Diversity and abundance of birds in disturbed and undisturbed wetlands of Manipur River basin

Dissertation submitted to Saurashtra University, Rajkot

In partial fulfilment of

The Masters' of Science Degree in Wildlife Science

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CERTIFICATE

This is to certify that Mr. **Sijagurumayum Rohikanta Sharma** has carried out original research from the Wildlife Institute of India titled **"Diversity and abundance of birds in disturbed and undisturbed wetlands of Manipur River basin"**, in partial fulfilment of a Master's Degree in Wildlife Science from **Saurashtra University**, Rajkot, India. The study was carried out under our supervision from December 2016 to June 2017. We hereby certify that this work has not been submitted for any other degree to any other University.

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Abstract

1. The Northeast (NE) Indian region is one of the hotspot of Indo Malayan biodiversity that remains largely unexplored. For this study, two wetlands in the NE Indian region of Manipur, *viz* Keibul Lamjao National Park (KLNP) and Pumlen pat (PP) were selected as the study site. Diversity and abundance of bird species in the region were assessed because of their prominence in the landscape.
2. Twenty girds of 1 km × 1 km were sampled in each site and each grid had 3 sampling points (60 point in each site) for point count. The sampling points were replicated once. Variable-radius point counts were carried out for the duration of 10 minutes in morning and evening. Boat survey was carried out for waterbird count. Any direct sightings (bird seen or call heard) during the point count were recorded. A distance of minimum 300 m and maximum 500 m is maintained between the three sampling points of a grid. To assess the habitat heterogeneity, four quadrats of 1 m × 1 m were laid; one at the centre of the circle of the point count and the remaining three quadrats, randomly in three equally divided segments of the circle. 160 vegetation plots were sampled from KLNP and 201 were sampled from PP. Data was collected on plant height, number of plant species and number of individuals of each species and water depth. Any sign of disturbance such as foot trail, humans encountered and other mode of disturbances were collected to quantify the level of disturbance. Different habitat types were digitized using GIS tool. Shannon's Diversity Indices (H) was used to derive the species diversity. Checkerboard score (C score) was calculated to check if the bird species were segregated or aggregate. Rank abundance plot had been plotted. Density of bird species was also calculated. Two-way Indicator Species Analysis (TWINSPAN) was done to assess plant communities and the habitat heterogeneity in both the sites. The Non-metric Multidimensional Scaling (NMDS) was used to plot species clusters from the data. Sorensen's Coefficient (CC) was used to see the similarity in species composition in different habitat types and in disturbed and undisturbed sites.
3. Altogether, 136 bird species were recorded from KLNP and 94 species from the PP during the study. However, during point count only 91 and 79 species

were recorded from these two sites respectively. Densities of 22 species from the undisturbed (KLNP) site and 17 species from the disturbed (PP) sites were estimated. 14 species were common to both the sites. Some habitat specific birds were found to be lesser in density in the disturbed site as compared to the undisturbed site. Eight waterbird species and a globally threatened grassland bird species recorded in the undisturbed site were not recorded in the disturbed site. Some of the species were found exclusively in the sites.

4. Six plant communities from the undisturbed site and seven plant communities from the disturbed site were recorded. The plant communities in different habitat types of disturbed and undisturbed sites differed which seems to be artefacts of anthropogenic disturbance. NMDS plots showed overlaps of bird species between different habitats and between the two sites. To examine the extent of species overlaps, Sorensen's Coefficient was calculated. The extent of overlap was justified by the arrangement of these habitat types in the sites. The species overlap between the sites may be due to the similar habitat characteristics.
5. Conservation measures are needed for both the sites in terms of these threatened bird species. Site-specific management strategies need to be incorporated in the management plan for the management of the isolated local populations of Black-breasted Parrotbill and Yellow-breasted Bunting in the undisturbed site (KLNP). Whereas some legal conservation measure is needed for conserving threatened grassland birds in the disturbed site (PP). It is also mandatory to monitor the population of Yellow-breasted Bunting population discovered from both the sites.

CHAPTER 1

INTRODUCTION, LITERATURE REVIEW, RESEARCH QUESTION AND OBJECTIVES

1.1 Introduction

Wetlands have been long known to harbour a myriad of endangered species. However, the wetland biodiversity has declined drastically since the 1970s (Wetland International 2017) Water, being one of the naturally available resources, is also an important source for sustaining life on earth. Mitsch and Gosselink (1986) referred to wetlands as "kidneys of the landscape" solely because of the ecological function of carbon storage, source of water, catchment area and protection from natural disasters like flood (Wetland International 2017) performed by them. Wetlands associate with different habitats giving unique habitat types like marshes, peatlands, rivers and deltas, mangroves and wet grassland (Wetland International 2017). Grasslands, being a seral stage habitat, are one of the most vulnerable ecosystems as they are exposed to myriad drivers of change. As a result, they face high competition for light and nutrients from several gregarious woody species and alien invasive plants (Rawat and Adhikari 2015). One more driver of change will be the unavailability of adequate space and natural regime of flood and fire, as it is necessary for wet grasslands of *Terai* and *Duars*, otherwise they are found to degrade fast (Rawat 2005, Rawat and Adhikari 2015). White et al. (2000) also agrees with fact that fire, grazing, drought and/or freezing temperature maintain the grassland ecosystem. They are highly dynamic (White et al. 2000) and have co-evolved with ungulates since the Pleistocene era (Stebbins 1981, Rawat and Adhikari 2015). They provide critical habitat for various wild herbivores and for breeding, migration and wintering purposes for other faunal taxa also (Rahmani 2006, Verma and Prakash 2007, Rawat and Adhikari 2015). However, due to severe biotic pressure and lack of scientific monitoring framework, their ecological uniqueness and the services they provide have declined dramatically (Dixon et al. 2014). Increase in human and livestock population, changes in land use practices and transformation of traditional pastoral practices have led to loss of biodiversity, and ecological services, decrease in quality and quantity of fodder, deterioration of pastoral livelihood and desertification of grasslands in the Asia-Pacific region (Faber-Langendoen and Jose 2010, Rawat and Adhikari 2015).

Wet grasslands are vulnerable as they are being utilized for agricultural and farming purposes, extraction of fodder, medicinal plants and other form of resource extraction (Tuboi et al. 2012, Solway Wetlands 2017).

Apart from being the grail for supporting ungulates, grasslands play a significant ecological role for the grassland birds, an obligate family of birds depending upon these grasslands. 1263 bird species have been reported and confirmed from the Indian Territory (Praveen et al. 2016) which includes 61 endemic species (Rahmani 2016). Collar et al. (1994) and Nilsson (2005) estimated 173 species which constitutes 15.6 % of the world's total endangered bird species, are found in grasslands, shrublands or desert ecosystem. Out of this 15.6%, 6.3% of the threatened birds are found in grasslands (Collar et al. 1994).

North-east India harbours various habitat types (Chatterjee et al. 2006*a*). Grassland habitat is one of the important habitat types found in this region. Grasslands found in the Brahmaputra floodplain are highly dynamic (Rahmani 2016). Out of estimated 1,100 sq. km of grassland in Assam, the alluvial floodplains of the Brahmaputra drainage system comprise two-third of it (Choudhury 2000, Rahmani, 2016). In the Loktak Lake of Manipur, grassland habitats are common in the floating meadows. Floating meadows are reported to occur in different parts of the world (Tuboi 2013). The floating meadow, locally known as *phumdi*, is a floating mass of vegetation consisting of floating organic substrate on which wet grasslands prevail (Tuboi 2013). For carrying out the research work, Keibul Lamjao National Park (KLNP) and Pumlen Pat (PP) were selected as my study sites. The floating meadows are found in Keibul Lamjao National Park, which is the last natural habitat for the Eld's deer *Rucervus eldii eldii* locally known as *Sangai*, and the adjoining area known as Pumlen Pat in Manipur.

These areas were selected for my research work as they are highly biodiverse areas with little information available. Comparatively, many studies have been carried out on *Sangai*, Hog deer, Wild Pig, habitat etc. (Angom et al. 2012, Tuboi et al. 2012, Hussain et al. 2015, Tuboi and Hussain 2016). However, studies pertaining to birds in the area are limited and the little information available is mostly outdated (Singh 1991, Shamungou 2010, Devi 2012). Therefore, there is a need to carry out a research to update the baseline information on bird diversity for the Park. A survey on the bird

diversity in Pumlen Pat also needs to be assessed in order to provide information for gaining its protected area status. Both these sites, being wetlands and being a part of Indo Burma Hotspot, have incredible ecological values.

Bird communities have been studied as indicator for evaluating the health of various ecosystems. Breeding birds, bird guilds, indicator species, feathers and health of birds and many more are used as indicators of ecological condition across the globe (Pilastro et al. 1993, Connell et al. 2000, Mikusinski et al. 2001, Browder et al. 2002). Bird, as taxa, can be taken as a surrogate for evaluating the ecological status of the study area.

1.2 Literature Review

Data deficiency serves as a major drawback in conserving threatened wetland species. Bird community inherently is dependent upon many factors such as patch size, rate of extinction and immigration, habitat types, height of foliage and the geographical features (Wiens 1989). Buxton and Benson (2016) found that level of development, grassland and forests cover and patch size influence the distribution of grassland birds. Canterbury and Blockstein (1997) found a decrease in number of bird territories per hectare in forested ecosystems, which they related to increase in ground vegetation and light levels. Anthropogenic disturbance in desert ecosystem also affects bird diversity and richness (Mills et al. 1989). A study conducted by Woltmann (2002) in Bolivia found higher species richness in altered areas than in undisturbed areas in the sub-tropical humid forest during the dry season. He also found that species with low habitat specificity were higher in richness and abundance in disturbed areas than in the intact forest areas. Anthropogenic disturbances had led to altered waterbird behaviour, increase flight distance and time spent on feeding (Borgmann 2011). Connell (2000) had listed various human-induced disturbances like agriculture, fisheries, industry, urbanization, mining and the range of these disturbances like temporal scale, severity and the type of impact, and whether it was impacting the population or community composition. Hunting disturbances not only decreased the number of birds but also disturbed the time spent on foraging and caused under-exploitation of potential feeding ground, hence affecting at population level (Madsen and Fox 1995). It is evident that in different types of habitat, anthropogenic pressures has affected, directly or indirectly, bird diversity and their

abundance. According to Buxton and Benson (2016), the disturbed grasslands, if protected, have the potential to support considerable amount of grassland birds. There has been equal number of studies of diversity increasing and decreasing and it depends on the taxa concerned (Hill and Hamer 2004). Elsen et al. (2016) found agricultural lands to be rich in bird diversity but it again depends on agricultural intensification, mainly through increased grazing. Hence, low intensity agricultural land supports good diversity of wintering Himalayan birds during winter (Elsen et al. 2016). Velasquez (1992) also found that saltpans providing resources to waders and shorebirds. When the resource is crucial during the winter season, these agricultural farms provides the resources.

Besides the factors that Wiens (1989) mentioned, heterogeneity in vegetation also influences the species richness of an area. Stein (2015) considers 'Spatial Environmental Heterogeneity' as one of the most important factor influencing species richness. This is primarily due to the increase in available different habitats and different species occupying those habitats (Allouche et al. 2012). But according to Allouche et al. (2012), in a given area, if the heterogeneity increases, the amount of effective area for an individual species decreases and the population decreases which can eventually lead to stochastic extinction. But, to counter this statement, Stein (2015) stated that the heterogeneity-richness relationship depends on the study design including the measure considered and the spatial scale. The statement is in agreement with Bar-Massada and Wood (2014) who stated that the relationship differed according to the heterogeneity measures within and among habitats. Another study by Clergeau et al. (2001) found that bird species richness (BSR) is not influenced by the surrounding landscape but by other factors like increased habitat heterogeneity. They also found a negative correlation of BSR with urbanization. This finding agrees with the findings that surrounding landscape has very little influence in explaining the species richness (Clergeau et al. 1998). In this study also, they found an increasing diversity in a gradient of most to least urbanized areas (Clergeau et al. 1998).Although the relationship seems variable, the heterogeneity in a wetland will have an influence on the species richness of the area.

1.3 Research Question

The research question behind my work is as follows-

How habitat heterogeneity influences the bird species composition and hence the diversity and abundance of birds?

1.4 Objectives

From the research question, two objectives were strategized which would be covered under this dissertation work. Since the study area currently lacks information on bird diversity, the first objective has been proposed as-

1. To examine the diversity and abundance of birds in Keibul Lamjao National Park (KLNP) and Pumlen Pat (PP).

There have been many studies on how habitat heterogeneity helps in influencing the species assemblage and how it forms the diversity of a particular area. Therefore, it is important to see how the bird community in these sites has been influenced by different habitat types and hence habitat heterogeneity of the sites. The second objective has been proposed as-

2. To assess habitat heterogeneity influencing the bird species composition in different habitat types.

CHAPTER 2

STUDY AREA

2.1 North-East India

The North-eastern region of India is well known for its high biodiversity value (Chatterjee et al. 2006*b*). On the basis of physical and geographical features, the region is divided into: Eastern Himalayas, North-east hills (Patkai-Naga Hills and Lushai Hills) and the Brahmaputra and Barak Valley plains (Chatterjee et al. 2006*a*, *b*) which facilitate the bird diversity (Wiens 1989). Being at the confluence of the Indo-Malayan, Indo-Chinese and Indian biogeographical realms, the region is rich in habitat diversity and supports high endemism (Chatterjee et al. 2006*a*). It supports 850 bird species which is probably the highest in India in terms of avian-diversity (Chatterjee et al. 2006*b*). The eight states of the North-east India are now a part of the Indo-Burma Hotspot (Chatterjee et al. 2006*a*). The region is also an Endemic Bird Area (EBA) (Chatterjee et al. 2006*a*). The region falls on the Central Asia Flyway and the East Asia or Australasia Flyway of the migratory birds which results in high biodiversity in this region (Birdlife International 2017).

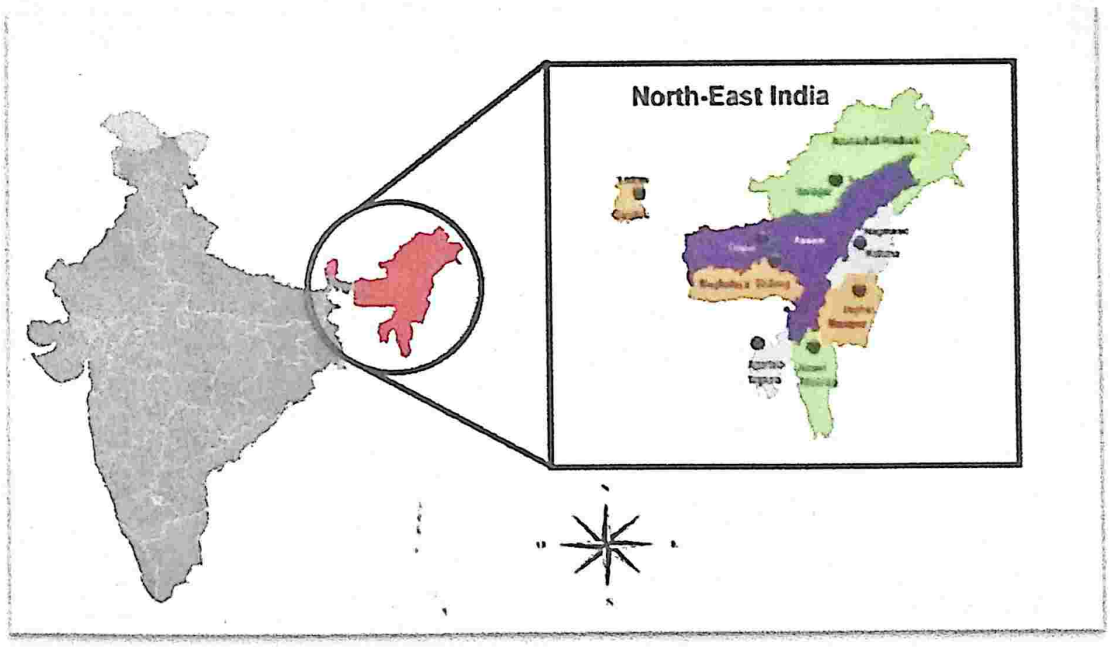

Figure 2.1: North-East Indian region in India.

2.2 Barak-Chindwin River Basin

The Barak-Chindwin Basin, being a part of the Indo-Malayan Hotspot, is rich in various avifaunal species but because of high anthropogenic pressures, it is under severe threats (Chatterjee et al. 2006*a*). The eastern highland of the region is often interrupted by the tributaries of the Chindwin River, by those of the Manipur River on the west and on the south-western hilly region, by the Barak River and its tributary, Tuivai (Dikshit and Dikshit 2013). The area is also one of the IBAs in the Indo-Malayan Hotspot (Chatterjee et al. 2006*b*). The Manipur River runs along the valley of Manipur and pours in the southern part of the region. The Loktak Lake in this region is not only rich in avifauna but also in floral diversity, herpetofauna, amphibians, fishes, insects and other taxa (Kangabam et al. 2015).

In a survey, a total of 121 species which belongs to 33 families were recorded from the Loktak Lake and the adjoining Keibul Lamjao National Park (KLNP) which also includes 43 migrant species (Devi 2012). This shows the importance of conserving the threatened avifauna found in this region and emphasizes on the need of an integrated conservation planning programme.

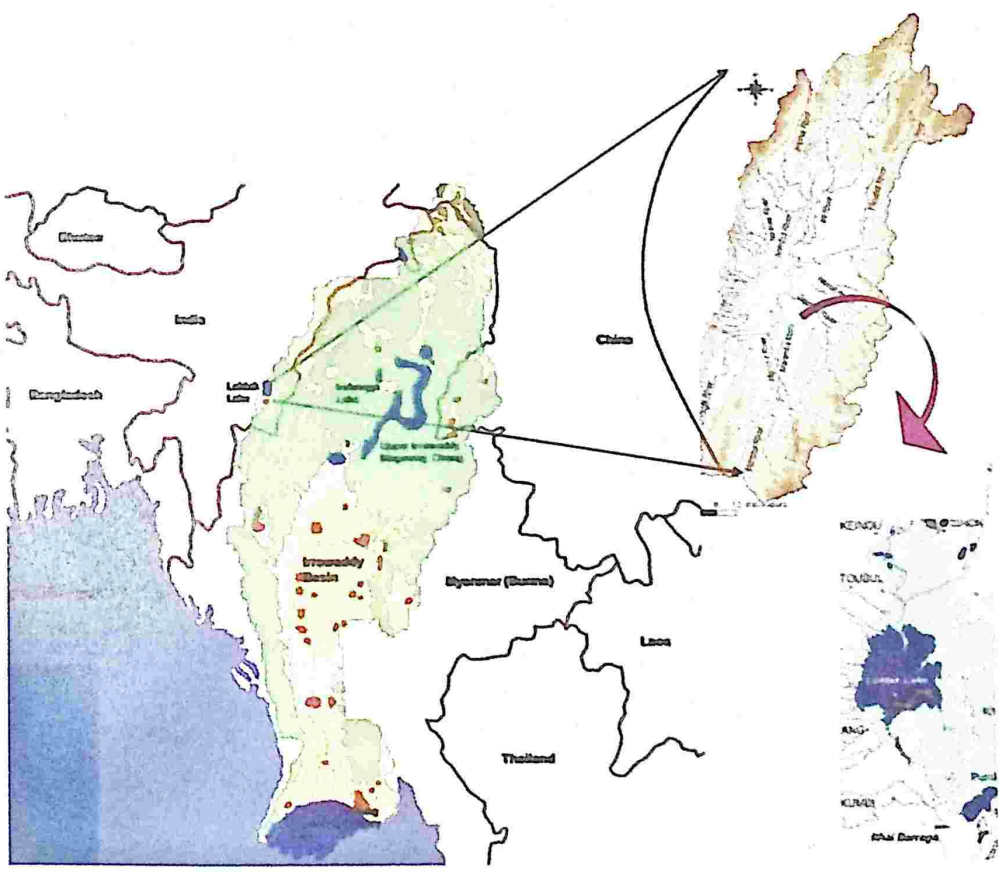

Figure 2.2: Major river basins of Manipur. (Source – LDA http://www.loktaklake.org/lwc.html#)

For carrying out the research work, Keibul Lamjao National Park (KLNP) and Pumlen Pat (PP) have been selected as the study sites. KLNP was selected as the undisturbed site due to its protected area status whereas PP as the disturbed site due to its high anthropogenic and other mode of disturbances. Both the sites have similar habitat types like woodland on hillocks, grassland on floating meadow locally known as *phumdi*, marshy areas, farming areas and open water with floating vegetation areas. This habitat similarity of both the sites will account for the effect of difference in habitat extent. To assess the effect of disturbance on bird diversity and abundance, PP is taken as the experimental site and KLNP is treated as the control site.

2.3 Keibul Lamjao National Park (KLNP)

Keibul Lamjao National Park is the last remaining natural home for the globally endangered Manipur Brow-antlered deer (*Rucervus eldii eldii*), which is locally also known as *Sangai*. The Park is also recently been known for a threatened bird species with global common name Black-breasted Parrotbill (*Paradoxornis flavirostris*) which was recently reported from the Park (Rahmani 2016). Both these species reside in the grassland habitat of the Park. Besides this, the open water habitat in the Park also support large congregation of both wintering and resident waterbirds. The local people seem to be unaware of the information regarding grassland birds. They seem to know much about only waterbirds as they are easily visible in the open water habitat. The grassland birds are hard to sight and do not occur in large congregations like waterbirds. The Park suffers from many issues like grass collection, fishing, vegetable collection, hunting of waterbirds and few more to mention. Since little is known about how diverse the grassland birds are in the grassland area, uncontrolled burning can be of serious threats to the diversity in such grassland. Species like Black-breasted Parrotbill, being a globally threatened species, is under serious threat. Certain management planning needs to be done for controlling these issues.

The Park is located in the south-eastern part of the Loktak lake between the coordinates 93°48'E to 93°52E longitude and 24°26'N to 24°31'N latitude. It is situated in Bishnupur District near Moirang, approximately 40 km south of Imphal.

The Park is part of the Loktak Lake but it is isolated by a strip of discontinuous hill range known as Thanga Hills. The northern part of the Park largely comprises of open

water habitat with thin floating vegetation. The eastern part comprises mainly of marshy land and open water habitat along with thin floating vegetation. Two blocks have recently been added to the southern part of the Park on the Kumbi side. These two blocks are comprised mainly of grassland, open water area with thin floating vegetation and a small farming area. Sampling had been carried out in these newly added blocks for assessing the diversity. The western part of the Park comprises of a strip of hill, elevated marshy land strip, hillocks and grassland. There are three hillocks, namely Pabot Chingjao, Pabot Chinglukok and Toya and a strip of hill known as Chingmei Hill inside the Park.

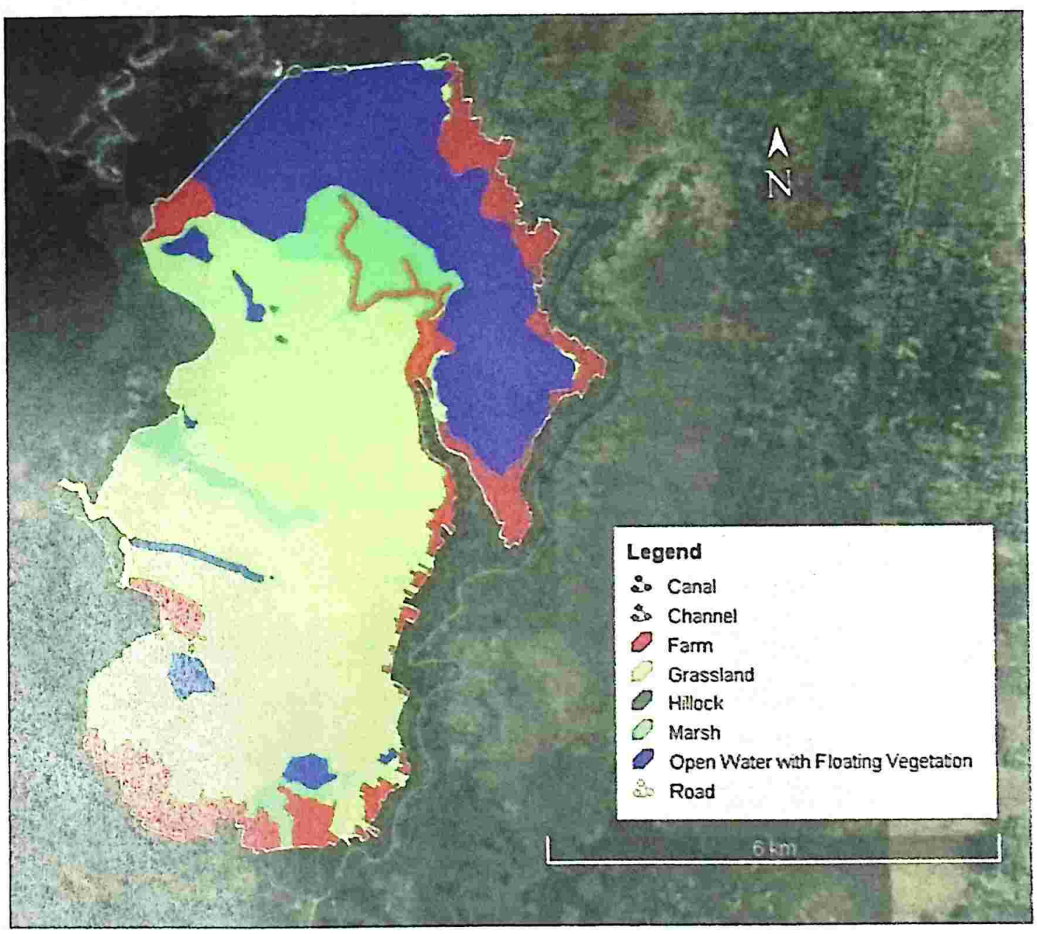

Figure 2.3: Different habitat types in KLNP.

The Park has open water habitat with thin floating vegetation which mainly harbours the wintering and resident waterbirds and some grassland birds, grasslands on the floating meadows, woodlands on the hillocks, elevated marshy habitat and farming areas. On the western part, a stripe of elevated marshy area known as Thangbirel Yangbi has been sandwiched by the grassland. The main villages on the western boundary of the Park are Sagram, Keibul and Chingmei. The northern part extends

eastward from Keibul Hill to Chingthi Hill and in the eastern part, it extends from Komlakhong village till Laphupat Tera. In the southern part of the Park, Ithai Wapokpi and Kumbi villages inhabit the fringe areas.

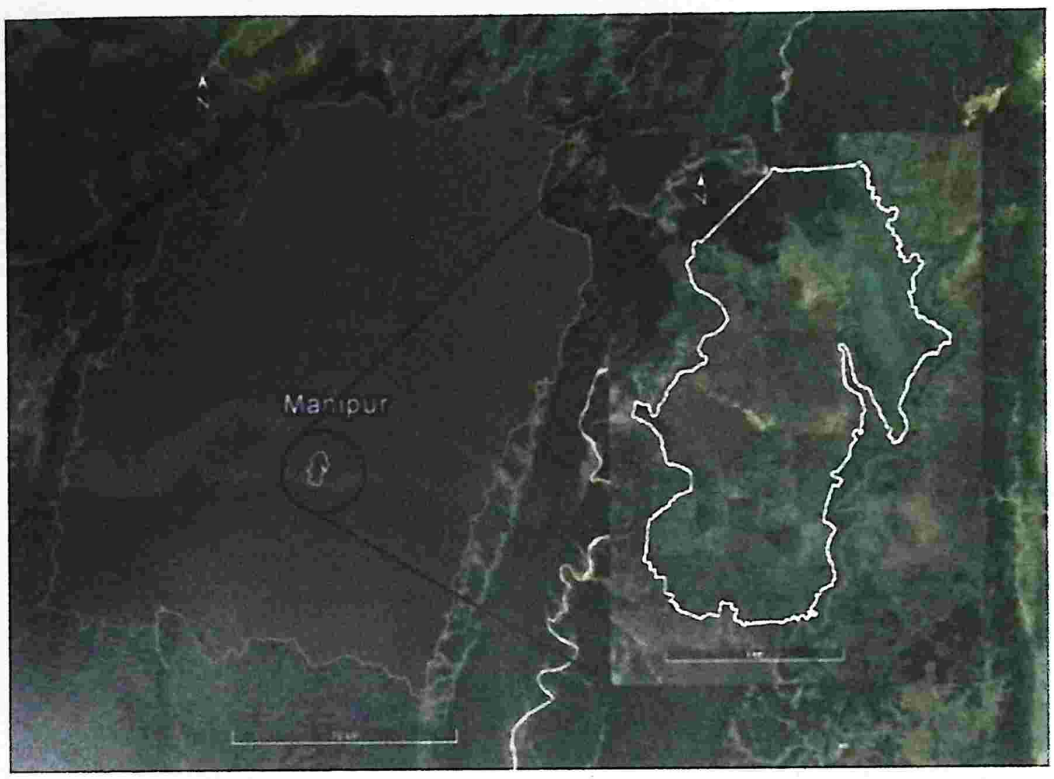

Figure 2.4: Location of Keibul Lamjao National Park (KLNP) in Manipur.

The total area of the study site was 40 sq. km. But, with the addition of the two new Kumbi blocks, the total area has become 44.8 sq. km. Out of the 40 sq. km area, thick contiguous mat of meadows covered 26 sq. km and the remaining 14 sq. km was made up of drylands, open water, uplands and sporadic hillocks (Singh 1992, Tuboi 2013).

The Manipur River Basin drains 30% of the total area of the state (Tuboi 2013). The catchments of Loktak Lake from the hilly areas and the wetlands associated with it are a part of the Manipur River Basin which covers an area of 6,872 sq. km (Tuboi 2013). Two major rivers system, Chindwin-Irrawady System and the Barak Drainage System, make up the Manipur River valley (Fig. 2.2). The first system have the following rivers, Iril, Imphal, Thoubal, Khuga and Chakpi, which do not flow directly into the Lake but do so through Khordak and Ungamen channels. The second system feeds the Lake directly through Nambol, Nambul and Thongjaorok Rivers. During the dry season, the Lake acts as a temporary reservoir and the Khordak and Ungamen

channels drain out the water. These channels meet up the Imphal River that flows on the eastern side of the Park. After the channels and the river meet up, the system becomes the Manipur River further along.

2.3.1 Floral and Faunal Diversity

During the fieldwork, more than 100 species of plants have been sampled. In the grassland habitat, species like *Zizania latifolia, Phragmites karka, Saccharum munja* and few more were recorded, and *Pinus kesiya, Bauhinia variegate, Lantana camara, Ageratum conyzoides* and few others were recorded from the woodlands on hillocks. Besides plant species, KLNP is also rich in faunal diversity. The faunal diversity includes 22 species of mammal and 25 species of reptile (Singh 1991, Tuboi 2013) and 135 species of bird (personal observation. Major waterbirds recorded are Lesser-whistling Duck *Dendrocygna javanica,* Asian Openbill *Anastomus oscitans*, Gadwall *Mareca strepera* and Ferruginous Pochard *Aythya nyroca*. Important grassland birds are Black-breasted Parrotbill *Paradoxornis flavirostris*, Slender-billed Babbler *Chatarrhaea longirostris* and Jerdon's Bushchat *Saxicola jerdoni*.

2.4 Pumlen Pat

During a survey for the possible reintroduction site for the endangered Manipur Brow-antlered deer, a site similar to KLNP, in terms of habitats, was found on the eastern side of the Park, known as Pumlen Pat. The site has similar floating *phumdi*, hillocks, grassland and open water area with floating vegetations. However, the site is highly disturbed due to anthropogenic activities like agricultural practices, pisciculture, and vegetable collection.

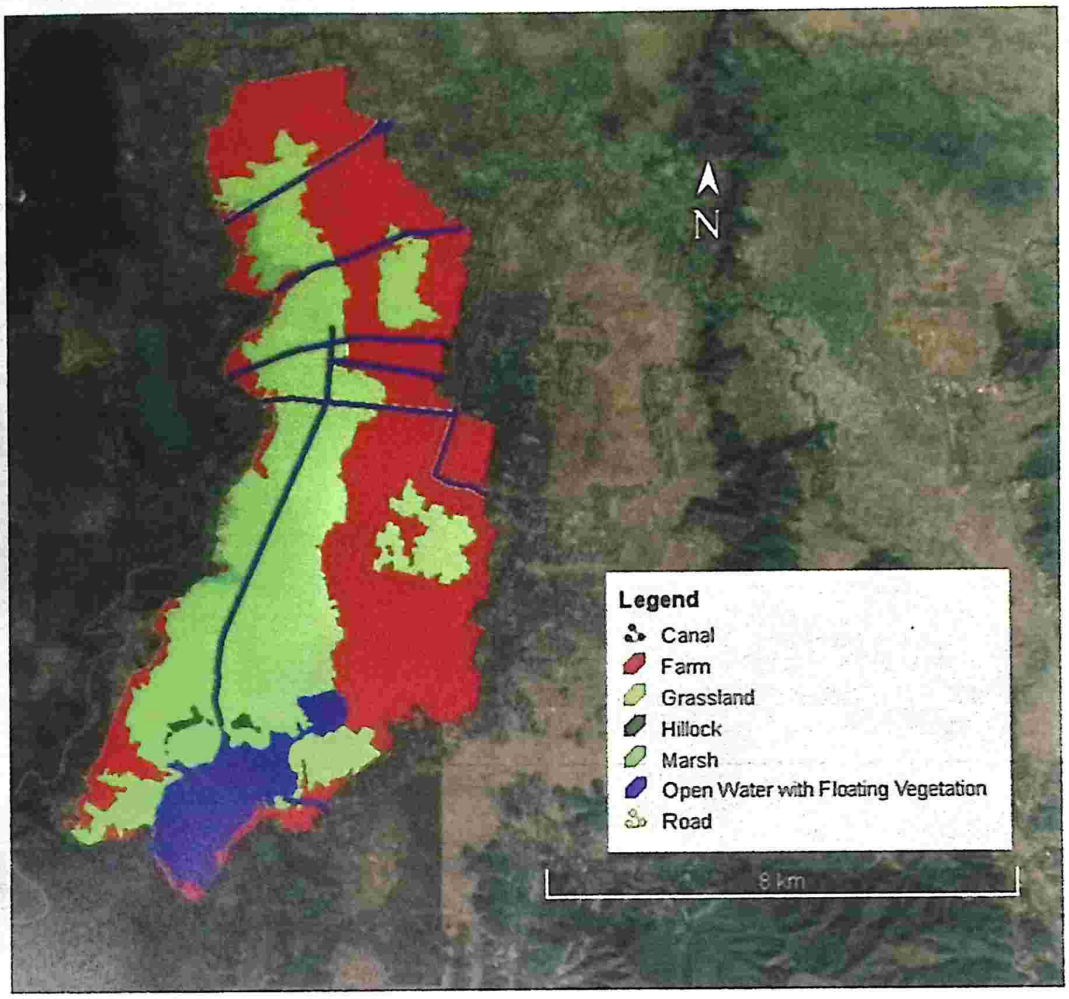

Figure 2.5: Different habitat types in PP.

Starting from early morning, the area is infested by an army of humans for various reasons in different regions of the site. Although it is highly disturbed, the area supports good diversity of birds. A globally endangered species with global common name Yellow-breasted Bunting has also been recorded from this area which itself shows the potential of the area that with good management in place, the area can be of good quality in terms of habitat for globally endangered bird species.

It is located in the eastern side of KLNP between the coordinates 93°51'E and 93°55'E longitudes and 24°24'N and 24°33'N latitudes. The site is located in Kakching District. The Imphal River runs between KLNP and Pumlen Pat. Like KLNP, Pumlen Pat is also a part of the Loktak Lake ecosystem. It receives the annual water inflow mainly from the Imphal River and adjoining channels like Ningol Khong and Dabalo Khong, on the western side and a channel named Maram Maril feeds the area on the eastern side.

Pumlen pat is surrounded by villages on all its sides. On the northern flank, it is surrounded by Phoubakchao, Thongam and Hayel-Hangool villages. The eastern flank is surrounded by villages like Wabagai, Hiyanglam, Khoidum Pat, Laphupat, Langmeidong, Yangdong and Elangkhangpokpi. The southern part has a reserve forest area known as Thongam Mondum Reserve Forest area and villages like Nungpakthabi, Tokpaching, Sarik and Nongmaikhong. The western part is flanked by Khordak, Laphupat Tera, Arong Nongmaikhong, Hiyanglam Li and Komlakhong villages.

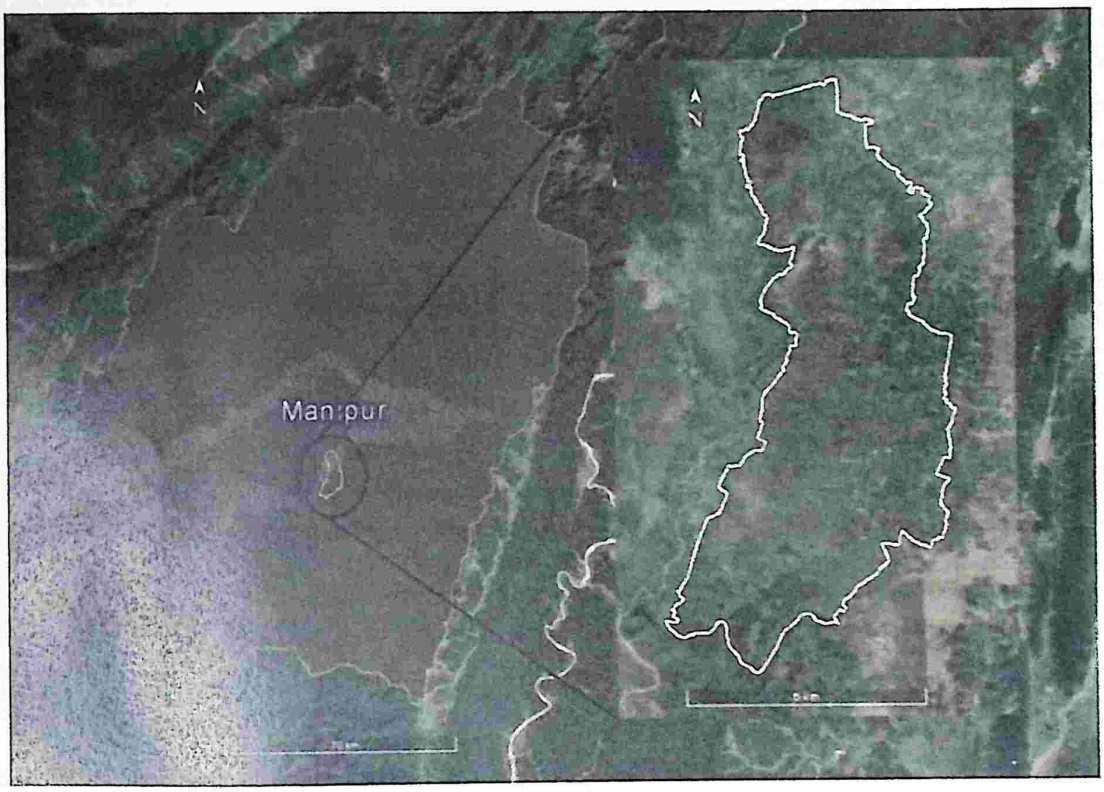

Figure 2.6: Location of Pumlen Pat (PP) in Manipur.

The site is 60 sq. km in size and is very similar to KLNP in terms of habitat. It has woodlands on hillocks, open water habitat with floating vegetation, grasslands, marshy habitat and farming areas. The site is highly transacted by myriad boat trails, channels, canal and roads. Farming intensity is very high. Fish farms and agricultural farm comprise the main land use in the area. During the course of the fieldwork, more grassland areas were being converted into farms. The process of digging farms starts during February when the site is almost devoid of water. The grasslands are burnt first and then the digging starts using heavy machineries or normal tractors or human labours. The farms get ready before the arrival of monsoon rain. And then the farming

season goes on till September-October. The open water areas with floating vegetation are filled with fishermen early in the morning and evening. However, fishing intensity decreases in the evening. Grasslands were mainly under pressure due to the large numbers of vegetable collectors, grass collectors and herders. *Phramites karka* was mainly collected for using as firewood and fencing purposes. Marshy areas were mainly treated as grazing grounds. Farming was active even during the dry season. Pumping water out and fishing in the farms and planting paddy crops were carried out from December to February. The site has three hillocks on the southern part of the site. Firewood collection and wood cutting have been carried out in these hillocks. The biggest is called Chinglukok, Chingjao is smaller and the smallest is the Hapsa. Hapsa hillock is important because it harbours roosting sites of birds like Intermediate Egret, Asian Openbill, Black-winged Kite and Flying Fox.

2.4.1 Floral and Faunal Diversity:

Although the area does not have a protected area status and therefore, is not legally protected under any policy or law, the area is highly biodiverse. 94 species of birds have been reported from this area (personal observation). The local people have also reported sightings of mammals like Hog Deer and Wild Pig. Besides mammals and birds, reptiles, fishes, amphibians and few other taxa are reported by the local people but information pertaining to this is currently lacking.

2.5 Climate

The area experiences winter season from December till February and summer season extends from March till May. From June onwards, the area receives monsoon rain (Tuboi 2013). During winter, mornings are foggy, sometimes till 10:00 AM local time. The lowest temperature experienced during winter during the course of fieldwork was 8°C. Evenings are also cold and slightly hazy. The day breaks at 05:30 AM local time and ends at 17:00 PM local time. During early summer, temperature reaches highest at around 30°C and the day breaks at 4:30 AM local time and ends at 18:00 PM local time.

CHAPTER 3

MATERIALS AND METHODS

3.1 Methods for sampling

The sampling was carried out from 24th December, 2016 till 15th February, 2017. 20 girds (1 km × 1 km) were sampled in each site and each grid had 3 sampling points which gives a total of 60 point counts in each site giving in total 120 point counts during the study period. The sampling points were again replicated in each site over the course of the research. The sampling for replication was carried out from 24th March, 2017 till 18th April, 2017. Each sampling point has four habitat plots. Therefore, each grid has a total of 12 habitat variable plots and a total 240 habitat variable plots in each site over the course of the research. 160 vegetation plots were sampled from KLNP and 201 vegetation plots from PP. Vegetation data was collected only for the winter season. Equipment used during the point counts was Hawke Nature-Trek binocular, Hawke Laser Range Finder 400M, Garmin eTrex Vista Hcx GPS and Suunto see-through Compass.

3.1.1 To examine the diversity and abundance of grassland birds in KLNP and Pumlen

Pat.

- Stratified random sampling was done and both the sites were divided into 1 km × 1 km grids (Tuboi et al. 2012). Sampling grids were selected through a random process and based on accessibility in the sites.
- A reconnaissance survey was carried out and for the threatened bird species, call playbacks were used (Rahmani 2016).
- Each grid had 3 sampling points at which variable-radius point count had been carried out. Boat survey was carried out for waterbird census.
- Any direct sightings (bird calls heard or bird seen) during the point count were recorded.
- A distance of minimum 300 m and maximum 500 m is maintained between the three sampling points of a grid. 300 m interval was used

between some sampling points in the grassland habitat due to accessibility issues. Variable-radius point counts were carried out for duration of 10 minutes twice a day (morning and evening).

- Sampling was carried out in the morning from 06:00 hrs till 10:00 hrs and in the evening from 13:00 hrs till 17:00 hrs during winter and 13:00 hrs till 18:00 hrs during early summer.

3.1.2 To assess habitat heterogeneity influencing the species composition in different

habitat types.

- Bar-Massada and Wood (2014) method for sampling habitat variable was followed. One quadrat of 1m × 1m was laid on the centre of the circle made with the radius of the point count and the remaining three quadrats are laid randomly in three equally divided segments in the circle.

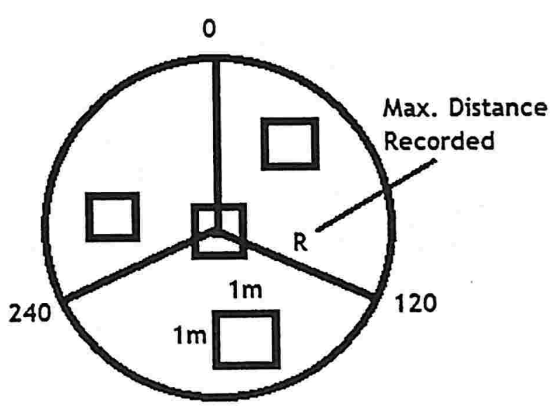

Figure 3.1: Diagramatic representation of habitat sampling methods.

- Data was collected on vegetation structure like plant heights, number of plant species and number of individuals of each species; water depth and size of the water body. Any signs of disturbance like humans encountered, human foot trail, boat trails and other mode of disturbances were also collected to quantify the level of disturbance in the disturbed wetland.

3.2 Analytical methods

3.2.1 To examine the diversity and abundance of grassland birds in KLNP and Pumlen

Pat.

- Shannon's Diversity Indices (H) was calculated for both the sites on MS Excel 2010.
- Checkerboard score (C score) was also calculated for both sites using vegan package and "C.score" command on R 3.2.3 software to check if the bird species were segregated or aggregated and to see how it differed between the sites.
- Rank abundance plot had been made in R software using "BiodiversityRGUI ()" function.
- Density of bird species were calculated in Distance 6.2 software.

3.2.2 To assess habitat heterogeneity influencing the species composition in different

habitat types.

- For analyzing plant community, TWINSPAN (Two-way Indicator Species Analysis) was run for both the sites in PC-ORD 4.
- Checkerboard score values of disturbed and undisturbed sites could be used to infer to see how different the two sites are in terms of habitat heterogeneity.
- The communities of plants had been classified based on the divisions made by TWINSPAN and communities were selected based on the habitat types found in the study sites.
- NMDS (Non-metric Multidimensional Scaling) was used to plot species clusters in different habitat types in R software using vegan package, Bray-Curtis distance and "metaMDS" command. Bray-Curtis distance was used as the data matrix had various null values. To put ellipses of different habitat types or sites, "ordiellipse" command was used in ggplot2 package in R software.

- Sorensen's Coefficient (CC) was calculated to see the similarity in species composition in different habitat types and in between disturbed and undisturbed sites using the formula-

$$CC = {}^{2C}/_{(S1+S2)}$$

where, C is the number of common species and $S1$ and $S2$ are the species richness of the two variables in concerned.

- Disturbance type and their extents had been calculated using the data collected on disturbances, in MS Excel 2010.
- Percent coverage of different habitat types in both the sites was calculated by digitizing the habitats using polygons in Google Earth Pro 7.1.7.2606 and ground-truthing was done to check accuracy.

CHAPTER 4

RESULT

4.1 Bird Richness

Altogether, 136 bird species belonging to 40 families were sighted from the undisturbed site (KLNP) and 94 bird species belonging to 35 families were sighted from the disturbed site (PP). Out of these, 91 bird species from the undisturbed and 79 bird species from disturbed site were recorded only during point count. 60 bird species have been found to be common, 31 bird species were exclusively found in KLNP and 19 bird species were found exclusively in PP. Based on number of species recorded during the point count, the species richness curve of both the sites has been plotted using rarefaction function in R software using random method. Rarefaction analysis shows that the species richness is higher in undisturbed site as compared to disturbed site.

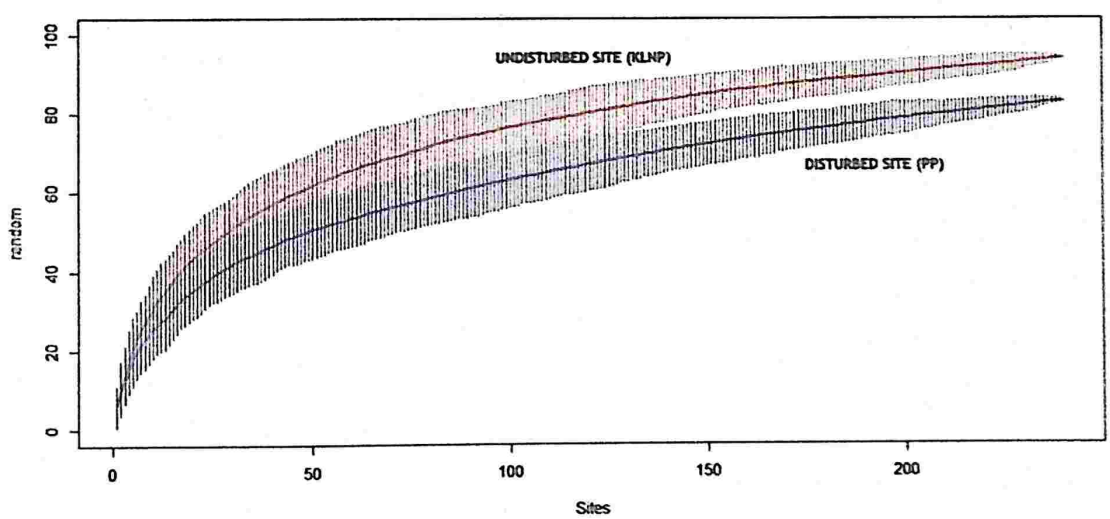

Figure 4.1: Species Richness curve of undisturbed site (Red) and disturbed site (Blue).

Species richness were also calculated in different habitat types in both the sites and plotted. In open water with floating vegetation (OWFV) in KLNP seems to have higher richness as compared to the same habitat type of PP. Similar result was found in grassland, marsh and hillock habitat types except for the farming area. Disturbed site has higher richness in farming area compared to the farming area of the

undisturbed site. This trend may be due to the fact that the disturbed site had larger farming area than the farming area in the undisturbed site.

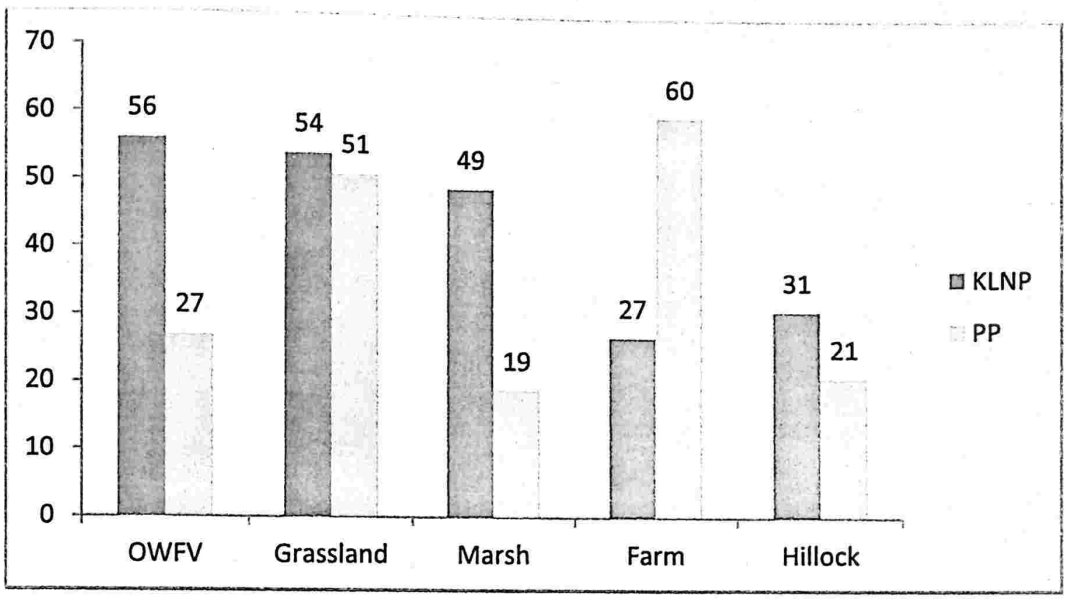

Figure 4.2: Species Richness per habitat type in KLNP and PP.

4.2 Bird Abundance

Figure 4.1 and 4.2 shows the rank abundance plot for undisturbed and disturbed sites. For the undisturbed site, Lesser-whistling Duck has the highest rank, followed by Eurasian Coot and Asian Pied Starling. Black Bulbul, Bronze-winged Jacana, Common Hoopoe, Common Kestrel, Crested Serpent Eagle, Eastern Marsh Harrier, Osprey and Red-breasted Flycatcher all had the lowest rank with just one sighting.

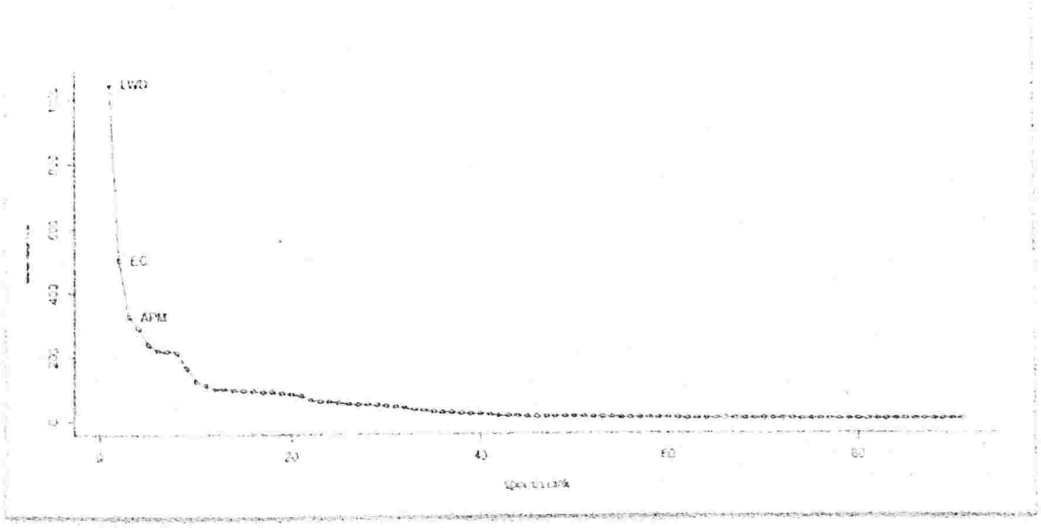

Figure 4.3: Rank Abundance plot of bird species of the undisturbed site (KLNP).

In the disturbed site, Striated Grassbird has the highest rank, followed by Citrine Wagtail and Little Egret. Black Francolin, Black Kite, Black-winged Cuckooshrike, Common Tailor Bird, Coppersmith Barbet, Eastern Marsh Harrier, Great Cormorant, Large Cuckooshrike, Large Hawk Cuckoo, Paddyfield Pipit, Purple Heron, Rufescent Prinia, Rufous-rumped Warbler, Shikra, White-browed Wagtail and Wood Sandpiper all share the lowest rank with just one sighting each.

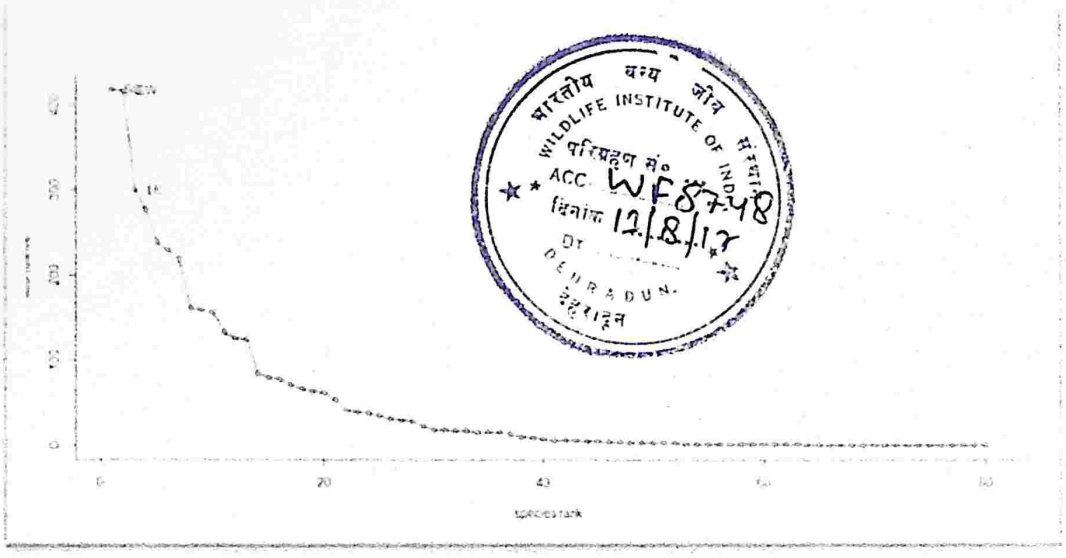

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Figure 4.4: Rank Abundance plot of bird species of disturbed site (PP).

Shannon Diversity Indices (H) was created for both the sites. The undisturbed site has slightly similar diversity with the disturbed site (H_{KLNP}=3.379 and H_{PP}=3.305). The following figure shows the graphical representation of the Shannon diversity index (H) of both the sites.

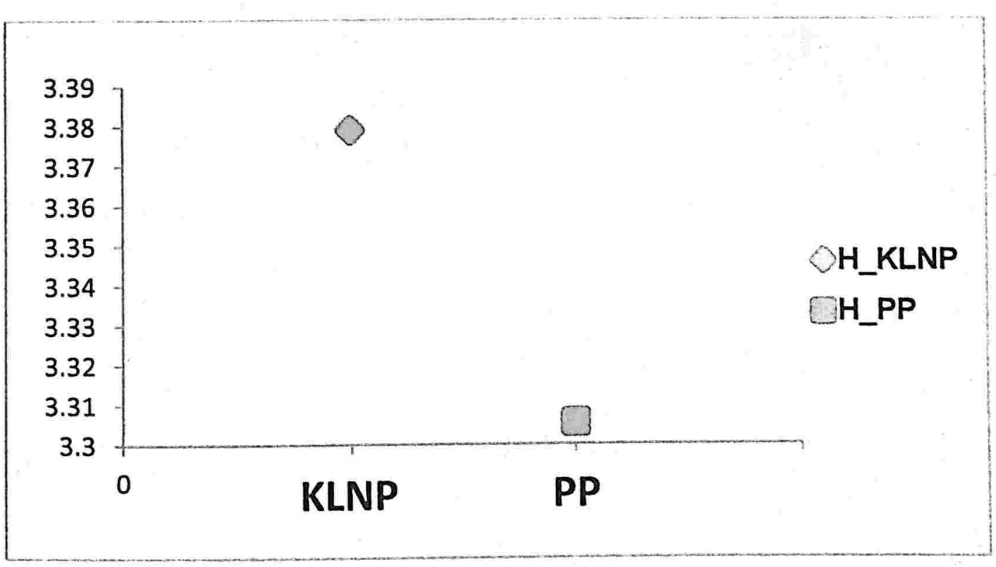

Fig. 4.5: Shannon Diversity Index (H) of both disturbed (PP) and undisturbed (KLNP)

Density of total 25 bird species was calculated using Distance 6.2 software from the landscape. Out of these, 22 bird species were from undisturbed site and 17 bird species were found to be in the disturbed site. These species had sightings more than 15. 14 bird species were found to be common from both the sites. Table 1 shows the outcome of the analysis of the 14 common species.

Table 4.1: Density of bird species from undisturbed and disturbed sites.

Observations		**KLNP (Undisturbed)**		**PP (Disturbed)**	
Species Name	**Scientific Name**	**Density**	**% CV**	**Density**	**% CV**
Black Drongo	*Dicrurus macrocercus*	25.9	32.5	30.3	27.1
Striated Grassbird	*Megalurus palustris*	182.9	13.2	262.5	22.2
Citrine Wagtail	*Motacilla citreola*	549.7	24.6	609.7	13.9
Common Stonechat	*Saxixola torquatus*	203.8	15.2	189.6	13.6
Graceful Prinia	*Prinia gracilis*	28.0	31.9	73.9	14.6
Yellow-bellied Prinia	*Prinia flaviventris*	149.3	14.2	125.6	16.4
Long-tailed Shrike	*Lanius schach*	14.9	24.0	7.3	21.2
Plain Prinia	*Prinia inornata*	82.8	21.1	56.8	24.9
Red-vented Bulbul	*Pycnonotus cafer*	64.2	21.6	248.1	23.1
Asian Pied Starling	*Gracupica contra*	136.4	21.4	101.0	30.9
Hume's Leaf Warbler	*Phylloscopus humei*	163.0	41.5	111.9	38.7
White-tailed Stonechat	*Saxicola leucurus*	35.8	26.5	30.9	19.8
Western Yellow Wagtail	*Motacilla flava*	85.1	29.1	37.7	39.8
Little Egret	*Egretta garzetta*	15.9	33.6	27.6	35.4

The rest of the 69 bird species from the undisturbed and 62 bird species from the disturbed sites did not have enough sightings although some bird species have high abundance. Due to this, these bird species could not be used for analysing in Distance software. The lists of the remaining species left out from analysis are given in the appendix I and II.

4.3 Habitat Heterogeneity

4.3.1 Plant communities in different habitat types

A total of 101 plant species from KLNP and 88 plant species from PP were recorded during the study period. Rarefaction of plant species of both the sites was performed in R software using random method. The result shows that KLNP has higher species richness than in PP. A total of 160 plots from KLNP and 201 plots from PP were analysed.

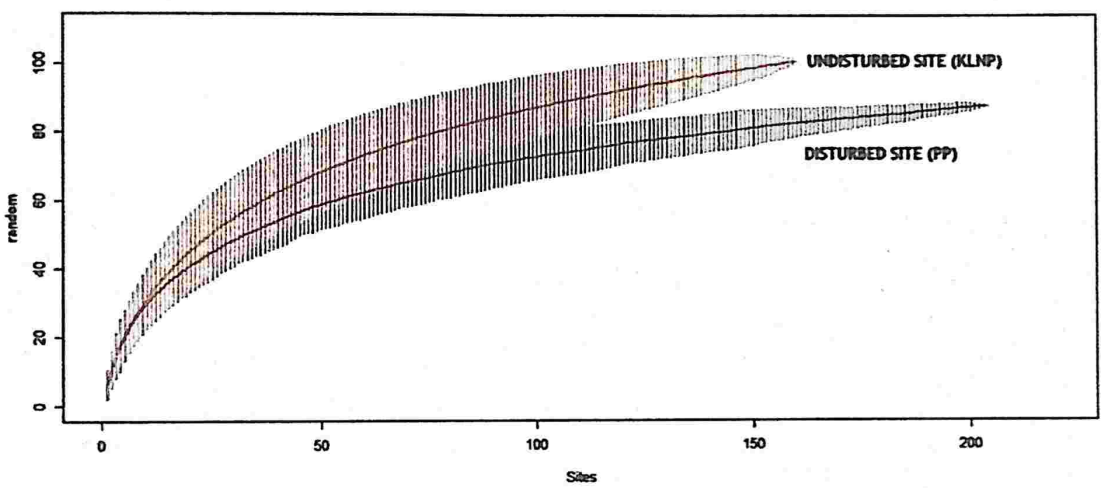

Figure 4.6: Species Richness curve of undisturbed site (Red) and disturbed site (Blue).

Plant species community in different habitat types has been identified along with indicator species using TWINSPAN (Two Way Indicator Species Analysis) in PC-ORD 4.2 software. The analysis gave six different communities from KLNP and seven communities from PP, except for OWFV habitat type. The c score values were also calculated in R software. There seems to be no significant difference in habitat heterogeneity between undisturbed site and the disturbed site which is evident from the checkerboard score calculated in R software using "C.score" command (C $score_{KLNP}$= 0.8803; C $score_{PP}$= 0.8599).

4.3.1.1 Plant communities in KLNP

The six plant communities were selected through several divisions. The first division was achieved at the iteration 1000 giving an eigenvalue 0.7295. It gave two communities, community 1 (N=148) has *Leersia hexandra* and *Pteridium aquilinum*

as the indicator species and the community 2 (N= 12) has *Heliotropium indicum* and *Oxalis corniculata* as indicator species. From these two communities, the community 2 has been chosen and the community 1 is further subdivided.

The community 1 is further divided and the division is reached at the iteration 48 giving an eigenvalue 0.4863. Community 3 (N=18) has *Brachiaria mutica* and *Mikania chordata* as the indicator species and community 4 (N=130) has *Pteridium aquilinum* and *Phragmites karka* as the indicator species. The community 3 is taken and community 4 is further subdivided into two more communities at the iteration 5 giving an eigenvalue 0.4262. Community 5 (N=60) has *Leersia hexandra* and *Alternanthera philoxeroides* as the indicator species and community 6 (N=70) has *Capillipedium assimile* and *Phragmites karka* as the indicator species. Both community 5 and 6 are further subdivided.

Community 5 is divided into two communities at the iteration 37 giving an eigenvalue 0.3736. Community 7 (N=27) has *Alternanthera philoxeroides* and *Brachiaria mutica* as indicator species. And community 8 (N=33) has *Leersia hexandra* and *Zizania latifolia* as indicator species. Both communities 7 and 8 are chosen. Community 6 is divided into two more communities at the iteration 11 giving an eigenvalue 0.3818. Community 9 (N=33) has *Zizania latifolia* and *Polygonum perfoliatum* as the indicator species. And community 10 (N=37) has *Leersia hexandra* and *Hedychium coronarium* as the indicator species. Both communities 9 and 10 are chosen. From all these divisions six communities, namely community 2, community 3, community 7, community 8, community 9 and community 10, are the preferred communities selected based on the habitat types of the undisturbed site.

Table 4.2: Six plant communities and their indicator species in the undisturbed site (KLNP).

Community No.	Type of Community
Community 2	*Heliotropium indicum-Oxalis corniculata*
Community 3	*Brachiaria mutica-Mikania cordata*
Community 7	*Alternanthera philoxeroides-Brachiaria mutica*
Community 8	*Leersia hexandra-Zizania latifolia*
Community 9	*Zizania latifolia-Polygonum perfoliatum*
Community 10	*Leersia hexandra-Hedychium coronarium*

Community 2 is found in hillock habitat type whereas community 3 is found in the farming area. Communities 7 and 9 are found in marshy habitat type and communities 8 and 10 are found in grassland habitat type.

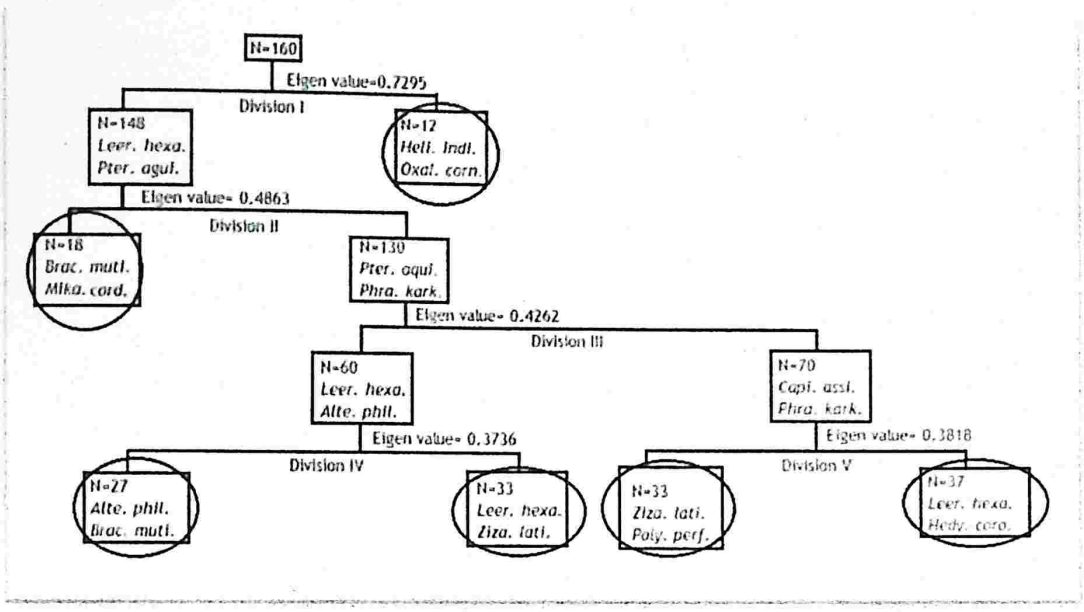

Figure 4.7: Pictorial representation of the division by TWINSPAN of plant communities in undisturbed site (KLNP); the circled communities are the selected ones.

4.3.1.2 Plant Community in PP

As mentioned above, seven plant communities have been recorded from the disturbed site. The first division was achieved at the iteration 5 giving an eigenvalue of 0.6369. Community 1 (N=136) has *Zizania latifolia* and *Leersia hexandra* as indicator species. Community 2 (N=65) has *Cynodon dactylon* and *Brachiaria mutica* as indicator species. Both communities 1 and 2 are further subdivided into two communities each. Community 1 is divided at the iteration 5 giving an eigenvalue 0.5880. Community 3 (N=8) has *Imperata cylindrica* and *Artemisia nilagirica* as the indicator species. Community 4 (N=128) has *Leersia hexandra* and *Zizania latifolia* as the indicator species. Community 2 is also divided into two communities at the iteration 7 giving an eigenvalue 0.3272. Community 5 (N=45) has *Brachiaria mutica* and *Alternanthera philoxeroides* as the indicator species. Community 6 (N=20) has *Ageratum conyzoides* and *Cynodon dactylon*. Out of these divisions, communities 3 and 6 have been chosen. Communities 4 and 5 are further subdivided into two communities each further.

The division for community 4 has achieved at the iteration 7 with an eigenvalue 0.3637. Community 7 (N=100) has *Dactyloctenium aegyptium* and *Zizania latifolia* as the indicator species. Community 8 (N=28) has *Ludwigia clavellina* and *Brachiaria mutica* as the indicator species. Community 5 is also divided into two communities and the division is achieved at the iteration 6 with an eigenvalue 0.3335. Community 9 (N=29 has *Cynodon datylon* and *Leersia hexandra* as the indicator species. Community 10 (N=16) has *Ageratum conyzoides* and *Galinsoga parviflora* as the indicator species. Out of all these divisions, the communities 8, 9 and 10 have been selected and communities 7 will be further subdivided.

The division is achieved at the iteration 7 giving an eigenvalue of 0.3228. Community 11 (N=46) has *Arundo donax* and *Dactyloctenium aegyptium* as indicator species. Community 12 (N=54) has *Zizania latifolia* and *Phragmites karka* as the indicator species. Both the communities 11 and 12 are selected.

Table 4.3: Seven communities of plants and their indicator species in the disturbed site (PP).

Community No.	Type of Community
Community 3	*Imperata cylindrica-Artemisia nilagirica*
Community 6	*Ageratum conyzoides-Cynodon dactylon*
Community 8	*Ludwigia claveliana-Brachiaria mutica*
Community 9	*Cynodon datylon-Leersia hexandra*
Community 10	*Ageratum conyzoides-Galinsoga parviflora*
Community 11	*Arundo donax-Dactyloctenium aegyptium*
Community 12	*Zizania latifolia-Phragmites karka*

Communities 8, 11 and 12 are found in grassland habitat type whereas communities 6 and 10 are found in farming area. Community 3 is found in hillock habitat and community 9 is found in marshy habitat.

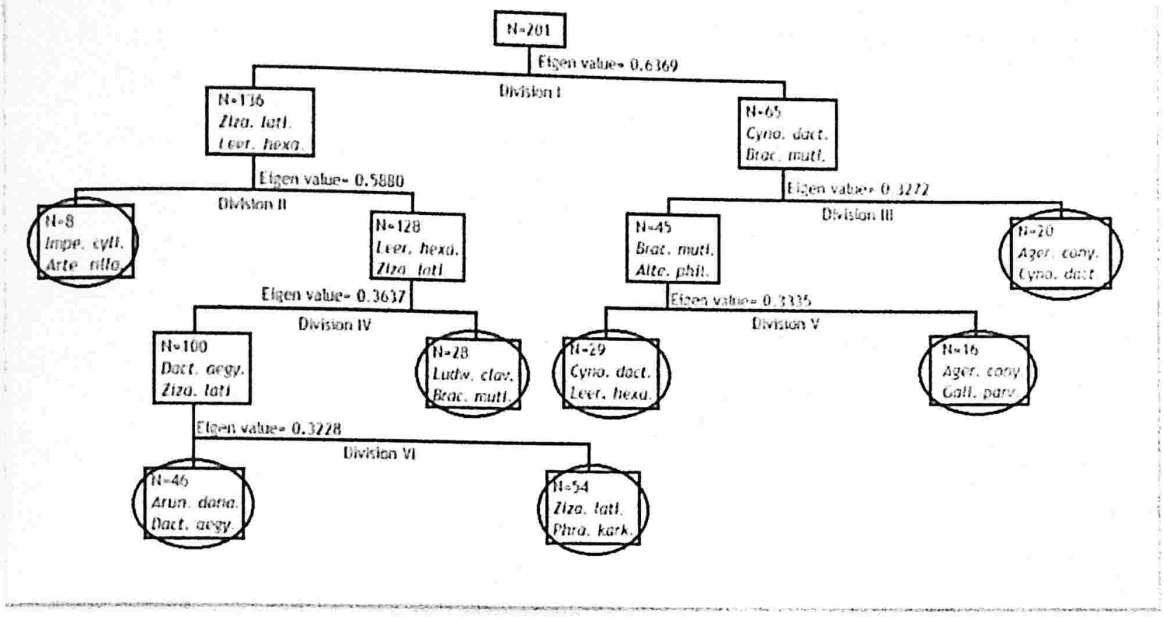

Figure 4.8: Pictorial representation of the division by TWINSPAN of plant communities in disturbed site (PP); the circled communities are the selected ones.

4.3.2 Species Composition in different habitat types

As mentioned above, both the habitats have the same habitat types, namely open water with floating vegetation (OWFV), grassland (Grlnd), marshy (Marsh), farming area (Farm) and hillock (Hillock). Although the sites have same habitat types, these habitats differ in extent. The farming area in disturbed site covers almost half the area. OWFV is larger in undisturbed site (KLNP) than in disturbed site (PP). Grassland and hillock is of almost the same size. The diversity in each habitat has been calculated using Shannon's index for both the sites. Species diversity is higher in all habitat types of KLNP except for the farming area.

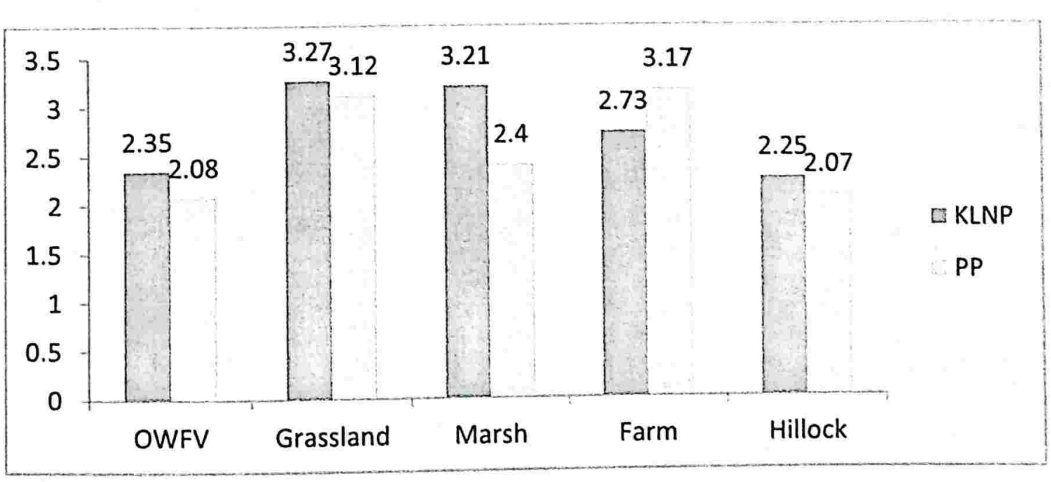

Figure 4.9: Species diversity in different habitat types in KLNP and PP.

To see the change in species composition between different habitats, NMDS (Non-metric Multidimensional Scaling) was run in R software using "metaMDS" command in which the habitat parameter is used on the matrix. Stress plots have been plotted to see how the model fits with the observations for both the sites (Non-metric fit, R^2=0.973 and linear fit, R^2= 0.833 for KLNP and Non-metric fit, R^2= 0.972 and linear fit, R^2= 0.828 for PP).

The observations were plotted in 2-dimensions and ellipse were put using habitat type as the factor to represent different habitat types and to see how the species composition changes according to it.

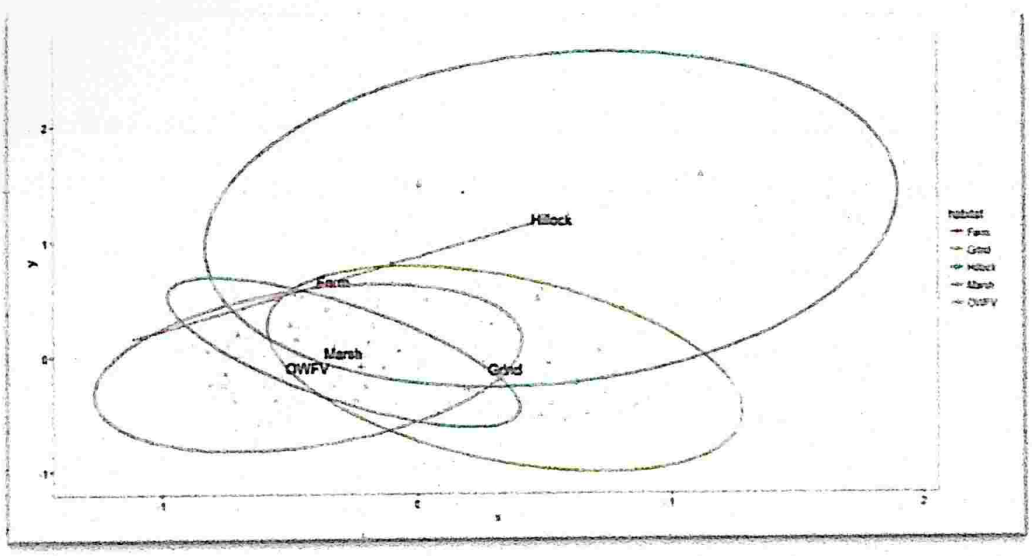

Figure 4.10: Species composition along different habitats in KLNP (Undisturbed).

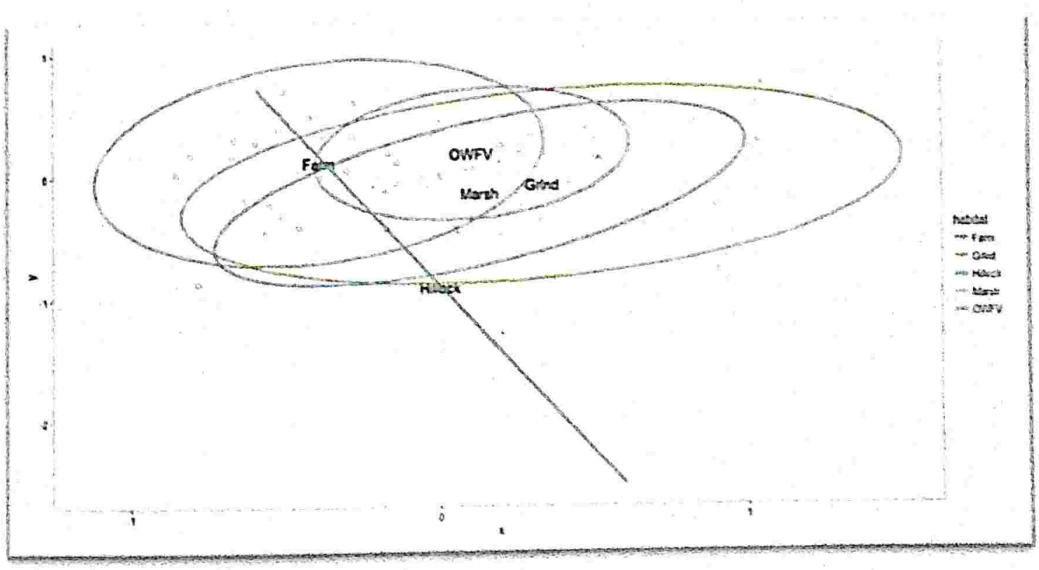

Figure 4.11: Species composition in PP (Disturbed) along different habitat types.

Since it is evident that there are overlaps amongst the habitat types, Sorensen's Coefficient (CC) of each habitat type with all the other habitat types has been calculated and a matrix has been made for both the disturbed and undisturbed sites.

Table 4.4: Sorensen's Coefficient (CC) of bird species between different habitat types in undisturbed site (Open water with floating vegetation= O, Grassland= G, Marsh= M, Farm= F and Hillock= H).

Habitat Type	O	G	M	F	H
O	1	0.55	0.59	0.53	0.30
G	0.55	1	0.68	0.52	0.45
M	0.59	0.68	1	0.61	0.33
F	0.53	0.52	0.61	1	0.24
H	0.30	0.45	0.33	0.24	1

Table 4.5: Sorensen's Coefficient (CC) of bird species between different habitat types in disturbed site (Open water with floating vegetation= O, Grassland= G, Marsh= M, Farm= F and Hillock= H).

Habitat Types	O	G	M	F	H
O	1	0.49	0.61	0.53	0.54
G	0.49	1	0.51	0.63	0.42
M	0.61	0.51	1	0.43	0.55
F	0.53	0.63	0.43	1	0.35
H	0.54	0.42	0.55	0.35	1

The proportion of farming area was very less in the undisturbed site whereas in the disturbed site, the proportion of hillock habitat type was very small. It is due to this reason that the Farm ellipse and Hillock ellipse in undisturbed plot (Fig. 4.12) and disturbed plot (Fig. 4.13) respectively, appears as a line. And because of this reason, the sampling effort was small compared to other habitat types.

Similarly, NMDS was run for both disturbed and undisturbed sites combined in R using the same metaMDS command, using site as the factor. A stress plot was plotted to see how well the selected model fits in with the observations (Non-metric fit, R^2= 0.968 and linear fit, R^2= 0.797).

Using R software, ellipses are plotted against the matrix using site as the factor.

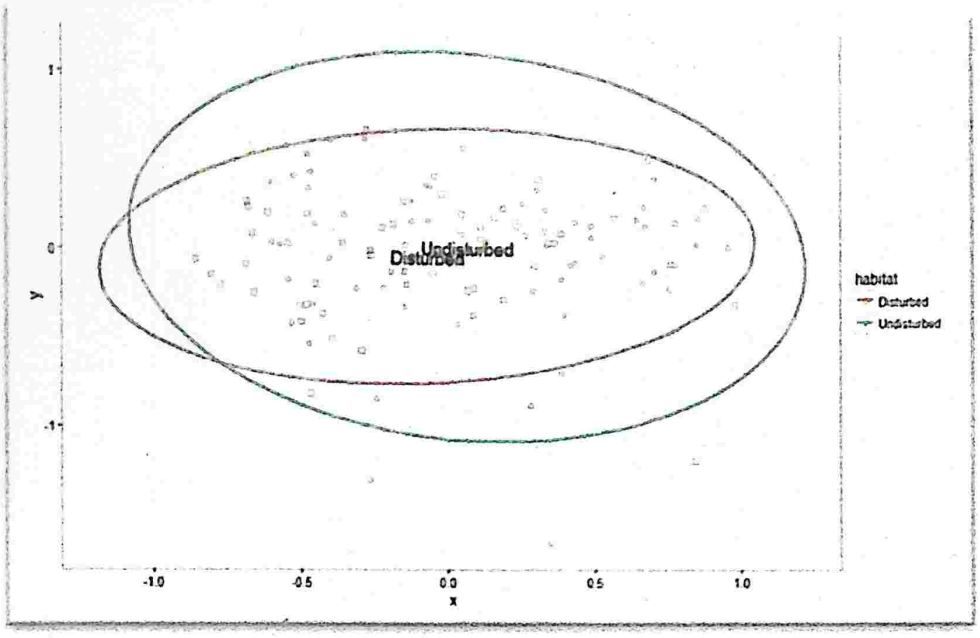

Figure 4.12: Species composition in disturbed and undisturbed sites.

From the plot, the species composition in disturbed site is a large subset of the species composition in undisturbed site. Different types of disturbances prevailing in the disturbed site may be the reason of this result (Fig. 4.17). Sorenson's coefficient (CC) was calculated to see the similarity in species composition in both the sites (CC= 0.7017). Almost 70% of the species found in both the sites are similar. This is accounted by the similarity in habitat types found in both sites.

Different types of disturbances were recorded from both the sites. Number of humans encountered, fishing events, cattle encountered, wood extraction, foot trails, hunting event and grass extraction, per grid was recorded. These have been clubbed into four major classes. Anthropogenic pressure which includes human and cattle encountered, wildlife resource extraction which includes fishing event and bird hunting, plant resource extraction which includes wood collection, grass extraction and vegetable collection. Standardizing the values into per km^2, the following plot has been prepared for better understanding of the disturbance types and extent of each disturbance types in both the sites.

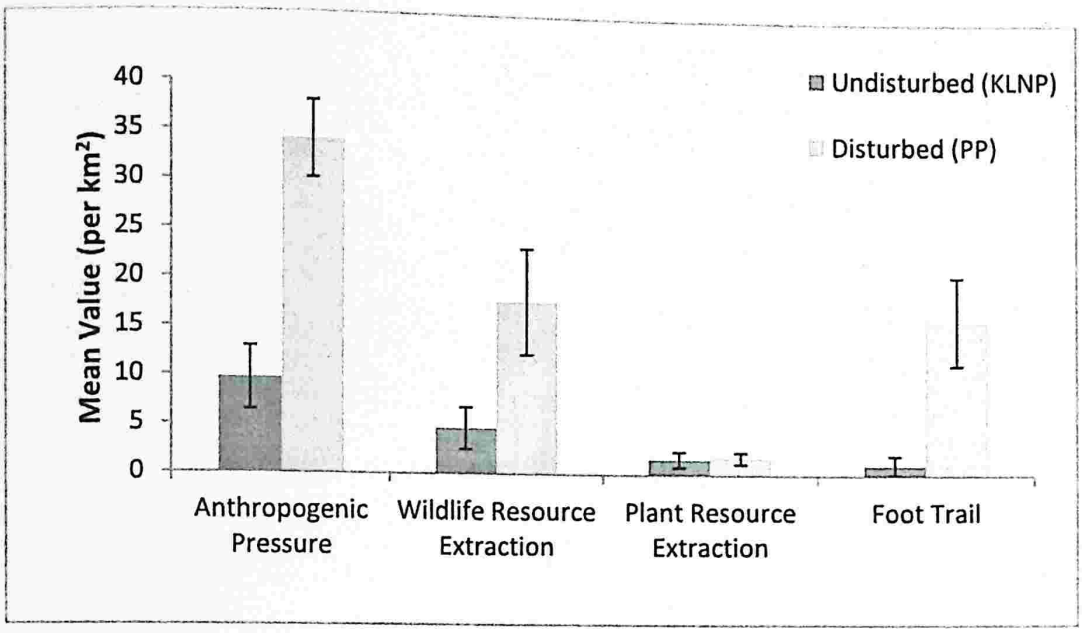

Figure 4.13: Level of disturbance type in disturbed and undisturbed sites (in km^2).

In all the four classes of disturbance types, disturbed site has higher frequency per km^2 compared to those of undisturbed site. Plant resource extraction was particularly lower in both the sites because the disturbance data was of winter season only and in winter, grass extraction, vegetable collection and wood collection seems to be lower due to dry grasses. Hunting events seem to be sporadic in both sites and no vehicles were recorded apart from the tourism area for KLNP. Although catching birds using fish nets seems to be an easy way of catching birds in the disturbed site. The farmers leave the nets hanging over the farms and when there is enough catch, they take away the harvest or they keep checking the nets every evening. Recorded birds that get entangled in the nets mostly were barn swallow, snipes and cuckoos and birds that were being hunted using slingshots were mynas and bulbuls. Hunting using guns were reported mostly of waterbirds in both sites.

CHAPTER 5

DISCUSSION

Various modes of disturbance have been affecting the diversity and abundance of bird species (Madsen and Fox 1995, Elsen et al. 2016, Clergeau et al. 2001, Martin et al. 2014). Although the Shannon diversity indices (H) of undisturbed and disturbed sites shows almost similar diversities, the abundances of some disturbance-sensitive species will be either absent or low in abundance. It is important to note that species diversity measures are inappropriate for conservation assessment. The presence of any species belonging to such mobile taxa as birds from a particular habitat does not certify the extensive use of that habitat by that animal. Abundance measures can provide better explanations to habitat use in such scenarios. The abundance of grassland specific bird species like Black-breasted Parrotbill, White-tailed Stonechat, Slender-billed Babbler, Striated Babbler and Jerdon's Bushchat was compared between KLNP and PP. Black-breasted Parrotbill, a globally threatened species, was not recorded from the disturbed site. White-tailed Stonechat has higher density in undisturbed site as compared to disturbed site (D_{KLNP}=35.77; D_{PP}=30.87). Slender-billed Babbler has a density of 29.63 in the undisturbed site (KLNP) whereas its density could not be calculated in Distance software due to low sighting (N=12). This shows the abundance of this species is lower in the disturbed sites. Jerdon's Bushchat and Striated Babbler have the density 46.05 and 43.99 respectively in the KLNP. Whereas, in the disturbed site, the sighting of both the species were also low that the density could not be calculated (N_{JB}=13; N_{SB}=10). To summarize, this trend may be because of the better condition of the particular habitat type in the undisturbed site compared to the disturbed site. The grassland habitat has been utilised in several ways by the locals, grass collection, vegetable collection and grazing of cattle being the major activities.

Same effect was seen in the open water with floating vegetation (OWFV) habitat type. Indian Spot-billed Duck, Lesser Whistling-duck, Northern Pintail, Purple Swamphen, Little Grebe, Gadwall, Eurasian Wigeon and Eurasian Coot were sighted from the undisturbed site but these species were not seen in the disturbed site. The level of fishing event in this particular habitat type may be the reason. Fishing frequency was

recorded to be 17.45 per km^2 in the disturbed site as compared to the 4.65 per km^2 in the undisturbed site.

A particular characteristic about the farmland area in the disturbed site was the availability of different habitat types. The fish farms that have been harvested provide habitat suitable for the waders. In such farms, species like Little Ringed Plover, Common Greenshank and Wood Sandpiper were sighted foraging. In the abandoned farms covered with sedges, snipes were seen to be foraging. The farmland area of KLNP is very small and no such sightings were reported. Since the construction of the Ithai Barrage, the water level has not been receding to the level it used to be historically (Shamungou 2010). Because of this change, such habitat variation has not been available to the birds for utilization.

As mentioned above, the sites have similar species diversity. It may be due to some limitation of the analytical tool used here. Since the minimum distance between the sites is about 300 m only and the only barrier is a small-width river and settlements all along the river but with good tree covers, it may be possible that both the sites are acting as almost contiguous patches from a bird's view. An empty habitat in the disturbed site might be filled up with species dispersing from the undisturbed site. A demographic study of different bird species in future will be needed to fully understand the dynamics.

Six plant communities have been recorded from the undisturbed site and seven plant communities from the disturbed site. The communities are given in the tables 4.2 and 4.3 for the undisturbed (KLNP) and the disturbed site (PP). The plant communities in these different habitat types for both the sites are different. Wood collection from the hillock habitat types is done by the locals and grazing of cattle is mainly done in the marshy area and farm habitat types in both the sites. This might be the reasons for different plant communities in different habitat types in both the areas.

From the NMDS plots (Fig. 4.12 and Fig. 4.13), it is evident that there are overlaps amongst the species in different habitat types. The plot in fig. 4.16 also shows the overlap between the species composition of the undisturbed site and disturbed site. To quantify the extent of overlaps, Sorensen's Coefficient (CC) was calculated for different habitat type overlaps. Table 4.4 and 4.5 shows the matrix with Sorensen's

Coefficient values showing the extent of overlaps between different habitat types in the undisturbed and disturbed sites respectively.

In KLNP, open water with floating vegetation (OWFV) has the highest overlap with the grassland habitat type (59.05%). This is logical because the floating vegetation in the open water habitat type supports good amount of grassland birds. The least overlap is found with the hillock habitat type (29.88%). The overlap is because the hillocks have only a small portion of the OWFV habitat type nearby and for this, only a few bird species are utilizing both habitat types. Grassland has the highest overlap with marsh (67.96%) and the least overlap is recorded with hillock habitat type (44.71%). Grassland habitat has higher overlaps to other habitats because it has the largest proportion. Grassland surrounds the hillocks and the farmlands lie adjacent to the grasslands. Marsh and grassland have higher overlap (67.96%) because both the habitat types support grass communities. Hillock habitat type has the least overlap with farmland habitat type (24.14%) because both the habitat types lie far apart.

For PP, the hillocks are surrounded by OWFV from the southern side and by grasslands from the northern, western and eastern. Grasslands and farmlands also lie side by side and there are small patches of grassland in between the farms. Farm habitat type, like in the undisturbed site, lies far apart from the hillocks. Grassland and marsh habitat types support grassland bird community and hence share common grassland bird species. For this interspersion matrix, different habitat types have different extent of overlaps.

From the NMDS plot (Fig. 4.16), the species composition of PP is found to be a subset of the species composition of KLNP. 70.17% bird species overlap was found between the sites, which might be due to the overlaps in species composition in different habitat types, and the similarity in the habitat types in both the sites. The manner in which different habitat types have been arranged influences the species composition of both the sites.

Although PP has different modes of disturbances, a globally threatened species, Yellow-breasted Bunting has been recorded from the site in the farmland habitat type. It has also been recorded in the grassland habitat type from KLNP. It is important to monitor the isolated local population in both the sites concerning the species being globally threatened. Some legal measure needs to be prepared for the species'

population in the disturbed site whereas for the population in the undisturbed site, a proper management plan from bird's point of view is needed. Apart from this species, Jerdon's Bushchat, Slender-billed Babbler, Striated Babbler and White-tailed Stonechat are also found in KLNP and PP. Moreover, some species like Black Francolin, Jack Snipe, Jungle Prinia, Little Ringed Plover, Wood Sandpiper and Common Greenshank are recorded from PP which is not recorded from KLNP. This shows that if PP (disturbed site) is protected under some legal conservation measure, the site can provide a good habitat for many bird species. KLNP has also been harbouring two globally threatened bird species, Black-breasted Parrotbill and Yellow-breasted Bunting, in such a small area. This shows that the grassland habitat needs to be well-managed making proper conservation plans for these threatened species. If the area is not managed strategically with proper management planning in place, the survival of these globally threatened species in these sites will be severely compromised.

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Appendix I

List of birds recorded from Keibul Lamjao National Park (KLNP).

Sl. No.	Common Name	Scientific Name
1	Aberrant Bush Warbler	*Horornis flavolivaceus*
2	Ashy Drongo	*Dicrurus leucophaeus*
3	Ashy Prinia	*Prinia socialis*
4	Asian Koel	*Eudynamys scolopaceus*
5	Asian Openbill	*Anastomus oscitans*
6	Asian Palm Swift	*Cypsiurus balasiensis*
7	Asian Pied Starling*	*Gracupica contra*
8	Baillon's Crake	*Zapornia pusilla*
9	Common Barn Owl	*Tyto alba*
10	Barn Swallow	*Hirundo rustica*
11	Black Bulbul	*Hypsipetes leucocephalus*
12	Black Drongo*	*Dicrurus macrocercus*
13	Black Kite	*Milvus migrans*
14	Black-breasted Parrotbill*	*Paradoxornis flavirostris*
15	Black-crowned Night Heron	*Nycticorax nycticorax*
16	Black-faced Bunting	*Emberiza spodocephala*
17	Black-naped Monarch	*Hypothymis azurea*
18	Black-naped Oriole	*Oriolus chinensis*
19	Black-winged Cuckooshrike	*Lalage melaschistos*
20	Black-winged Kite	*Elanus caeruleus*
21	Bluethroat	*Cyanecula svecica*
22	Blue-throated Barbet	*Psilopogon asiaticus*
23	Blunt-winged Warbler	*Acrocephalus concinens*
24	Blyth's Reed Warbler	*Acrocephalus dumetorum*
25	Bronze-winged Jacana	*Metopidius indicus*
26	Brown Shrike	*Lanius cristatus*
27	Cattle Egret	*Bubulcus ibis*
28	Chestnut-capped Babbler	*Timalia pileata*
29	Chestnut-eared Bunting	*Emberiza fucata*
30	Chestnut-tailed Starling	*Sturnia malabarica*
31	Chinese Pond Heron	*Ardeola bacchus*
32	Cinnamon Bittern	*Ixobrychus cinnamomeus*
33	Citrine Wagtail*	*Motacilla citreola*
34	Clamourous Reed Warbler	*Acrocephalus stentoreus*
35	Common Chiffchaff	*Phylloscopus collybita*
36	Common Hawk-cuckoo	*Hierococcyx varius*
37	Common Kestrel	*Falco tinnunculus*
38	Common Kingfisher	*Alcedo atthis*
39	Common Moorhen*	*Gallinula chloropus*
40	Common Myna	*Acridotheres tristis*
41	Common Rosefinch	*Carpodacus erythrinus*

42	Common Snipe*	*Gallinago gallinago*
43	Common Stonechat*	*Saxicola torquatus*
44	Common Tailorbird	*Orthotomus sutorius*
45	Coppersmith Barbet	*Psilopogon haemacephalus*
46	Crested Serpent Eagle	*Spilornis cheela*
47	Eastern Jungle Crow	*Corvus (macrorhynchos) levaillantii*
48	Eastern Marsh Harrier	*Circus spilonotus*
49	Eurasian Coot	*Fulica atra*
50	Eurasian Cuckoo	*Cuculus canorus*
51	Eurasian Tree Sparrow	*Passer montanus*
52	Eurasian Wigeon	*Mareca penelope*
53	Eurasian Wryneck	*Jynx torquilla*
54	Ferruginous Pochard	*Aythya nyroca*
55	Fulvous-breasted Woodpecker	*Dendrocopos macei*
56	Gadwall	*Mareca strepera*
57	Glossy Ibis	*Plegadis falcinellus*
58	Golden-headed Cisticola	*Cisticola exilis*
59	Graceful Prinia*	*Prinia gracilis*
60	Great Cormorant	*Phalacrocorax carbo*
61	Great Egret	*Casmerodius albus*
62	Great Myna	*Acridotheres grandis*
63	Greater Coucal	*Centropus sinensis*
64	Greenish Warbler	*Phylloscopus trochiloides*
65	Grey Bushchat	*Saxicola ferreus*
66	Grey Wagtail	*Motacilla cinerea*
67	Grey-chinned Minivet	*Pericrocotus solaris*
68	Grey-headed Lapwing	*Vanellus cinereus*
69	Himalayan Buzzard	*Buteo refectus*
70	Common Hoopoe	*Upupa epops*
71	Hume's Leaf Warbler*	*Phylloscopus humei*
72	Indian Cormorant	*Phalacrocorax fuscicollis*
73	Indian Cuckoo	*Cuculus micropterus*
74	Indian Pond Heron	*Ardeola grayii*
75	Indian Spot-billed Duck	*Anas poecilorhynca*
76	Intermediate Egret*	*Ardea intermedia*
77	Jerdon's Baza	*Aviceda jerdoni*
78	Jerdon's Bushchat*	*Saxicola jerdoni*
79	Large Hawk-cuckoo	*Hierococcyx sparverioides*
80	Lesser Coucal	*Centropus bengalensis*
81	Lesser Whistling-duck	*Dendrocygna javanica*
82	Little Cormorant	*Microcarbo niger*
83	Little Egret*	*Egretta garzetta*

84	Little Grebe	*Tachybaptus ruficollis*
85	Long-tailed Shrike*	*Lanius schach*
86	Northern Pintail	*Anas acuta*
87	Olive-backed Pipit	*Anthus hodgsoni*
88	Oriental Honey-buzzard	*Pernis ptilorhynchus*
89	Oriental Magpie Robin	*Copsychus saularis*
90	Oriental Turtle Dove	*Streptopelia orientalis*
91	Oriental White-eye	*Zosterops palpebrosus*
92	Osprey	*Pandion haliaetus*
93	Paddyfield Pipit	*Anthus rufulus*
94	Pale-footed Bush Warbler	*Hemitesia pallidipes*
95	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*
96	Pied Bushchat	*Saxicola caprata*
97	Pied Harrier	*Circus melanoleucos*
98	Pin-tailed Snipe	*Gallinago stenura*
99	Plain Prinia*	*Prinia inornata*
100	Plaintive Cuckoo	*Cacomantis merulinus*
101	Purple Heron	*Ardea purpurea*
102	Purple Swamphen	*Porphyrio porphyria*
103	Red-vented Bulbul*	*Pycnonotus cafer*
104	Red-whiskered Bulbul	*Pycnonotus jocosus*
105	Richard's Pipit	*Anthus richardi*
106	River Lapwing	*Vanellus duvaucelii*
107	Rosy Pipit	*Anthus roseatus*
108	Ruddy-breasted Crake*	*Zapornia fusca*
109	Rufous-necked Laughingthrush	*Garrulax ruficollis*
110	Rufous-rumped Grassbird	*Graminicola bengalensis*
111	Collared Sand Martin	*Riparia riparia*
112	Scaly-breasted Munia	*Lonchura punctulata*
113	Siberian Rubythroat	*Calliope calliope*
114	Slaty-breasted Rail	*Lewinia striata*
115	Slender-billed Babbler*	*Chatarrhaea longirostris*
116	Spot-breasted Scimitar Babbler	*Erythrogenys mcclellandi*
117	Striated Babbler*	*Argya earlei*
118	Striated Grassbird*	*Megalurus palustris*
119	Taiga Flycatcher	*Ficedula albicilla*
120	Tickell's Leaf Warbler	*Phylloscopus affinis*
121	Verditer Flycatcher	*Eumyias thalassinus*
122	Watercock	*Gallicrex cinerea*
123	White Wagtail	*Motacilla alba*
124	White-breasted Waterhen	*Amaurornis phoenicurus*
125	White-browed Wagtail	*Motacilla maderaspatensis*
126	White-rumped Munia	*Lonchura striata*

127	White-tailed Stonechat*	*Saxicola leucurus*
128	White-throated Fantail	*Rhipidura albicollis*
129	White-throated Kingfisher	*Halcyon smyrnensis*
130	Yellow Bittern	*Ixobrychus sinensis*
131	Western Yellow Wagtail*	*Motacilla flava*
132	Yellow-bellied Prinia*	*Prinia flaviventris*
133	Yellow-breasted Bunting	*Emberiza aureola*
134	Zitting Cisticola	*Cisticola juncidis*
135	Red-breasted Flycatcher	*Ficedula parva*
136	Paddyfield Warbler	*Acrocephalus agricola*

Note: Bird species marked with "*" are used in analysis in Distance software.

Appendix II

List of birds recorded from Pumlen Pat (PP).

Sl. No.	Common Name	Scientific Name
1	Ashy Prinia	*Prinia socialis*
2	Asian Koel	*Eudynamys scolopaceus*
3	Asian Openbill	*Anastomus oscitans*
4	Asian Palm Swift	*Cypsiurus balasiensis*
5	Asian Pied Starling*	*Gracupica contra*
6	Barn Swallow	*Hirundo rustica*
7	Black Francolin	*Francolinus francolinus*
8	Black Kite	*Milvus migrans*
9	Black-faced Bunting	*Emberiza spodocephala*
10	Black-winged Cuckooshrike	*Lalage melaschistos*
11	Black-winged Kite	*Elanus caeruleus*
12	Bluethroat	*Cyanecula svecica*
13	Blyth's Reed Warbler	*Acrocephalus dumetorum*
14	Brown Shrike	*Lanius cristatus*
15	Chestnut Munia	*Lonchura atricapilla*
16	Chestnut-capped Babbler	*Timalia pileata*
17	Chestnut-crowned Bush Warbler	*Cettia major*
18	Chestnut-eared Bunting	*Emberiza fucata*
19	Citrine Wagtail*	*Motacilla citreola*
20	Common Chiffchaff	*Phylloscopus collybita*
21	Common Greenshank	*Tringa nebularia*
22	Common Kingfisher	*Alcedo atthis*
23	Common Moorhen	*Gallinula chloropus*
24	Common Myna*	*Acridotheres tristis*
25	Common Stonechat*	*Saxicola torquatus*
26	Common Snipe	*Gallinago gallinago*
27	Common Tailorbird	*Orthotomus sutorius*
28	Coppersmith Barbet	*Psilopogon haemacephalus*
29	Eastern Jungle Crow	*Corvus (macrorhynchos) levaillantii*
30	Eastern Marsh Harrier	*Circus spilonotus*
31	Eurasian Tree Sparrow*	*Passer montanus*
32	Eurasian Wryneck	*Jynx torquilla*
33	Ferruginous Pochard	*Aythya nyroca*
34	Glossy Ibis	*Plegadis falcinellus*
35	Graceful Prinia*	*Prinia gracilis*
36	Great Cormorant	*Phalacrocorax carbo*
37	Great Myna	*Acridotheres grandis*
38	Grey Wagtail	*Motacilla cinerea*
39	Grey-crowned Warbler	*Phylloscopus tephrocaphalus*
40	Hume's Leaf Warbler*	*Phylloscopus humei*
41	Indian Cuckoo	*Cuculus micropterus*
42	Indian Pond Heron	*Ardeola grayii*

43	Intermediate Egret	*Ardea intermedia*
44	Jack Snipe	*Lymnocryptes minimus*
45	Jerdon's Bushchat	*Saxicola jerdoni*
46	Jungle Prinia	*Prinia sylvatica*
47	Large Cuckoo-shrike	*Coracina macei*
48	Large Hawk-cuckoo	*Hierococcyx sparverioides*
49	Little Cormorant	*Microcarbo niger*
50	Little Ringed Plover	*Charadrius dubius*
51	Long-tailed Shrike*	*Lanius schach*
52	Little Egret*	*Egretta garzetta*
53	Oriental Magpie Robin	*Copsychus saularis*
54	Oriental Turtle Dove	*Streptopelia orientalis*
55	Oriental White-eye	*Zosterops palpebrosus*
56	Paddyfield Pipit	*Anthus rufulus*
57	Pale-footed Bush Warbler	*Hemitesia pallidipes*
58	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*
59	Pin-tailed Snipe	*Gallinago stenura*
60	Plain Prinia*	*Prinia inornata*
61	Plaintive Cuckoo	*Cacomantis merulinus*
62	Purple Heron	*Ardea purpurea*
63	Red-breasted Flycatcher	*Ficedula parva*
64	Red-vented Bulbul*	*Pycnonotus cafer*
65	Red-wattled Lapwing	*Vanellus indicus*
66	Richard's Pipit	*Anthus richardi*
67	River Lapwing	*Vanellus duvaucelii*
68	Rosy Pipit	*Anthus roseatus*
69	Ruddy-breasted Crake	*Zapornia fusca*
70	Rufescent Prinia	*Prinia rufescens*
71	Collared Sand Martin	*Riparia riparia*
72	Scaly-breasted Munia	*Lonchura punctulata*
73	Shikra	*Accipiter badius*
74	Siberian Rubythroat	*Calliope calliope*
75	Slaty-bellied Rail	*Lewinia striata*
76	Slender-billed Babbler	*Chatarrhaea longirostris*
77	Striated Babbler	*Argya earlei*
78	Striated Grassbird*	*Megalurus palustris*
79	Tickell's Leaf Warbler	*Phylloscopus affinis*
80	Watercock	*Gallicrex cinerea*
81	White Wagtail*	*Motacilla alba*
82	White-breasted Waterhen	*Amaurornis phoenicurus*
83	White-browed Wagtail	*Motacilla maderaspatensis*
84	White-spectacled Warbler	*Seicercus affinis*
85	White-tailed Stonechat*	*Saxicola leucurus*
86	White-throated Kingfisher	*Halcyon smyrnensis*
87	Wood Sandpiper	*Tringa glareola*
88	Yellow-breasted Bunting	*Emberiza aureola*
89	Western Yellow Wagtail*	*Motacilla flava*
90	Yellow-bellied Prinia*	*Prinia flaviventris*

91	Black Drongo*	*Dicrurus macrocercus*
92	Lesser Coucal	*Centropus bengalensis*
93	Golden-headed Cisticola	*Cisticola exilis*
94	Greater Coucal	*Centropus sinensis*

Note: Bird species marked with "*" are used in analysis in Distance software.

Annexure III

Families of birds for both Keibul Lamjao National Park (KLNP) and Pumlen Pat (PP)

Sl. No.	Sites	KLNP	PP
	Family	Species No.	Species No.
1	Anatidae	6	1
2	Podocipedidae	1	
3	Ciconiidae	1	1
4	Threskiornithidae	1	1
5	Phalacrocoracidae	3	2
6	Falconidae	4	2
7	Accipitridae	6	2
8	Rallidae	8	5
9	Ardeidae	10	4
10	Charadriidae	2	3
11	Jacanidae	2	1
12	Scolopacidae	2	5
13	Columbidae	1	1
14	Cuculidae	8	6
15	Tytonidae	1	
16	Apopidae	1	1
17	Upupidae	1	
18	Alcedinidae	2	2
19	Ramphastidae	2	1
20	Picidae	2	1
21	Campephagidae	2	2
22	Laniidae	2	2
23	Dicruridae	2	1
24	Oriolidae	1	
25	Rhipiduridae	1	
26	Monarchidae	1	
27	Corvidae	1	1
28	Pycnonotidae	3	1
29	Cisticolidae	9	9
30	Sylviidae	10	8
31	Timaliidae	6	3
32	Zosteropidae	1	1
33	Sturnidae	4	3
34	Muscicapidae	11	7
35	Passeridae	1	1
36	Estrildidae	2	2
37	Motacillidae	9	8
38	Fringillidae	1	
39	Emberizidae	3	3
40	Hirundinidae	2	2
41	Phasianidae		1

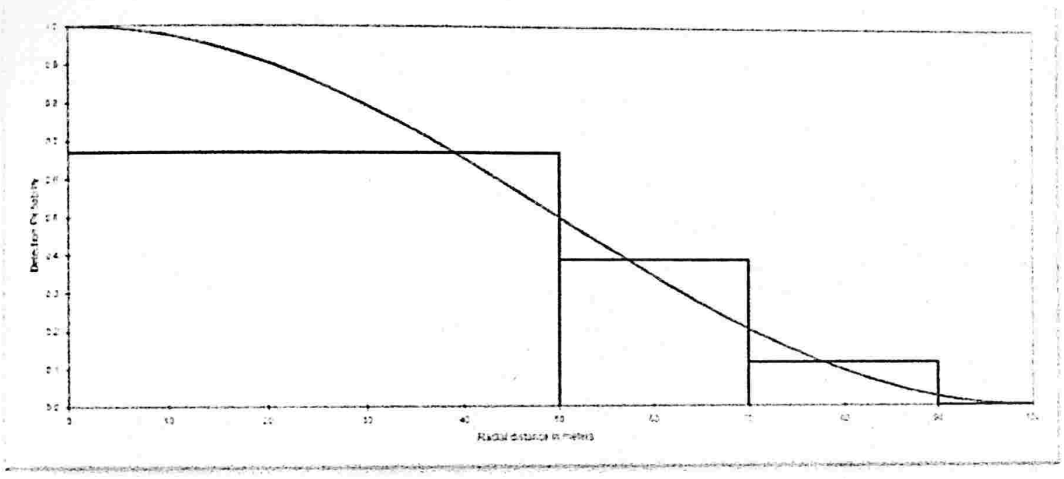
Appendix IV

Results of distance analysis for 22 bird species from KLNP.

Asian Pied Starling:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	DS	14.270	17.11	265.08	10.213	19.939
AIC = 63.35	D	136.45	21.43	169.39	89.817	207.31
	N	136.00	21.43	169.39	90.000	207.00
	EDR	54.54				

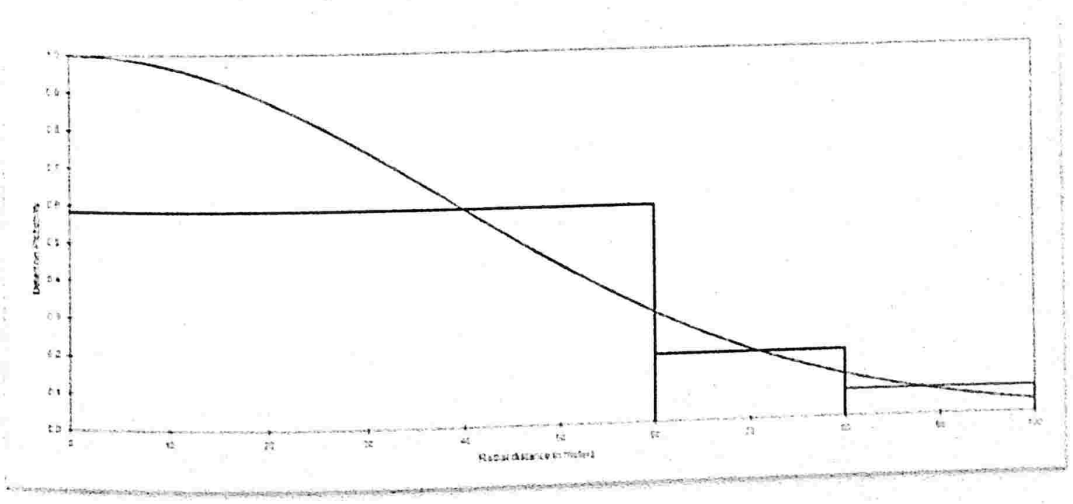
Chi-square value, p = 0.90



Black Drongo:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	15.853	27.36	77.61	9.2858	27.066
AIC = 52.79	D	25.988	32.48	109.60	13.874	48.679
	N	26.000	32.48	109.60	14.000	49.000
	EDR	52.79				

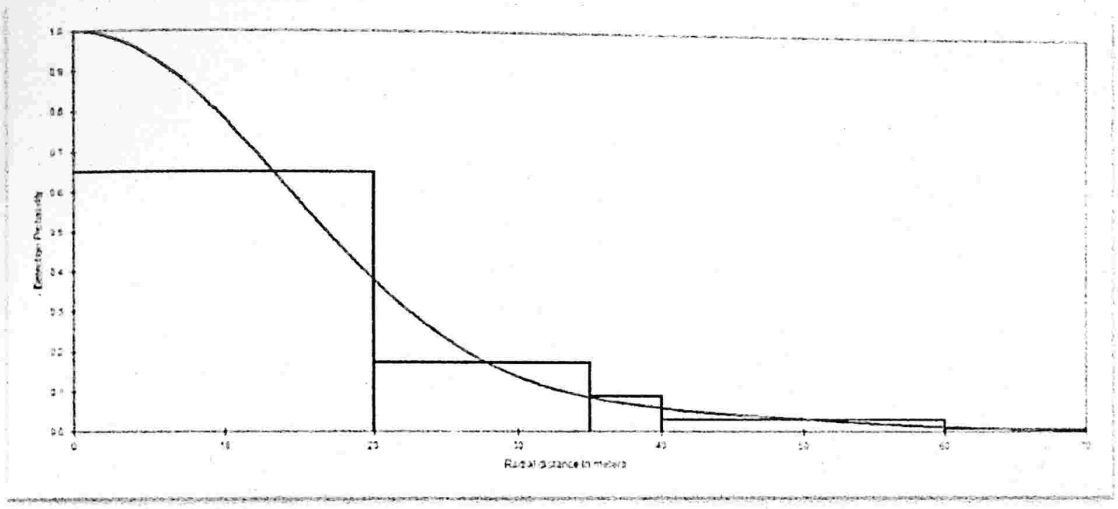
Chi-square value, p = 0.86



Citrine Wagtail:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	158.22	22.00	105.56	102.82	243.48
AIC = 148.04	D	549.71	24.56	147.70	340.72	886.90
	N	550.00	24.56	147.70	341.00	887.00
	EDR	22.43				

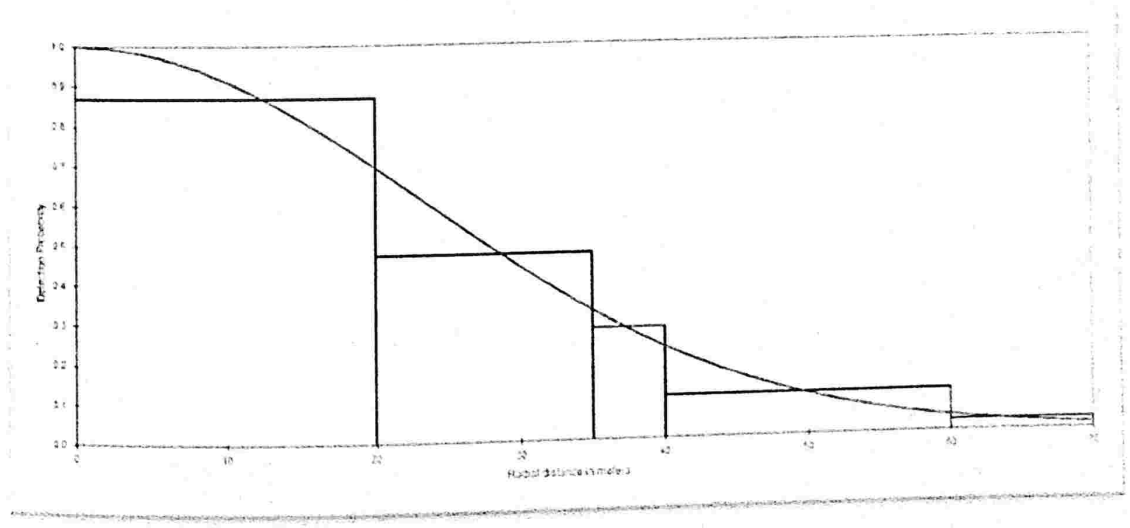
Chi-square value, p = 0.86



Common Stonechat:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	126.16	13.81	211.06	96.220	165.41
AIC = 286.42	D	203.82	15.21	283.73	151.35	274.48
	N	204.00	15.21	283.73	151.00	274.00
	EDR	32.91				

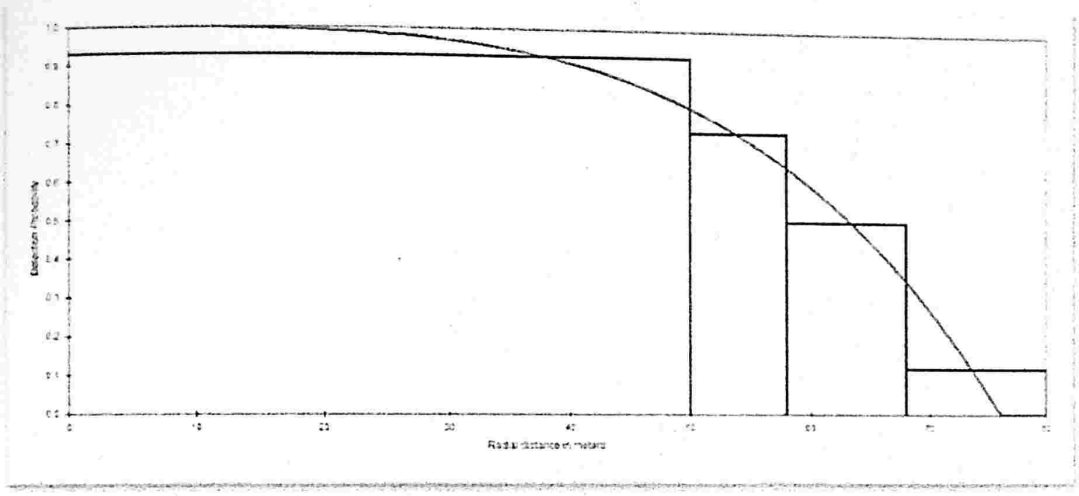
Chi-square value, p = 0.98



Graceful Prinia:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	18.830	31.25	71.10	10.244	34.609
AIC = 118.35	D	28.025	31.90	76.97	15.078	52.088
	N	28.000	31.90	76.97	15.000	52.000
	EDR	61.67				

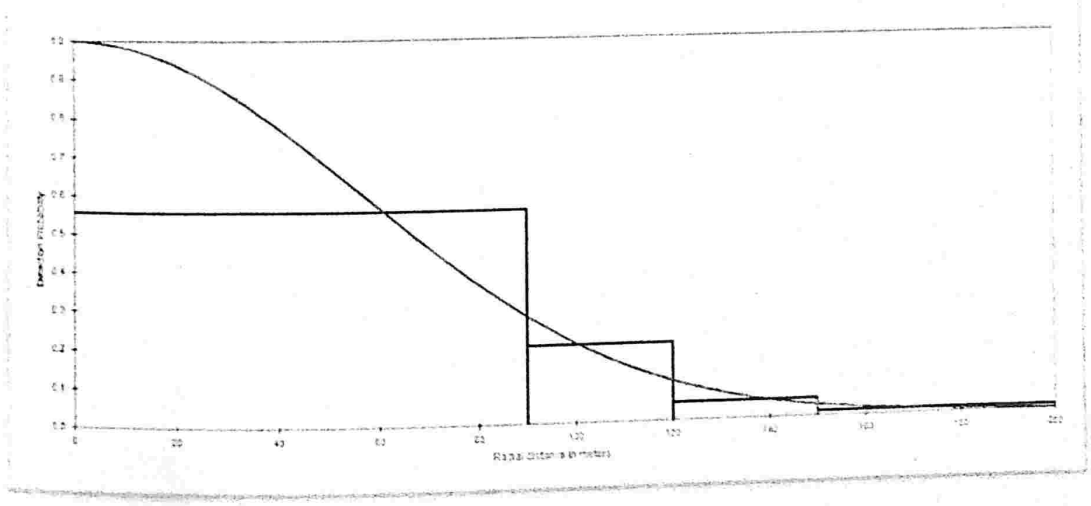
Chi-square value, p = 0.97



Intermediate Egret:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	7.3736	24.35	92.23	4.5776	11.877
AIC = 60.19	D	17.114	29.56	123.13	9.6509	30.347
	N	17.000	29.56	123.13	10.000	30.000
	EDR	79.34				

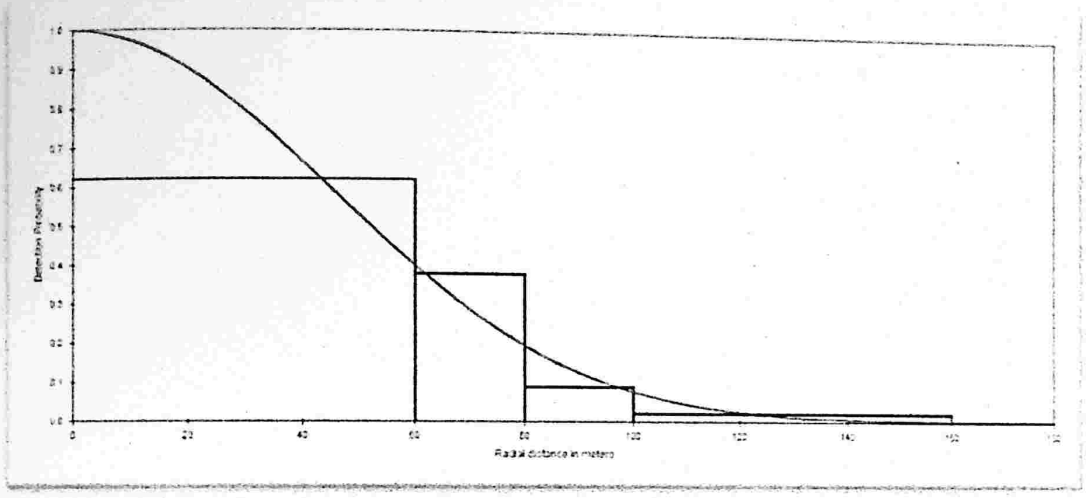
Chi-square value, p = 0.87



Long-tailed Shrike:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	12.479	23.50	105.68	7.8800	19.762
AIC = 83.47	D	14.916	24.02	114.58	9.3306	23.844
	N	15.000	24.02	114.58	9.0000	24.000
	EDR	62.71				

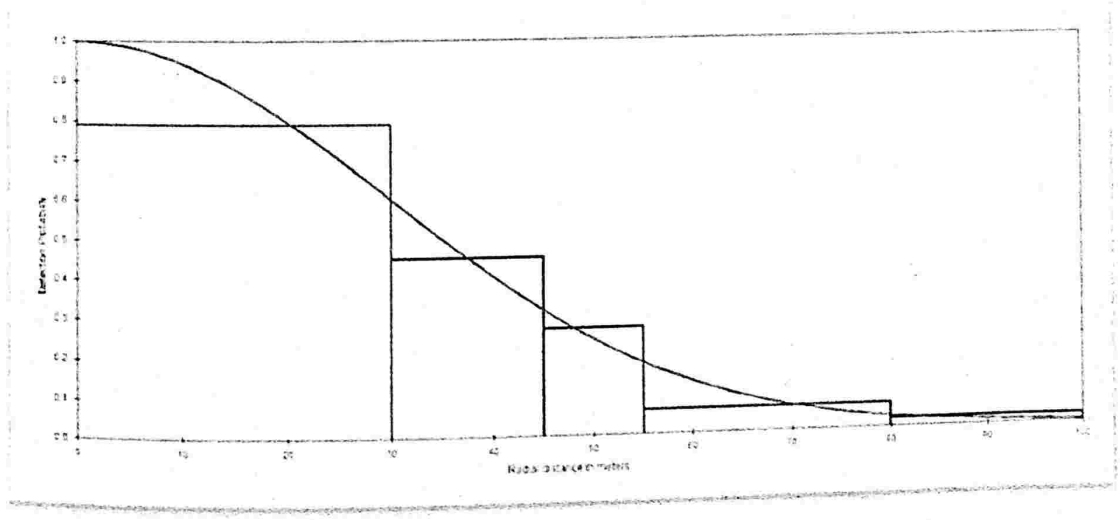
Chi-square value, p = 0.85



Plain Prinia:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	39.185	19.97	141.93	26.507	57.927
AIC = 147.36	D	82.854	21.15	171.38	54.827	125.21
	N	83.000	21.15	171.38	55.000	125.00
	EDR	41.95				

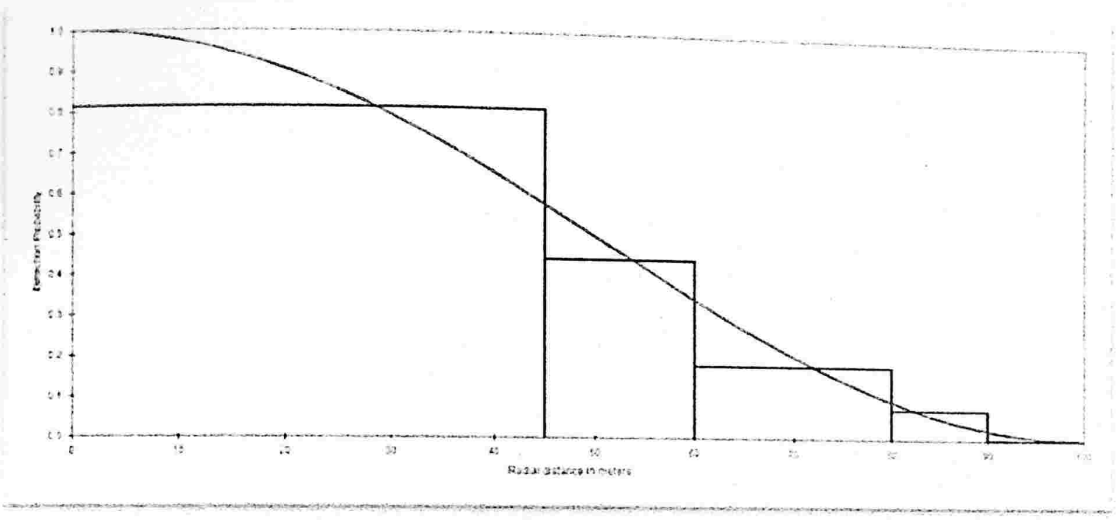
Chi-square value, p = 0.77



Red-vented Bulbul:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	DS	20.960	13.95	268.78	15.946	27.551
AIC = 106.52	D	64.240	21.61	121.93	42.084	98.060
	N	64.000	21.61	121.93	42.000	98.000
	EDR	54.53				

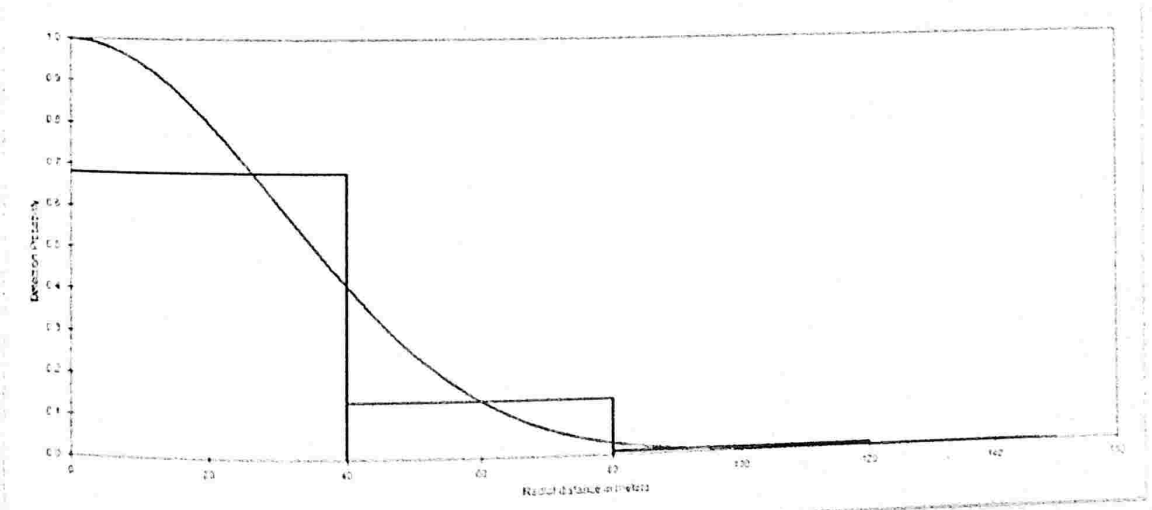
Chi-square value, p = 0.89



Striated Babbler:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	20.760	27.87	73.06	12.035	35.810
AIC = 46.36	D	43.985	30.21	92.81	24.461	79.095
	N	44.000	30.21	92.81	24.000	79.000
	EDR	42.29				

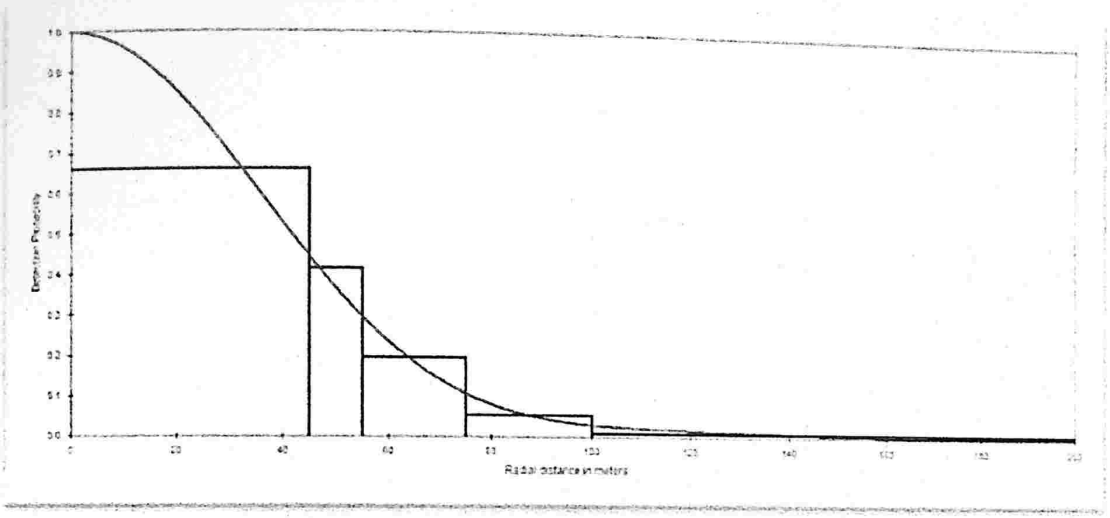
Chi-square value, p = 0.94



Striated Grassbird:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	57.561	11.73	255.18	45.725	72.461
AIC = 322.14	D	182.98	13.18	352.72	141.36	236.84
	N	183.00	13.18	352.72	141.00	237.00
	EDR	51.92				

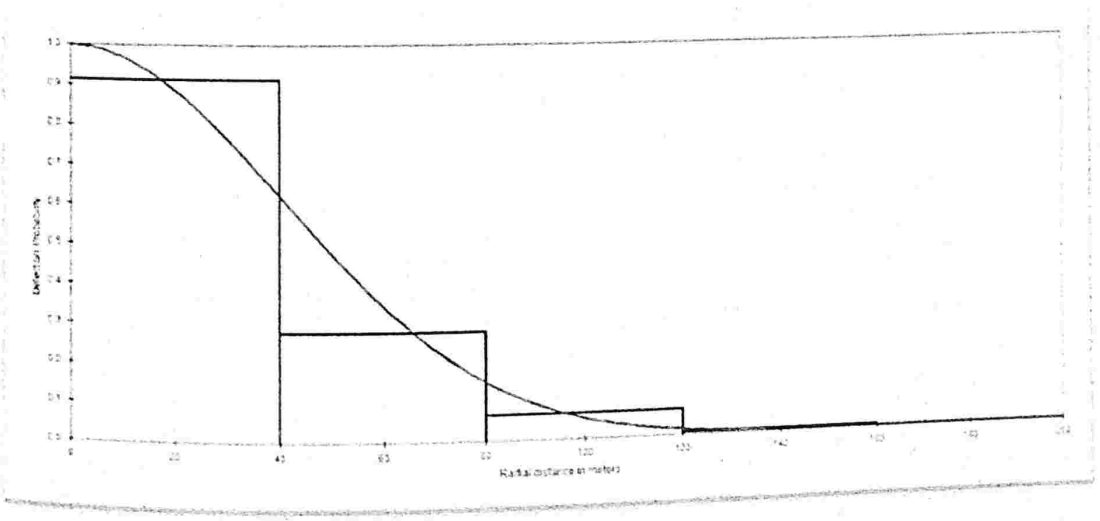
Chi-square value, p = 0.79



Jerdon's Bushchat:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	20.891	19.32	136.76	14.306	30.507
AIC = 118.83	D	46.046	20.73	170.72	30.714	69.031
	N	46.000	20.73	170.72	31.000	69.000
	EDR	58.01				

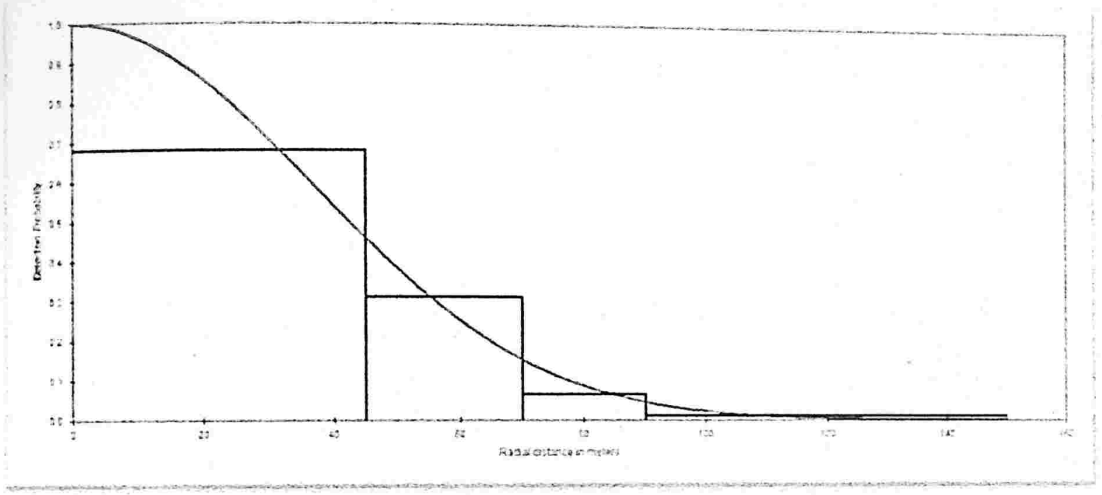
Chi-square value, p = 0.72



Ruddy-breasted Crake:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	19.274	23.42	112.89	12.195	30.463
AIC = 83.11	D	30.588	25.43	142.68	18.647	50.175
	N	31.000	25.43	142.68	19.000	50.000
	EDR	51.14				

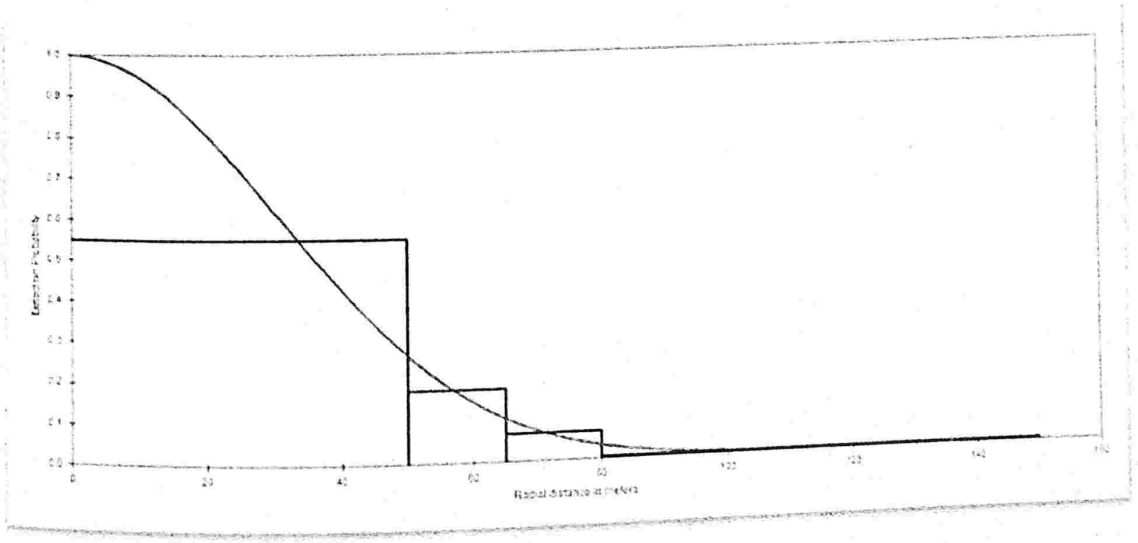
Chi-square value, p = 0.77



Yellow-bellied Prinia:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	73.446	13.10	212.45	56.796	94.977
AIC = 173.68	D	149.31	14.24	277.73	112.96	197.34
	N	149.00	14.24	277.73	113.00	197.00
	EDR	43.34				

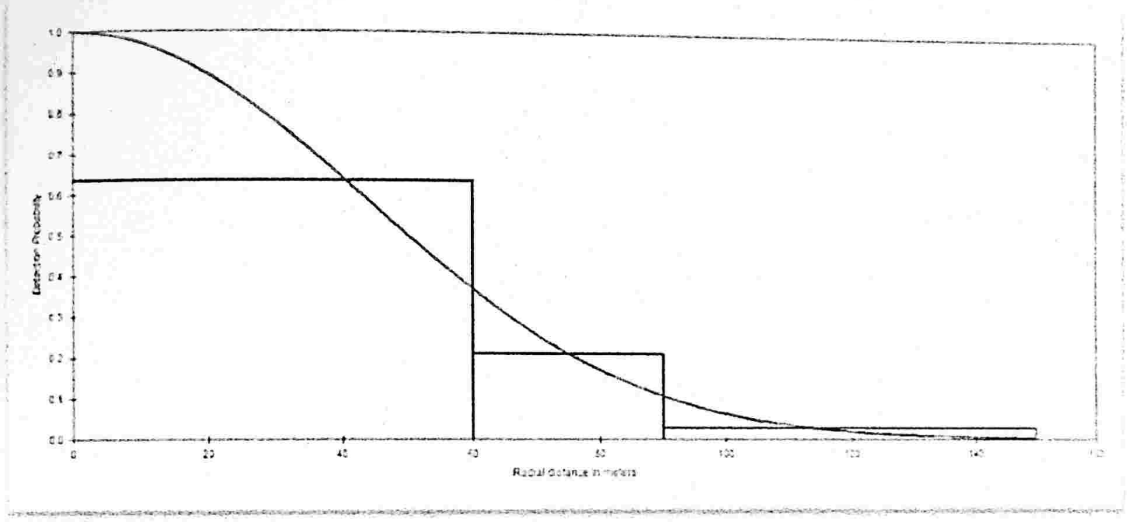
Chi-square value, p = 0.95



Black-breasted Parrotbill:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	6.9680	35.56	61.06	3.4948	13.893
AIC = 35.38	D	9.8820	37.06	70.14	4.8320	20.210
	N	10.000	37.06	70.14	5.0000	20.000
	EDR	77.90				

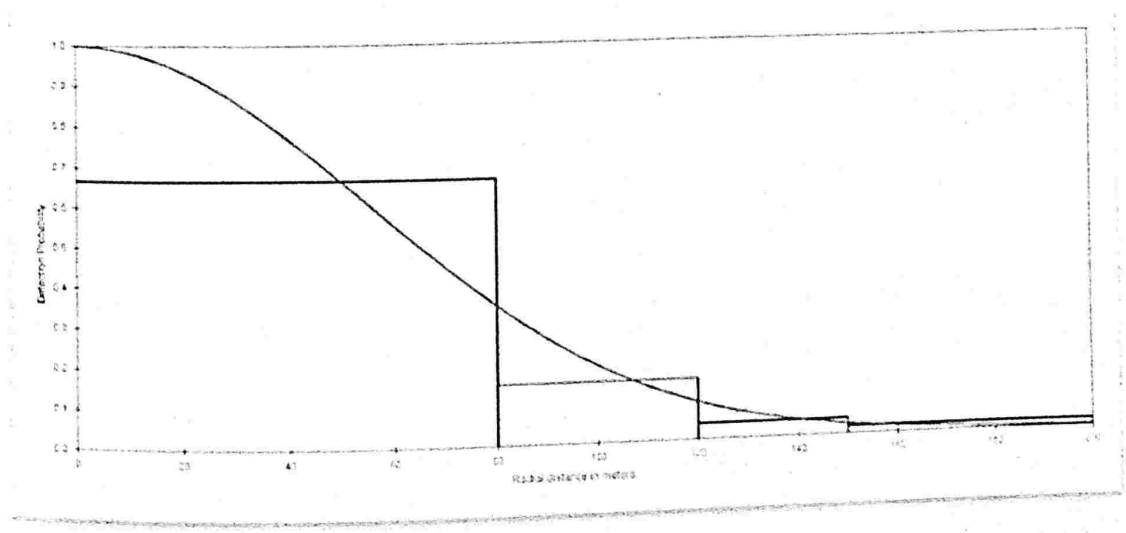
Chi-square value, p = 0.99



Common Moorhen:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	4.3709	33.95	67.23	2.2608	8.4505
AIC = 37.75	D	11.918	38.24	85.23	5.7173	24.844
	N	12.000	38.24	85.23	6.0000	25.000
	EDR	77.90				

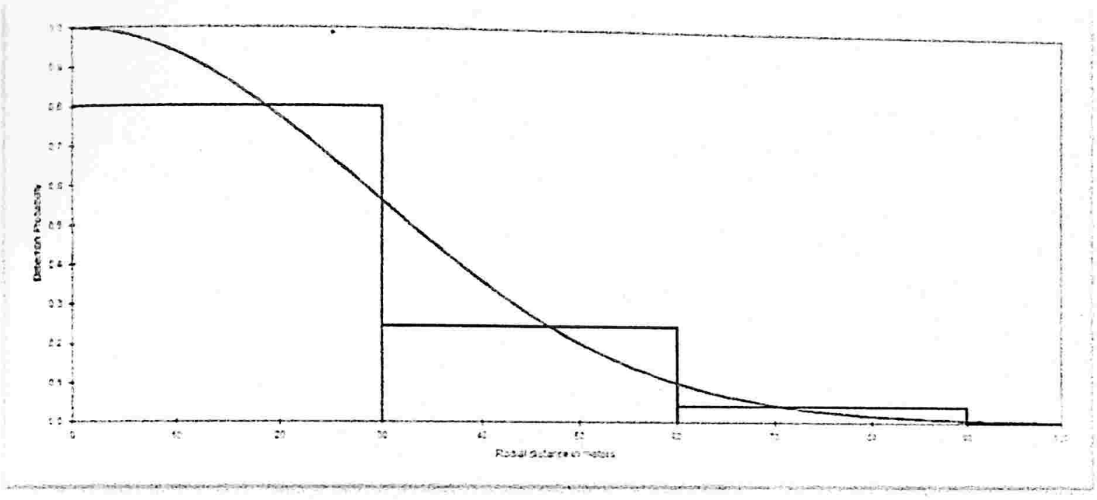
Chi-square value, p = 0.59



Common Snipe:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	22.065	29.83	78.18	12.339	39.455
AIC = 52.88	D	27.054	31.37	92.29	14.722	49.717
	N	27.000	31.37	92.29	15.000	50.000
	EDR	39.53				

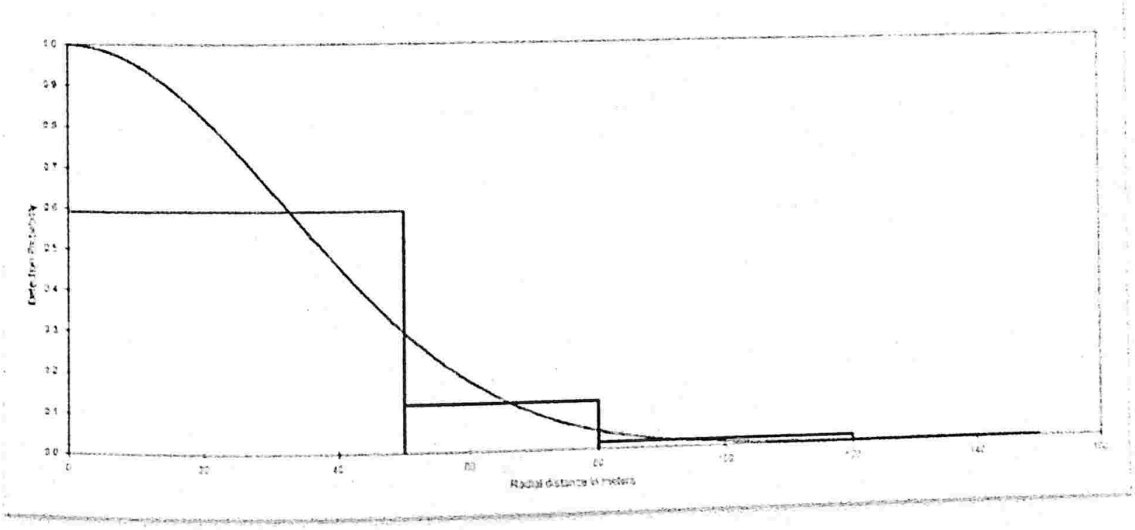
Chi-square value, p = 0.84



Hume's Leaf Warbler:

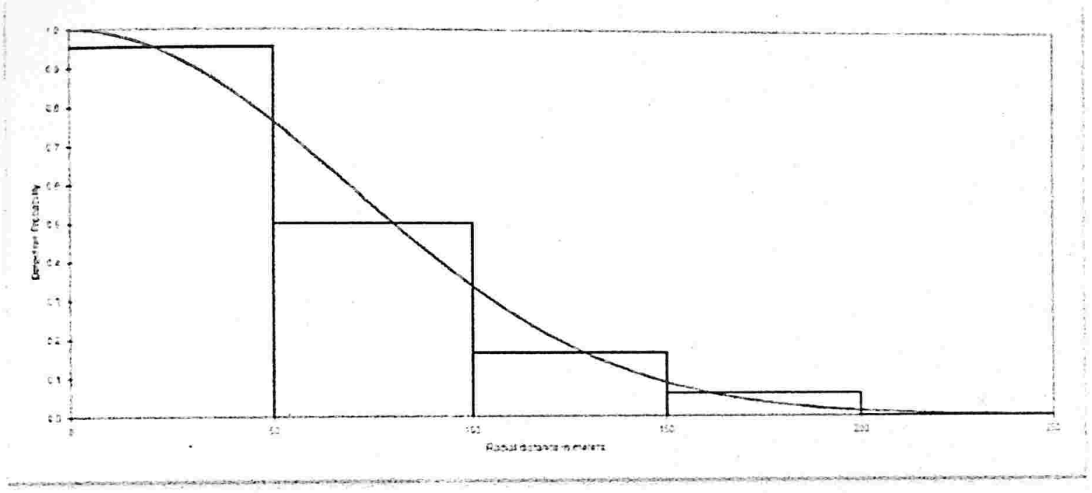
		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	11.683	35.39	55.71	5.8702	23.251
AIC = 28.43	D	163.00	41.54	70.64	73.558	361.21
	N	163.00	41.54	70.64	74.000	361.00
	EDR	45.20				

Chi-square value, p = 0.92



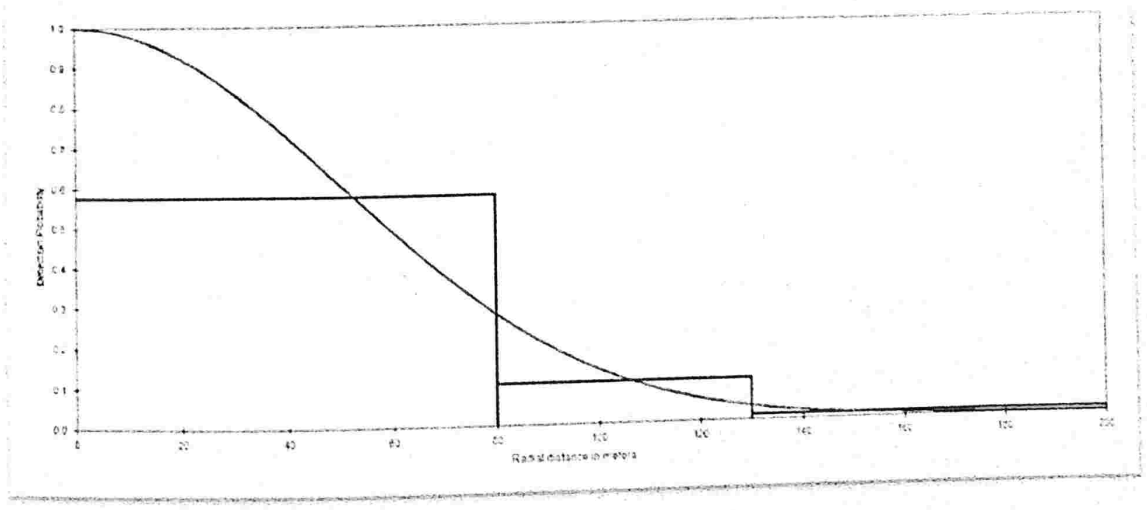
Little Egret:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	3.8924	28.40	87.32	2.2378	6.7705
AIC = 73.13	D	15.917	33.57	109.89	8.3288	30.419
	N	16.000	33.57	109.89	8.0000	30.000
	EDR	95.92				
	Chi-square value, p = 0.80					



Slender-billed Babbler:

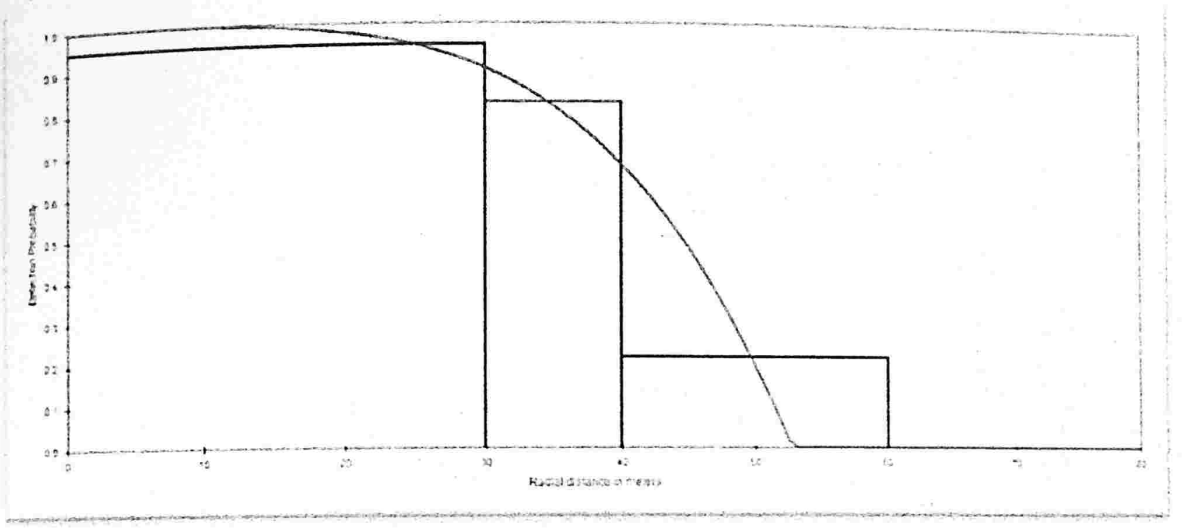
		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	6.1150	31.32	66.62	3.3205	11.261
AIC = 33.95	D	28.136	33.60	82.29	14.681	53.925
	N	28.000	33.60	82.29	15.000	54.000
	EDR	70.63				
	Chi-square value, p = 0.69					



White-tailed Stonechat:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	18.610	23.28	138.35	11.816	29.312
AIC = 59.02	D	35.765	26.51	154.30	21.372	59.849
	N	36.000	26.51	154.30	21.000	60.000
	EDR	43.05				

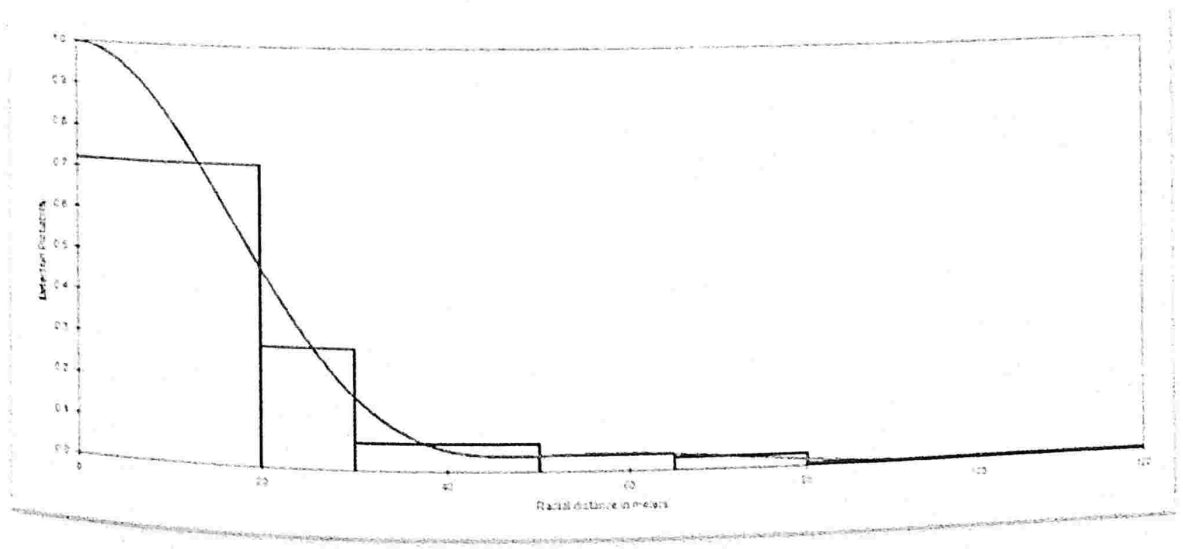
Chi-square value, p = 0.92



Western Yellow Wagtail:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	64.688	27.96	92.55	37.517	111.54
AIC = 106.44	D	85.115	29.10	106.49	48.361	149.80
	N	85.000	29.10	106.49	48.000	150.00
	EDR	26.01				

Chi-square value, p = 0.95



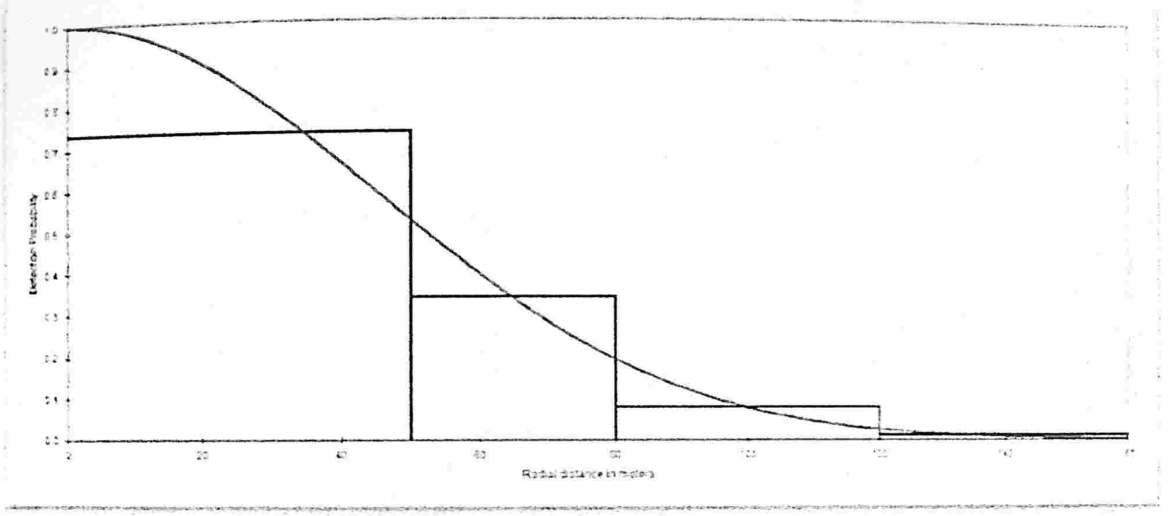
Appendix V

Results of Distance analysis for 17 bird species and their detection probability graphs (PP).

Black Drongo:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	13.006	23.63	110.23	8.1948	20.643
AIC = 86.26	D	30.273	27.10	146.20	17.886	51.238
	N	30.000	27.10	146.20	18.000	51.000
	EDR	62.25				

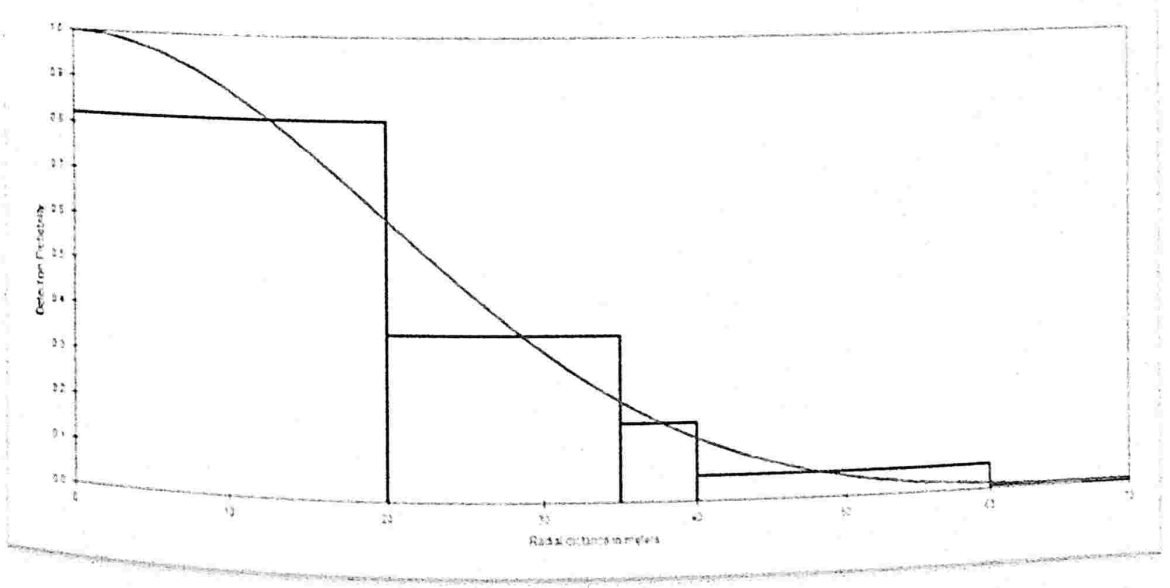
Chi-square value, p = 0.97



Citrine Wagtail:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	210.87	11.57	237.31	168.02	264.65
AIC = 317.53	D	609.73	13.91	360.11	464.46	800.45
	N	610.00	13.91	360.11	464.00	800.00
	EDR	28.26				

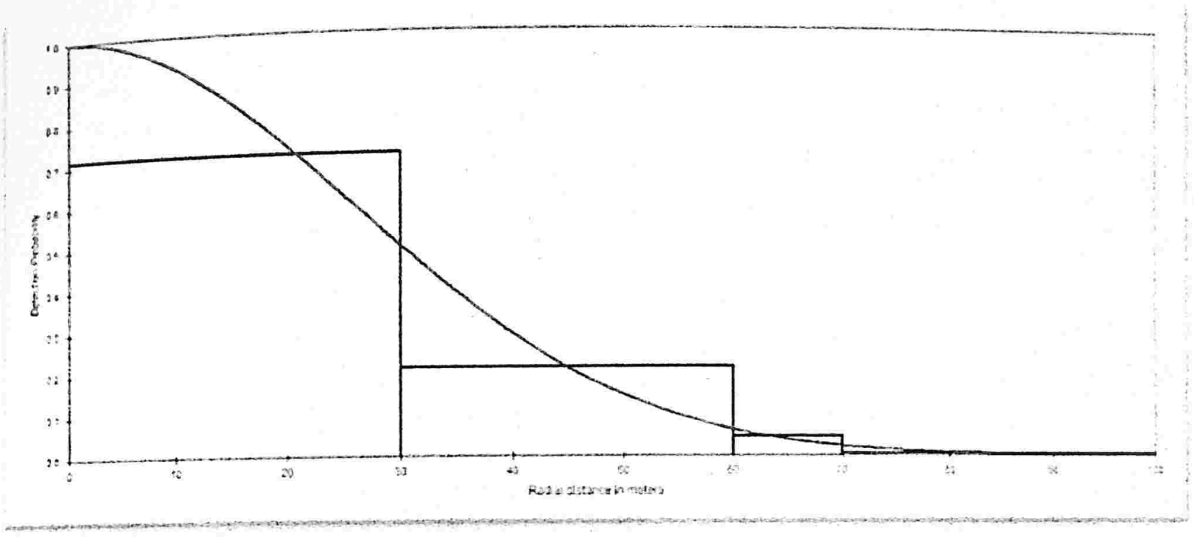
Chi-square value, p = 0.95



Common Stonechat:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	117.68	12.73	227.30	91.667	151.07
AIC = 211.05	D	189.57	13.64	287.24	145.10	247.67
	N	190.00	13.64	287.24	145.00	248.00
	EDR	35.84				

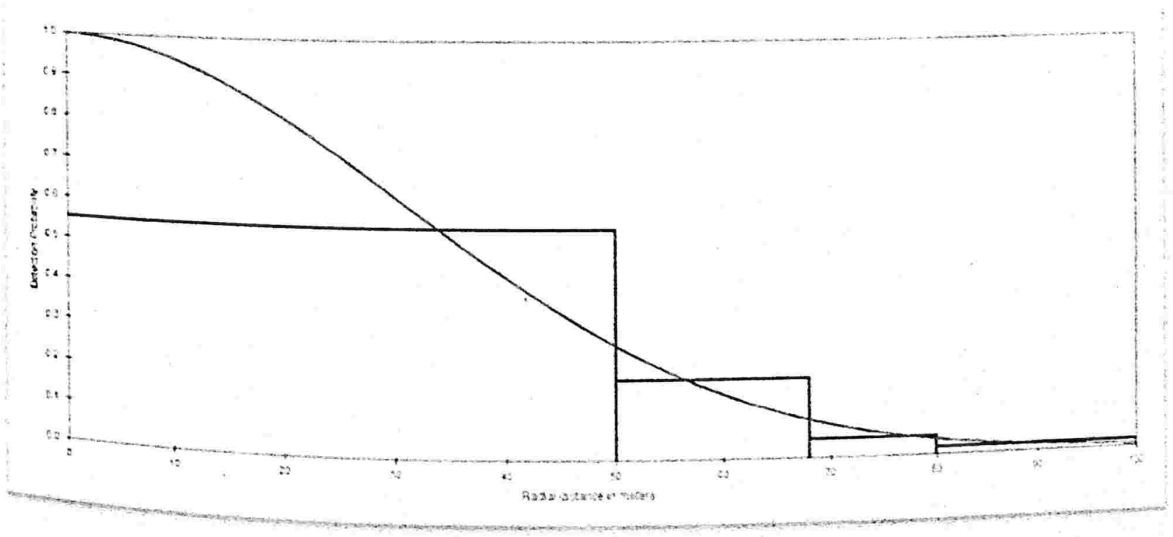
Chi-square value, p = 0.92



Graceful Prinia:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	68.398	13.89	194.12	52.078	89.833
AIC = 161.85	D	73.972	14.57	230.24	55.601	98.412
	N	74.000	14.57	230.24	56.000	98.000
	EDR	43.81				

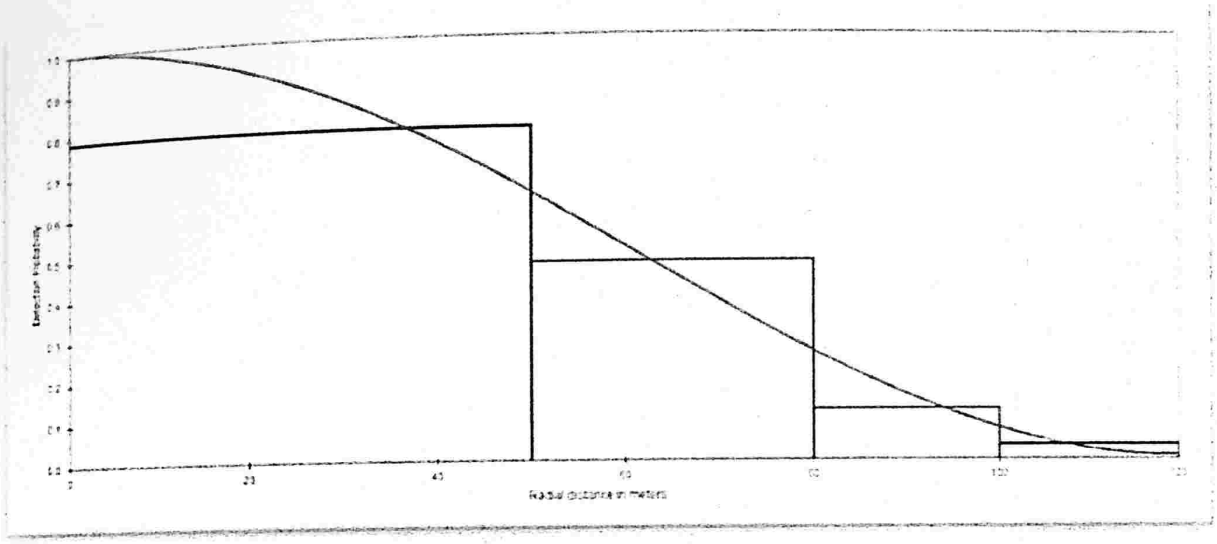
Chi-square value, p = 0.65



Long-tailed Shrike:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	6.6098	20.76	195.72	4.4081	9.9112
AIC = 68.11	D	7.3240	21.23	211.15	4.8414	11.080
	N	7.0000	21.23	211.15	5.0000	11.000
	EDR	65.99				

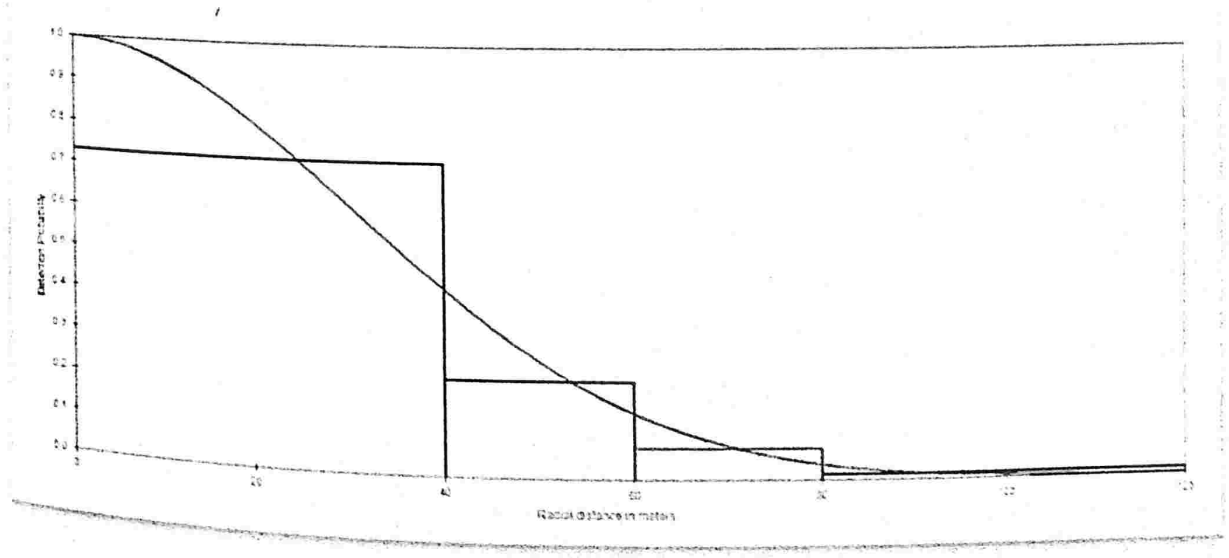
Chi-square value, p = 0.84



Plain Prinia:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	26.186	23.16	107.86	16.645	41.196
AIC = 81.54	D	56.793	24.92	134.56	34.950	92.287
	N	57.000	24.92	134.56	35.000	92.000
	EDR	43.87				

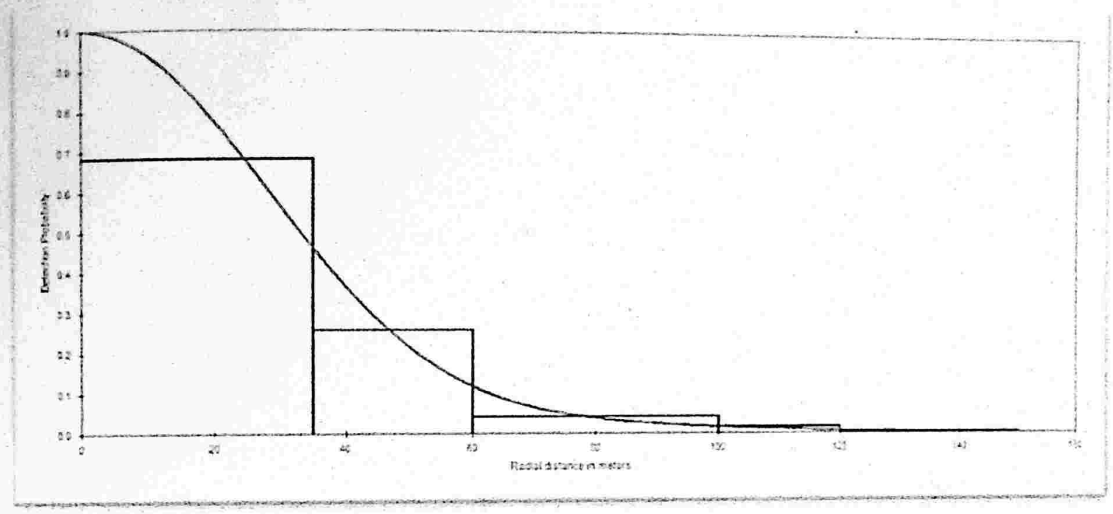
Chi-square value, p = 0.69



Red-vented Bulbul:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	41.211	20.34	119.76	27.662	61.396
AIC = 128.81	D	248.10	23.14	167.81	158.05	389.46
	N	248.00	23.14	167.81	158.00	389.00
	EDR	42.07				

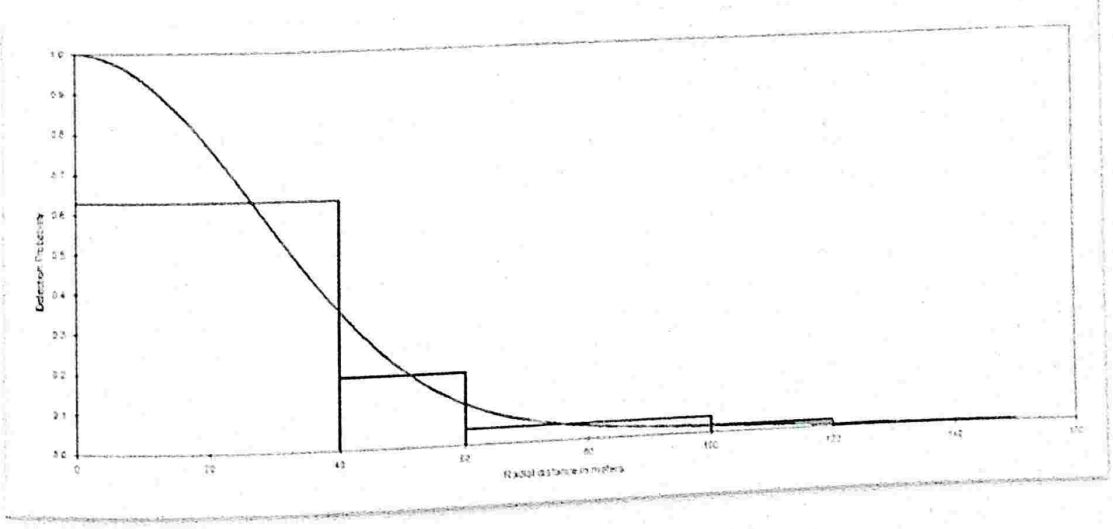
Chi-square value, p = 0.61



Striated Grassbird:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	43.637	19.23	133.50	29.934	63.613
AIC = 119.77	D	262.46	22.19	185.36	170.31	404.47
	N	262.00	22.19	185.36	170.00	404.00
	EDR	40.89				

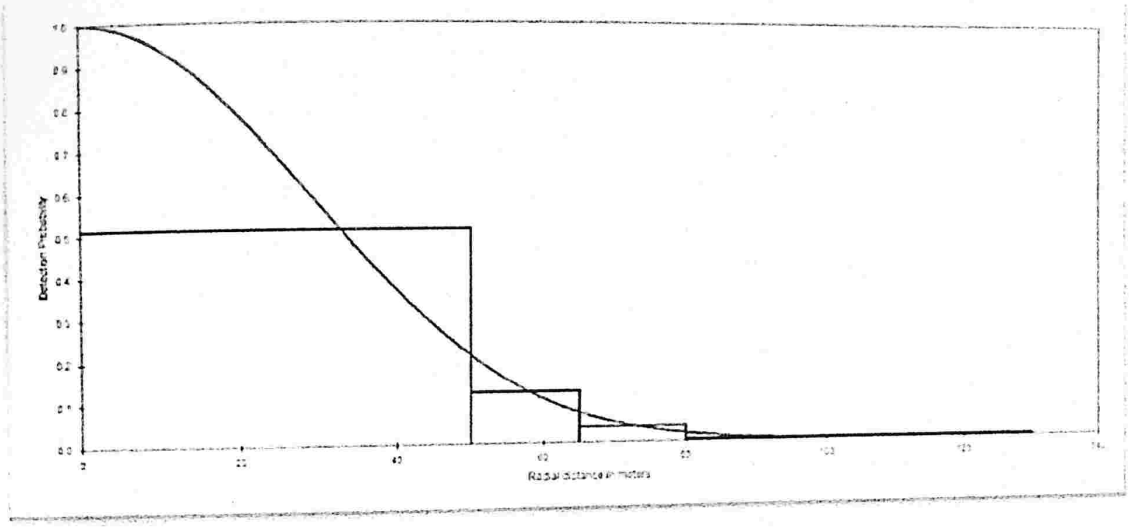
Chi-square value, p = 0.61



Yellow-bellied Prinia:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	68.326	15.13	179.90	50.773	91.948
AIC = 116.07	D	125.56	16.42	233.20	91.044	173.16
	N	126.00	16.42	233.20	91.000	173.00
	EDR	40.14				

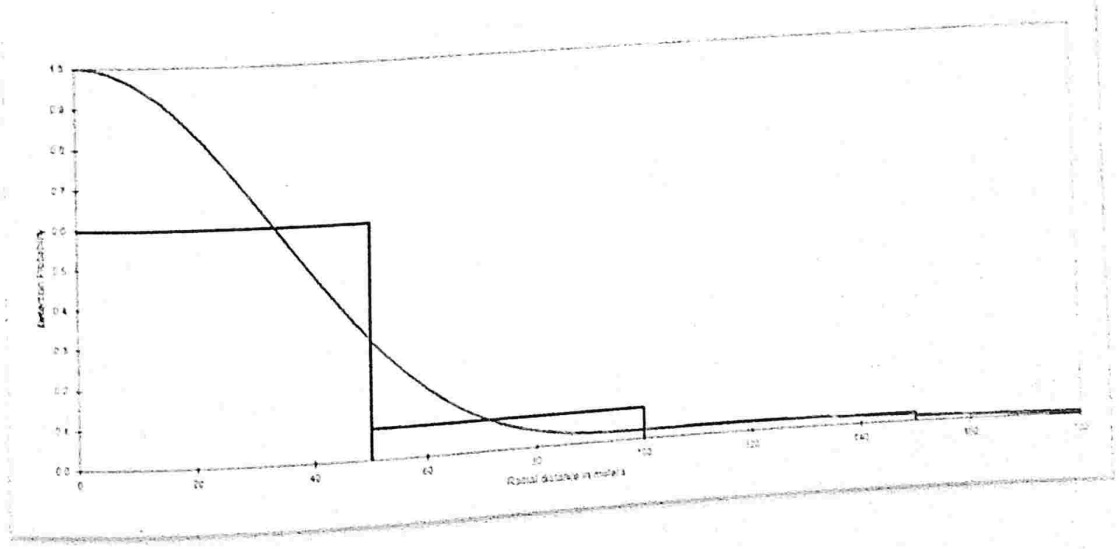
Chi-square value, p = 0.90



Asian Pied Starling:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	16.017	26.68	77.54	9.5029	26.998
AIC = 61.46	D	101.03	30.86	104.53	55.556	183.72
	N	101.00	30.86	104.53	56.000	184.00
	EDR	49.00				

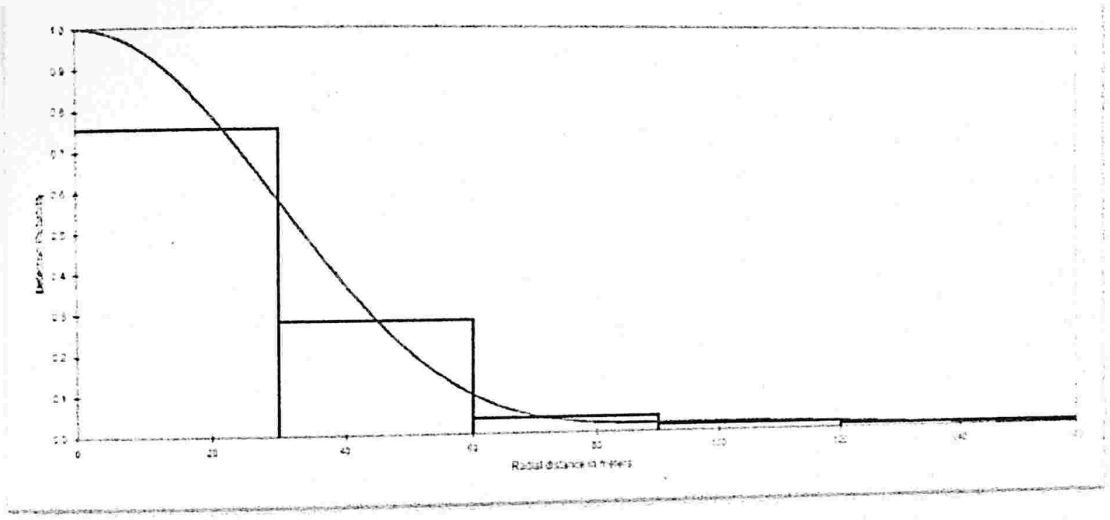
Chi-square value, p = 0.82



Common Myna:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	15.671	28.76	77.47	8.9404	27.469
AIC = 56.41	D	109.34	33.23	94.71	57.508	207.89
	N	109.00	33.23	94.71	58.000	208.00
	EDR	42.16				

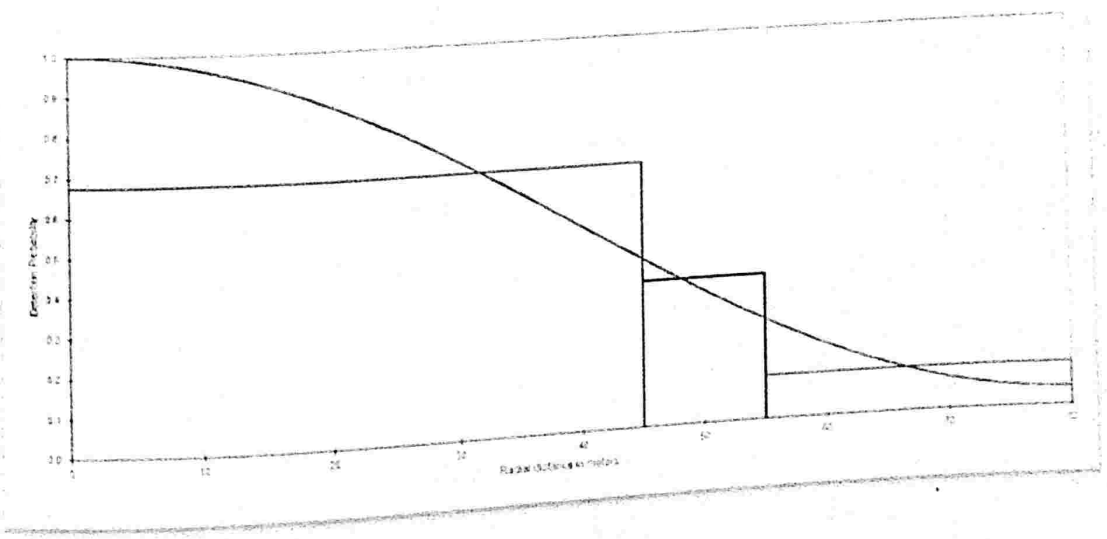
Chi-square value, p = 0.94



Eurasian Tree Sparrow:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	DS	10.683	29.31	101.42	6.0445	18.881
AIC = 32.42	D	108.49	37.96	69.56	52.187	225.56
	N	108.00	37.96	69.56	52.000	226.00
	EDR	45.94				

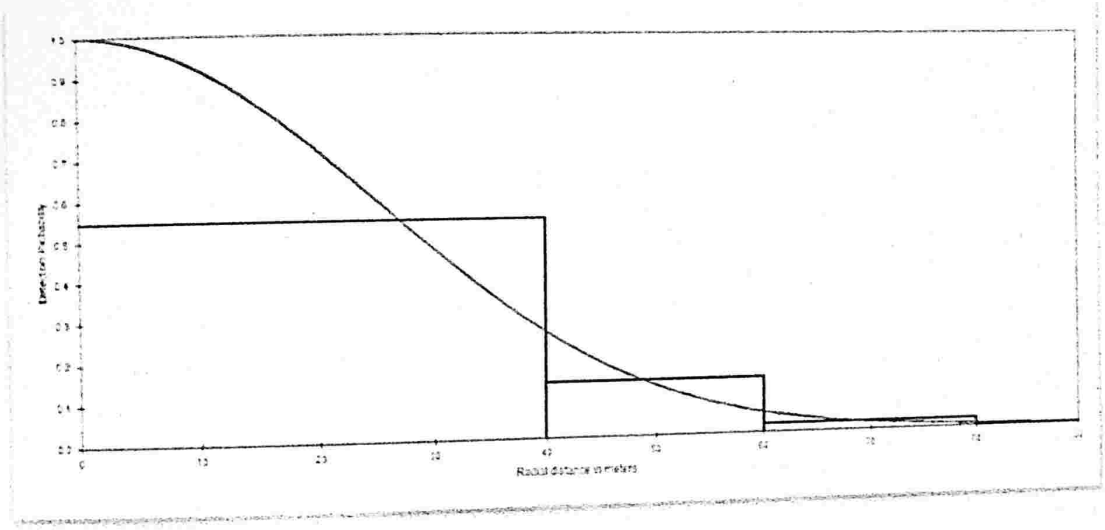
Chi-square value, p = 0.86



Hume's Leaf Warbler:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	24.309	32.00	64.60	13.028	45.357
AIC = 33.37	D	111.90	38.70	81.73	53.221	235.28
	N	112.00	38.70	81.73	53.000	235.00
	EDR	34.65				

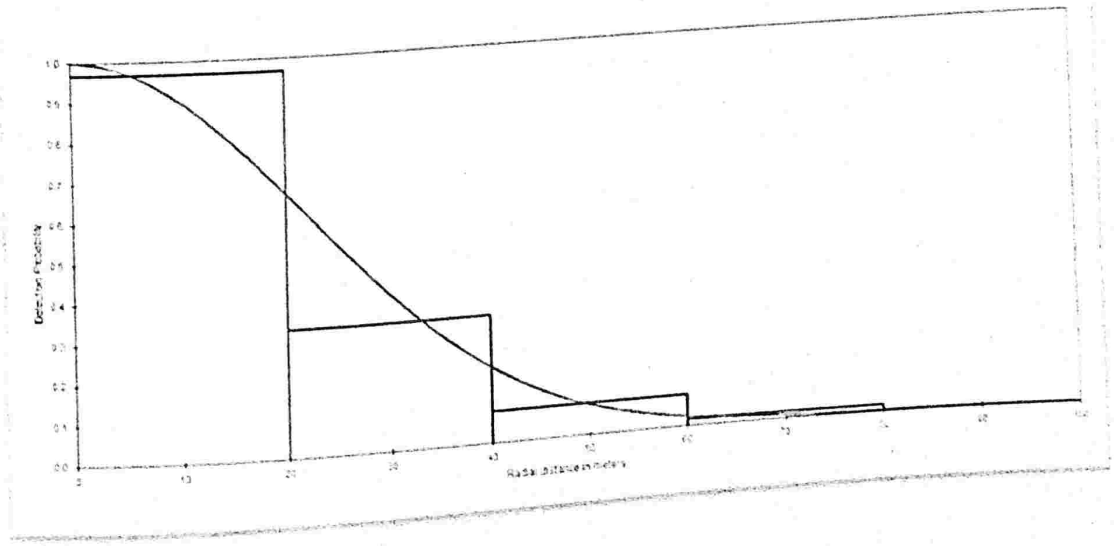
Chi-square value, p = 0.95



White Wagtail:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Polynomial						
	DS	34.283	29.13	77.20	19.422	60.513
AIC = 60.62	D	53.164	30.52	90.18	29.384	96.189
	N	53.000	30.52	90.18	29.000	96.000
	EDR	31.10				

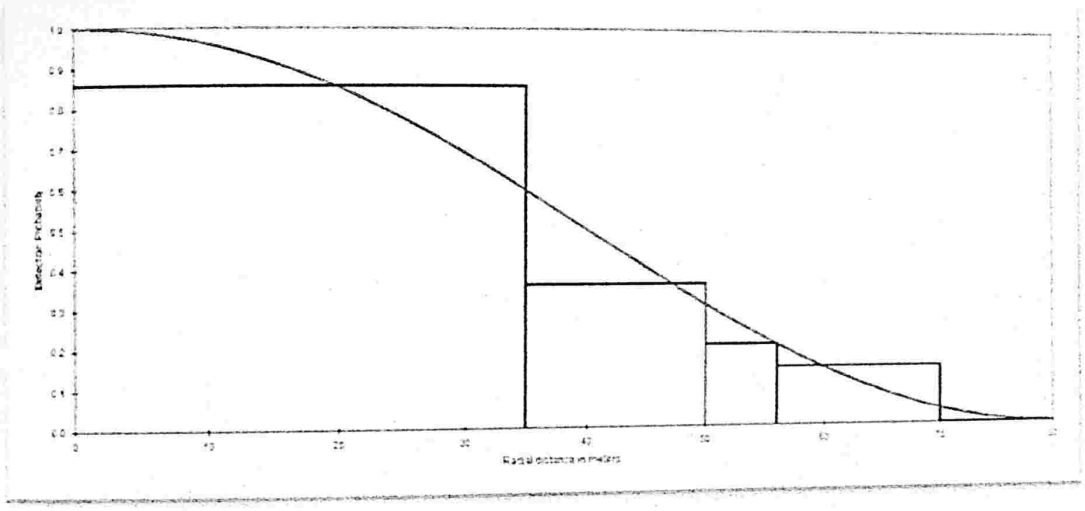
Chi-square value, p = 0.82



White-tailed Stonechat:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	DS	20.208	18.28	266.28	14.142	28.876
AIC = 68.92	D	30.891	19.82	282.03	20.989	45.465
	N	31.000	19.82	282.03	21.000	45.000
	EDR	43.63				

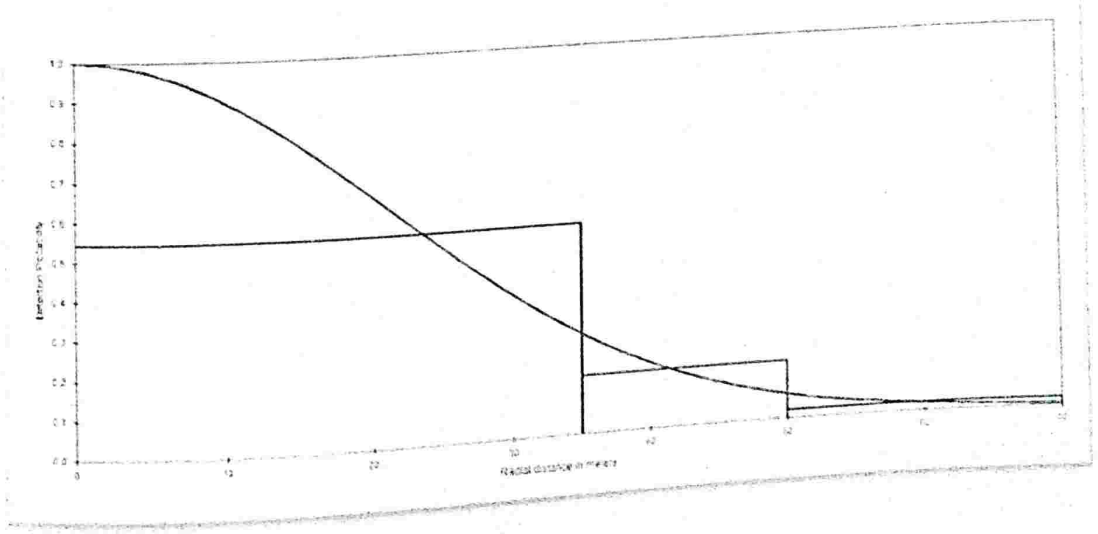
Chi-square value, p = 0.76



Western Yellow Wagtail:

		Estimate	%CV	df	95% Confidence Interval	
Half-normal/Cosine						
	DS	27.924	35.32	53.92	14.041	55.534
AIC = 28.94	D	37.683	39.80	70.63	17.541	80.956
	N	38.000	39.80	70.63	18.000	81.000
	EDR	30.04				

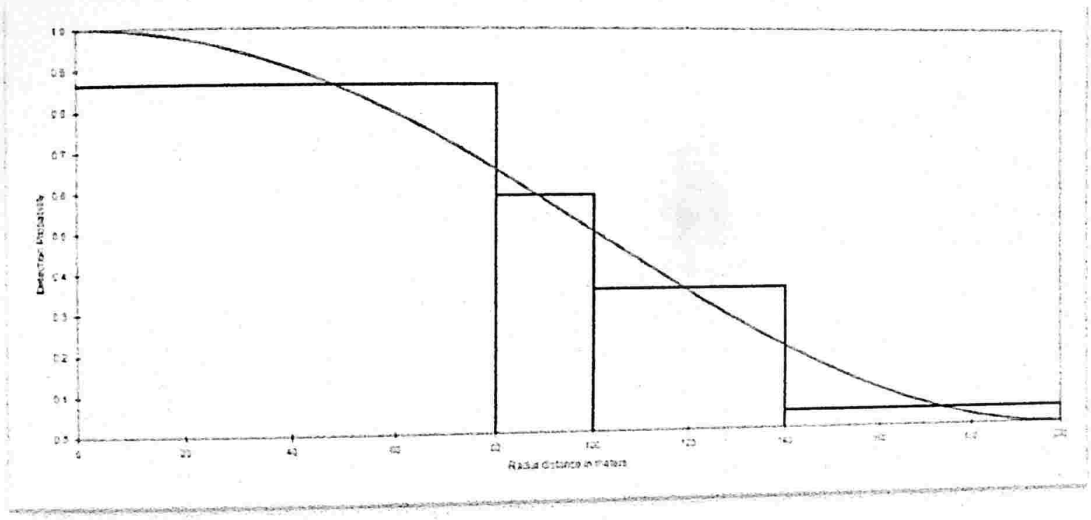
Chi-square value, p = 0.85



Little Egret:

		Estimate	%CV	df	95% Confidence Interval	
Uniform/Cosine						
	DS	3.1220	21.77	228.53	2.0429	4.7710
AIC = 70.28	D	27.636	35.39	64.61	13.917	54.881
	N	28.000	35.39	64.61	14.000	55.000
	EDR	109.06				

Chi-square value, p = 0.80



Appendix VI

60 bird species common in both Keibul Lamjao National Park (KLNP) and Pumlen Pat (PP).

Sl. No.	Common name	Scientific name
1	Ashy Prinia	*Prinia socialis*
2	Asian Openbill	*Anastomus oscitans*
3	Asian Pied Myna	*Gracupica contra*
4	Black Drongo	*Dicrurus macrocercus*
5	Black Kite	*Milvus migrans*
6	Black-winged Cuckooshrike	*Lalage melaschistos*
7	Black-winged Kite	*Elanus caeruleus*
8	Bluethroat	*Cyanecula svecica*
9	Blyth's Reed Warbler	*Acrocephalus dumetorum*
10	Chestnut-capped Babbler	*Timalia pileata*
11	Chestnut-eared Bunting	*Emberiza fucata*
12	Citrine Wagtail	*Motacilla citreola*
13	Common Kingfisher	*Alcedo atthis*
14	Common Moorhen	*Gallinula chloropus*
15	Common Myna	*Acridotheres tristis*
16	Common Snipe	*Gallinago gallinago*
17	Common Stonechat	*Saxicola torquatus*
18	Great Cormorant	*Phalacrocorax carbo*
19	Glossy Ibis	*Plegadis falcinellus*
20	Eastern Jungle Crow	*Corvus (macrorhynchos) levaillantii*
21	Eastern Marsh Harrier	*Circus spilonotus*
22	Ferruginous Pochard	*Aythya nyroca*
23	Graceful Prinia	*Prinia gracilis*
24	Great Myna	*Acridotheres grandis*
25	Greater Coucal	*Centropus sinensis*
26	Grey Wagtail	*Motacilla cinerea*
27	Hume's Leaf Warbler	*Phylloscopus humei*
28	Indian Cuckoo	*Cuculus micropterus*
29	Indian Pond Heron	*Ardeola grayii*
30	Intermediate Egret	*Ardea intermedia*
31	Jerdon's Bushchat	*Saxicola jerdoni*
32	Little Cormorant	*Microcarbo niger*
33	Little Egret	*Egretta garzetta*
34	Long-tailed Shrike	*Lanius schach*
35	Oriental Magpie Robin	*Copsychus saularis*
36	Oriental Turtle Dove	*Streptopelia orientalis*

37	Pale-footed Bush Warbler	*Hemitesia pallidipes*
38	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*
39	Pin-tailed Snipe	*Gallinago stenura*
40	Plain Prinia	*Prinia inornata*
41	Plaintive Cuckoo	*Cacomantis merulinus*
42	Purple Heron	*Ardea purpurea*
43	Red-vented Bulbul	*Pycnonotus cafer*
44	Richard's Pipit	*Anthus richardi*
45	River Lapwing	*Vanellus duvaucelii*
46	Ruddy-breasted Crake	*Zapornia fusca*
47	Rufous--rumped Grassbird	*Graminicola bengalensis*
48	Scaly-breasted Munia	*Lonchura punctulata*
49	Slaty-bellied Rail	*Lewinia striata*
50	Slender-billed Babbler	*Chatarrhaea longirostris*
51	Striated Babbler	*Argya earlei*
52	Striated Grassbird	*Megalurus palustris*
53	Tickell's Leaf Warbler	*Phylloscopus affinis*
54	Watercock	*Gallicrex cinerea*
55	Western Yellow Wagtail	*Motacilla flava*
56	White Wagtail	*Motacilla alba*
57	White-breasted Waterhen	*Amaurornis phoenicurus*
58	White-tailed Stonechat	*Saxicola leucurus*
59	White-throated Kingfisher	*Halcyon smyrnensis*
60	Yellow-bellied Prinia	*Prinia flaviventris*

Appendix VII

Bird Species found exclusively in Keibul Lamjao National Park (KLNP) during point count.

Sl. No.	Common Name	Scientific Name
1	Black Bulbul	*Hypsipetes leucocephalus*
2	Black-breasted Parrotbill	*Paradoxornis flavirostris*
3	Bronze-winged Jacana	*Metopidius indicus*
4	Cattle Egret	*Bubulcus ibis*
5	Chinese Pond Heron	*Ardeola bacchus*
6	Clamourous Reed Warbler	*Acrocephalus stentoreus*
7	Common Hawk-cuckoo	*Hierococcyx varius*
8	Common Kestrel	*Falco tinnunculus*
9	Crested Serpent Eagle	*Spilornis cheela*
10	Eurasian Coot	*Fulica atra*
11	Eurasian Cuckoo	*Cuculus canorus*
12	Eurasian Wigeon	*Mareca penelope*
13	Gadwall	*Mareca strepera*
14	Golden-headed Cisticola	*Cisticola exilis*
15	Great Cormorant	*Phalacrocorax carbo*
16	Great Egret	*Casmerodius albus*
17	GreyBushchat	*Saxicola ferreus*
18	Grey-headed Lapwing	*Vanellus cinereus*
19	Common Hoopoe	*Upupa epops*
20	Indian Spot-billed Duck	*Anas poecilorhynca*
21	Jerdon's Baza	*Aviceda jerdoni*
22	Large Hawk-cuckoo	*Hierococcyx sparverioides*
23	Lesser Whistling-duck	*Dendrocygna javanica*
24	Little Grebe	*Tachybaptus ruficollis*
25	Osprey	*Pandion haliaetus*
26	Purple Swamphen	*Porphyrio porphyria*
27	Red-breasted Flycatcher	*Ficedula parva*
28	Rufous-necked Laughingthrush	*Garrulax ruficollis*
29	Spot-breasted Scimitar Babbler	*Erythrogenys mcclellandi*
30	White-throated Fantail	*Rhipidura albicollis*
31	Indian Cormorant	*Phalacrocorax fuscicollis*

Appendix VIII

Bird species exclusively found in Pumlen Pat (PP) during point count.

Sl.No.	Common name	Scientific name
1	Black Francolin	*Francolinus francolinus*
2	Black-faced Bunting	*Emberiza spodocephala*
3	Brown Shrike	*Lanius cristatus*
4	Chestnut-crowned Bush Warbler	*Cettia major*
5	Common Tailorbird	*Orthotomus sutorius*
6	Coppersmith Barbet	*Psilopogon haemacephalus*
7	Eurasian Tree Sparrow	*Passer montanus*
8	Eurasian Wryneck	*Jynx torquilla*
9	Grey-crowned Warbler	*Phylloscopus tephrocaphalus*
10	Large Cuckoo-shrike	*Coracina macei*
11	Large Hawk-cuckoo	*Hierococcyx sparveriodes*
12	Little Ringed Plover	*Charadrius dubius*
13	Oriental White-eye	*Zosterops palpebrosus*
14	Paddyfield Pipit	*Anthus rufulus*
15	Rufescent Prinia	*Prinia rufescens*
16	Shikra	*Accipiter badius*
17	Siberian Rubythroat	*Calliope calliope*
18	White-breasted Waterhen	*Amaurornis phoenicurus*
19	Wood Sandpiper	*Tringa glareola*

Appendix IX

Stress Plots for NMDS:

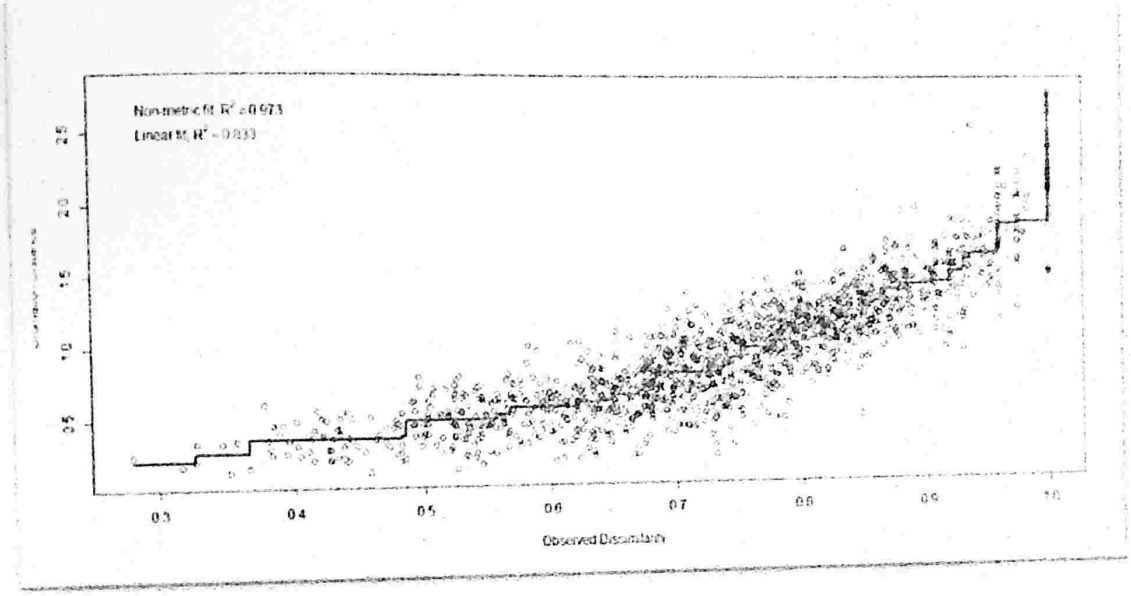


Figure 4.10: Stress plot for the observations from KLNP.

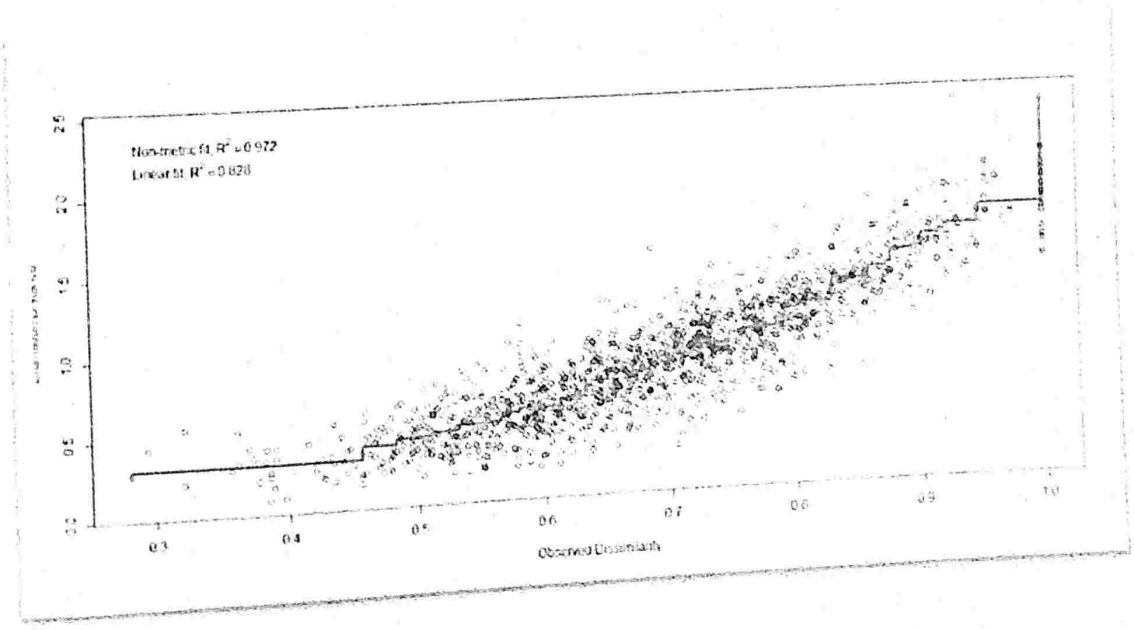


Figure 4.11: Stress plot for the observations from PP.

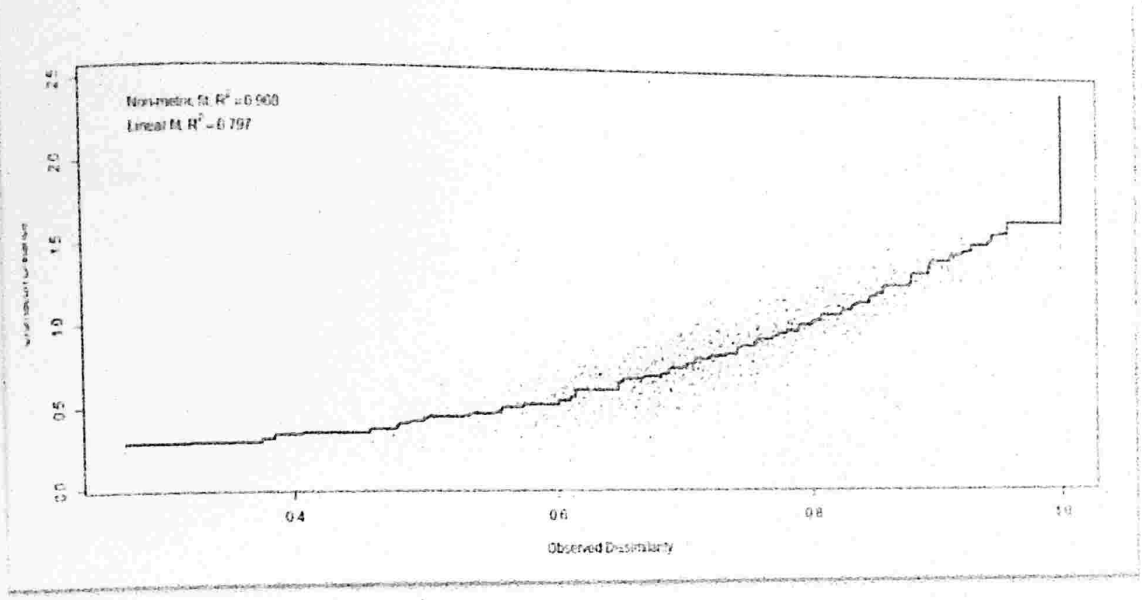
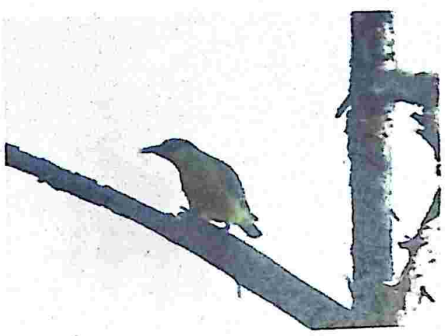


Figure 4.15: Stress plot for both sites.

Appendix X

Some bird species sighted during the study period from both sites.

Himalayan Buzzard



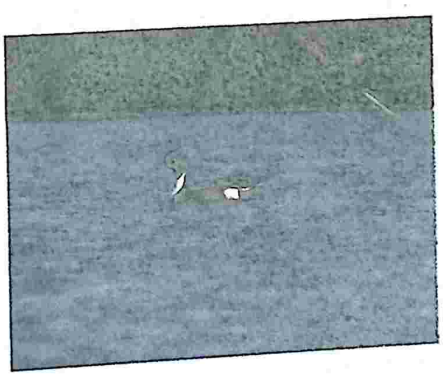
Black-naped Oriole

Rosy Pipit

Chestnut-eared Bunting

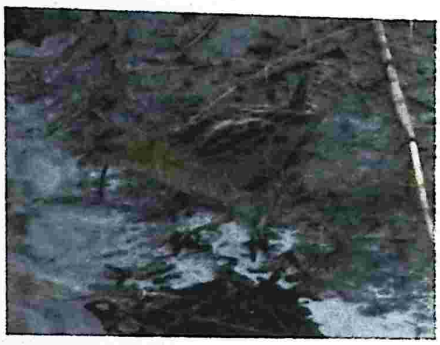
Black-faced Bunting

Yellow Bittern



Northern Pintail

Red-breasted Flycatcher



Baillon's Crake

Rufous-rumped Grassbird

Jerdon's Bushchat

Chestnut-capped Babbler

Siberian Rubythroat

Black-winged Cuckooshrike

Black-breasted Parrotbill

Yellow-breasted Bunting

Eurasian Wryneck

Little Ringed Plover

Golden-headed Cisticola

Lesser Coucal