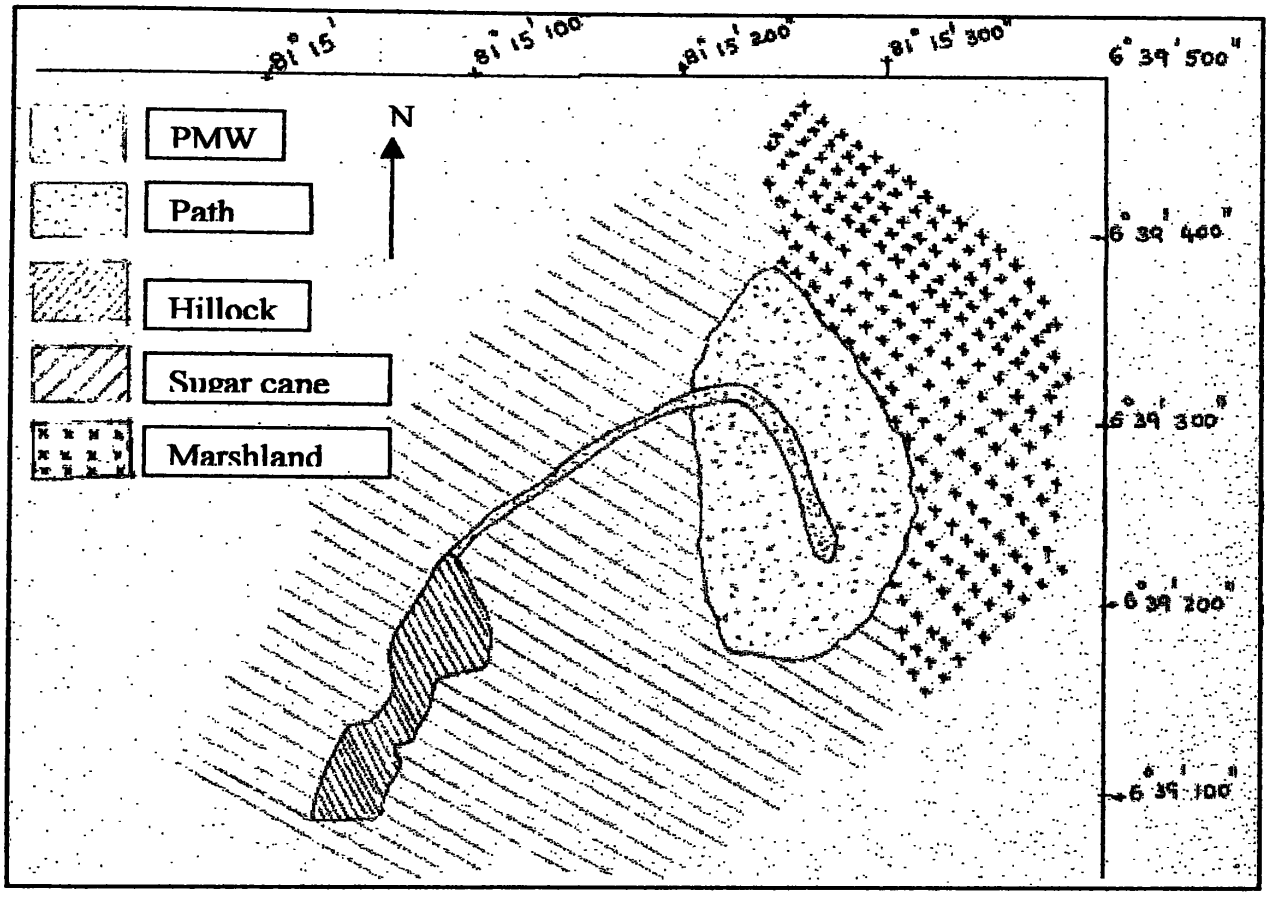


Figure 4.9 Map Interpretation of the PMW water body and hillock

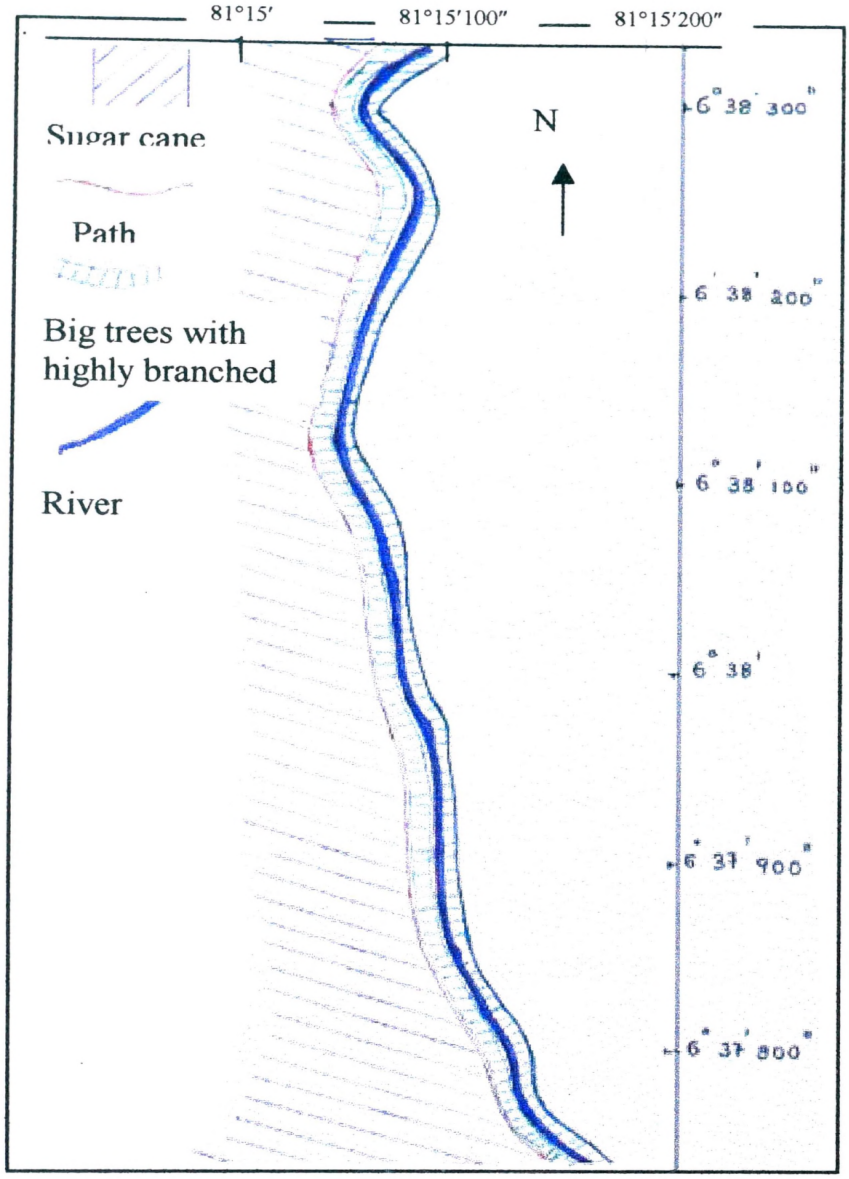


Figure 4.10Map Interpretation of the riverine habitat

CHAPTER 5

Conclusion and Recommendations

5.1 Conclusion

The study showed that that there is a marked difference in bird species diversity and distribution between old, man made water body (IPW), New, man-made water body (PMW), Riverine habitats and hillock. The study area was once under dry mixed evergreen forest in the past and abandoned. As such the present sugar cane cultivation and most of the forest patches found are secondary. The vegetational survey of the study area indicated that the plant species composition different from typical vegetation type of the area. This confirms the secondary nature of the vegetation highly disturbed by human activities.

Although in the study the habitats in the area are categorized in to four types, there are no specific boundaries that separate them. But different communities of birds were present in the four habitat types. This pattern of distribution of bird species could also be due to local patchiness caused by the fragmentation of historically contiguous habitat due to sugar cane plantation development in the area.

Conservation and protection programs for habitats of Pelwatta sugar plantation area should be prioritized based on records of some endangered and vulnerable bird species. The study shows the presence of Red faced Malkoha in the Menik Ganga riverine area.

Red faced Malkoha is a species qualifies as vulnerable because it has a small declining population as a result of loss and degradation of its forest habitat (Bird Life, 2000). There fore it shows the protection of riverine habitats is important.

The results of IPW water body shows very rare species like blue-eared kingfisher in the area. Also it shows spot billed pelicans and other groups of birds crossing the IPW water body in their flying path. Trees in this habitat are used as nesting habitats by most of bird species in the area. Therefore management plan for the water bodies, to

conserve the bird species diversity in IPW and also for the habitat quality of PMW is required in any concern of birds.

According to the reports of PSI, IPW was reestablished in 1990 but PMW was reestablished in 2002. According to the results it shows the IPW is habitat and diversity wise more stabilized than PMW. But it can be assumed that after about 10 years PMW will reach a more ecologically stabilized stage given that the habitat exists. Also in the present PMW water body is used by migratory birds like Green sandpiper which is good indicator of the environmental recovery.

The habitats harbor a rich diversity of flora and fauna with endemic and endangered species giving it a high biological value. Other than that riverine habitats and water bodies are probably the most susceptible to threats within the plantation area owing to human activities. Collecting of eggs in the habitats of the PSI is one such threat.

No avifaunal study has been carried out at the Pelwatta sugar plantation area during the past. Thus this study can be used as a guideline to study the bird communities of sugar plantation area as well as monoculture plantations.. The study shows the comparison of bird species diversity with respect to different habitat types, Old and New water bodies, riverine habitats and hillock with rocks and mostly bare land. It might also hold interests of researchers and naturalists concerned of specific bird species. The study can also be used if an eco-tourism model is developed for the area with special preference to birds.

Even after so many years since sugar cane planting took place in Moneragala district, its effect on forest structure and on the bird community is still distinguishable especially where the intensity of sugar planting and settlements are highest. It is also important that leaving interlinked patchy habitats intact with in plantations can certain extent contribute to the reduction of its damaging effects on nature.

Of the habitat type variables examined, water bodies and riverine areas had far the most significant, positive relationship with abundance and richness of bird community and recovery. The results of this study suggest that more attention should be given to water bodies and riverine habitats.

5.2 Recommendations

Conservation and management measures are required in future according to these values of habitat patches in the sugar plantation area.

A proper management plan with suitable regulation is needed if these habitats are to be protected on any interest.

The study area within which this research was conducted (PSI sugar plantation area) can be considered as a remarkable site for bird watching and diversity studies with a very good checklist of birds. Therefore considering birds, there is a high eco-tourism potential.

The duration of the study was not sufficient to detect any changes of the diversity with the seasons. Therefore further studies can be done to detect any on the seasonal changes of bird diversity over a long period. Effect of the sugarcane cycle to the diversity is also a potential study area.

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APPENDIX I

Table I.1 Checklist of Birds species recorded from the four habitats

English Name	Scientific Name	Family	Order	R	IPW	PMW	H		
Babbler ,Yellow-billed	*Turdoides affinis taprobanus*	Timaliidae	Passeriformes	1	1	1	1	vc	BrR
Babbler ,Yellow-eyed	*Chrysomma sinense nasale*	Timaliidae	Passeriformes	*	*	*	1	r	BrR
Barbet ,Brown-headed	*Megalaima zeylanica*	Capitonidae	Piciformes	1	1	1	1	c	BrR
Barbet ,Crimson-fronted	*Megalaima rubricapilla rubricapilla*	Capitonidae	Piciformes	1	1	1	1	c	BrR
Barbet, Coppersmith	*Megalaima haemacephala*	Capitonidae	Piciformes	1	1	1	1	c	BrR
Bee-eater ,Blue-tailed	*Merops philippinus*	Meropidae	Coraciiformes	1	1	1	1	c	M
Bee-eater ,Chestnut-headed	*Merops leschenaulti*	Meropidae	Coraciiformes	1	*	*	*	c	BrR
Bee-eater ,Little-Green	*Merops orientalis ceylonicus*	Meropidae	Coraciiformes	1	1	1	1	vc	BrR
Besra	*Accipiter virgatus*	Accipitridae	Falconiformes	*	1	*	*	r	BrR
Bittern, Yellow	*Ixobrychus sinensis*	Ardeidae	Ciconiiformes	*	1	*	*	c	BrR
Bulbul ,Red-vented	*Pycnonotus cafer cafer*	Pycnonotidae	Passeriformes	1	1	1	1	vc	BrR
Buttonquail, Barred	*Turnix suscitatur leggei*	Turnicidae	Gruiformes	1	*	*	1	c	BrR
Cisticola ,Zitting	*Cisticola juncidis*	Sylviidae	Passeriformes	1	*	*	1	c	BrR
Cormorant, Indian	*Phalacrocorax fuscicollis*	Phalacrocoracidae	Pelecaniformes	1	1	1	*	vc	BrR
Cormorant, Little	*Phalacrocorax niger*	Phalacrocoracidae	Pelecaniformes	1	1	1	*	vc	BrR
Coucal ,Greater	*Centropus sinensis*	Cuculidae	Cuculiformes	1	1	1	1	vc	BrR
Crow ,House	*Corvus splendens*	Corvidae	Passeriformes	*	1	1	1	vc	BrR
Crow,Large-billed (Jungle Crow)	*Corvus macrorhynchos*	Corvidae	Passeriformes	1	1	1	1	vc	BrR
Darter, Oriental	*Anhinga melanogaster*	Anhingidae	Pelecaniformes	*	1	*	*	c	BrR
Dove ,Spotted	*Streptopelia chinensis ceylonensis*	Coloumbidae	Columbiformes	1	1	1	1	vc	BrR
Drongo ,White-bellied	*Dicrurus caerulescens*	Dicruridae	Passeriformes	1	1	1	1	vc	BrR
Duck, Lesser Whistling	*Dendrocygna javanica*	Anatidae	Anseriformes	*	1	1	*	c	BrR
Eagle, Crested Serpent	*Spilornis cheela spilogaster*	Accipitridae	Falconiformes	1	1	1	1	vc	BrR
Eagle, Grey-headed Fish	*Ichthyophaga ichthyaetus*	Accipitridae	Falconiformes	1	1	*	*	r	BrR
Egret ,Cattle	*Bubulcus ibis*	Ardeidae	Ciconiiformes	1	1	1	1	vc	BrR
Egret ,Great	*Egretta alba*	Ardeidae	Ciconiiformes	*	1	*	*	c	BrR
Egret, Intermediate	*Egretta intermedia*	Ardeidae	Ciconiiformes	1	1	1	*	vc	BrR
Egret, Little	*Egretta garzetta*	Ardeidae	Ciconiiformes	1	1	1	*	vc	BrR
Fantail ,White-browed	*Rhipidura aureola*	Monarchidae	Passeriformes	1	1	1	1	vc	BrR

Flameback ,Greater	*Chrysocolaptes lucidus stricklandi*	Picidae	Piciformes	1	1	*	*	c	BrR
Flowerpecker ,Pale-billed	*Dicaeum erythrorhynchos ceylonense*	Dicaeidae	Passeriformes	1	1	1	1	vc	BrR
Grebe, Little	*Tachybaptus rufficollis*	Podicipedidae	Podicipediformes	*	1	*	*	c	BrR
Heron ,Black-crowned night	*Nycticorax nycticorax*	Ardeidae	Ciconiiformes	*	1	*	*	c	BrR
Heron ,Gray	*Ardea cinerea*	Ardeidae	Ciconiiformes	*	1	*	*	c	BrR
Heron ,Purple	*Ardea purpurea*	Ardeidae	Ciconiiformes	*	1	*	*	c	BrR
Heron, Indian Pond	*Ardeola grayii*	Ardeidae	Ciconiiformes	1	1	1	1	vc	BrR
Hornbill ,Malabar Pied	*Anthracoceros coronatus*	Bucerotidae	Coraciiformes	1	1	*	*	c	BrR
Ibis, Black-headed	*Threskiornis melanocephalus*	Threskiornithidae	Ciconiiformes	*	1	*	*	vc	BrR
Iora ,Common	*Aegithina tiphia*	Irenidae	Passeriformes	1	1	*	1	vc	BrR
Jacana ,Pheasant-tailed	*Hydrophasianus chirurgus*	Jacanidae	Charadriiformes	*	1	1	*	vc	BrR
Kingfisher ,Common	*Alcedo atthis*	Alcedinidae	Coraciiformes	1	1	1	*	vc	BrR
Kingfisher, Blue-eared	*Alcedo meninting*	Alcedinidae	Coraciiformes	*	1	*	*	vr	BrR
Kingfisher, Pied	*Ceryle rudis*	Alcedinidae	Coraciiformes	*	1	1	*	c	BrR
Kingfisher, White-throated	*Halcyon smyrnensis*	Alcedinidae	Coraciiformes	1	1	1	1	vc	BrR
Kite, Black winged	*Elanus caeruleus*	Accipitridae	Falconiformes	1	1	1	1	c	BrR
Kite, Brahminy	*Haliastur indus*	Accipitridae	Falconiformes	1	1	1	1	vc	BrR
Koel ,Asian	*Eudynamys scolopacea*	Cuculidae	Cuculiformes	1	1	*	*	c	BrR
Lapwing ,Red-wattled	*Vanellus indicus*	Charadriidae	Charadriiformes	1	1	1	*	vc	BrR
Malkoha ,Red-faced	*Phaenicophaeus pyrrhocephalus*	Cuculidae	Cuculiformes	1	*	*	*	vr	BrR
Moorhen ,Common	*Gallinula chloropus*	Rallidae	Gruiformes	*	1	*	*	c	BrR
Munia,White-rumped	*Lonchura striata*	Estrildidae	Passeriformes	1	*	*	1	vc	BrR
Munia, Black-headed	*Lonchura malacca*	Estrildidae	Passeriformes	1	1	1	1	vc	BrR
Munia, Scaly-breasted	*Lonchura punctulata*	Estrildidae	Passeriformes	1	1	*	*	vc	BrR
Myna ,Common	*Acridotheres tristis melanosturnus*	Sturnidae	Passeriformes	1	1	1	1	vc	BrR
Needletail ,Brown-backed	*Hirundapus giganteus*	Apodidae	Apodiformes	1	1	1	*	r	BrR
Nightjar	*Caprimulgus spp*	Caprimulgidae	Caprimulgiformes	1	*	*	*	c	BrR
Openbill, Asian	*Anastomus oscitans*	Ciconiidae	Ciconiiformes	*	1	*	1	c	BrR
Parakeet ,Alexandrine	*Psittacula eupatria*	Psittacidae	Psittaciformes	1	1	*	*	c	BrR
Parakeet Rose-ringed	*Psittacula Krameri*	Psittacidae	Psittaciformes	1	1	1	1	vc	BrR
Peafowl, Indian	*Pavo cristatus*	Phasianidae	Galliformes	1	1	1	1	c	BrR
Pelican, Spot-billed	*Pelecanus philippensis*	Pelecanidae	Pelecaniformes	*	1	*	*	vc	BrR
Pigeon ,Green Imperial	*Ducula aenea*	Coloumbidae	Columbiformes	1	*	*	*	c	BrR
Pigeon ,Pompadour Green	*Treron pompadora pompadora*	Coloumbidae	Columbiformes	1	*	*	1	c	BrR

Pigeon, Rock	*Columba livia*	Coloumbidae	Columbiformes	1	1	1	1	vc	BrR
Pipit ,Paddyfield	*Anthus rufulus*	Motacillidae	Passeriformes	1	1	1	1	vc	BrR
Pipit,Richard	*Anthus richardi*	Motacillidae	Passeriformes	1	*	*	*	c	M
Pitta ,Indian	*Ritta brachyura*	Pittidae	Passeriformes	1	*	*	*	c	M
Prinia ,Ashy	*Prinia socialis brevicauda*	Sylviidae	Passeriformes	*	1	*	1	c	BrR
Prinia ,Grey-breasted	*Prinia hodgsonii leggei*	Sylviidae	Passeriformes	1	1	1	1	c	BrR
Prinia ,Jungle	*Prinia sylvatica valida*	Sylviidae	Passeriformes	1	1	*	1	r	BrR
Prinia ,Plain	*Prinia subflava insularis*	Sylviidae	Passeriformes	1	1	1	1	vc	BrR
Robin ,Black	*Saxicoloides fulicata leucoptera*	Turdidae	Passeriformes	1	1	1	1	vc	BrR
Robin ,Oriental Magpie	*Copsychus saularis*	Turdidae	Passeriformes	1	1	1	1	vc	BrR
Roller ,Indian	*Coracias benghalensis*	Coraciidae	Coraciiformes	1	1	1	1	c	BrR
Sandpiper, Common	*Tringa hypoleucos*	Scolopacidae	Charadriiformes	*	1	1	*	vc	M
Sandpiper, Green	*Tringa ochropus*	Scolopacidae	Charadriiformes	*	*	1	*	r	M
Sandpiper, Marsh	*Tringa stagnatilis*	Scolopacidae	Charadriiformes	*	*	1	*	vc	M
Shama ,White-rumped	*Copsychus malabaricus leggei*	Turdidae	Passeriformes	1	*	*	1	vc	BrR
Shikra	*Accipiter badius*	Accipitridae	Falconiformes	1	1	1	1	vc	BrR
Shrike ,Brown	*Lanius cristatus cristatus*	Laniidae	Passeriformes	1	1	1	1	c	M
Skylark ,Oriental	*Alauda gulgula*	Alaudidae	Passeriformes	1	1	1	1	c	BrR
Sparrow ,House	*Passer domesticus*	Ploceidae	Passeriformes	1	1	1	1	vc	BrR
Stilt, Black-winged	*Himantopus himantopus*	Recurvirostridae	Charadriiformes	*	1	*	*	vc	BrR
Stork, Painted	*Mycteria leucocephala*	Ciconiidae	Ciconiiformes	*	*	1	1	c	BrR
Stork, Woolly-necked	*Ciconia episcopus*	Ciconiidae	Ciconiiformes	1	*	*	1	r	BrR
Sunbird ,Long-billed	*Nectarinia lotenia lotenia*	Nectariniidae	Passeriformes	1	*	1	1	vc	BrR
Sunbird ,Purple	*Nectarinia asiatica*	Nectariniidae	Passeriformes	1	1	1	1	vc	BrR
Sunbird ,Purple-rumped	*Nectarinia zeylonica zeylonica*	Nectariniidae	Passeriformes	1	*	1	1	vc	BrR
Swallow ,Barn	*Hirundo rustica*	Hirundinidae	Passeriformes	1	1	1	*	vc	M
Swallow ,Red-rumped	*Hirundo daurica*	Hirundinidae	Passeriformes	1	1	1	1	c	BrR
Swamphen ,Purple	*Porphyrio porphyrio*	Rallidae	Gruiformes	*	1	*	*	vc	BrR
swift , Alpine	*Tachymaptis melba*	Apodidae	Apodiformes	1	1	1	*	r	BrR
Swift ,Asian Palm-	*Cypsiurus balasiensis*	Apodidae	Apodiformes	1	*	*	1	c	BrR
Swift ,Little	*Apus affinis*	Apodidae	Apodiformes	1	1	1	1	c	BrR
Swiftlet, Indian	*Aerodramus unicolor*	Apodidae	Apodiformes	1	1	*	*	c	BrR
Tailorbird, Common	*Orthotomus sutorius sutorius*	Sylviidae	Passeriformes	1	1	1	1	vc	BrR
Tern ,Whiskered	*Chlidonias hybridus*	Laridae	Charadriiformes	1	1	1	*	vc	M

Treeswift ,Grey-rumped	*Hemiprocne longipennis*	Hemiprocnidae	Apodiformes	*	1	1	*	c	BrR
Wagtail ,Forest	*Dendronanthus indicus*	Motacillidae	Passeriformes	1	1	*	1	c	M
Warbler ,Clamorous Reed	*Acrocephalus stentoreus meridionalis*	Sylviidae	Passeriformes	*	1	*	*	c	BrR
Waterhen ,White-breasted	*Amaurornis phoenicurus*	Rallidae	Gruiformes	1	1	1	*	vc	BrR
Weaver ,Baya	*Ploceus philippinus*	Ploceidae	Passeriformes	1	1	1	1	vc	BrR
Weaver ,Streaked	*Ploceus manyar*	Ploceidae	Passeriformes	*	1	*	*	vc	BrR

vc-very common, c-common, r-rare, vr-very rare, M-Migrant, BrR-Breeding Resident

APPENDIX II

Table II.1 Species counts of IPW water body (species in the other habitat types also count as the following manner)

	IPW	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Babbler ,Yellow-billed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Barbet ,Brown-headed	1	1	*	*	1	*	1	1	*	*	1	1	1	1	1	1	*	1	*	1	1
Barbet ,Crimson-fronted	1	*	*	1	1	1	1	1	1	*	*	1	1	*	1	1	1	1	1	*	*
Barbet, Coppersmith	1	*	1	1	1	1	1	1	*	1	1	1	1	1	*	*	*	1	1	1	1
Bee-eater ,Blue-tailed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Bee-eater ,Little-Green	1	1	1	*	1	1	1	1	1	*	1	1	1	1	1	1	1	1	1	1	1
Besra	1	*	*	*	1	*	*	*	*	*	*	1	*	*	*	*	*	*	*	*	*
Bittern, Yellow	1	*	*	*	*	*	*	1	1	1	1	*	1	1	1	1	1	1	1	1	1
Bulbul ,Red-vented	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cormorant, Indian	1	*	*	*	*	1	1	*	*	1	*	*	1	1	*	1	*	1	1	1	1
Cormorant, Little	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Coucal ,Greater	1	1	1	1	1	1	1	1	1	*	1	1	1	1	1	1	*	*	1	1	1
Crow ,House	1	*	*	1	*	*	*	1	*	*	1	1	*	1	1	1	1	1	1	*	*
Crow,Large-billed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Darter, Oriental	1	*	*	*	*	*	1	1	1	*	*	*	1	*	*	*	1	*	*	1	*
Dove ,Spotted	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Drongo ,White-bellied	1	*	*	*	*	*	1	1	*	*	*	*	1	1	1	*	*	*	*	1	1
Duck, Lesser Whistling	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Eagle, Crested Serpent	1	1	*	1	1	1	1	1	*	*	*	1	1	*	1	*	*	1	*	*	*
Eagle, Grey-headed Fish	1	1	*	1	1	1	1	1	1	*	1	*	1	1	*	*	1	1	1	*	1
Egret ,Cattle	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Egret ,Great	1	*	*	*	1	*	*	1	1	1	*	*	*	*	1	*	*	*	1	1	*
Egret, Intermediate	1	*	*	1	*	*	*	*	1	*	1	1	1	1	1	1	1	1	1	*	*
Egret, Little	1	1	1	1	1	1	1	1	*	1	1	1	1	1	1	*	1	1	1	1	1
Fantail ,White-browed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Flameback ,Greater	1	*	*	1	*	*	*	*	*	*	1	*	*	*	*	1	1	*	*	*	*
Flowerpecker ,Pale-billed	1	*	1	*	*	*	1	1	1	*	*	*	1	*	*	*	1	*	1	1	*
Grebe, Little	1	1	1	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Heron ,Black-crowned night	1	*	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Heron ,Gray	1	*	*	*	*	*	*	1	*	1	*	*	*	*	1	*	*	*	*	*	*
Heron ,Purple	1	1	*	1	1	1	1	1	1	*	1	1	1	*	*	*	1	1	1	*	1
Heron, Indian Pond	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hornbill ,Malabar Pied	1	*	*	*	*	*	*	*	1	*	*	1	*	*	*	*	1	*	*	1	1
Ibis, Black-headed	1	*	1	1	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Iora ,Common	1	*	1	*	1	1	*	*	*	1	*	*	*	*	1	1	*	1	*	*	*
Jacana ,Pheasant-tailed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kingfisher ,Common	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kingfisher, Blue-eared	1	*	*	*	1	*	*	*	1	*	*	1	*	*	*	*	*	*	*	*	*
Kingfisher, Pied	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kingfisher, White-throated	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kite, Black winged	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Kite, Brahminy	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Koel ,Asian	1	*	*	*	1	*	*	*	*	1	*	*	1	1	*	1	*	*	*	*	*
Lapwing ,Red-wattled	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Moorhen ,Common	1	*	*	*	*	*	*	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Munia, Black-headed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Munia, Scaly-breasted	1	*	1	*	*	1	*	1	1	1	*	1	1	1	1	*	*	1	1	1	1
Myna ,Common	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Needletail ,Brown-backed	1	*	*	1	1	*	1	*	*	*	1	*	1	1	*	1	*	1	1	1	*
Openbill, Asian	1	*	*	*	*	*	*	1	*	*	*	*	*	*	*	*	*	*	*	*	*
Parakeet ,Alexandrine	1	1	1	1	1	*	1	1	*	1	1	1	1	*	*	1	1	1	1	1	1
Parakeet Rose-ringed	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Peafowl, Indian	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pelican, Spot-billed	1	*	*	*	*	*	*	*	1	1	*	*	*	*	*	*	*	*	*	*	*
Pigeon, Rock	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pipit ,Paddyfield	1	*	1	*	1	1	1	1	*	*	*	1	*	*	*	1	*	1	1	1	1

Prinia ,Ashy	1	*	1	*	1	1	1	*	*	1	1	1	1	1	1	1	*	*	1	1	1
Prinia ,Grey-breasted	1	1	*	1	*	1	1	1	*	*	*	*	1	*	*	*	*	*	*	*	*
Prinia ,Jungle	1	*	*	*	1	*	*	*	*	1	*	*	*	1	*	*	1	1	*	*	*
Prinia ,Plain	1	1	*	1	*	*	*	1	*	*	1	*	1	*	*	*	*	*	*	*	*
Robin ,Black	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Robin ,Oriental Magpie	1	1	1	1	1	*	1	*	1	1	1	1	1	*	*	1	1	1	1	1	1
Roller ,Indian	1	*	1	1	1	1	1	1	1	*	*	1	*	1	1	1	1	1	*	1	1
Sandpiper, Common	1	*	*	*	*	*	1	*	*	1	*	*	*	1	*	*	*	*	*	*	*
Shikra	1	1	1	1	1	1	1	1	*	1	1	1	1	1	1	*	1	1	1	1	1
Shrike ,Brown	1	1	1	1	1	*	1	*	1	1	1	1	*	1	1	1	1	1	*	*	1
Skylark ,Oriental	1	1	*	*	1	*	*	*	*	*	*	*	1	*	*	*	*	*	*	*	*
Sparrow ,House	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Stilt, Black-winged	1	*	*	1	1	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Sunbird ,Purple	1	1	*	1	1	1	1	1	*	1	1	1	*	*	1	1	1	1	1	*	1
Swallow ,Barn	1	1	1	1	1	*	*	1	1	*	*	1	*	1	1	1	1	1	*	*	*
Swallow ,Red-rumped	1	1	1	1	1	1	1	1	1	1	1	1	1	1	*	1	1	1	1	1	1
Swamphen ,Purple	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
swift , Alpine	1	1	1	1	*	*	*	*	1	1	1	*	*	1	1	*	1	1	1	1	*
Swift ,Little	1	1	1	1	*	1	1	1	1	1	1	1	1	1	1	*	1	1	1	1	*
Swiftlet, Indian	1	*	*	1	1	*	1	1	*	*	*	1	*	*	*	*	*	*	*	*	1
Tailorbird, Common	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Tern ,Whiskered	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Treeswift ,Grey-rumped	1	*	1	1	1	*	*	*	*	*	*	*	*	1	*	*	1	*	*	*	*
Wagtail ,Forest	1	*	*	*	*	*	*	*	1	*	*	1	1	*	*	*	*	*	*	*	*
Warbler ,Clamorous Reed	1	*	*	*	*	*	*	*	*	1	*	*	*	1	*	*	*	*	*	*	*
Waterhen ,White-breasted	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Weaver ,Baya	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Weaver ,Streaked	1	1	1	1	1	1	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
no of bird species per day		50	52	58	61	50	56	59	52	52	52	57	58	56	52	51	54	57	54	53	52
no of new bird species per day		50	10	7	5	1	3	4	3	1	*	*	*	*	*	*	*	*	*	*	*
Dumulative new spp		50	60	67	72	73	76	80	83	84	0	0	0	0	0	0	0	0	0	0	0

APPENDIX III

Following data were analyzed using MINITAB statistical package under the null hypothesis bird diversity of all habitats are same and under alternative hypothesis at least one habitat is different from others. The table depicts the daily species count for each habitat. The analysis was done at 5% level of significance.

IPW	50	52	58	61	50	56	59	52	52	52	57	58	56	52	51	54	57	54	53	52
IMW	37	35	42	39	40	33	40	41	39	36	32	36	38	38	38	41	39	42	44	41
MGR	51	50	54	46	57	58	54	52	54	55	52	53	53	56	58	54	54	58	57	59
HILLOCK	36	35	34	36	36	34	35	36	36	36	36	37	39	37	35	33	35	40	39	40

Results of the above programme were as follows.

One-way ANOVA: Value versus Treatment (trt)

Analysis of Variance for value

Source	DF	SS	MS	F	P
trt	3	5748.24	1916.08	227.30	0.000
Error	76	640.65	8.43		
Total	79	6388.89			

Individual 95% CIs For Mean

Based on Pooled Standard Deviation (StDev)

Level	N	Mean	StDev	--+---------+---------+---------+----
1	20	54.250	3.193	(-*--)
2	20	54.300	3.213	(--*-)
3	20	38.550	3.069	(-*-)
4	20	36.250	1.943	(-*--)
				--+---------+---------+---------+----
Pooled StDev = 2.903				36.0 42.0 48.0 54.0

Statistical analysis showed that the P-value was 0.0000. So, the null hypothesis is rejected and alternative hypothesis should be accepted. That means at least one habitat is different from others. To find which habitats are different from others comparison test was done. The results as follows.

General Linear Model: value versus trt

Factor	Type	Levels	Values
trt	fixed	4	1 2 3 4

Analysis of Variance for value, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
trt	3	5748.2	5748.2	1916.1	227.30	0.000
Error	76	640.6	640.6	8.4		
Total	79	6388.9				

Unusual Observations for value

Obs	value	Fit	SE Fit	Residual	St Resid
13	46.0000	54.2500	0.6492	-8.2500	-2.92R
14	61.0000	54.3000	0.6492	6.7000	2.37R
43	32.0000	38.5500	0.6492	-6.5500	-2.31R

R denotes an observation with a large standardized residual.

Tukey 95.0% Simultaneous Confidence Intervals

Response Variable value

All Pair wise Comparisons among Levels of trt

trt = 1 subtracted from:

trt	Lower	Center	Upper	----------+---------+---------+------
2	-2.37	0.05	2.47	(--*---)
3	-18.12	-15.70	-13.28	(---*--)
4	-20.42	-18.00	-15.58	(--*---)

----------+---------+---------+------

-14.0 -7.0 0.0

trt = 2 subtracted from:

trt	Lower	Center	Upper	----------+---------+---------+------
3	-18.17	-15.75	-13.33	(---*--)
4	-20.47	-18.05	-15.63	(--*---)

----------+---------+---------+------

-14.0 -7.0 0.0

trt = 3 subtracted from:

trt	Lower	Center	Upper	----------+---------+---------+------
4	-4.715	-2.300	0.1151	(---*--)
				----------+---------+---------+------
				-14.0 -7.0 0.0

Tukey Simultaneous Tests

Response Variable value

All Pairwise Comparisons among Levels of trt

trt = 1 subtracted from:

Level trt	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
2	0.05	0.9181	0.05	0.9999
3	-15.70	0.9181	-17.10	0.0000
4	-18.00	0.9181	-19.61	0.0000

trt = 2 subtracted from:

Level trt	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
3	-15.75	0.9181	-17.15	0.0000
4	-18.05	0.9181	-19.66	0.0000

trt = 3 subtracted from:

Level trt	Difference of Means	SE of Difference	T-Value	Adjusted P-Value
4	-2.300	0.9181	-2.505	0.0672

APPENDIX IV

Shannon-Wiener Index

This is given by the formula,

Where P_i is proportional frequency of the i^{th} species.

$$H = - \Sigma (P_i \log P_i)$$

Calculation:

Multiply the frequency of a species by the logarithm of the frequency. Add all these values to get the diversity index.

Below table shows the Shannon-Wiener Index for IPW. Index for the other habitats calculate as same as this.

Species	Frequency	P_{ii}	log pi	pi log pi
1	12	0.03561	-1.44845	-0.0515768
3	5	0.01484	-1.82866	-0.0271315
4	7	0.02077	-1.68253	-0.0349487
5	3	0.00890	-2.05051	-0.0182538
6	15	0.04451	-1.35154	-0.0601575
8	10	0.02967	-1.52763	-0.0453303
9	1	0.00297	-2.52763	-0.0075004
10	5	0.01484	-1.82866	-0.0271315
11	6	0.01780	-1.74948	-0.0311480
14	2	0.00593	-2.22660	-0.0132142
15	10	0.02967	-1.52763	-0.0453303
16	3	0.00890	-2.05051	-0.0182538
17	2	0.00593	-2.22660	-0.0132142
19	8	0.02374	-1.62454	-0.0385647
21	30	0.08902	-1.05051	-0.0935171
24	10	0.02967	-1.52763	-0.0453303
40	10	0.02967	-1.52763	-0.0453303
42	6	0.01780	-1.74948	-0.0311480
43	6	0.01780	-1.74948	-0.0311480
44	6	0.01780	-1.74948	-0.0311480
45	7	0.02077	-1.68253	-0.0349487
46	3	0.00890	-2.05051	-0.0182538
47	10	0.02967	-1.52763	-0.0453303
48	15	0.04451	-1.35154	-0.0601575
50	25	0.07418	-1.12969	-0.0838049
51	14	0.04154	-1.38150	-0.0573918
55	22	0.06528	-1.18521	-0.0773726
57	10	0.02967	-1.52763	-0.0453303
62	15	0.04451	-1.35154	-0.0601575
Swallows	30	0.08902	-1.05051	-0.0935171
swifts	29	0.08605	-1.06523	-0.0916668

Shannon Wiener Index for IPW =-(-1.3773) = 1.3773
Shannon Wiener Index for PMW =-(-1.3404) =1.3404
Shannon Wiener Index for MGR =-(-1.3150) =1.3150
Shannon Wiener Index for hillock =-(-1.2604) =1.2604

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