Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality

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CERTIFICATE

This is to certify that, this thesis is a record of the bonafide research work carried out by Mr. Seedikkoya. K, from May 1999 to September 2003 under our supervision and guidance and that neither this thesis nor any part of the same has previously formed the basis for the award of any degree / diploma / associateship / fellowship or other similar title to any candidate of any university.

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DECLARATION

I, **K. Seedikkoya** hereby declare that the thesis entitled "**Comparative ecology of certain paddy field birds with emphasis on the habitat quality**", submitted to the University of Calicut, in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy in Zoology is a record of original and independent research work done by me during May 1999 to September 2003 under the supervision and guidance of **Dr. E. A. A. Shukkur**, Selection Grade Lecturer, Division of Wildlife Biology, Farook College, Calicut and **Dr. P.A. Azeez,** Senior Principal Scientist, Division of Environmental Impact Assessment, Sálim Ali Centre for Ornithology and Natural History, Coimbatore and it has not formed the basis for the award of any Degree or Diploma.

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ABSTRACT

Herons (Order Ciconiiformes, family Ardeidae) are the most common group of birds frequenting the wetlands. Habitat quality is one of the important factors in the conservation of herons. The paddy fields and other forms of wetlands are fast depleting in the Kerala State for noticeable socio-economic changes. Use of agrochemicals of which pesticides are a major ones are rampant in the state. Pesticide contamination is widespread and they have high potential to bioaccumulate to have detrimental impact on reproduction and survival. Due to their top position in the food chain, predator birds are good bioindicators of contamination by chemicals such as pesticide and heavy metals. Predators accumulate these pollutants making them particularly suitable as bioindicators to study environmental residues. Considering these factors, the comparative ecology of three common paddy field birds, Cattle Egret (*Bubulcus ibis*), Little Egret (*Egretta garzetta*), and Pond Heron (*Ardeola grayii*) was selected for the present study.

The study area extended over North, South and Central Malabar, and encompasses mainly the districts of Malappuram, Kozhikode, Palakkad and Wayanad. The study was concentrated in selected habitats of Malappuram and Kozhikode districts. The study was started in May 1999. However intensive fieldwork was undertaken since January 2000 up to December 2001.

The objectives of the present study are to

1. Explore the characteristics of the habitats used by the herons under study and relate their influence with their distribution,
2. Investigate the feeding and breeding biology,
3. Study the association of cattle and cattle egret,
4. Analyse the Organochlorine pesticides and the heavy metal concentration each in the tissues and eggs of different bird species.

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Altogether 11 types of different habitats were selected for the present study. The study area was classified on the basis of dominant plant species available. There were 3 types of jheels (Azhinjilam jheel, Calicut Jheel, and Feroke Jheel), 2 types of rivers (Karimpuzha and Kadalundy rivers), 2 types of grass fields (Wet and Dry Grass fields), paddy field, Hillock, plantation and waste dump. The characteristics of different habitats under the study area were seasonally analysed by the abundance and composition of vegetation, aquatic and terrestrial prey organisms and water depth. The vegetation of different habitats was quantified by the quadrate charting method. Larval forms of waste dumping sites were also studied by the quadrate charting method. Aquatic organisms were collected by sweeping through "D" frame nylon cloth net. Birds were counted by spot map method.

Among the three jheels, Azhinjilam jheel was characterised by three dominant species of vegetation namely *Salvinia molusta, Oryza sativa* and *Cynodon dactylon.* Totally 1593 aquatic organisms distributed over 27 families and 1191 terrestrial arthropods distributed over 31 families were found in the samples collected from this habitat. Among the fishes and aquatic insects *Macropodus cupanus* and dragonfly naiads were frequently seen in this habitat. Plant species like *Ipomea aquatica, Alternanthera philoceroides* and *Eichhornia crassipes* were the most dominant species in Calicut jheel. Altogether 1581 aquatic organisms distributed over 26 families were found in this habitat. Belostomatids and naiads of damselflies dominated this habitat. Feroke jheel was dominated by *Ipomea carnea, Hydrilla verticillata* and *Oryza sp.* Totally 1947 aquatic organisms distributed over 31 families were collected from this habitat. Of the three types of jheels *Palaemon sp.* was highest in Feroke jheel. The water depth in all the three jheels varied from 20-120cm from June to March.

Kadaundy riverine habitat was characterised by the vegetations such as *Avicennia marina, Acanthes ilicifolinus, Sphaeranthus indica* and the algal forms, *Enteromorpha sp.* Altogether 1122 aquatic organisms distributed over 20 families were collected from this location. Among crustaceans *Penaeus sp.* and *Macrobrachium sp.* were abundant in this

habitat. Algal forms, *Spirogyra sp.* and other vegetations like *Cyperus sp. Cynodon dactylon, Polygonium glabrum, Fimbristylis milliaceae* and *Paspalum conjugtum* were prominent in Karimpuzha river. Totally 1335 aquatic organisms distributed over 34 families were collected from this location. *Palaemon sp.* was highest in Karimpuzha river.

In Vadapuram Wet Grass field *Cyrtococcum trigonum, Ischaemum sp. Sporobolus diander* and *Fimbristylis milliaceae* were the dominant vegetation. Since this location has both aquatic and terrestrial parts, it forms an ideal habitat for foraging birds. Altogether 1153 aquatic organisms distributed over 26 families and 1627 terrestrial arthropods distributed over 40 families were collected from this habitat. Acridids and Gryllids among terrestrial organisms and Notonectids and *Palaemon sp.* among aquatic organisms were dominant.

Eragrostris unioloides, Desmodium triflorum, Arundinella mesophylla, and *Perotis indica* mixed with other herbs and shrubs predominantly covered dry grass field. Since this area had less vegetation, very few organisms were seen. In all, 767 terrestrial arthropods distributed over 19 families were collected from this area. Occasionally Cattle Egrets were seen here in association with grazing cattle.

Kundayithode solid waste dumping site was completely covered with various types of decaying solid wastes. This prevented the growth of vegetation in this habitat resulting in the absence of insects other than muscids and calliphorids, which were found developing from decaying, wastes, especially chicken wastes, carcasses and fish wastes.

Oryza sativa, Ischaemum sp., Eriocaulon quinquangulare, Echinochloa colonum, Fimbristylis milliaceae, and *Desmodium triflorum* dominated paddy field. Paddy field provided both aquatic and terrestrial habitats at different seasons. During paddy cultivation i.e., from June-September and October-February paddy fields hold water supporting a variety of aquatic organisms while the boundary area with predominantly grass serves as a substratum for terrestrial arthropods. During non-cultivated seasons i.e.,

from February-May it remains fallow and serves as pastures for grazing cattle with which Cattle Egrets usually gets associated. Totally 2386 terrestrial arthropods and 1149 aquatic organisms were collected from the paddy fields. Naiads of dragonflies and damselflies, Mayfly nymphs, Gerrids and Notonectids were abundant. Hillock was dominated by *Lantana camara, Anacardium occidentale, Terminalia paniculata* and *Clerodendrum viscosum*. Lepidopteran families like Papilionidae, Pieridae, Nymphalidae, Hesperiidae and Danaidae were abundant in this habitat. Altogether 1521 terrestrial arthropods distributed over 29 families were collected from the hillock. Pond Herons and Little Egrets being more closely associated with water did not prefer this habitat whereas the only heron seen here was Cattle Egret. Compared with other habitats under study, Plantation had very low species composition with respect to vegetation. Rubber, *Hevea braziliensis,* mixed with other herbs and shrubs represented the dominant vegetation of this area. Since vegetation was less, vegetation dependent insects were also very much reduced. Few grasshoppers, cockroaches, gryllids and tetrigids include mainly the terrestrial insects of this area. Among the three species of herons, Cattle Egrets were occasionally seen foraging in this habitat in association with grazing cattle while Little Egret and Pond Herons were seldom found.

The present study reveals that among the three bird species under study, the cattle egrets use more variety of habitats than the other two species. In aquatic habitats they being insectivorous prefer mostly shallow areas having vegetation. Cattle Egrets were found associated with all sorts of habitats except estuarine habitats in Kadalundy, where the habitat is inundated and vegetation is sparse. Presence of grazing cattle and availability of vegetation are two major criteria for its presence in hillocks and plantations.

Pond Herons prefer aquatic habitats with or without vegetation. Adults of the species are mostly insectivorous, but also take considerable invertebrates and rarely vertebrates such as reptiles. For the nestlings fishes are more important than invertebrates. They explore paddy fields, Grass fields, Jheels, Riverine and estuarine habitats but have a strong preference towards jheels (52.3%). Plantations and hillocks are virtually out of bounds for Pond Herons.

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Little Egrets being mostly piscivorous are always associated with water and they utilise habitats with water regime. Accordingly they prefer paddy fields, grass fields, jheels, riverine and estuarine habitats and never were seen in hillocks, plantations and in waste dumps. Of the three species Little Egret was more abundant (42.7%) in Kadalundy habitat.

Paddy fields, jheels, wet grass fields, riverine and estuarine habitats provide both aquatic as well as terrestrial prey organisms to these birds, while hillock, plantation and waste dump sites offer only terrestrial prey items. Since plantations and hillocks are comparatively dry these habitats are very rarely used by cattle egrets except during habitat expansion in wet months. Cattle egrets have comparatively more percentage abundance in paddy fields (58.8%) and grass fields (58.9%) compared to the other two species.

The population of Cattle Egrets at waste dump showed that their number ranged from 98-386 and 85-254 during the period 1999-2000 and 2000-2001 respectively. The maximum number was observed from January 2000 to April 2000 and from January 2001 to March 2001 respectively. Cattle egret being a strong insectivorous bird it resorts to feed on dipteran maggots of calliphorids and muscids, which multiply in decaying solid wastes.. So they show a strong preference towards the waste dumpsite. The wriggling maggots are enormous and can be very easily pecked at. It seems that Cattle Egrets play an important role in controlling the proliferation of these insect pests, which would otherwise multiply and act as vectors in transmitting various contagious diseases. It acts as a biological controlling agent.

Prey species of the three herons under study were identified by analysing the stomach contents of adult birds and the regurgitated boluses from the guts of nestling. The foraging behavior of the birds was studied in five major habitats, namely, paddy fields, wet grass fields, Jheels, riverine habitats and waste dump. The comparative prey abundance was also studied.

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Cattle Egrets are more terrestrial than the other two species and they prefer terrestrial insect species to aquatic species as their food. Insects form 87% of their food. Out of the 166 prey items collected from adult Cattle Egrets of 13 samples, Acridids accounted for 70 over 10 samples. Not even a single fish was identified from the gut contents of these birds. In the present study they were never seen in estuarine (Kadalundy) areas. Cattle Egrets were the only birds utilising the waste dumpsites. They used 7 types of common feeding techniques out of the 13 techniques adopted by the herons in the study area. The commonly used foraging techniques were *walk slowly*, *walk quickly* and *running*.

Little Egrets feed mostly on fishes (96.24%) and hence have more preference to aquatic medium. Out of 532 prey items identified from 13 gut content samples from adult Little Egrets, 264 (nearly half the total number) was composed of *Lepidocephalus thermalis* and 109 with *Macropodus cupanus*, which were abundant in different jheels. Out of 366 food items distributed over 22 samples collected from their nestlings, 126 was again formed of *Macropodus cupanus*. They were totally absent in two natural (hillock and plantation) and the artificial (Waste dump) habitats. Among the natural habitats they preferred estuarine (Kadalundy) areas maximum. They used 9 types of common feeding techniques out of the thirteen techniques used by herons. The commonly used foraging techniques of this bird were *walk quickly, walk slowly* and *running*. Little Egrets were comparatively least abundant in paddy fields (12.2 %) than the other two species.

Pond herons are terrestrial cum aquatic species, and they feed on both terrestrial and aquatic prey species. Insects constitute 71.2% (adult) compared to Cattle Egrets (87%) and have less preference to terrestrial and more preference to aquatic habitats than in Cattle Egrets. Out of the 258 prey organisms identified from the adult gut contents 116 were Acridids or short horned grasshoppers. Out of the 41 prey items identified from the gut contents of nestlings, fishes were represented by *Parluciosoma daniconius, Macropodus cupanus, Puntius amphibius*, *Danio acquipinnatus* and *Aplocheilus lineatus*. These birds were not observed in hillock and plantation. Jheels were their most preferred habitat. They used 6 common types of feeding techniques out of the thirteen

techniques used by herons. The most commonly used foraging technique was *stand and wait.*

The association between Cattle and Cattle Egret was studied to examine the benefits that the egrets derive from the association. Diurnal and seasonal pattern in association, and the factors controlling association of cattle and cattle egrets in different habitats were also studied by spot mapping (Dickson 1979; Cody 1968 and Subramanya et al. 1998) and direct visual count (Altmann 1974). The number of steps is a measure of energy expenditure in obtaining food. Assuming that the size and quality of food collected by associated and non-associated egret is same, the number of steps taken by the associated and non-associated birds for successful feeding was counted to evaluate whether associated egret gets more preys with comparatively fewer number of steps than non-associated birds.

Out of a total of 1118 birds, 652 birds (58.3% of the total) were observed associated with cattle during the study period. An associated Cattle Egret had mean capture of 1.33 $\pm$ 0.86 while that of non-associated Cattle Egret was 0.87 $\pm$ 0.75 per minute. The mean steps used by an associated egret and non-associated egret was 19.78 $\pm$ 2.06 and 29.51 $\pm$ 2.54 respectively whereas mean strike was 4.80 $\pm$ 1.77 and 3.55 $\pm$ 1.29 in associated and non-associated egrets respectively. The association was highest in grass fields than in jheel and Paddy fields. Least association was observed in plantations. Association was observed highest from 0900 in the morning till 1200 at the noon and again from 1400 in the afternoon till 1600 in the evening.

Nesting sites, nests, morphometry of the eggs, clutch size, incubation, egg mortality, and hatching success were studied in respect of all the three species. The nesting colonies were investigated regularly from April to September every year starting from 1999 to 2002. Nesting trees were numbered and nests were marked by numbered plates during nest building stage. The nests were checked at intervals, the freshly laid eggs were numbered with a felt-tipped pen, measured with a vernier calipers and weighed to the nearest 0.5 g with a Pesola balance. The nests were checked every day during the laying

period; at four or five-day intervals during incubation and hatching and at weekly intervals from the time chicks hatched, till they reached the age of 24 days.

In all the three species the breeding plumage appear before the onset of the monsoon season. The nesting colonies of Pond Herons and Little Egrets were observed in the study areas while that of Cattle Egrets were observed neither in the study area nor in the entire State of Kerala. Pond Herons and Little Egrets build platform type of nests. Cattle Egrets also make similar nests (observations outside Kerala State). The clutch size varies from 2-5 in Pond Heron; 2-6 in Little Egret and 1-4 in Cattle Egret. The maximum length and breadth of eggs respectively was 48.0 x 32.0 mm in Pond Heron (N=58) and 52.5 x 35 mm in Little Egret (N=82). The minimum length and breadth was 33.3 mm x 24.1 in Pond Heron and 42.6 x 29 mm in Little Egret. The longer and thinner eggs had lower shape index while shorter and thicker eggs higher shape index. A positive correlation existed between the weight and shape index of the eggs in Little Egrets. The mean incubation period was 20.9 in Pond Heron (N=62); 21.18 in Little Egrets (N=60) and it is reported that it varied from 20.6-20.8 days in Cattle Egrets. The hatching success was 82% (N=85) in Pond Herons; 74 % in Little Egrets (N=82) and it varied from 87.4% to 95.5% in Cattle Egret.

The pesticide residues in different tissues and eggs of these birds were analysed. The tissues selected for the pesticide analysis include heart, liver and muscles from dead specimens of Pond heron, Little Egret and Cattle Egret. The birds were dissected out and tissue samples were stored in clean polythene vials, labeled and transported to Ecotoxicology laboratory at SACON (Salim Ali Centre for Ornithology and Natural history), where analysis of metals and pesticides were carried out using AAS (Atomic Absorption Spectroscopy) and GC (Gas Chromatography) respectively.

The egg samples of Pond Herons and Little Egret was collected from different breeding colonies at Malappuram and Palakkad districts. The eggs were stored in a refrigerator until they were weighed and measured for length and breadth. Each egg was opened at the equator and its contents poured into a chemically cleaned jar. Shells of all eggs were

rinsed in tap water and dried. Eggshell thickness was measured at three sites on the equator with a micrometer graduated in units of 0.01 mm: an average of three measurements represented shell thickness.

No significant variation in the mean concentration of organochlorine residue among the three species of birds under study was found. In the individual tissues of these three species of herons the residue level ranged from BDL – to 0.39 ± 0.22 ppm. The species wise mean total of DDT was comparatively more than the other pesticides.

Among the eggs of two species there exists little variation in concentration of organochlorine residues The concentration of DDE, which has a major role in shell thinning, was not significantly high in any of these species. Compared to Little Egret (mean = 0.02 ± 0.04 ppm) Pond Heron (mean = 0.01 ± 0.02 ppm) had lower amount of DDE. In the two species studied no significant correlation between pesticide concentration and eggshell thickness could be found.

The accumulation of heavy metals namely copper, cadmium, chromium, lead and zinc in different tissues and eggs of the birds were studied. Heart, muscle and liver tissues from dead specimens of Pond Heron, Little Egret and Cattle Egret were collected. The tissue samples were processed and analysed in the Ecotoxicology laboratory at SACON for heavy metals. One egg each from 9 clutches of pond herons and 13 clutches of Little Egrets were also collected for heavy metal analysis. The concentration of Cu and Zn was comparatively low in the eggs of Pond Heron (mean= 2.05 ± 1.51ppm and 14.24 ± 11.08 ppm respectively) than that of Little Egret (3.41 ± 2.81 ppm and 28.20 ± 28.69 ppm). The concentration of lead, cadmium and chromium where BDL in the eggs of two species of birds under study.

Among the tissues of three species of birds namely Pond Heron, Little Egret and Cattle Egret the variation in heavy metal residues was not statistically significant. The order of metal accumulation in the organs was Liver > Heart > Muscle which can be substantiated

by the metabolic role of liver in detoxifying and excreting the pollutants. The species-wise metal contamination was in the order Little Egret > Pond Heron > Cattle Egret.

Among the eggs collected from two species of birds for metal analysis the eggs of Little Egrets (N=13) contained the highest mean concentration of copper and zinc than that in Pond Heron (N=9). This shows the possibility of accumulation of these heavy metals in birds, which are exclusively piscivorous.

GENERAL INTRODUCTION

Seedikkoya .K “Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality ” Thesis. Department of Zoology , Farook College Calicut ,University of Calicut, 2003

Chapter I

GENERAL INTRODUCTION

1.1 Introduction

Herons are large, popular, and in many cases spectacular birds having long legs, long bills, and long necks with a wading mode of life. They have worldwide distribution especially in temperate and tropical wetlands. Wading birds, an integral part of wetlands, are one of the easier components to base quantitative studies and hence may be useful indicators of biological change and ecological conditions of wetland ecosystems (Kushlan 1993, 1997; Grull and Ranner 1998). Herons use a variety of habitats, both natural and many human-altered landscapes. Most species are highly dependent on wetlands like paddy fields, which support several other species of birds coexisting using the available mosaic of niches and resources in different ways. Wetlands are under increasing pressure worldwide. Herons of the family Ardeidae are the most common groups frequenting wetlands. Among herons, many are migratory and depend for their survival upon conservation of the wetland habitats that they visit during seasons.

In developing countries natural wetland habitats are widely being converted to agricultural use. Price guarantees for the agricultural products have encouraged increased production levels achieved through heavy use of agrochemicals that ultimately find their way into the running water and thereby into wetlands (Pineau 2000). Such wetlands can still play an important role for Ardeids, and other paddy field birds provided they are comparatively free from highly mechanized agriculture, and heavy pesticide and other chemicals use. Paddy fields, a type of wetland, common in the tropical nations where rice forms the staple diet are often important habitats for some species of waterbirds particularly in regions where the natural marshes has diminished (Fasola and Ruiz 1996). In developed countries, the conversion of wetlands into agricultural land in large scale is an old practice that increased enormously with the advent of steam and diesel powered pump sets. Such changes are still taking place despite concern for conservation measures.

1.2 Importance of the study

Rice fields are now fast disappearing due to noticeable shift in land use patterns promoted by agricultural, economic and social changes, which are affecting life of some heron species. In south India, two heron species (Striated Herons and Cinnamon Bittern) use rice fields planted with tall indigenous varieties, and the extensive cultivation of dwarf hybrids may affect their use of this habitat (Subramanya 1990). Local changes of land-use around breeding colonies are suspected to have affected the breeding population of Little egrets in Vedanthangal colony, around which dry crops have replaced rice fields (Perennou et al. 2000).

The effects of industrial development and urbanisation are also serious on wetlands. Apart from landfilling and dredging for urban and industrial developments, wetlands are polluted with domestic sewage, industrial effluents and other waste products. Transformation of wetlands into fish farms common in both developed and developing countries also cause degradation of habitats. Conversion of wetlands into fish farms renders them unavailable for herons because of excessive water depth, netting and scaring techniques adopted to prevent birds landing in the farms (Pineau 2000).

In Kerala, replacement of rice fields by cash crops such as banana plantations, areca nut and coconut plantations and for small industrial activities is affecting the extensive Kole wetland, the " rice bowl of central Kerala", where up to 10000 herons have been recorded in winter (Nameer 1993; Perennou et al. 2000). Therefore, the shift towards a more commercially lucrative agriculture such as cash crops, new varieties of rice, increasing use of agrochemicals, and large open landscapes is a potential long-term threat to many heron populations that had been adapted to a traditional agriculture. These birds are essential components of wetland ecosystem, capable of bringing thousands of tones of nutrients within a single season and play an important role in energy dynamics in the ecosystem (Kahl 1964, Kushlan 1976a, 1977, and Christy et al.1981). These Piscivorous birds occupy a high position in the food chain and represent a variety of predatory niches (Kushlan 1978b). It is being recognized that understanding ecology of these birds is of utmost importance in appreciating the functioning of the system as well as in determining

the management options so that these birds can be effectively conserved despite increasing threats.

Habitat quality is as important as habitat availability in conserving herons. Important approaches to maintaining habitat quality are those that seek to retain habitat diversity, natural functioning, food supplies and sustainable human use of wetland ecosystems (Boyd and Pirot 1989; Kushlan 2000). Contamination with agrochemicals and pesticides has been spread over wide areas. Since they are being transported by air or in water currents, their presence is detected all over the world. Pesticides have a wide spectrum of effects and detrimental impacts on reproduction and survival. They as well have indirect impacts by reducing food supply and or altering other components of habitat quality. Therefore monitoring contaminants and their impact should be a priority within the framework of conservation (Berny et al. 2002).

Because of their top position in the food chain, predator birds have high potential to act as bioindicators of environmental changes. By virtue of their trophic status they accumulate pollutants such as organochlorine pesticides and heavy metals making them particularly suitable for revealing environmental contamination. Fish-eating birds such as raptors, cormorants, and herons have been severely affected by persistent pollution. Hence, they may be highly useful as an early warning system and for describing the health of environment. However, birds are the most mobile animals and the source of the contamination is often difficult to locate. Hence, use of birds as monitors of habitat quality requires high understanding of their ecology and other aspects.

In view of the threats posed to the common Ardeids from various factors as discussed above, a comparative ecology of three common paddy field birds namely, Cattle Egret, Little Egret, and Pond Heron (family Ardeidae, Order Ciconiiformes) have been selected for the present study. Taxonomy of these birds is well known (Baker 1928, Whistler 1935, Kahl 1971a, and Hancock and Kushlan 1984) and various workers have investigated biology of these birds in different parts of the world.

1.3 Study species

1.3.1 *Pond Heron (Ardeola grayii)*

Indian Pond Heron, *Ardeola grayii*, generally known as paddy bird (Plate 1a) is an Asiatic species inhabiting ponds, natural wetlands, rice fields and reservoirs. They are chiefly solitary ground feeders and feed on animal matter mainly aquatic in nature (Ali and Ripley 1987). The plumage is cryptic in nature. The Camouflage plumage is an adaptation for its solitary foraging (Kushlan, 1978). Pond Heron exhibits local movements within peninsular India, linked to availability of water (Santharam 1987, 1988). Some behavioural aspects of this bird were recorded by (Mathew 1984 b). Parasharya (1985) reports the pairing between this bird and the intermediate egret. The details on red legged pond herons and genetics of the red tarsi and feet are also investigated (Wesley 1996; Wesley 1993 b). Altitudinal extension of this species was recorded in Pin Valley National Park, in the Trans-Himalayan Spiti region of Himachal Pradesh (Manjrekar and Mehta 1999). A preliminary survey of Egrets and Pond Herons in the water resources of Sivakasi was documented by Rajan et al (1993). Documentation on the maintenance behavior of this bird is done by Sodhi and Kera (1984). Studies on this bird on aspects such as their breeding biology and pesticide contamination are comparatively less.

1.3.2 *Little Egret (Egretta garzetta)*

It is probably the most widespread heron in south and southwest Asia (Plate 1b), occurring in all wetland habitats, including man-made ones such as paddy fields, and even heavily polluted areas. It is second in number among the most common species of the Bharathpur colony (Ali and Vijayan 1986). They were reported in the Bagmati River in Nepal (Tyler and Ormerod 1993). Studies on the species are available from different parts of the country. The behavior of Little Egrets during solar eclipse has been reported by Kumar (1981). Relationship between heavy metal and metallothionein-like protein levels in the liver and kidney of this bird is discussed by Cosson (1989). In India, only few studies are available on their feeding aspects and information available on their breeding biology and pesticide contamination are also limited.

1.3.3 Cattle Egret (Bubulcus ibis)

This species is one of the most widely distributed herons (Plate 1c) in our country. Its ability to exploit human-interfered habitats (Subramanya 1996) and to associate to the vicinity of human beings, even nesting within urban areas has been recognized as the main cause for their success. They show regular local movements within India, closely linked to availability of water. It keeps associated with human interfered habitats and even act as a scavenger (Javed 1983). It scavenges on invertebrates and fishes, which are usually laid out for drying, and frequents paddy fields in India. Biology of these birds has been investigated in detail in different parts of the world. In India, studies on its biology, movements etc. are comparatively less. Most of the works are concentrated on their food and feeding behaviour. Studies on their breeding biology and Pesticide contamination are scanty.

1.4 Study Area

The study area broadly extends over the North, South and Central Malabar, which encompasses mainly the districts of Malappuram, Kozhikode, Palakkad and Wayanad (Map I and Map II) of Kerala State. The co-ordinates of the study sites are shown in Appendix-1.1. The major part of the study was concentrated in selected habitats of Malappuram and Kozhikode districts. All these districts have a variety of habitats such as paddy fields, jheels, grass fields, rivers, ponds and solid waste yards, which attract many birds especially herons for feeding and breeding. For the present study, based on a preliminary survey, suitable habitats and locations were identified and selected. The study sites falls within three river basins namely Chaliyar, Bharathapuzha and Kadalundy. Chaliyar river basin has both study areas and nest sites (Map III). The Bharathapuzha river basin (Map IV) and Kadalundy river basin (Map V) has only nest sites. Karimpuzha river, Vadapuram Grassfield, Mampad (which includes paddy field, hillock, dry grass field and rubber plantation), Feroke jheel, Azhinjilam jheel, Kundayithode solid waste dump yard, Kozhikode jheel, and Kallampara river are the study areas falling within the Chaliyar river basin. The nest sites in the basin included Mampad, Pathapiriyam, Vaniyambalam, Kizhisseri, Ramanattukara and Eranhipalam.

The study sites under Bharathapuzha river basin include three nesting sites only. They are Pattambi, Ottapalam and Shoranur respectively.

1.4.1 Topography

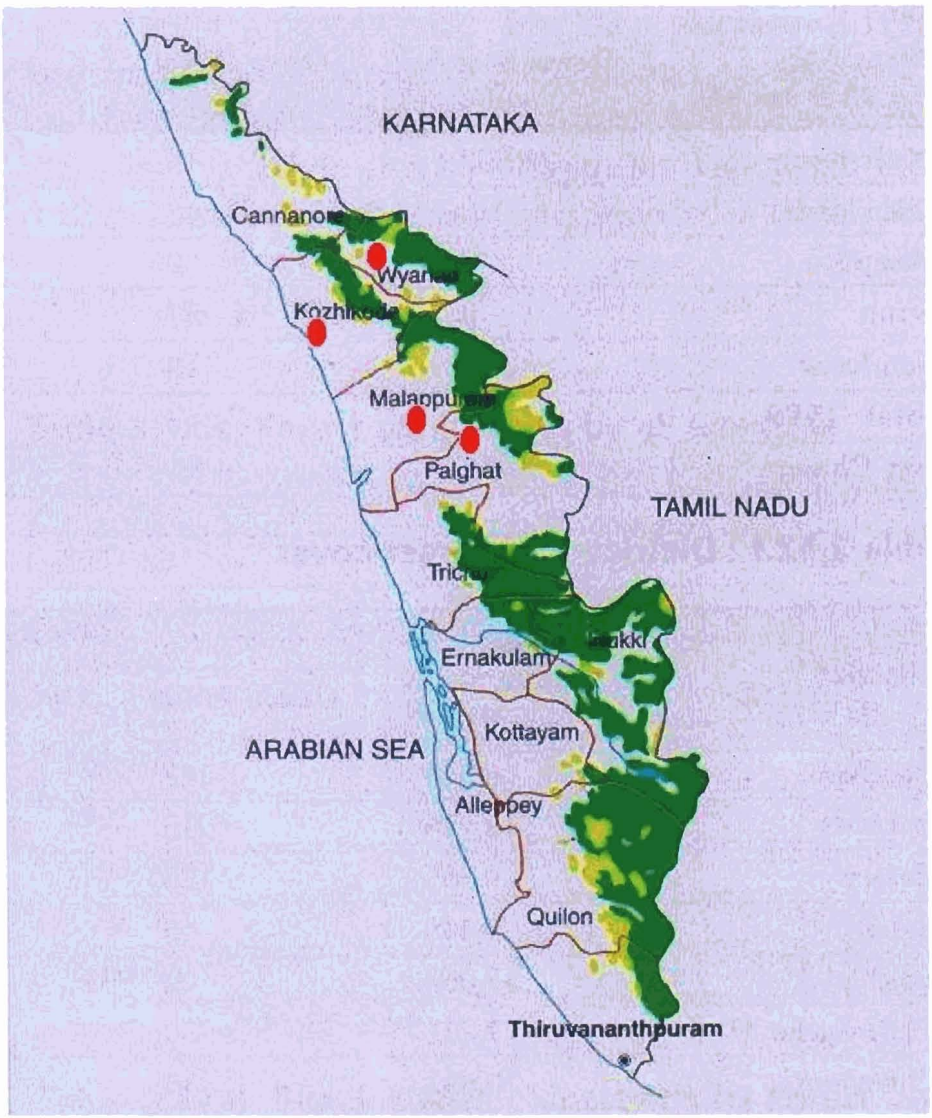
Study area is an undulating terrain having low land or seaboard, mid land and high land. The fertility of mid-land is enriched by rivers, grass fields, jheels and paddy fields. The high land forms the hillocks and plantations, interspersed by cashew and other shrubby hills. The low land is located close to the Arabian Sea which borders the western boundary of Malappuram and Kozhikode districts.

1.4.2 Soil

The study area is covered by laterite soil. They are formed from the withering acidic rocks under alternate wet and dry tropical conditions. They are generally developed in regions of heavy rainfall and high temperature. Laterite soils are usually of low fertility. Those found in the hilly areas are gritty and shallow and are stated to be deficient in essential plant nutrients. Those occurring in plains of Palakkad, Malappuram, Kozhikode and Wayanad districts are deeper with fine texture enriched with organic matter but lack potassium, phosphorous and calcium. In the lower plains where paddy field and wetlands are seen the soil is with more silt or fine sands with notable clay components. Areas rich in silt are also rich in organic contents (Anonymous 1974).

1.4.3 Climate

The study area is tropical in climate, the temperature falling low in winter and rising in summer. The summer starts from March and extends up to June. Summer is hot and dry especially in Palakkad and adjacent areas. The Southwest monsoon starts from June and continues till August-September. October onwards northeast monsoon starts and extends up November. The winter season, which extends from December to February, is cold with chilly winds.



Map-1 showing the districts under the study area

1.4.4 Temperature

The lowest monthly average temperature was minimum 16.7° C, 13.9° C, and 22° C in January 1999, January 2000, and March 2001 respectively; while the highest monthly average minimum was 22 ° C, 25° C, and 24.5° C in April 1999, May 2000 and April 2001 respectively. The highest monthly average maximum temperature was 37 ^{0} C, 36.2^{0} C and 35° C respectively during those years. The maximum and minimum temperature recorded in the study area is shown in figure-1.1. The data presented in the figure was obtained from Cashew Research centre at Anakkayam, Malappuram district.

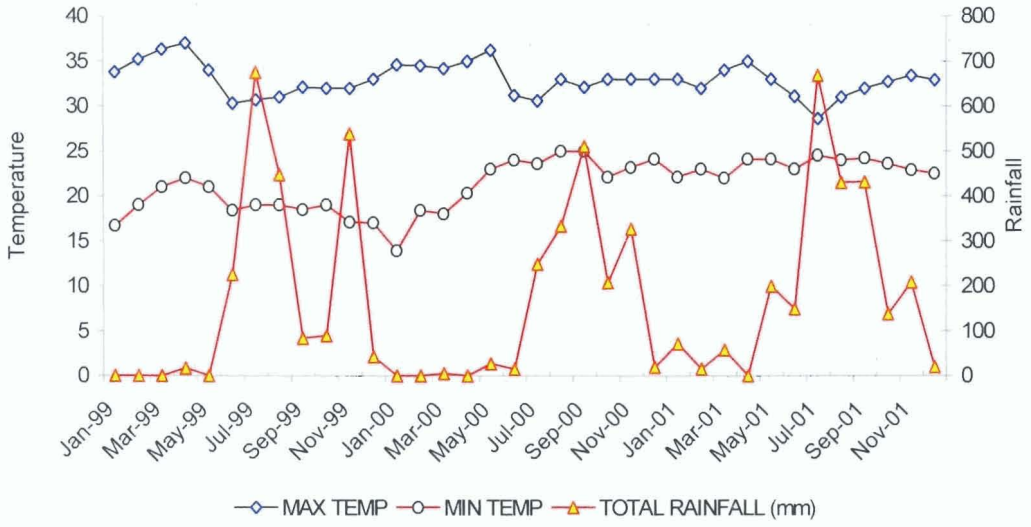


Figure-1.1 Maximum and minimum temperature and total rainfall of the study area from January 1999 to December 2001.

1.4.5 Rainfall

The area receives heavy rain during southwest monsoon, which usually sets in during the middle of June or towards its end and extends up to August or the middle of September. Thereafter north- east monsoon starts and continues up to November. The highest rainfall recorded in June 1999 was 675.3 mm, 510.1 mm in August 2000, and 669 mm in June

1.5 Study Period

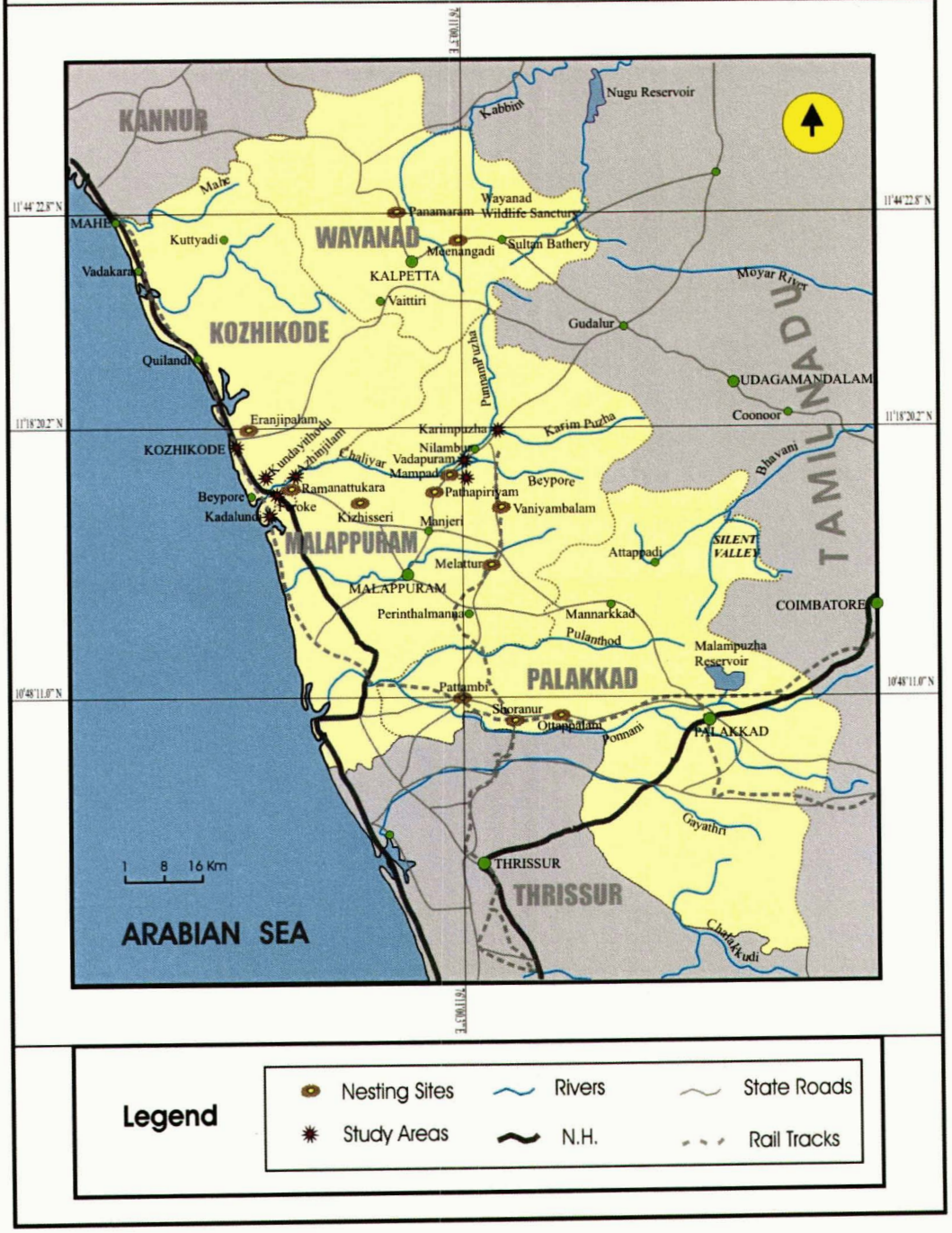
The study was started in May 1999 and continued up to 2003 September. The preliminary work was carried out from May 1999 to December 1999. During this period study of relevant research materials were collected and studied. Identification and testing of field methodology were also carried out. The intensive field work for data collection and literature reference was done from January 2000 to December 2001. Data analysis and thesis work was started in January 2002 and continued up to September 2003.

1.6 Objectives of the study

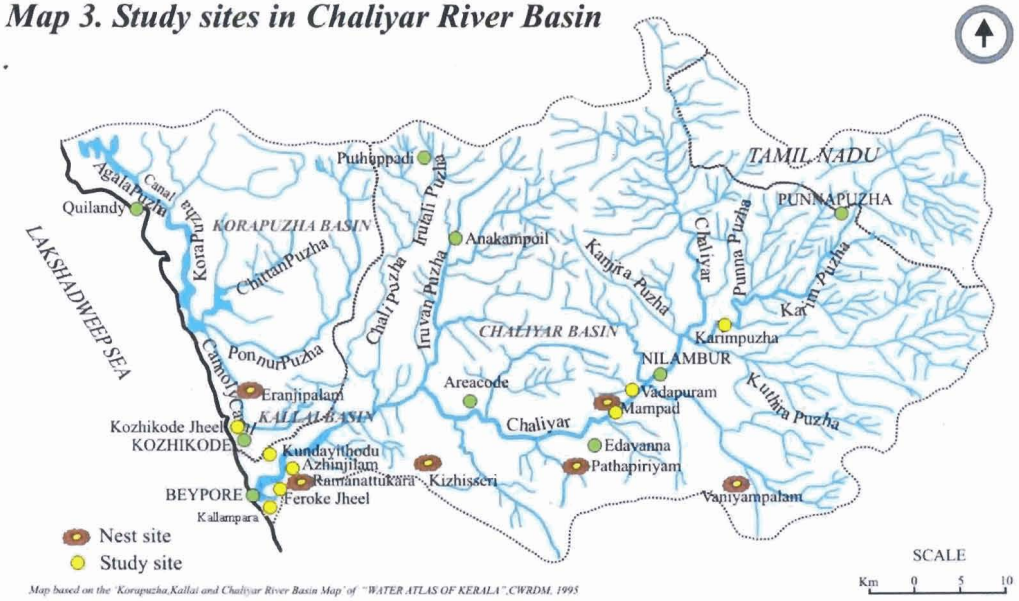
The objectives of the present study are given below:

1. To explore the characteristics of the habitats used by the herons selected for the study
2. To investigate the feeding and breeding biology and certain associations of the herons and
3. To analyze residue levels of certain select pollutants in different bird species.

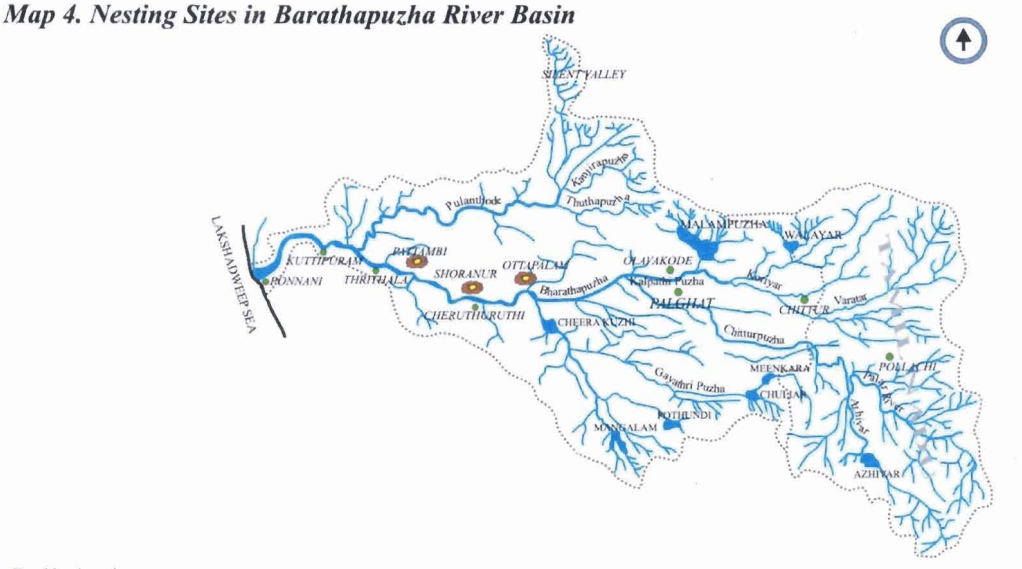
Map 2. Study area



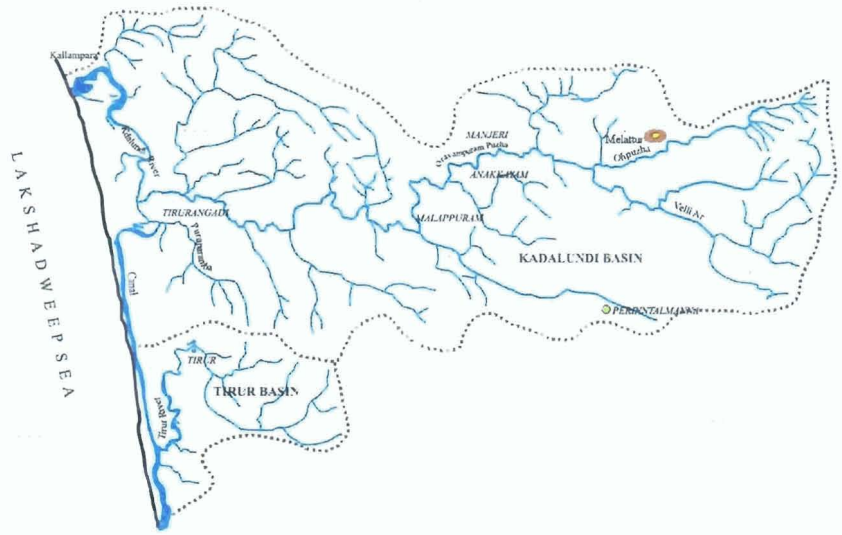
Map 3. Study sites in Chaliyar River Basin



Map 4. Nesting Sites in Barathapuzha River Basin



Map 5. Nesting Site in Kadalundy River Basin



Nesting site

SCALE
Km 5 0 5 10 Km

Map based on the "Kadlundi and Tirur River Basin Map of "WATER ATLAS OF KERALA" CWRDM, 1995

HABITAT CHARACTERIZATION

Seedikkoya .K “Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality ” Thesis. Department of Zoology , Farook College Calicut ,University of Calicut, 2003

Chapter-II

HABITAT CHARACTERIZATION

2.1 INTRODUCTION

Habitat generally refers to the place where an organism normally lives and changes in the habitat can critically influence the survival of an organism. The study of the characteristics of the habitat is to get an idea about the species richness, both of flora and fauna, the niches available to the organisms of that habitat, the reasons for the preference of a particular habitat by a particular organism, resource requirements of the particular species, the presence and absence of preys and predators and a variety of other factors. Learning the habitat is one of the important steps when one studies an organism (Odum 1971). According to Smith (1980) habitat preference in the case of birds may be a matter of imprinting. In land bird species habitat association have been evaluated primarily using foliage measurements, like volume of foliage diversity (MacArthur and MacArthur 1961; Sundaramurthy 1991).

Wetlands are the ideal habitats of herons, which are basically adapted to feed by wading around in shallow water. Some species use dry land usually while many others use it facultatively. Wetlands are themselves diverse and changeable (Finlayson and Moser 1991; Kushlan 2000). Most herons are flexible in their ability to make use of different kinds of shallow aquatic habitats. This flexibility is the main aspect to the success of this group.

2.2 BACKGROUND

Birds are highly dependent upon the available vegetation for nest sites, food, and other natural history requirements. But use of an area is associated more with the structure and cover pattern of the vegetation than the actual plant species that are present (Weller 2001). Some species use uplands periodically whereas birds like Cattle Egrets depend on grasslands both natural and man-made.

The Cattle Egret is well known as a dry land heron, especially in association with grazing animals (Kushlan 2000). They prefer short–grass margins of the damp places especially flood plains facing seasonal flooding and slow drying (Siegfried 1988).

One of the most important artificial habitats for herons is the rice field as some of the Asian herons are highly dependent on this habitat (Subramanya 1990). Rice fields being an integral part of wetland are often viewed as important habitat for some species of waterbirds particularly in regions where the availability of natural marshes has diminished (Fasola and Ruiz 1996). The use of rice fields by Cattle Egrets during winter was heaviest during post harvest ploughing (by tractors), which can result in surges of prey availability (Bredin 1983). Recent studies also indicate that Cattle Egrets are not able to catch prey in deep water (Katzir and Martin 1998).

In freshwater marshes and jheels presence of surface water and abundance of suitable prey items are the main features of importance to herons. Wetlands, which are largely used by herons, can be characterised as being larger, sufficiently watered, having prey abundance, with suitable feeding sites, productive and naturally fluctuating (Kushlan 2000). Stream-edge forest is the preferred feeding site for pond herons. Estuarine wetlands along both temperate and tropical coasts support large number of herons. Salt marshes, mangrove swamps, coastal lagoons, tidal flats and shallow coastal streams are largely used by many species of herons. Fresh water marsh was the most important feeding habitat for Cattle Egrets particularly during the breeding season, and for intermediate Egrets (Wong et al. 2001). Herons often use waste dumps and sewage ponds (Frederick and McGehee 1994).

Although observations on the field characteristics, status, distribution and general ecology of most of the Indian birds are available (Baker 1922-32, 1932-35; Ali and Ripley 1983; Bhupathy 1991; Sivasubramanian 1992), it is felt that more detailed information on the habitat characteristics of most of these birds is essential.

2.3 HABITATS UNDER STUDY

Totally 11 habitats were selected for the present study. The habitats were broadly grouped into seven categories namely Jheels (three types), Rivers (two types), Grass fields (two types), Paddy field, Hillock, Plantation and Solid waste dump. Based on the major differences in the vegetation cover three types of jheels are included in this chapter. They were Azhinjilam Jheel, Calicut Jheel and Feroke Jheel. The two rivers included in the present study were Karimpuzha river in Malappuram district and Kadalundy River extension at Kallampara in Kozhikode district. The grassfields selected for the present study were of two types- grassfields in dry area and grass fields in wet area, which were named as Dry Grass fields, and Wet Grass fields respectively. The remaining four habitats were named as Paddy field, Hillock Plantation and Waste dump.

Of these 11 habitats, data were collected on the composition of vegetation from eight major habitats only. The remaining habitats namely Karimpuzha River, dry grassland and waste dump were not subject to vegetation estimation. The river Karimpuzha was flooded from June to November. From December onwards the river bottom gets exposed. Along with the sparse vegetation along the sides also gets exposed. Dry Grass field had laterite soil and scanty vegetation. Solid waste dump was fully covered with solid wastes, and therefore vegetation was totally absent except for a few herbs. Data on aquatic organisms were collected from seven habitats that hold water either throughout the year or partially (paddy field). Data on terrestrial organisms were collected from five major habitats that usually have more vegetation either throughout the year or at least partially (as in dry grassland).

2.3.1 JHEELS

Jheels are the marshy areas covered with weeds and other types of vegetations, which remains fully waterlogged throughout the year except during the summer season. They have different composition of vegetation. It is known that in general the chemical and physical quality of water varies with the nature of the jheels. The water depth, which influences the association of bird species with jheels, also varies seasonally. The

terrestrial and aquatic organisms in jheels are mainly dependent on the availability of both terrestrial and aquatic macrophytes, which in turn influences the distribution of birds. The distribution of some of the aquatic organisms on the other hand is mainly determined by the distribution of some specific vegetation types. Similar to other habitats the abiotic factors such as temperature, wind, rainfall, humidity and salinity of the water also control the distribution of aquatic organisms. The combined effects of both biotic and abiotic factors shape the overall ecological makeup and species composition of a Jheel. The following three types of jheels were included in the present study.

2.3.1.1 Azhinjilam Jheel

This wetland is situated at Azhinjilam (Plate 2a), falling in the northern border of Malappuram district, 11° 11′ 55.8″ N, 075° 52′ 04.5″ E, half a kilometer away from the river Chaliyar on its south bank and about 15 km by road from Calicut on the Calicut-Karad route. The area of the wetland is about 30 hectares. It remains fully waterlogged from June to November. During South West monsoon, the whole area gets flooded. The excess water is drained to the nearby Chaliyar through a rivulet of about 1.5km. The jheel has maximum depth during the monsoon and minimum during summer. The Azhinjilam jheel was formed nearly a hundred years ago due to removal of topsoil from the paddy fields for the tile factories operating at Feroke. Before that this area was a plain terrain with rice as the major crop and is an example of man made wetland inhabited by large number of aquatic birds. Luxuriant cluster of Pandanus odarissimum around 5 m high grows towards the center of the jheel. Around this clusters, there are four deep-water patches almost 1.5-2m deep. These depressions have water even at the close of summer when all other areas of the jheel is dried.

2.3.1.2 Calicut Jheel

The second site selected for the present study was a recently abandoned paddy field at Thondayad falling in the eastern border of Kozhikode district, 11°15′32.8″N, 075°47′22.4″ E, about 2 km from Arayidathupalam River and along the northern side of the Mavoor – Medical College route. As the core area of Azhinjilam jheel this area was

also a paddy field earlier but is now an abandoned patch of land covered with a variety of aquatic macrophytes. During Southwest monsoon the entire area gets fully waterlogged and much of this water remains up to December. From this jheel water drains in to the Arayidathupalam River through a sluice located towards the southeast. This jheel holds water up to December and thereafter the water depth gets reduced slowly to reach the minimum level by the end of February or at the beginning of March. The water depth was minimum from March to May.

2.3.1.3 Feroke Jheel

The third habitat under study is another wetland (Plate 2b) at Feroke town falling in the southern border of Kozhikode district, 11° 10′ 52.9″ N, 075° 50′ 48.5″ E, and about 3 km away from the river Chaliyar on its southern bank and about 11 km by road from Kozhikode on the Kozhikode – Manjeri route. The jheel has maximum water depth during monsoon and minimum during summer.

Feroke town was famous for tile industry for more than a century the topsoil from most of the paddy fields in the suburbs of this area was removed and used in tile factories for manufacturing roofing and flooring tiles and bricks. Consequently a lot of the paddy fields in due course were converted to jheels and lost to paddy cultivation. The Jheel holds water throughout the years except during April and May.

2.3.2 RIVERS

Of the two rivers selected for the study, one is exclusively of fresh water in the Chaliyar river basin (Map-3) and flow through the Karimpuzha village located 5 km north of Nilambur town nearby Nilambur-Ooty road. The other one is estuarine having connection with intertidal area at Kallampara, located at the border of Kadalundy panchayath and Feroke Panchayath. These two rivers were named as Karimpuzha and Kadalundy rivers respectively.

2.3.2.1 Karimpuzha River

It is one of the westward flowing river systems in the Chaliyar river basin 11° 18′ 20.2″ N, 076° 15′ 17.8″ E. It originates from the Kundha hills and drains through the steep western slopes of the Nilgiri hills (Nilambur, Mancheeri, Edakode and New Amarambalam) with a series of cascades and falls. Of the other three major tributaries (Chaliyar puzha, Punna puzha, and Pallisseri puzha) of the Chaliyar river (Map-3) Karimpuzha is the main water source. Maximum water depth is seen during monsoon and minimum during summer.

This river overflows during the months of heavy monsoon. The river here is an open water body having scanty vegetation (Plate 2c) at its banks in all seasons except during heavy monsoon. During monsoon it gets fully flooded. The vegetation in the banks gradually gets exposed September onwards. Maximum area is exposed during summer, especially during March- April. The northern side of the river is bounded by the teak forests of the Kerala Forest Research Institute (KFRI) substation at Karimpuzha. The southern side is also covered by natural vegetation.

2.3.2.2 Kadalundy (Kallampara) River

Kallampara river (11° 09′ 25.5″ N, 075° 51′ 02.0″ E, Plate 3a,b) is a distributary of Beypore River, the estuarine portion of the river Chaliyar, which joins with Arabian Sea. The western side of the river is an estuarine extension of the Chaliyar River. This area is subjected to regular tidal flux of water depending on the lunar cycle. It is located at the border of Kadalundy panchayath and Feroke Panchayath. The river here is extensively used for retting coconut husk. The riverbed gets exposed during the low tide and serves as an ideal habitat for waders, egrets and herons. The area under study extends up to ten hectares and is rich in algae such as *Enteromorpha sp.*

2.3.3 VADAPURAM GRASS FIELD (WET GRASSFIELD)

Vadapuram grassfield (11° 15′ 21.4″ N, 076° 11′ 58.0″ E) was primarily rice fields that in due course were abandoned, and gradually got transformed into wet grassfields. Since

they were abandoned and cultivation was stopped for several years the entire area is overgrown by a variety of grass and other herbaceous vegetations holding water throughout the year.

This habitat is located at a place called Vadapuram 3 Km away from Mampad. the nearest town in Malappuram district. The area, extended over 10 hectares, is bordered on its western margin by a rubber plantation. A streamlet flows between the rubber plantation and the western margins of this grass field. Through the eastern side passes the Nilambur- Manjeri main road. The Vadapuram River, a tributary of Chaliyar, and the Rubber plantations, demarcates the north and south border of this area respectively.

During monsoon the river Chaliyar overflows and the surplus water inundates the entire grassland. Consequently, the streamlet flowing at the side and the whole of this grass field get flooded with water containing a variety of fishes and other aquatic organisms. The small puddles also get filled with water and other aquatic organisms. Since this habitat is fringed with streamlets and also has pools and puddles it is rich in aquatic organisms at least up to January or February. Thereafter the water holding pools and puddles along with the streamlets gets dried up. But the field still remains moist and accommodates a variety of grasses and other terrestrial organisms even in summer.

2.3.4 PADDY FIELD

The paddy field habitat selected for the present study (11° 14′ 23.5″ N, 076° 11′ 46.8″ E), was situated near Mampad College Malappuram district. The area under study provides a variety of niches for birds. A stretch of paddy field extending up to ten hectares and skirted by Cashew plantation at its northern boundary was selected for the present study. A tarred road connecting Mampad town and Pulikkalody, two small places lying at a distance of 2.5 Km apart, separated the paddy field from the cashew hillock. A thick coconut plantation separated the paddy field at its southern boundary. Rubber plantations cover the western boarder of the paddy field whereas the eastern side is lined by a grassy meadow intermixed with bushes. A streamlet flows through the eastern side of the grassy area. Two small pools, one on the eastern side, and the other at the western side. were

also present. The paddy field selected for the present study had paddy cultivation twice in a year. The first crop is raised from June and was harvested in late September or early October. The second crop is planted in October and harvested during early February or late February. Thereafter the area remains fallow till the next monsoon.

2.3.5 HILLOCK

A small hillock lying continuous with a Rubber Estate and covered with grasses, shrubs and trees was selected at Pongallur (11° 14′ 01.1″ N, 076° 10′ 20.0″), a small village pocket in Mampad Panchayath, about 2 km South of the Mampad town, and Malappuram district. This covers an area of 5 hectares, and is used by locals for grazing cattle from October to January during which there is luxuriant growth of vegetation. Thereafter the vegetation in the area gradually dries up.

2.3.6 PLANTATIONS (RUBBER ESTATE)

About ten hactares of Rubber plantation located towards the eastern side of the hillock at Pongallur (11° 14′ 06.1″ N, 076° 10′ 23.9″ E) is selected for the present study. It is covered with sparse vegetation and is occasionally frequented by the grazing cattle. Though it is not an ideal habitat for wetland birds, occasionally this habitat is used by cattle egrets in association with grazing cattle. A tarred road connecting the Nilambur-Manjeri road demarcates the eastern boundary. A portion of the same estate extends towards the north. Adjacent to the estate a few houses are situated. A coconut plantation separates the southern boundary of the rubber estate.

2.3.7 GRASSES IN DRY AREA (DRY GRASSFIELD)

These are patches of unirrigated, uncultivated patches of dry land distributed in the suburbs of the hillock areas. They are open and get wet only during monsoon season. The area is covered mostly by laterite gravels and hold scarce grasses and herbs from July to the next January. This habitat, though not normally frequented by wetland birds, is occasionally utilised by the Cattle Egrets in the presence of cattle. The area under study

(11° 14′ 16.8″ N, 076° 11′ 47.2″ E) is located near Mampad College towards its western side and 2.5 km away from Mampad town. The paddy fields and coconut plantations demarcate the western boundary of this habitat. On its eastern side lies the college compound wall and adjacent Rubber estate. Towards the south lie a few houses and extensions of paddy fields while a few houses and paddy fields demarcate the northern boundary.

2.3.8 WASTE DUMP

The exact location of the study area is at Njaliyanparambu (11°12′ 01.7″ N, 075° 48′ 59.8″ E), Kundayithode that is being used as a waste-dumping site by the Kozhikode municipal Corporation. The study site is about 15 hectares in the southern side direction of Kozhikode City, 8Km by road from Kozhikode railway station and 6 km by road from Farook College, the Research Centre with which the present study is attached. This waste dumping yard was formed in the last five decades or more as a result of the solid waste deposition from Kozhikode Chicken stalls, fish market, vegetable market, hotels, stationery shops and so on. This area is under the strict control of the Corporation and entry is restricted.

The area is waterlogged from June to September. During southwest monsoon, the area gets inundated and the whole area gets slushy. The stringent smell of putrefying corporation waste is intolerable from June to September. The solid waste is deposited at various locations in the yard. After depositing a large quantity of waste in a particular slot, it is fully covered with soil. The sequence of deposition goes on in cycles. After one or two months all the area gets covered by recent deposits and the cycles continues.

2.4 OBJECTIVES

The main objectives of the present study are:

1. To analyse the composition of flora and fauna of different habitats which determines the distribution of the birds under study,

2. To study the seasonal abundance of the birds based on habitat characteristics, and

3. To investigate the reasons for the congregation of certain species in wholly man-made habitats such as solid waste dump.

2.5 METHODOLOGY

2.5.1 HABITAT

Habitats of the study area were classified on the basis of dominant plant community and water regime. To assess the habitat characteristics, a monthly survey was conducted. The habitat quantification was made by the quadrate charting method (Ramachandran and Vijayan 1992). The quadrate (0.5 x 0.5m) laid at random was divided into 50 columns by means of strings and all the plants in each column was identified and quantified. Water depth was also measured at each sampling site. Related plant species, which occur in a quadrate, were grouped. Thus percentage cover of vegetation in each habitat was obtained for all sampled quadrates. The trees and shrubs were counted by laying down quadrates of the size 10 x 10m and 5 x 5m respectively at random in several points of the study area. Plants having diameter more than 20 cm GBH were included as trees. Those above 1cm and below 20cm GBH were included under shrubs. All plants having diameter less than 1cm were included under herbs. Plant species were identified from the Division of Taxonomy, Department of Botany, University of Calicut, Kerala.

Totally 11 habitats are discussed in this chapter. Seven of these habitats, namely Azhinjilam jheel, Feroke jheel, Calicut Jheel, Karimpuzha river, Kadalundy river, Wet Grassfield, and Paddy field were mainly aquatic and partly terrestrial. Accordingly, aquatic organisms were sampled from all of these 7 areas, which hold water at least in some seasons of the year. In addition, terrestrial insect samples were also collected from Azhinjilam, paddy field and wet grass field, as they possess considerable portion of vegetation. The remaining 4 habitats namely, plantation, hillock, dry grassfield, and waste dump supported terrestrial organisms. In these 4 habitats, insects and other

terrestrial prey organisms were sampled only from 2 habitats namely dry grassfield and hillock, as they possess such vegetation.

Waste dump, an artificial terrestrial habitat, was discussed separately because the prey organisms were the maggots and adults of Muscids and Calliphorids that lived on the decaying municipal wastes.

2.5.2 AQUATIC ORGANISMS

The aquatic organisms were collected by sweeping the water bodies 25 times randomly in each location through the "D" frame nylon cloth net having a diameter of 0.5 m (Saksena and Kausik 1994). After each sweep the net was washed with water in white enameled trays. The aquatic organisms thus collected were sorted out groupwise, preserved in 90% alcohol and identified under simple microscope in the laboratory. Out of 11 habitats, data on aquatic organisms was collected only from six major habitats. Aquatic insects and fishes were identified following Elzinga (1978) and Talwar and Jhingran (1991) respectively.

2.5.3 MAGGOTS

The data on the maggots of the houseflies and Calliphorids and the percentage composition of wastes were collected by laying quadrates of 1x 1m size randomly twice in a month at different locations on different types of decaying substances in the study site. Quadrates were laid for quantifying the maggots of houseflies and Calliphorids separately on different types of solid wastes. Wastes were classified into five types namely, chicken parts, hotel wastes, vegetables, fish wastes and miscellaneous. The percentage of maggots of houseflies and Calliphorids were quantified separately on separate quadrates of these solid wastes having only one of these maggot species. Counts of adult houseflies were also made by the same method that was used for counting maggots from a few nearby houses in the vicinity of the study site. Apart from this, the quantity of Calliphorids developing from 500gm of decaying meat, fish parts and chicken

parts were also quantified. Maggots and adult flies were identified following Nayar et al. (1976).

2.5.4 BIRDS

Birds were counted regularly at each site by spot map method formulated by the International Bird Census Committee (1970). Census was performed within two hours after the sunrise, following standard methods (Dickson 1979; Cody 1968 and Subramanya et al. 1988) by walking along a fixed route within each study area. Spot mapping was also supplemented by flushing birds from the standing crops. This method was followed to count the individuals, which had the habit of lurking inside the cover of Standing crop or feeding among the bases of standing crop. Birds flying overhead were not included in the census. Birds were identified following Ali (1979).

Four censuses were conducted in a month in the morning hours (0600-0900). On rainy and heavy misty mornings conducting census was avoided. Rest of the day was spent recording data on the food habits and general ecological observations on the three species of birds.

Of 11 habitats, comparative abundance of three bird species under study and their monthly percentage composition were pooled under 8 major habitats by clubbing the 3 types of jheels (Azhinjilam, Calicut and Feroke) into one unit and 2 types of grassfields (Wet and Dry) into another single unit. The 8 major habitats so studied were paddy field, Grassfield, Jheel, Riverine (Karimpuzha), Hillock, Plantation, Kadalundy river, and waste dump.

2.6 RESULTS

2.6.1 ABUNDANCE

2.6.2 BIRDS

Comparative abundance of three bird species under study (Table-2.1) and their monthly percentage composition are shown in Appendix 2.1.

2.6.2.1 Pond Heron

The habitatwise comparative abundance of the Pond heron showed that they prefer paddy fields, Grass fields, Jheels, Riverine (Karimpuzha), and estuarine (Kadalundy) habitats. They visit waste dumps very rarely. They were not seen in the hillock and plantations. They have highest abundance in jheels compared to other habitats. Numerically 52.3% of all the birds in the habitat are formed of Pond Herons.

2.6.2.2 Little Egret

Out of 8 habitats studied, Little Egret frequents five habitats. Similar to the Pond Herons Little Egret also does not use hillock, plantation and waste dump. Among the various habitats they are most abundant (52.9%) in Kadalundy (estuarine) habitat.

2.6.2.3 Cattle Egret

Among the 8 habitats analysed for abundance, Cattle Egrets frequent the seven habitats exception being Kadalundy (estuarine) area. Among the herons Cattle Egrets are more abundant in grassfields (58.9%) and Paddy fields (58.8%) respectively. Their abundance is maximum in waste dump forming 99.1% of the total birds (herons) seen in that area. Among the three species of birds under study, Cattle Egret is seen in the highest density in the waste dump. They are the only heron species, which makes use of hillocks and plantations.

Table-2.1. Comparative abundance of the three species of birds in different habitats

Bird Species	HABITAT								Total
	Paddy	Grass field	Jheel	Riverine	Hillock	Plantation	Kadalundi Estuary	Waste dump	
	%	%	%	%	%	%	%	%	%
Cattle Egret	58.83	58.93	29.88	31.13	100.00	100.00	.00	99.15	59.08
Little Egret	12.18	3.29	17.79	27.63	.00	.00	52.94	.00	12.03
Pond Heron	28.99	37.78	52.33	41.25	.00	.00	47.06	.85	28.89
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

2.6.3 OTHER ORGANISMS

2.6.3.1 Terrestrial Arthropods

Monthly abundance of insects (Figure-2.1) were analysed only in Azhinjilam jheel, Dry grassfield, Paddy field, Hillock and wet grassfield as these habitats had enough vegetation. In all these habitats observed, the number of insects increases from August onwards reaching at its maximum in October. Thereafter the number gradually gets decreased to reach its minimum in April. Altogether 7492 terrestrial arthropods were collected in the present study (Appendix-2.2). The areawise details of insects are given below under the result portion of each habitat.

2.6.3.2 Aquatic Organisms

Aquatic organisms in different habitats of the study area are given in Appendix-2.3. Aquatic organisms were collected from Azhinjilam Jheel (1593 number), Calicut jheel (1581 number), Feroke jheel (1947 number), Kadalundy river (1122 number), Karimpuzha river (1335 number) Vadapuram grass field or wet grassfield (1153 number) and paddy field (1149 number) as they had water most of the season. Altogether 9880 organisms were collected from these six habitats (Appendix-2.3). Totally 60 different types of aquatic organisms including 27 species of fishes were collected from the entire study area. The areaways details of aquatic organisms are given under the results of each habitat. Altogether 60 taxonomic groups of organisms were collected from the entire aquatic habitats (Appendix-2.5).

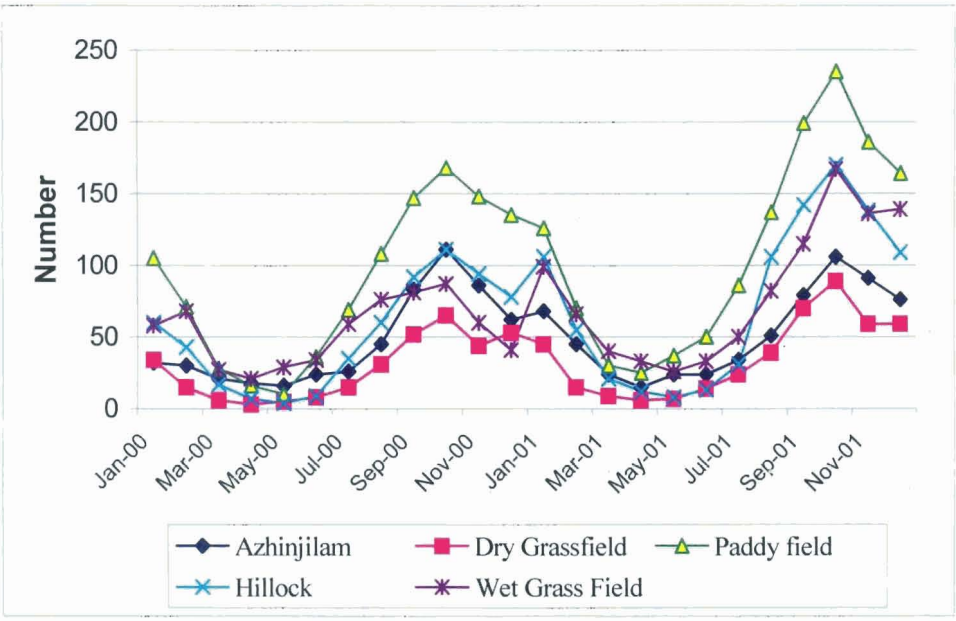


Figure-2.1 Monthly abundance of insects in different habitats

2.6.4 HABITATS

2.6.4.1 Azhinjilam Jheel

2.6.4.1.1 Vegetation

Data on species and their composition in various types of vegetations in each habitat were analysed. The vegetation of Azhinjilam mainly includes *Salvinia molusta*, *Oryza* sp., *Cynodon dactylon*, *Hydrilla verticillata*, *Nymphoides hydrophylla* and *Nymphaea stellata* (Appendix-2.6). The species on the bank included *Desmodium triflorum*, *Heteropogon contortus, Ischaemum sp. Ludwigia adscendens, Polygonum glabrum, Mimosa pudica and Kyllinga sp.* Dominant plant species in Azhinjilam jheel is shown in Figure-2.2.

As mentioned earlier there is a cluster of *Pandanus odarissimum* almost 5 metres high at the centre of the jheel that is surrounded by four deep water of depth 1.5-2 m. These deep areas contain water even at the close of summer when all other areas of the jheel gets dried up.

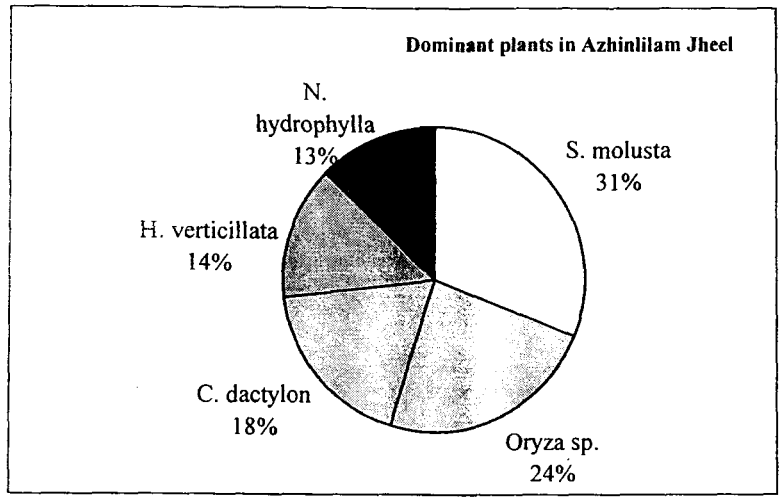


Figure-2.2 Dominant plant species in Azhinjilam Jheel

2.6.4.1.2 Aquatic organisms

Totally 1593 aquatic organisms were collected from Azhinjilam jheel (Appendix- 2.3). It included fishes, amphibians, annelids, molluscs, insects, arachnids and crustaceans. Fishes were the most dominant groups in this habitat. The most abundant species was the fish *Macropodus cupanus* (Family Belontiidae), the total number of which were 277 followed by 192 Palaemon Sp (Family Palaemonidae). Of the total 677 *Macropodus cupanus* collected from six aquatic habitats in total, the highest proportion was observed in this habitat. Out of 182 *Aplocheilus lineatus* (Family Aplocheilidae) collected from six habitats 66 numbers were in this habitat. Naiads of dragonflies (181 nos.) and damselflies (82 nos.) were also abundant in this habitat. Major aquatic organisms in Azhinjilam jheel are shown in Figure-2.3. Monthly abundance of aquatic organisms and species richness in different habitats of the present study is given in Table-2.2 and Table-2.3.

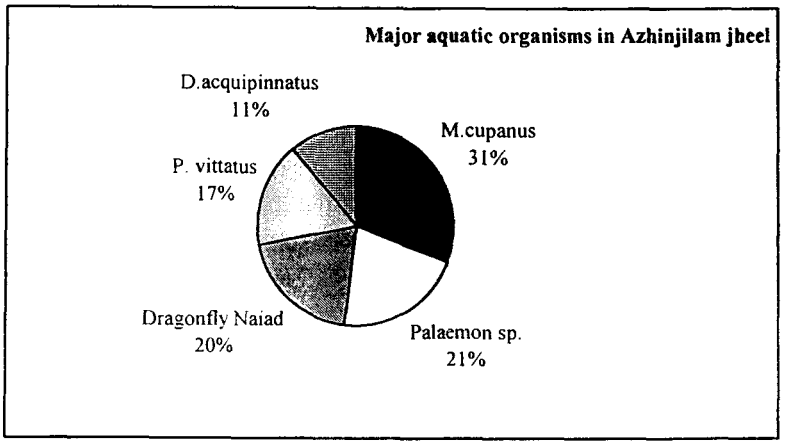


Figure-2.3 Major aquatic organisms in Azhinjilam jheel

Table-2.2 Monthly abundance of aquatic organisms (0.5 m^3) in different locations

Month	Azhinjilam jheel	Calicut Jheel	Feroke Jheel	Kadalundy river	Karimpuzha river	Vadapuram grass field	Grand Total
Jan-00	70	67	57	54	55	60	363
Feb-00	49	105	33	51	48	61	347
Mar-00	56	39	58	52	53	117	375
Apr-00	115	80	70	39	48	70	422
May-00	77	62	35	30	30	24	258
Jun-00	49	14	89	41	71	50	314
Jul-00	45	27	85	53	76	48	334
Aug-00	48	87	69	40	44	28	316
Sep-00	48	86	147	53	54	27	415
Oct-00	36	71	91	43	44	32	317
Nov-00	65	105	103	47	23	29	372
Dec-00	63	66	62	68	47	31	337
Jan-01	63	62	62	62	68	65	382
Feb-01	72	100	35	42	54	46	349
Mar-01	72	50	62	75	67	106	432
Apr-01	107	54	82	33	48	57	381
May-01	62	81	95	33	45	16	332
Jun-01	30	20	90	44	101	55	340
Jul-01	53	33	103	28	97	62	376
Aug-01	90	65	88	31	96	43	413
Sep-01	59	54	174	54	63	34	438
Oct-01	119	71	108	47	25	43	413
Nov-01	73	106	90	41	27	27	364
Dec-01	72	76	59	61	51	22	341
Total	1593	1581	1947	1122	1335	1153	8731

Table-2.3 Monthly variation of species richness of Aquatic organisms in different habitats						
Month	Azhinjilam jheel	Calicut jheel	Feroke Jheel	Kadalundy river	Karimpuzha river	Vadapuram grass field
Jan-00	14	8	15	7	11	7
Feb-00	13	9	9	7	13	6
Mar-00	9	7	5	5	9	9
Apr-00	10	7	6	4	12	7
May-00	12	7	10	8	8	3
Jun-00	15	6	9	6	10	9
Jul-00	11	6	15	5	11	11
Aug-00	15	13	11	5	7	11
Sep-00	12	11	15	4	8	11
Oct-00	13	11	13	4	5	11
Nov-00	12	14	15	9	6	7
Dec-00	13	12	15	5	7	9
Jan-01	11	8	13	7	12	8
Feb-01	13	7	10	8	12	5
Mar-01	10	8	6	7	10	7
Apr-01	10	6	5	6	11	5
May-01	13	7	8	5	11	3
Jun-01	10	6	8	6	13	9
Jul-01	12	6	14	5	15	11
Aug-01	14	8	13	5	7	10
Sep-01	12	9	14	8	8	11
Oct-01	15	13	13	5	5	11
Nov-01	13	14	8	8	6	7
Dec-01	12	11	10	5	11	6
Mean	12.25	8.92	10.83	6.00	9.50	8.08

2.6.4.1.3 Terrestrial arthropods

In Azhinjilam jheel totally 1191 terrestrial arthropods, comprising mainly of insects distributed over 31 families was observed during 2000-2001-study period. Of these Acrididae, the short horned grasshoppers, was represented by 192 numbers and were the most abundant family. The families Cicadellidae and Lestidae were the next most abundant families, the number of which was 131 and 98 respectively (Appendix-2.2). Moths and butterflies (Order Lepidoptera) were seen least in number. The most abundant terrestrial arthropods in Azhinjilam jheel are shown in Figure-2.4.

The mean maximum and mean minimum size of insects in Azinjilam jheel during the entire study period was recorded to be 4.23 cm, of family Libellulidae (Order Odonata)

and 0.50 cm, of family cassididae (Order Coleoptera) respectively (Appendix-2.7). The monthly abundance of the insects was maximum in number in October and minimum in April (Figure-2.1).

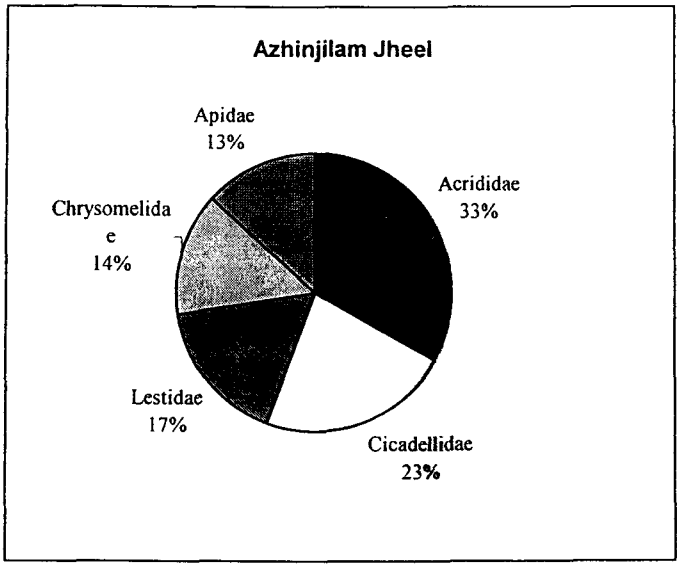


Figure- 2.4 showing the most abundant terrestrial arthropods in Azhinjilam jheel

2.6.4.1.4 Avifauna

In total 17 bird species were recorded during the study period. The common among them were Purple Moorhens, Grey Herons, Bronzewinged Jacanas, White breasted King fishers, Black capped King fishers, Pied King fishers, Median egrets, Purple Herons, Black Drongos, Indian Mynas, Brahminy Kites, Cattle Egrets, Little Egrets and Pond Herons (Appendix-2.8).

2.6.4.1.5 Mammalian fauna

Since the study area falls within highly human habited area where no forest or large natural vegetation is present no large wild mammals are seen. The major mammalian species were livestock species; grazing cattle, buffaloes and goats to a lesser extend. Other mammalian species seen were domesticated ones such as dogs and cats, and rarely wild species such as fox, mongoose, toddy cats, rats, mouse and shrews. No attempt was made to document these species.

2.6.4.2 Calicut Jheel

2.6.4.2.1 Vegetation

During the study 31 species of plants were recorded in the study area. The vegetation mainly includes *Eichhornia crassipes, Salvinia molusta, Ipomea aquatica, Alternanthera philoceroides, Lemna sp., Wedelia trilobata, Sphaeranthus africanus, and Cyperus sp.* etc. (Appendix-2.9). The most abundant vegetation in Calicut jheel is shown in Figure-2.5.

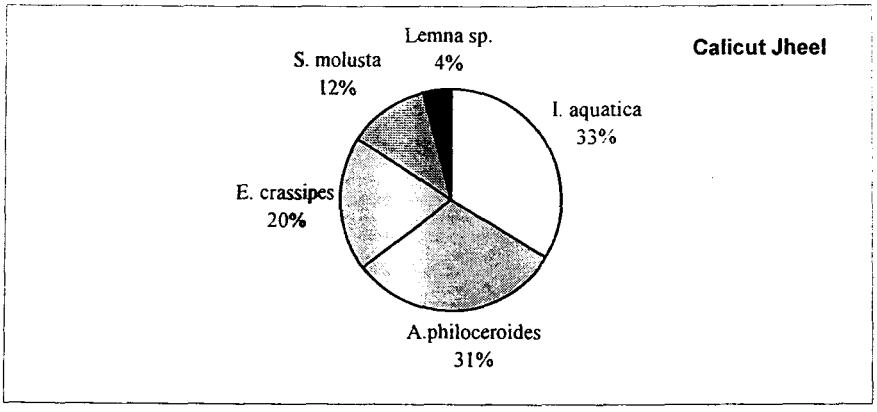


Figure-2.5 showing the most abundant vegetation

2.6.4.2.2 Aquatic organisms

Totally, 1581 organisms were collected from Calicut Jheel during the entire study period. Families of insects represented the most abundant groups. Altogether 395 members of family Belostomatidae (giant water bugs) and 214 members of family Pleiidae (small aquatic beetles) were collected from this area. The least abundant group among insects was family Dytiscidae. Among fishes family Belontidae and species *Macropodus cupanus* represented the most abundant group by 205 numbers. Among the fishes *Oreochromis mossambica* was least abundant. Only one idividual of this species was obtained during the study (Appendix-2.3). The most abundant aquatic organisms in Calicut jheel are shown in Figure-2.6. The mean minimum and mean maximum water depth of this area varied from 20-120 cm in April and June of 2001 and 2002 respectively (Figure-2.7).

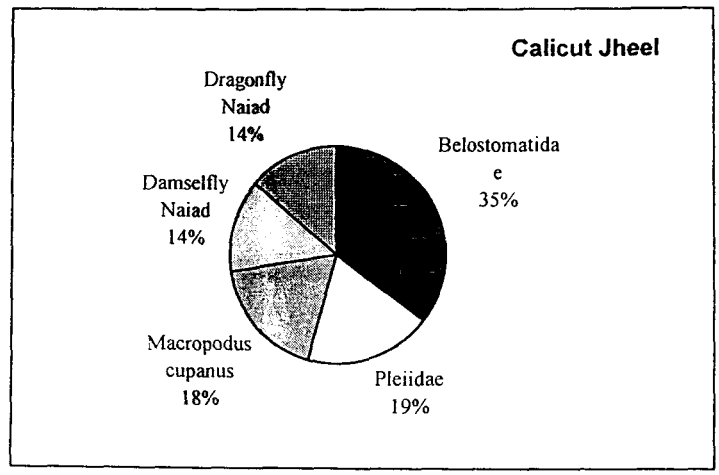


Figure-2.6 showing the most abundant aquatic organisms

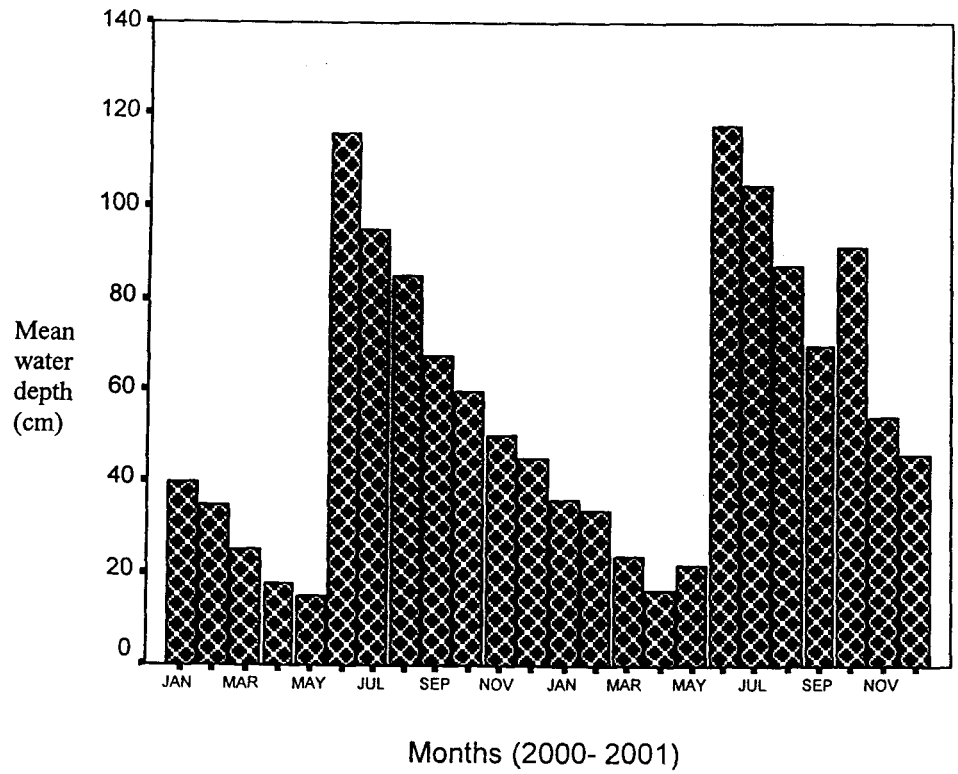


Figure-2.7 showing the mean water depth of Calicut Jheel

The monthly variation of aquatic organisms showed that a maximum of 14 species was observed during the years 2000 and 2001. The lowest number of species observed was 6, seen during June and July of the years 2000 and 2001(Table-2.3).

2.6.4.2.3 Avifauna

The avifauna of the area includes White breasted Kingfishers, Pied Kingfishers. Sandpipers, Cattle Egrets, Little Egrets and Pond Herons (Appendix-2.8). Pond Herons were observed throughout the season but cattle egrets and little egrets were observed only during summer i.e., from March to May, when water becomes shallow.

2.6.4.2.4 Mammalian Fauna

Grazing cows and buffaloes represented the common mammalian fauna. Since this habitat is adjacent to residential areas of Calicut town, dogs and cats were often observed. Wild species such as mongoose and mouse were rarely seen.

2.6.4.3 Feroke Jheel

2.6.4.3.1. Vegetation

This Jheel is covered over by species such as *Ipomea carnia, Hydrilla verticillata, Salvinia molusta, Nymphaea stellata, Oryza sp., Ludwigia adscendens, Nymphoides hydrophylla, Blyxa auberti* and a few other types of minor species (Appendix-2.10). The most abundant vegetation in Feroke jheel is shown in Figure-2.8.

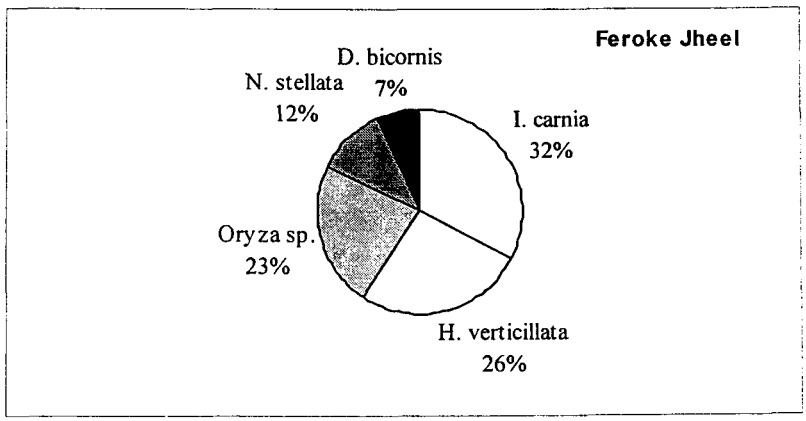


Figure-2.8 showing the most abundant species of vegetation

2.6.4.3.2 Aquatic organisms

Altogether 1947 aquatic organisms were collected during the entire study period (Appendix-2.3). Fishes belonging to the family Cyprinidae represented the most abundant two species. They were 447 *Danio acquipinnatus* and 254 *Puntius vittatus* respectively. Of the six habitats studied (from a total of 11 habitats) for aquatic organisms, only 2 *Anabas sp.* (Family Anabantidae) were collected and it was confined to this locality. Among Arthropods, Crustaceans of family Palaemonidae were abundant and represented by 236 *Palaemon sp.* The only two Dytiscid larvae collected from this aquatic habitat were confined to this locality. Among aquatic insects the naiads of dragonflies and damselflies were present. Their number was represented by 138 and 39 respectively. The most abundant aquatic organisms in Feroke jheel are shown in Figure-2.9.

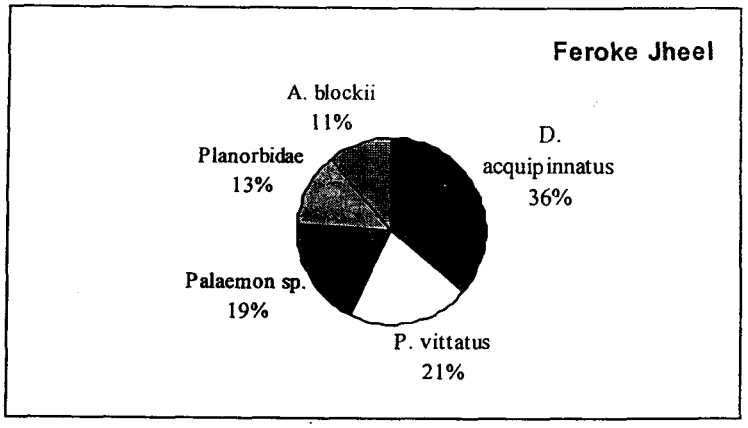


Figure-2.9 showing the most abundant aquatic organisms

The monthly variation of aquatic organisms showed that in the year 2000, the maximum species richness was 15 each during the months of January, July, November and December. In the year 2001 the maximum species abundance recorded were 14 each during the months of July and September. Since this jheel is always inundated with water at different depth and covered by aquatic vegetation, many heron species use this habitat as their feeding sites. The mean minimum and mean maximum water depth of this area varied from below 20 to 120cm. (Figure-2.10).

2.6.4.3.3 Avifauna

The common bird species of the area includes Little Egrets, Cattle Egrets, Pond Herons, Sandpipers, White breasted Kingfishers, and Pied Kingfishers (Appendix-2.8).

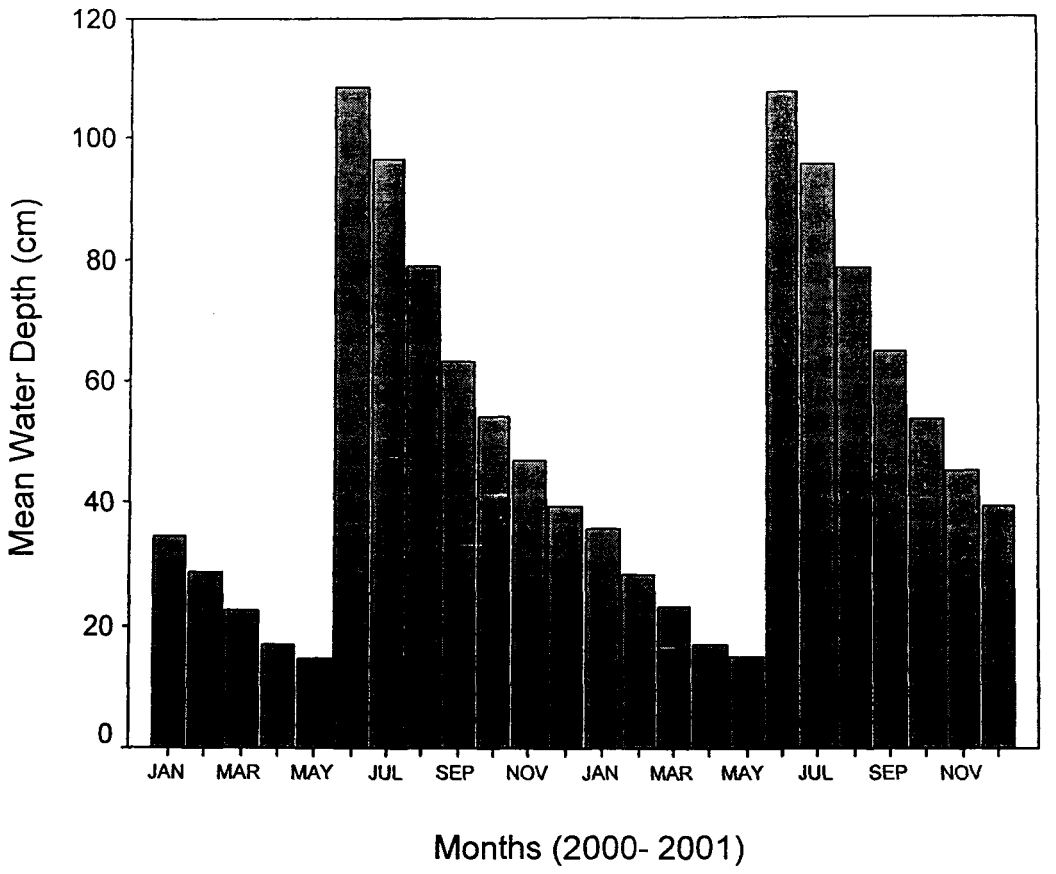


Figure-2.10 showing the mean water depth of Feroke Jheel

2.6.4.3.4 Mammalian fauna

Grazing cattle such as cows and Buffaloes were observed in this habitat. Since this habitat is in the proximity of human dwellings, dogs and cats were very common. Mouse and mongoose were observed very rarely and attempt was made to document them.

2.6.4.4 Rivers

2.6.4.4.1 Karimpuzha River

2.6.4.4.1.1 Vegetation

The herbaceous vegetation at the exposed banks of the river includes *Cyperus sp., Fimbristylis milleaceae, Cynodon dactylon, Polygonium glabrum, Paspalum conjugatum, Paspalum scrobiculatum, Cyrtococcum sp., Eragrostis unioloides, Sphaeranthus africanus, Ludwigia hyssopifolia, Bulbostylis barbatus Ceratopteris thalictroides, Echinochloa colonum, Lindernia ciliata, Blumea oxyodonta,* etc. The shallow bottom areas of the river up to a depth of about 0.5 m contains Spirogyra sp. and it helps concealing a number of aquatic organisms like naiads of dragonfly, naiads of damselfly, hydrometrids and *Palaemon sp.* (Appendix-2.3).

September onwards the bed of the river gets exposed and the shrubs slowly starts appear. The *major shrubs distributed along the banks include the Eupatorium odoratum and Cassia tora, Datura stramonium.*

2.6.4.4.1.2 Aquatic organisms

Totally 1335 organisms were observed distributed in this riverine habitat. Among arthropods, the most abundant species was *Palaemon sp.* (Appendix-2.3). Among fishes all the 16 *Mastacembelus armatus* of family Mastacembelidae collected during the study were from Karimpuzha River only while it was totally absent in all other habitats. All 7 *Xenentedon cancila* of the family Beloniidae collected belonged to Karimpuzha River. Totally 95 *Tetraodon travancoricus* were collected during the study and they all belonged to this habitat (Appendix-2.3). The most abundant aquatic organisms in Karimpuzha river are shown in Figure- 2.11.

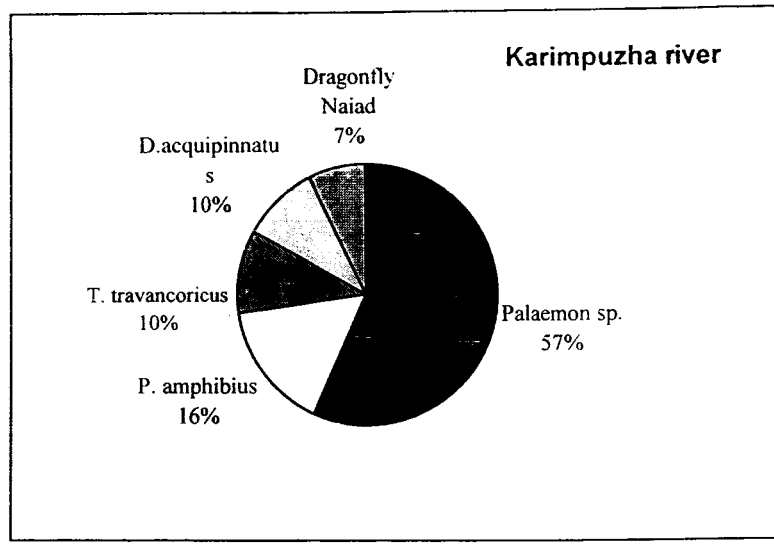


Figure-2.11 showing the most abundant aquatic organisms

The monthly variation of species richness showed that the maximum number of species recorded was 13 and 12 respectively in February and April 2000 respectively while that in 2001 was 15 during July (Table-2.3).

2.6.4.4.1.3 Terrestrial arthropods

Since this habitat is mainly aquatic, arthropods were represented by only very few insects. They were observed among the vegetations scattered around the banks of the river and hence no attempt was made to document them. The major insects collected during some months here included short horned grasshoppers of the family Acrididae, some Lepidopterans like Pyralids, members of the family Apidae, Gryllids and Coleopterans like Chrysomelids and Carabids.

2.6.4.4.1.4 Avifauna

Among birds seen in the habitat the common were Median Egrets, Little Egrets, pond herons, Cattle Egrets, Pied Kingfishers, Small Blue Kingfishers, Sandpipers, white-breasted Kingfishers and Little Cormorants (Appendix-2.8). Among Ardeids under study, Pond Heron was seen highest number in the riverine habitat (41.2%) followed by Cattle Egret (31.0%) and Little Egret (27.6%).

2.6.4.4.1.5 Mammalian Fauna

Primarily grazing cows and goats represented the mammals and occasionally few stray dogs were also observed. Other mammals include mangoose and mouse that were observed along the boundary of the river and the adjacent forest area. Wild animals such as toddy cats and fox were rarely seen.

2.6.4.4.2 Kadalundy River (Kallmpara Estuarine)

2.6.4.4.2.1 Vegetation

The important vegetation of the area includes the alga *Enteromorpha sp.*, *Salvinia molusta, Sphaeranthus indica, Acanthus ilicifolius, Avicennia marina, Connarus monocarpus, Exoccaria agallocha, Derris trifoliata, and Cyperus sp.* (Appendix-2.4). The most abundant species of vegetation in Kadalundy is shown in Figure-2.12.

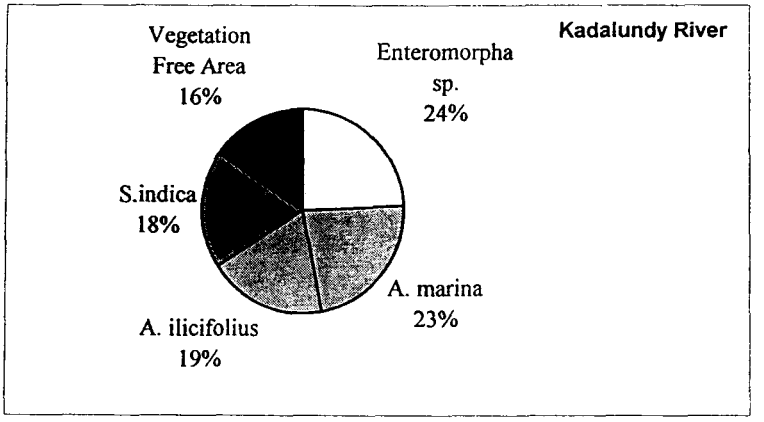


Figure-2.12 showing the most abundant species of vegetation

2.6.4.4.2.2 Aquatic Organisms

Altogether 1122 aquatic organisms were obtained in this habitat during sampling. Among Crustaceans, the *Penaeus sp.* (Family Penaidae) with 376 numbers was exclusively confined to this area and outnumbered the members of the other families of the Kadalundy habitat. The only annelidan, *Nereis sp.* collected from the six aquatic habitats under observation belonged to this habitat. Of 243 *Macrobrachium sp.* collected among

Crustaceans during the study, the whole belonged to this habitat. Of 498 *Aplocheilus blockii* collected among fishes, from the entire six aquatic study areas over a period of 2 years 159 was obtained from this locality. The fish *Eleotris sp.* (Family Eleotridae) was present only in this habitat. The fish *Oreochromis mossambica* was also seen, but only a single individual was obtained in the collection. The major species of aquatic organisms in Kadalundy river is shown in Figure-2.13. Though comparative abundance of certain species was much higher in this area the species richness in this area was lower than other habitats (Table-2.3). Regarding the monthly variation of species richness the maximum number was 9 in November 2000 and 8 in February 2001.

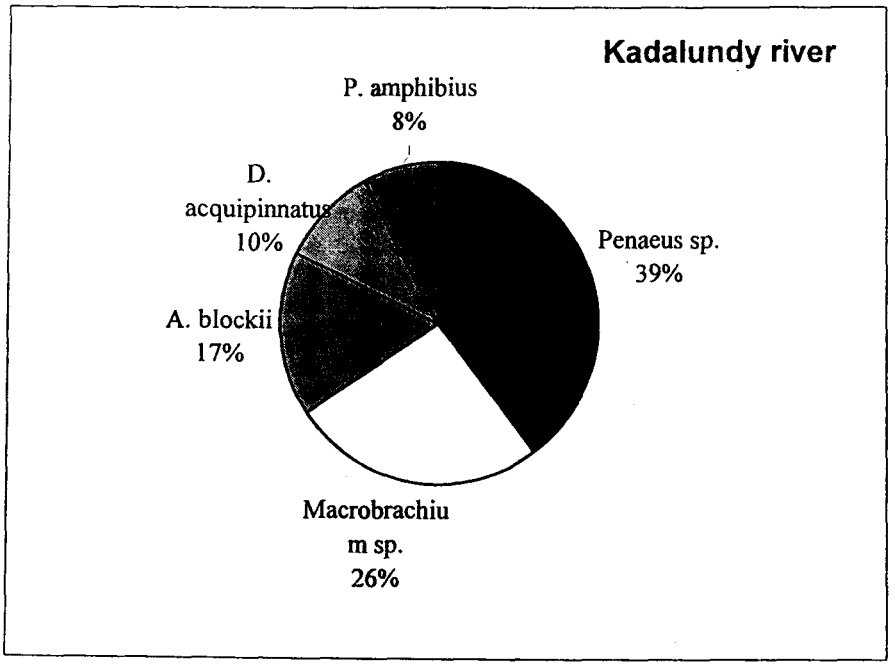


Figure-2.13 showing the most abundant species of aquatic organisms

2.6.4.4.2.3 Avifuna

Grey Herons, Purple Herons, Darters, Little Cormorants, Large egrets, Little Egrets, Pond Herons, Sandpipers, Little ringed Plovers, Brahminy Kites, Black Kites, White breasted King fishers, Black capped King fishers, and Pied King fishers were the commonly seen species of birds here. Little Egret (52.9%) was seen in highest number in this habitat than that of Pond Heron (47 %). Cattle Egret was not seen in this estuarine habitat.

2.6.4.4.2.4 Mammalian fauna

No grazing mammals were noticed here. Since this area is subjected to daily flow and ebb of water it is inaccessible to grazing animals. Few dogs and cats were observed at its margins, as some houses are located very close to this habitat.

2.6.4.4.3 Vadapuram grass field (Wet Grass field)

2.6.4.4.3.1 Vegetation

The important plant species includes mainly grasses such as *Cyrtococcum trigonum, Sporobolus diander, Paspalum conjugatum, Paspalum scrobiculatum, Fimbristylis milliaceae, Kyllinga monocephala, Kyllinga brevifolia, Eragrostis viscosum, Eragrostis unioloides, Digitaria bicornis, Eichhornia crassipes, Monochoria vaginalis* and ischaemum spp. Apart from this other plants like *Mimosa pudica, Desmodium triflorum,* and *Desmodium heterophyllum* were also observed in this locality (Appendix-2.11). The major species of plants in Vadapuram grass field is shown in Figure-2.14.

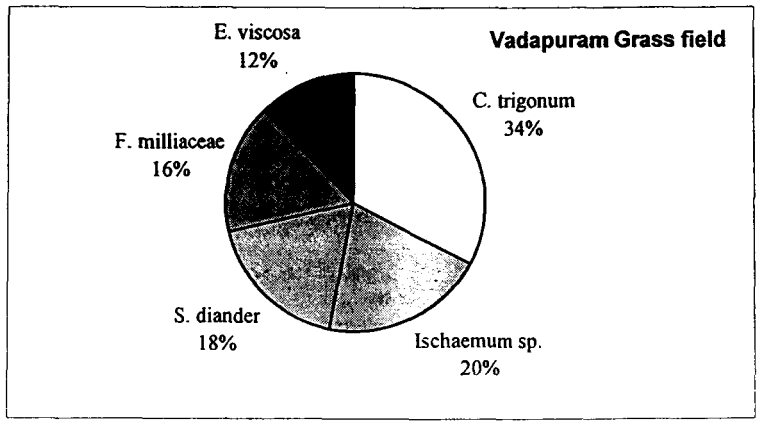


Figure-2.14. The major species of plants in the Vadapuram Grass field

2.6.4.4.3.2 Terrestial arthropods

Totally 1627 arthropods, comprising mainly of insects were collected from this habitat. Family Acrididae dominates in this habitat. Of the five habitats from which the terrestrial insects were collected, maximum (292indviduals) Acridids were collected from this

habitat (Appendix-2.2). Out of the total 331 Tettigoniids collected from the five localities the maximum number, 77 were observed in this habitat. Of 174 Coccinellids collected from the five habitats under study, maximum of 68 belonged to this locality. The common terrestrial arthropods in Vadapuram grassfield are shown in Figure-2.15.

2.6.4.4.3.3 Aquatic organisms

Totally 1153 aquatic organisms distributed over 26 different groups were observed in this habitat (Appendix-2.3). The fish *Danio malabaricus* (acquipinnatus) and *Chela* (Neochela) *dadyburjori* of the family Cyprinidae were the most dominant and least dominant species respectively in this habitat. Compared to other habitats, the fish species *Parluciosoma* (Rasbora) daniconius belonging to the family Cyprinidae was maximum in this habitat and was represented by 45 numbers. Of 47 *Rana spp.* collected throughout the entire study period, 19 individuals were from this area. Among aquatic insects naiads of dragonfly dominated while family Corixidae was least abundant. The abundant aquatic organisms in Vadapuram grassfield are shown in Figure-2.16.

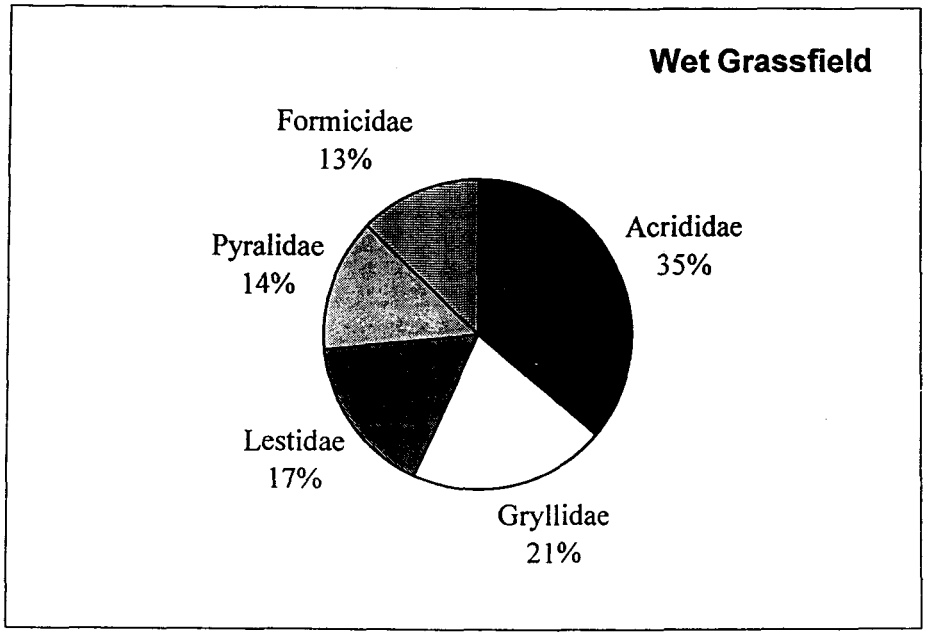


Figure- 2.15. The major terrestrial arthropods in wet Grass field

2.6.4.4.3.4 Avifauna

The birds of this habitat includes Median Egrets, Cattle Egrets, Little Egrets, Pond Herons, Sandpipers, Common Babblers, Indian Mynas, White breasted Kingfishers and Pied Kingfishers and Black Drongos (Appendix-2.8). Cattle Egret was in highest numbers (58.9%) in Grass field than Pond Herons (37.8%) and Little Egrets (3.29 %).

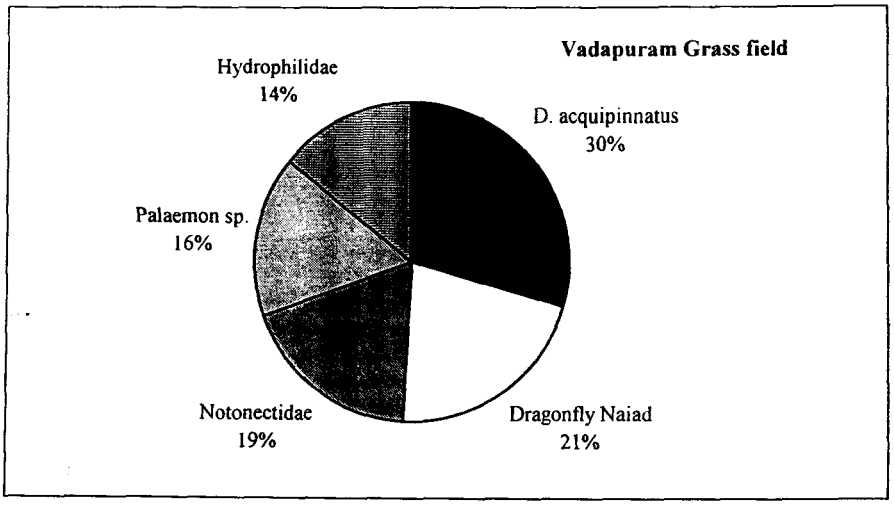


Figure-2.16. The major aquatic organisms in the wet Grass field at Vadapuram

2.6.4.4.3.5 Mammalian fauna

Very often cows and goats were observed grazing in association with Cattle Egrets. Since this area lies very close to human residence cats, mouse and dogs also frequented this habitat. Mongoose was very rarely seen in this habitat.

2.6.4.4.4 Paddy Field

2.6.4.4.4.1 Vegetation

Paddy cultivation was usually carried out after ploughing, puddling, and levelling the land. When the harvest is over, the land is left fallow in dry or inundated conditions before the next season's activity is started. These plots when left uncultivated and inundated are covered by the sprouting stubbles among which *Cyperus sp.* and

Echinochloa sp are common. In puddled fields that were left inundated and uncultivated for months, extensive patch of *Spirogyra Spp.* also developed.

These wetlands were seasonally flooded to approximately 10 cm from June through January. From February through May it was not irrigated and often left fallow. The number and periods of paddy cultivation in a year depends on irrigation facilities. Some farmers planted paddy only during monsoon leaving the land fallow for the remaining season. Such paddy fields are covered with grass and herbaceous vegetation from November to February that it is used by cattle and herons. During cultivation, although fields were mostly covered with paddy, other vegetations including weeds are common growing in the field. Such species include *Echinochloa colonum*, *Ishaemum sp.*, *Eriocaulon quinquangulare*, *Cynodon dactylon* and *Paspalum scrobiculatum* (Appendix-2.12) The common species of plants in paddy field is shown in Figure-2.17.

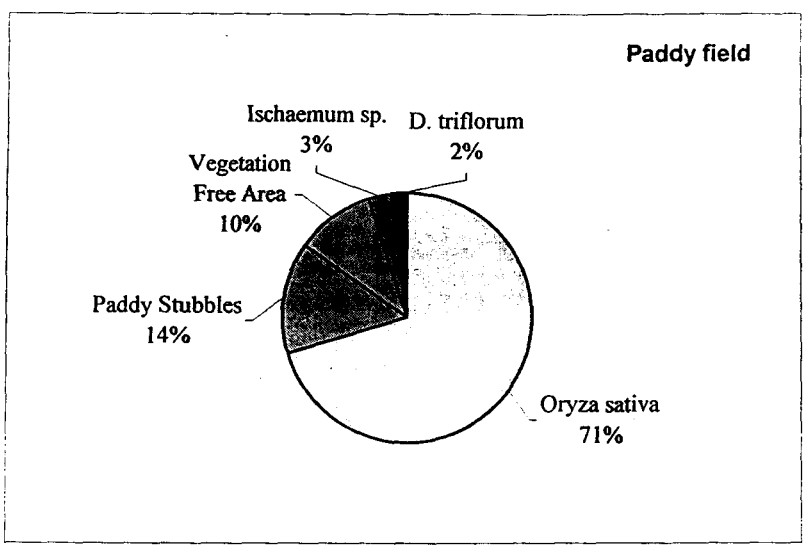


Figure-2.17 showing the most abundant species of vegetation in the Paddy field

2.6.4.4.4.2 Terrestrial arthropods

Totally 2386 arthropods were collected from this habitat. The dominant family was the Acrididae comprising the short horned grasshoppers (Appendix-2.2) and the least abundant families were Arctiidae and Staphylinidae. Only two individuals each of these

families could be found in the collections over the entire study period. Totally 223 Pyraustids were collected and all of them belonged to this habitat. The most abundant arthropods in paddy fields are shown in Figure-2.18.

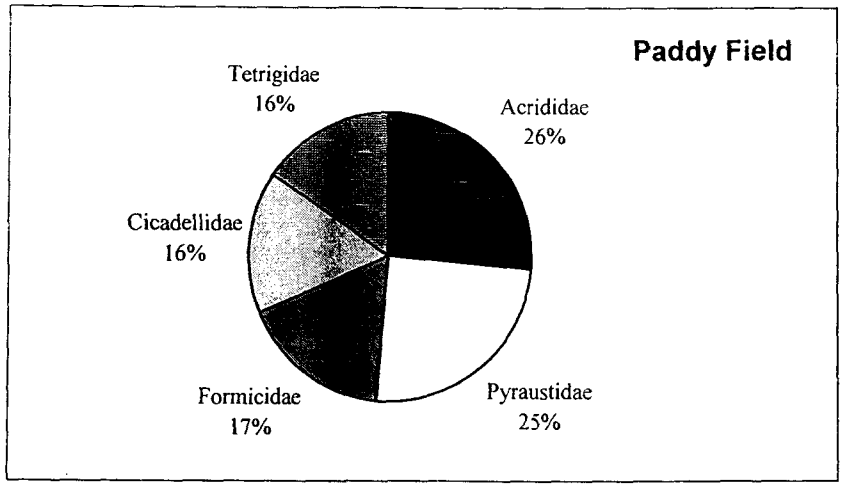


Figure-2.18. The common terrestrial arthropods in the paddy fields

2.6.4.4.4.3 Aquatic organisms

The paddy fields, both cultivated as well as uncultivated, contain a lot of aquatic organisms especially after heavy rains during the monsoon season. During the peak monsoon the river Chaliyar, flood close by, overflows flooding the adjacent streams in the vicinity of the paddy field, which in turn receives lot of water and aquatic fauna along with the inflow of water. Most of the paddy fields in the study areas are cultivated twice in a year. The third crop or summer cultivation known locally as "Puncha" was not raised during the study period because of scarcity of water. However the majority of the paddy fields were water logged up to February until the second crop is harvested. These paddy fields offer a lot of aquatic organisms as prey for the birds especially wading types.

Paddy fields are linked with a nearby river through streamlets and channels that swell during monsoon. The floodwater enriches the paddy field with a variety of organisms. The common fishes and other aquatic organisms seen from paddy field are enlisted in Table-2.4. The aquatic organisms were comparatively more in the months of heavy monsoon when the field gets restocked with organisms lost during dry summer. Thus so

endowed paddy fields both with aquatic as well as terrestrial prey organisms attract a lot of wetland and other birds to this habitat.

Table-2.4. Aquatic organisms in paddy field during June 2000 – January 2001

No	Month	Species	Phylum	*Total /m^2
1	June-September	Mayfly Nymph	Arthropoda	56
2	June-September	Dragonfly Naiad	Arthropoda	62
3	June-September	Damselfly Naiad	Arthropoda	54
4	June-September	Tadpole	Chordata	92
5	June-September	Notonectidae	Arthropoda	24
6	June-September	Gerridae	Arthropoda	6
7	June-September	*Puntius vittatus*	Chordata	48
8	June-September	*Macropodus cupanus*	Chordata	104
9	June-September	*Aplocheilus lineatus*	Chordata	43
10	June-September	*Danio acquipinnatus*	Chordata	24
11	June-September	*Chela (Neochela) dadyburjori*	Chordata	35
12	June-September	*Megascolex* sp.	Annelida	42
13	June-September	Pila globosa	Mollusca	68
14	June-September	Unidentified Crab	Mollusca	36
15	June -September	*Parluciosoma daniconius*	Chordata	24
16	October -January	Mayfly Nymph	Arthropoda	28
17	October- January	Dragonfly Naiad	Arthropoda	43
18	October-January	Damselfly Naiad	Arthropoda	35
19	October- January	Tadpole	Chordata	12
20	October-January	Notonectidae	Arthropoda	72
21	October-January	Gerridae	Arthropoda	8
22	October-January	*Puntius vittatus*	Chordata	22
23	October-January	*Macropodus cupanus*	Chordata	45
24	October-January	*Prluciosoma daniconius*	Chordata	8

25	October-January	*Aplocheilus lineatus*	Chordata	22
26	October-January	*Danio acquipinnatus*	Chordata	12
27	October-January	*Megascolex* sp.	Annelida	32
28	October-January	*Pila globosa*	Mollusca	43
29	October-January	Unidentified Crab	Mollusca	21
30	October-January	*Chela (Neochela) dadyburjori*	Chordata	28
Total				1149
*Note: The water depth in paddy fields are very low and hence expressed in m^2				

2.6.4.4.4.4 Avifauna

Dry inundated and uncultivated plots were used by Cattle Egrets, larks, Red wattled lapwing and pipits. Occasionally Pond Herons were also observed foraging in dry plots covered with paddy stubbles. After the dry fields get inundated Little Egrets, Pond Herons and Sandpipers were observed frequenting the habitats. The inundated paddy fields when ploughed attracted numerous Pond herons, Little Egrets, Cattle Egrets, Crows, Mynas, Brahminy Kites and Common Snipes. Insectivorous birds such as Paddy field Warbler and Indian Wren Warbler were observed after the crop passed the mid tillering stage. The Little Egrets disappeared from the field after late tillering stage, but cattle egrets still foraged in areas with standing crops that are in flowering, grain-filling and maturing stage. Moving around dense paddy plants they flushed out insects and picked them up. The stubbles of the harvested paddy left inundated sprout and continue to attract Cattle egrets, Little Egrets and Pond herons until the next cultivation is started. Cattle Egret was seen in highest numbers (58.8%) in the paddy field than Pond Herons (29.0%) and Little Egrets (12.2%).

2.6.4.4.4.5 Mammalian fauna

The cows and goats were commonly observed grazing in the area. The grazing was intense in paddy fields that raise only one crop a year. Such paddy fields though remain fallow from October to May, have a luxuriant growth of vegetation from October to

January following the northeast monsoon. This attracted more cows and goats to this habitat. Since these paddy fields were very close to human habitats, cats and dogs were also very often observed. Occasionally field mice and mongoose were also seen.

2.6.4.4.5 Hillock

2.6.4.4.5.1 Vegetation

The vegetation of this habitat includes trees such as *Anacardium occidentale and Terminalia paniculata; shrubs like Clerodendrum viscosum and Lantana* camara; and herbs like *Desmodium triflorum, Heteropogon contortus, Eragrostis unioloides and Hyptis suaveolens* (Appendix-2.13). The most abundant species of vegetation in hillock is shown in Figure-2.19.

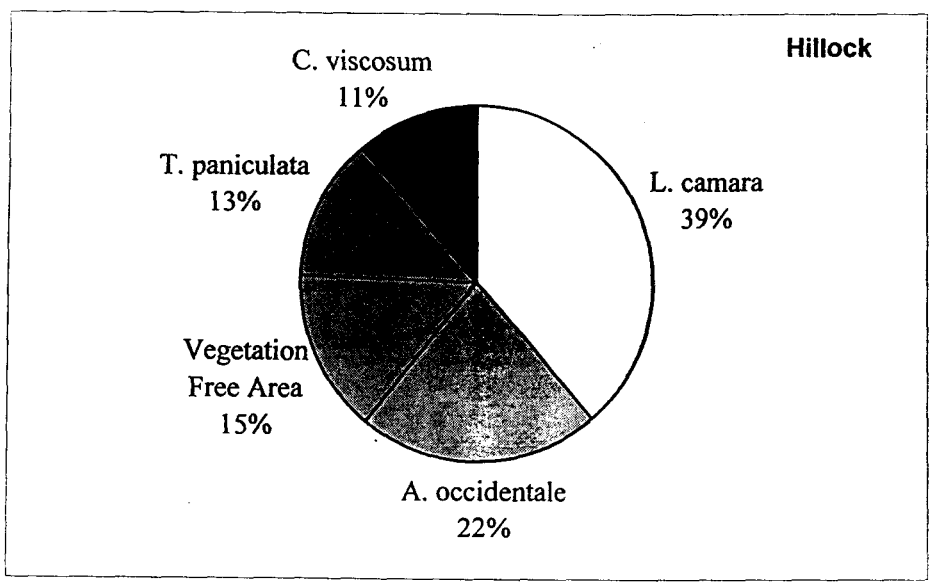


Figure-2.19. Common species of plants in the Hillock

2.6.4.4.5.2 Terrestrial arthropods

The details of the terrestrial arthropods observed in the samples collected during the study are given in Appendix-2.2. Totally 1521 terrestrial insects were collected from this habitat during the entire study period. Acrididae was the dominant family in this habitat. Among all the habitats, under the study, Cicadids, Blattids and Megachillids were

collected only from this habitat. The most common terrestrial arthropods are shown in Figure-2.20.

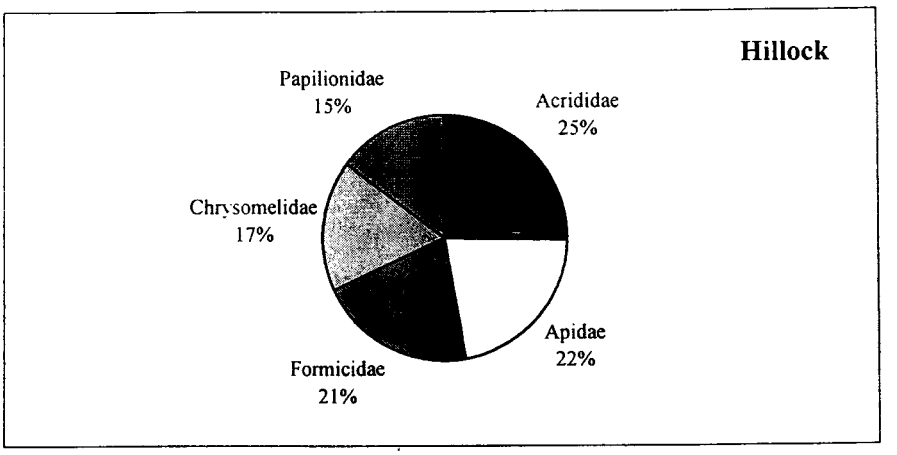


Figure- 2.20 Common terrestrial arthropods in the Hillock

2.6.4.4.5.3 Avifauna

The avifauna of this area includes Common Babblers, Indian Myna, Indian Robin, Redvented Bulbul, House Sparrows, Red Whiskered bulbul, Magpie Robin, Bee-Eaters, and Brown ringed pigeon (Appendix-2.8). Cattle Egrets were seen in highest number (100%) in this habitat where as Little Egrets and Pond Herons were not spotted during the study period.

2.6.4.4.5.4 Mammalian fauna

The grazing cows and goats were of common sight in this habitat. Wild species such as fox and mongoose were also seen.

2.6.4.4.6 Plantations (Rubber Estate)

2.6.2.8.1. Vegetation

Apart from the dominant species, *Hevea braziliensis* (Rubber) the vegetation of area mainly includes *Ipomea* sp., *Muraya exotica, Gloriosa superba, Ageratum conyzoides, Lantana camara, Leucas aspera* and *Sida rhommbifolia* (Appendix-2.14). The vegetation here becomes luxuriant and abundant during the monsoon. December onwards it

gradually reduces to become least in summer. The most abundant species of plants in plantation is shown in Figure-2.21.

2.6.4.4.6.1 Terrestrial arthropods

The arthropods of the area were represented by insects, which include Grasshoppers, Cockroaches, Gryllids and Tetrigids. They gradually gets increased during monsoon and reached the maximum in October and November. During this period the vegetation of the area also is dense.

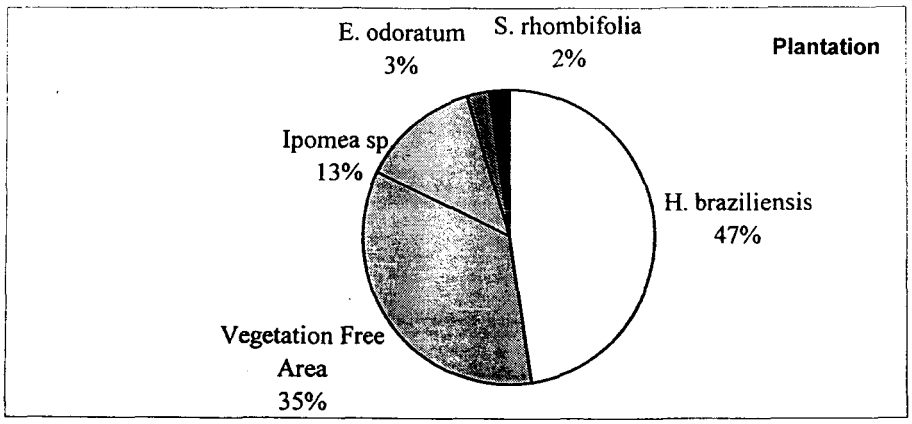


Figure-2.21 Common plants of the Plantation

2.6.4.4.6.2 Avifauna

The avifauna in the hillocks includes Common Mynas, Common Babblers, Indian Robins, Magpie Robins, Redvented bulbul, Red whiskered Bulbul, Bee-Eaters, House Crows, and Jungle Crows. Cattle Egrets, Little Egrets, Median Egrets and Pond Herons were also observed roosting in this habitat (Appendix-2.8). Among the herons under study Cattle Egrets were seen in highest numbers (100%) in Plantation. Pond Herons and Little Egrets were not recorded here during the study period.

2.6.4.4.6.3 Mammalian Fauna

Sometimes cows and goats are observed grazing here from October- December, depending on edible herbaceous and shrubby vegetation. Other mammals include mouse

and cats as this habitat is very close to human habitations. Mongoose was also seen very rarely. No attempt was made to conduct a documentation of these species.

2.6.4.4.7 Grasses in Dry area (Dry Grassfield)

2.6.4.4.7.1 Vegetation

The vegetation of the area is mainly composed of *Eragrostis unioloides, Heteropogon contortus, Arundinella mesophylla, Perotis indica, Ischaemum* indicum, *Dimeria hohenackeri, Desmodium triflorum and Spermacoce articularis*. The vegetation grows here luxuriently in June to December. Thereafter towards summer it gradually dries up.

2.6.4.4.7.2 Terrestrial arthropods

Totally 767 insects were collected from this habitat during the entire study period. The most abundant three groups of insects belonged to the families Formicidae, Acrididae and Apidae (Appendix-2.2). Members of the families Tipulidae, Cercopidae and Fulgoridae were seen in least numbers. The abundant terrestrial arthropods in dry grass field are shown in Figure- 2.22.

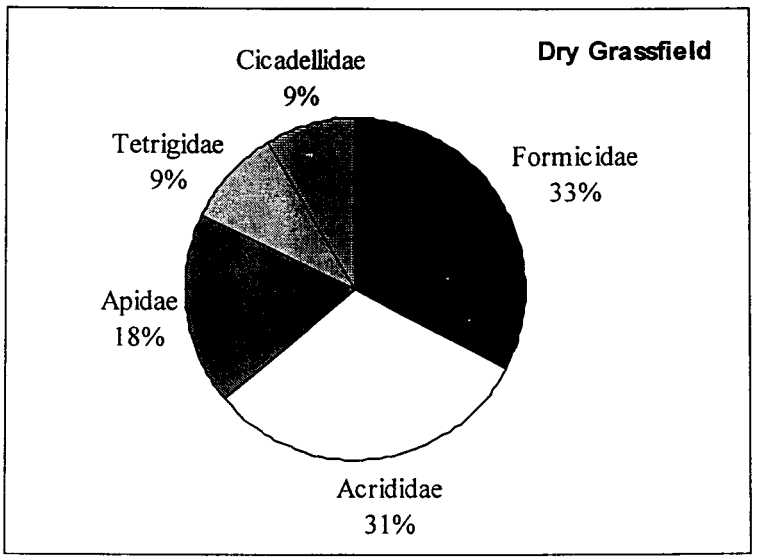


Figure- 2.22. The commonly seen terrestrial arthropods in dry grass field

2.6.4.4.7.3 Avifauna

Birds such as Indian Mynas, Indian Robins, Magpie Robins, and Common Babblers were commonly observed here (Appendix-2.8). Occasionally Cattle Egrets were also noticed in the presence of grazing cattle.

2.6.4.4.7.4 Mammalian Fauna

Occasionally from October to December cows and buffaloes used this habitat as this habitat has scanty vegetation. Goats were observed very rarely in this habitat. Other mammals visiting the location included stray cats and rats.

2.6.4.4.8 Waste dump

2.6.4.4.8.1 Vegetation

Since the entire area of the wasteyard compound was covered with decaying wastes, vegetation was totally absent except for some large trees like *Enterolobium saman* and a few coconut palms. The herbs and shrubs were also scanty and limited to the margins of the wasteyard. They were represented by *Eragrostis uniloides*, *Desmodium triflorum*, *Ageratum conyzoides*, *Eupatorium odoratum*, *Sida rhombifolia*, *Sida acuta*, *Mimosa pudica* etc.,

2.6.4.4.8.2 Terrestrial arthropods

As the wasteyard is completely covered with decaying wastes insects, which are feeding on decaying food substances, were mainly seen here. Adults and larval forms of the family Calliphoridae and Muscidae of the order Diptera were abundantly present in this habitat. The relative percentage of these maggot species on different decaying wastes is discussed elsewhere.

2.6.4.4.8.3 Avifauna

In the waste yard at Kundayithode, Cattle Egrets were observed in abundance. In addition to this some pond herons and common myna, scavengers like common crow and pariah kite were also observed.

2.6.4.4.8.4 Mammals

Dogs, *Canis familiaris*, wandering in the waste yard among cattle egrets feeding on the tit-bits, along with other mammals such as jackals and rarely palm civet *Paradoxus hermaphroditis* were of common sight.

2.6.4.4.8.5 Egret population

The waste yard has a population of cattle egret ranging from 98–386 and 85-254 during the period 1999-2000 and 2000- 2001 respectively. The maximum number of the birds was observed from January 2000 to April 2000 and from January 2001 to March 2001 (Table-2.5). It is seen that some of the freshly deposited areas had more cattle egret than earlier deposited areas. The analysis of solid wastes in the freshly laid areas showed that these wastes were collected from their original place a few days after deposition. This delay offers adequate time for the maggots to develop in sufficient numbers to attract the birds. As such wastes are brought in and dumped afresh in some corners of the wasteyard, larger number of Cattle Egrets congregated around them. The number of maggots apparently is the factor that determines the abundance of cattle egrets.

Abundance of egrets was comparatively low during April and May of 2001 than that of the year 2000. Heavy rains in April 2001 might have advanced the movement of cattle egrets from their feeding ground to their breeding ground. In 2001 the premonsoon showers were comparatively heavy and the rains continued till the onset of southwestern monsoon. Application of chemicals and establishment of incinerator also might have affected reduction in the cattle egrets in the location. Bleaching powder was applied in large amounts in 2001 in the waste yard, reducing the maggot's population. An incinerator was also installed to convert the wastes into biofertilizers, causing a decline in the availability of fresh wastes in the yard.

Table- 2.5 Weekly observation of Cattle Egret at Kundayithode waste dump (1999 October to 2001 September)						
Month	1999-2000	1999-2000	Monthly Average	2000- 2001	2000-2001	Monthly Average
	I Week	IV Week	-	I Week	IV Week	-
October	67	129	98	45	85	65
November	163	221	192	121	135	128
December	284	290	287	162	218	190
January	297	309	303	180	224	202
February	324	336	330	202	238	220
March	356	364	360	226	254	240
April	382	390	386	183	117	150
May	177	97	137	124	56	90
June	0	0	0	0	0	0
July	0	0	0	0	0	0
August	0	0	0	0	0	0
September	0	0	0	0	0	0

2.6.4.4.8.6 Composition of Wastes

Tones of solid wastes are dumped everyday in the wastedumping site at Kundayithode. These wastes come from various locations of Kozhikode Municipal Corporation. It is composed of a variety of items thrown away from shops, markets, slaughterhouses, hospitals, hotels and residences (Table-2.6). The wastes left out from vegetable markets and those from chicken stalls and hotels were the common items in the wastes. Apart from the chicken wastes and fish wastes, carrion of cows, sheep, buffaloes and dogs were also deposited in the waste yard.

Table- 2.6 Percentage composition of wastes in Kundayithode Waste dumping yard during 1999- 2000		
No	Types of wastes	Percentage
1	Chicken wastes	22
2	Hotel wastes	19
3	Vegetables	23
4	Wastes from stationery	9
5	Fish wastes	8
6	Hospital wastes	4
7	Miscellaneous	15

2.6.4.4.8.7 Food of Cattle Egrets in the Waste yard

As mentioned earlier large number of maggots grows in the decomposing waste. They included mainly the maggots of housefly, *Musca domestica* and that of blue bottle, *Calliphora sp.*, which belonged to families Muscidae and Calliphoridae respectively of the Order Diptera. Calliphorids are carrion feeders and are observed mostly on decaying chicken and fish wastes, while Muscids were mostly on hotel wastes and decaying vegetables. The maggots of Muscids are smaller than that of the Calliphorids. The length of a third instar Muscid larva was about 9 mm whereas that of a Calliphorid was about 12mm. Percentage of these two types of maggots varies in accordance with the composition of the wastes (Table-2.7) that indicates their food preference. From 500 gm of decaying fish, Indian Mackerel (*Rastrelliger kanagurta*), 6.7gm of Calliphorid maggots, 170 in number, could be counted.

Table- 2.7 Maggots in decaying wastes at Kundayithode Waste yard during 1999-2000			
S. No	Wastes	Percentage of maggot species	
		Musca domestica	*Calliphora sp.*
1	Chicken parts	5	50
2	Hotel wastes	40	12
3	Vegetables	30	3
4	Fish wastes	7	29
5	Miscellaneous	18	6

The maggots were seen usually 5 cm below the waste deposit. They move within a range of 10-20 cm depending on the moisture content of the area. Most of the dead parts and wastes of organisms dumped in this waste yard were tightly packed in plastic sacs or polythene bags. The maggots feeding on moist decaying inner soft parts wriggle all around the surface of the container that gets fully destroyed in due course. Since these larvae are negatively phototactic and prefer moist places, they feed just below the surface layer of the waste. Some of the decaying fish-parts or chicken parts were swarmed by thousands of maggots, which in turn was flocked by egrets to prey up on. In East Africa, Cattle Egrets feeding on flies attracted to decaying fish wastes were reported by Reynolds (1965)

Most of the deposited waste, packed in bags of various types, gets opened up on the very day of dumping itself, by dogs, Kites, Crows etc. Thus the wastes get spread within a few hours after deposition. The flies lay their eggs on these wastes and within a day or two maggots emerge out of them and wriggle all over. Normally a muscid takes 8.5-16 days for development from egg to adult where as a Calliphorid takes 9- 16 days for the same (Aravindakshan 1999). From all the vegetable and animal wastes thousands of Calliphorid and Muscid maggots emerge daily. So this wasteyard formed a 'feast yard' for cattle egrets. In a random estimation it was found that a Cattle Egret made 4-6000 pecks a day, suggesting that the bird removed about 100-150 gm of maggots /day. It is also suggestive of the magnitude of the service rendered by the birds in controlling the flies in and around the solid waste yard.

2.6.4.4.8.8 Flies

A lot of adult flies both of Muscids and Calliphorids were observed at Kundayithode waste dump during the present study. The Calliphorids and Muscids complete its life cycle within 9-15 days. The adult flies emerge everyday, especially in the morning hours, in large numbers from the decomposing wastes in the sites. The survey conducted in a house and hotel premises for a period of one year showed that their monthly variation ranged from 3-93 and 3-124 per 1 X 1m quadrate respectively (Figure-2.23). Their

number was highest during monsoon, during which the cattle egret migrates to their breeding sites elsewhere.

2.7 DISCUSSION

Totally 10 natural and one artificial habitat that are visited by the three heron species are discussed in this chapter. They were Azhinjilam jheel, Calicut jheel, Feroke jheel, Karimpuzha River, Kadalundy River, Vadapuram grass field, Paddy field, Hillock, Plantation (Rubber estate), Dry grass field and a solid waste dump yard. Altogether 7492 terrestrial arthropods belonging to 59 groups (Appendix-2.2) and 9880 aquatic organisms (Appendix-2.3 and Table-2.4) belonging 60 different taxa (Appendex 2.4) were collected from the entire study area.

Among the three jheels, Azhinjilam jheel was characterised by three dominant species of vegetation namely *Salvinia molusta*, *Oryza sp.* and *Cynodon dactylon* respectively. This area had high species composition with respect to vegetation (Appendix-2.6). Totally 1593 aquatic organisms distributed over 27 families and 1191 terrestrial arthropods distributed over 31 families were collected from this habitat. Among terrestrial insects, prey items of Cattle Egret and Pond herons namely the Acridids, Lestids, Libellulids, Tettigoniids, Tetrigids and Cicadellids were abundant in this habitat. *Macropodus cupanus*, a fish species was seen frequently in this habitat. Other fishes that were seen comparatively lesser in number included *Danio acquipinnatus*, *Aplocheilus blockii* and *Puntius vittatus*. Among aquatic insects the most dominant species was naiads of dragonflies. Among the three jheels studied, naiads of dragonflies were highest in Azhinjilam jheel. Unpolluted waters with rich oxygen concentration are favourable for Odonatan nymphs (Saksena and Kausik, 1994). Among the different habitats under study aquatic beetles of the family Hydrophilidae were seen highest in number in this habitat. Rich macrophyte vegetation is necessary for providing shelter, shade and suitable substratum for colonisation of such beetles (Saksena and Kausik 1994). Since this habitat is an admixture of aquatic and terrestrial prey species a visit to the area will be of high benefit to birds, possibly the reason for presence of the three herons in this habitat.

Calicut jheel differs from other jheels of the present study in the vegetation. Plant species like *Ipomea aquatica*, *Alternanthera philoceroides*, and *Eichhornia crassipes* dominated this habitat. Altogether 1581 aquatic organisms distributed over 26 families were collected from this habitat. This habitat holds water throughout the year except during April and May in which the major portion of this area becomes dry. Among aquatic insects, Belostomatids dominated this area than the other jheels under study. This may be due to the characteristic nature of vegetation present in this habitat. Among the three types of jheels under study, the naiads of damselflies were highest here. The reason for their abundance may be the presence of stragglers like *Alternanthera philoceroides* and *Eichhornia crassipes*, which usually harbours them. Naiads of damselflies were observed in the gut contents of all the tree species of birds under study. The herons will be abundant in this habitat from March to May during which water depth used to be at minimum and egrets harvest most number of fishes and other aquatic organisms.

The most dominant vegetation of Feroke Jheel included *Ipomea carnia*, *Hydrilla verticillata*, and *Oryza sp.* Totally 1947 aquatic organisms distrbuted over 31 families were collected from this habitat as it was fully inundated throughout the year except during April and May. Among the three types of jheels, *Palaemon sp.* was highest in this area. Their abundance may be due to availability of macrophytic vegetation such as *Hydrilla verticillata*, for their shelter, shade, substratum and colonisation. Among fishes Danio acquipinnatus was highest in number probably because of the thinner vegetation such as *Hydrilla verticillata* and nutrient rich sediments at the bottom. This area had more fishes such as *Puntius vittatus* and *Aplocheilus blockii*. Lymnidae, and Planorbidae among molluscs and Palaemon among Crustaceans were higher here than in other two areas.

In all the three jheels under study the aquatic insects were mostly present in littoral zone and the insect fauna was very poor in the deep-water areas. The water depth in all the three jheels under study varied between 20 cm to 120 cm from June to March. Thereafter it becomes lesser in April and May. Lesser water depth might be the reason for the high abundance of Cattle Egrets, Little Egrets and pond Herons in all the three jheels under study.

The vegetation at Kadalundy riverine area was dominated by the algae, *Enteromorpha sp.*, and other species such as *Avicennia marina*, *Acanthes ilicifolius* and *Sphaeranthus indica*. Altogether 1122 aquatic organisms falling under 20 families were collected from this habitat. Among all the aquatic habitats of the present study, Crustaceans namely, *Macrobrachium sp.* and *Penaeus sp.* were abundant and confined to this habitat (Appendix-2.3). The probable reason for their abundance may be the rich growth of the algae, *Enteromorpha sp.* This may give suitable substratum, necessary shelter and shade for them. The common fishes such as *Aplocheilus blockii*, *Aplocheilus lineatus*, *Danio acquipinnatus*, *Puntius amphibius*, *Etroplus maculatus* and *Macropodus cupanus* were also present. Since this estuarine area is exposed to daily tidal variations and as water level minimize during low tide, aquatic organisms get trapped in small pools. Such pools trigger aggregation of Pond Herons and Little Egrets in such locations.

The aquatic vegetation of Karimpuzha River was scanty. It was mainly formed of *Spirogyra sp.* Other species such as *Cyperus sp.*, *Cynodon dactylon*, *Polygonium glabrum*, *Fimbristylis milliaceae* and *Paspalum conjugatum* were also seen at the banks of this river. When the riverbeds get exposed in January they start to grow. Totally 1335 aquatic organisms distributed over 34 families were collected from this habitat. Among all the aquatic habitats of the present study, *Palaemon sp.* was seen highest in Karimpuzha River. The probable reason may be the presence of *Spirogyra sp.* that extends up to a depth of 0.5 m and provides shelter and concealment to them. The presence of naiads of dragonflies and damselflies is also promoted by thick Spirogyra growth. Among fishes *Puntius amphibius*, and *Aplocheilus blockii*, *Puntius vittatus* and *Etroplus maculatus* were commonly seen.

The vegetation in Wet Grassfield at Vadapuram was dominated by *Cyrtococcum trigonum*, *Ischaemum sp.*, *Sporobolus diander*, *and Fimbristylis milliaceae*. Among all habitats under study, the species composition of vegetation was highest in this area. Since this location is an admixture of aquatic and terrestrial area, it forms an ideal habitat for bird's foraging. Totally 1153 aquatic organisms distributed over 26 families and 1627 terrestrial arthropods spread over 40 families were collected from this habitat. All the three species of birds under study used this habitat as it offers a variety of aquatic and

terrestrial prey organisms. Among all the terrestrial arthropods, Acridids and Gryllids were highest in number while Notonectids and *Palaemon sp.* were dominant among the aquatic organisms. This abundance may be a reason for the abundance of Cattle Egrets and Pond Herons here.

The vegetation in Paddy field was dominated *Oryza sativa, Ischaemum sp. Eriocaulon quinquangulare, Echinochloa colonum, Fimbristylis milliaceae, and Desmodium triflorum.* Paddy field serves both as an aquatic and terrestrial resource. During paddy cultivation it holds water with a variety of aquatic organisms while its margins and boundaries serves as substratum for terrestrial arthropods. Paddy fields had highest number of Cattle Egrets followed by Pond Herons and Little Egrets. It is an important habitat for some species of wetland birds particularly in regions where the availability of natural marshes has diminished (Fasola and Ruiz 1996). Cattle Egrets were usually found in aggregations following tractors during ploughing which exposes a variety of prey species. Bredin (1983) also reports congregations of Cattle Egrets in winter during post harvest ploughing (by tractors) because of the surges in prey availability. During non-cultivated seasons the paddy fields remains fallow and serves as pastures for grazing cattle with which cattle egrets were usually found associated. The Cattle Egret is well known as a dry land heron in association with grazing animals (Kushlan 2000).

Altogether 2386 terrestrial arthropods and 1149 aquatic organisms were collected from the paddy fields. Among aquatic insects naiads of dragonflies and damselflies, Mayfly nymphs, Gerrids and Notonectids were abundant. Fishes represented *by Macropodus cupanus, Aplocheilus lineatus, Danio aqcuipinnatus, and Chela (Neochela) dadyburjori, and Parlucisoma daniconius.* Tadpoles represented the amphibians while Pila globosa and crabs represented mollusks and arthropods respectively. Among terrestrial arthropods Tetrigids and Tettigoniids, Noctuiids, Libellulids, Cicadellids and Pyraustids had highest number in paddy fields than in other habitats. This shows the importance of the rice fields in providing a variety of prey organisms to the birds under study. Subramanya (1990) recognized paddy field as one of the important artificial habitat for herons as some of the Asian herons are highly dependent on this habitat.

Lantana camara, Anacardium occidentale, Terminalia paniculata, and Clerodendrum viscosum dominated the vegetation in Hillock. Among the Lepidoptera, families of Papilionidae, Pieridae, Nymphalidae, Hesperiidae, and Danaidae were abundant in this habitat. Though they were abundant in this habitat, their capture by these herons was very difficult since they were very good fliers and most of them hover over tall shrubby vegetation. Between Coleoptera and Hymenoptera, families Chrysomelidae and Apidae respectively were abundant in hillock than other habitats. Totally 1521 terrestrial arthropods distributed over 29 families were collected from the hillock. Among all the habitats studied, Acridids were comparatively least in this habitat. Though a lot of insects were present in this habitat, the only heron seen here was Cattle Egret. Cattle Egrets were seen always associated with grazing cattle in this location. Pond Herons and Little egrets being more associated with water regime, they did not frequent this habitat.

Among the various habitats under study, plantation had very low species composition with respect to vegetation. Rubber, *Hevea braziliensis*, mixed with other herbs and shrubs represented the most dominant vegetation of this area. Of the different habitats under study, the plantation had lowest species richness of plants. Vegetation coverage was highest during October to January and thereafter the coverage gradually declines. Since vegetation was less, vegetation dependent insects were also very much reduced. The terrestrial insects of this area include mainly Grasshoppers, Cockroaches, Gryllids and Tetrigids. Cattle Egrets were not normally seen in this habitat except in association with grazing cattle. The proabable reason for this may be the low number of insects, the search of which demand more energy expenditure. This led them to associate with grazing cattle, which flushes out insects out of vegetation. Pond Herons and Little Egrets were totally absent in this habitat since they prefer habitats with water regime.

The most dominant vegetation of Dry Grassfield was *Eragrostis unioloides, Desmodium triflorum, Arundinella mesophylla, and Perotis indica* mixed with other herbs and shrubs. Since vegetation was comparatively less, it represented only few organisms. Altogether 767 terrestrial arthropods distributed over 19 families were collected from Dry grassfield. Short horned grasshoppers of the family Acrididae were only the most abundant insects in this habitat. All the three bird species under study were normally absent in this habitat

except a few Cattle Egrets that get associated with grazing Cattle only during October to January when growth of vegetation is at its high.

Since waste dump at Kundayithode is completely covered with various types of solid wastes from Kozhikode City, no notable vegetation grows in this habitat. This caused the absence of other insects except muscids and calliphorids, which depend on decaying wastes, especially chicken wastes, carrions and fish wastes. Relative percentage of Calliphorids was highest in decaying chicken parts (50%) than other wastes whereas that of *Musca domestica* was highest in decaying hotel wastes (40%, Table-2.7). Such artificial habitats were preferred by Cattle egrets, as they are more terrestrial and insectivorous. Frederick and McGehee (1994) also have reported usage of dumps and sewage ponds by these birds.

The present study shows that the Cattle Egret, Little Egret and Pond Heron are present in all of the 11 habitats under study but their frequency in each habitat varies widely probably due to differences in the distribution of the prey items and water depth. The cattle egrets being more terrestrial make use of the terrestrial area of the wetland than the aquatic parts since 87% of their food is insects. They were found mostly in wet grass fields and Paddy fields than in other natural habitats due to the shallow water. Since the wet grass field holds some water all through the seasons vegetation is also present throughout the year. Aquatic organisms like dragonfly naiads, damselfly naiads, Notonectids and tadpoles also are available. The Cattle Egrets are not found in paddy fields throughout the year because most of the paddy fields in the study area are left uncultivated due to scarcity of water for irrigation. They were found in abundance in all the three jheels in the present study only during the summer months. In all other season their number was comparatively few due to the high water depth. They have negligible preference for Hillock, Grass fields in dry areas and plantations, except in the presence of cattle with which they associate for flushing insects out. Their presence in riverine habitat such as Karimpuzha also showed their tendency to use the riverine habitats especially if they get cattle to associate with. Among all other habitats the most favorite habitat of cattle Egret is waste dump, which provides Dipteran maggots in abundance at low cost.

Of all the 11 types of habitats pond herons and little egrets are mostly observed in paddy fields, wet grass fields, jheels, rivers and estuarine areas whereas they are not commonly seen in grass field in dry areas, hillocks, plantations and waste dumps. This clearly shows that little egrets and pond herons share more or less common wetland habitat without any overlapping. In contrast, the cattle egret although frequent wetland habitats, prefer the terrestrial portions having more vegetation cover.

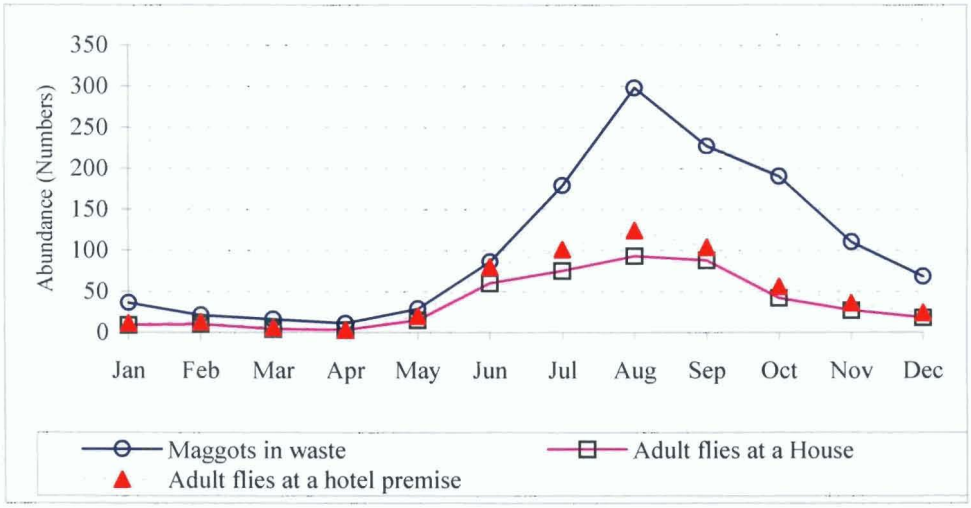


Figure- 2.23 Maggots and adults of Muscids at Kundayithode Wastedump during 1999-2000

The availability of a variety of decaying dead organisms and other leftovers makes the waste dump an ideal spot for multiplication of the Dipteran maggots that attract hundreds of cattle egrets into this habitat lured by easy prey capture. Thousands of maggots present in the waste dump were eaten up by Cattle Egrets and other scavengers like Pariah kite *(Mylvus migrans)* and House Crows (*Corvus splendens*). If cattle egrets were absent in such area, the metamorphosis of maggots would result in adult population beyond tolerable limit. Here Cattle egret acts as a check over the exceedingly multiplying maggots and prevents their metamorphosis and transformation into pest level. Thousands of maggots were consumed by individual Cattle Egret. A survey conducted of flies in the premises of the waste yard showed their profusion during southwest monsoon (Figure-2.23). This extremely high number of houseflies in rainy season is related with the

absence of cattle egrets during these months. It was seen that in the months when cattle egrets were abundant (November to April) population of house flies both in waste dump and the adjacent houses including hotel premises were considerably low. It suggests that the birds function as biological controlling agent of the insect vector.

The extremely high number of cattle egrets in the waste yard during severe drought may probably be owing to shrinkage of their natural habitat. Their extraordinarily high number in these artificial habitats also shows their opportunistic preference to waste dump over other natural habitats. This study again reveals that these birds are not strictly confined to natural wetland habitats. This observation apparently demonstrates the adaptability of the species to changes happening in nature due to human activities. With the advancement of industrialisation and mechanisation the anthropogenic pressure on wetland has become so high that a considerable portion of these habitats is prone to modification and disappearance. The impact may be comparatively lesser for Cattle Egret as it may overcome such situations by tuning to artificial locations.

2.8 SUMMARY AND CONCLUSION

The characteristics of any habitat have a major role in the distribution of the faunal elements of that area. The faunal composition in turn regulates the association of other related organisms. In the present study association of birds to their various habitats was documented by examining the type of vegetation, its composition and abundance, water proximity and its depth, prey abundance, seasonal variation, and association with other species.

The present study reveals that among the three bird species under study, the cattle egrets have high variability in habitat requirement than the other two species. They prefer mostly shallow habitats having vegetation and are more insectivorous (See chapter-3). Other studies also supports that Cattle Egrets are not able to catch prey in deep water (Katzir and Martin 1999). They were found associated with all sorts of habitats except estuarine habitats in Kadalundy, which is under tidal influence and with sparse

vegetation. Presence of grazing cattle and availability of vegetation are the two criteria for their presence in Hillocks and plantations.

Pond herons prefer aquatic habitats either with or without vegetation. They are mostly insectivorous, but also take fishes, vertebrates and other invertebrates along with their food. The gut content analysis of adult pond herons showed that insects composed of 71.7% of their food. Accordingly, they use paddy fields, grass fields, jheels, riverine and estuarine habitats except plantation and hillocks.

Little Egrets being mostly piscivorous in habit are always associated with water. The gut content analysis in adult Little Egrets showed that their 96.2% of their food was composed of fishes. The rest is mainly composed of insects. Accordingly they prefer paddy fields, grass fields, jheels, riverine and estuarine habitats except hillock, plantation and waste dumps.

Paddy fields, jheels, wet grass fields, riverine and estuarine habitats provide both aquatic as well as terrestrial prey organisms to the birds, while hillock, plantation and waste dump have terrestrial prey items only. Since plantations and hillocks are comparatively dry these habitats are very rarely used by cattle egrets except during habitat expansion in October to January. Cattle egrets extensively use solid waste dumps. The wriggling calliphorid and muscid maggots can be very easily picked up without taking much effort.

FEEDING AND FORAGING

Seedikkoya .K “Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality ” Thesis. Department of Zoology , Farook College Calicut ,University of Calicut, 2003

Chapter-III

FEEDING AND FORAGING

3.1 INTRODUCTION

Herons are comparatively large birds well adapted to a wading mode of life. They forage in a wide variety of wetlands ranging from paddy fields, jheels, ponds, marshes, wet grassfields, puddles and rivers. As an important component of the wetland system wading birds are suggested as valuable indicators of biological changes happening in such systems. To understand their value as indicators, detailed studies are required to know the manner in which these birds use wetlands.

For effective foraging, herons use a wide range of feeding techniques. Food preferences and feeding techniques are fundamentally based on the morphology of the species, especially the size and shape of the bill used for capturing food, and the long neck and leg, which determines accessibility to various depths. Each species of heron has evolved a repertoire of techniques, from which a bird selects an apt combination for successful collection of varying types of food. The use of these varied means for seizing prey is partially based on species morphological and physiological adaptations and on the availability of different types of prey. More than 30 feeding methods are used by herons (Kushlan 1978 a). However, only a few studies have quantitatively determined the frequency with which each species applies a feeding technique or varies the techniques according to environmental parameters (e.g. Willard 1977).

The present study attempts to bring out some important aspects related to the feeding and foraging each of Pond Heron, Little Egret and Cattle Egret.

3.2 BACKGROUND

3.2.1 Pond Heron

Valuable information on their feeding biology of Pond Heron is documented by a number of workers such as Mason&Lefroy 1912; D'Abreu 1920; KirckPatrick 1953; Navarro 1962; Kushlan 1978; Welty 1979; Grimwood and Brocklehurst 1984; Neelakantan 1986

b; Prasad and Hemanth 1992; Raza 1993; Matieswaran 1996; Palkiwala 1998 and Manjrekar and Mehta 1999). The information about the feeding habits of this bird from West Bengal (Mukherjee 1971), from Kerala (Mathew et al. 1990, Wesley 1990 b) and from Gujarath (Sodhi 1986) is also recorded. Information on the feeding biology of this bird being rather scanty, an attempt is made in this chapter to explore some details on these aspects and to document them.

3.2.2 Little Egret

Little Egrets are observed in a variety of habitats such as paddy fields, marshes, jheels, rivers, pools, puddles, ponds, grassfields etc. The ability to exploit food resources is one of the most frequently suggested reasons for habitat selection by birds (Caraco et al 1980 a), and would be a primary basis for selection of foraging habitat. Shallow coastal waters and mudflats were the most important habitats at low tide for Great and Little Egrets (*Egretta garzetta*), and Grey Herons (*Ardea cinerea*), while fishponds were the most important for the Black-crowned Night Herons (Wong et al .2001). At high tide, the water depth excluded Great and Little Egrets, and Grey Herons, from most of the shallow coastal waters and mudflats (Wong et al. 1999). Fish trapped in pools during falling tides in summer were a major food attraction for egrets and herons (Weller 1994).

Detailed information on the feeding ecology of these herons are deficient except for some studies on feeding methods, flock size and feeding success, change of foraging sites in relation to food supply in nesting little egrets (Hafner and Britton 1983), use of artificial and natural wetland as feeding sites (Hafner et al. 1986), mechanism of capturing submerged prey (Lotem, et al. 1991), flock feeding (Hafner et al. 1993), habitat use (Wong et al. 1999), foraging ecology (Jenni 1969; Richardson et al. 2001), resource use strategies (Kushlan 1978, 1981), and visually controlled prey capture (Katzir et al. 1998). Studies from India include observations on feeding association (Parasharya and Mathew 1994), on feeding technique (Serrao 1986), on feeding association (Balasubramanian, 1990), and on unusual fishing technique (Abdulali 1968).

3.2.3 Cattle Egrets

Cattle Egrets are known to be well adapted to agricultural and disturbed habitats. They use freshwater marsh as the most important feeding habitat, particularly during the breeding season (Wong et al 2001). They were usually found associated with cattle and sometimes with other hoofed mammals like pigs, goats, and horses. They were also reported to be associated with other moving vehicles (Heatwole 1965). Their association with grazing cattle helps increase their prey captures and utilise less energy than those of solitary feeders (Heatwole 1965; Grubb 1976). Meyerriecks (1962) has conducted a great deal of study on the behavioural aspects of Cattle Egrets.

Documentation on the feeding ecology of the Cattle Egret, *Bubulcus ibis* is insufficient. Ikeda (1956) has documented the food and feeding ecology of this bird in Japan. Kadry Bey (1942) in Egypt, and Gassette et al. (2000), in Surinam Haverschmidt (1957), in South Africa Skead (1966) and Siegfried (1971, 1972), in Florida Jenni (1973) and Forgatry and Hetrick (1973), in South-east Queensland McKilligan (1984), in Texas Scott (1984) and Mora and Miller (1998), in Hong Kong Wong et al. (1999), in Australia Richardson et al. (2001) and in France Lombardini et al. (2001) has worked on the associated aspects.

Studies on the feeding biology of Cattle Egret in India is very few except for some those from different states of the country (Ali 1979; Menon 1981; Javed 1983; Monga and Pandya 1984; Sodhi and Kera 1984; Singh and Sodhi 1985; Sodhi 1990; Serrao 1986; Newton 1986; Chaturvedi 1991; Sodhi 1992; Subramanya 1993; Mathew and Pethani 1997; Rao 1999; Varghese 1993 a, and Kasambe, 2003).

3.3 STUDY AREA

For the study of food, feeding and the foraging five types of habitats were selected including four natural and one man-made. The natural habitats include paddy fields, wet grassfields, and riverine areas and Jheels. The man-made habitat under study was a municipal solid waste dump yard. Cattle Egret – Cattle association was examined in paddy fields, wet grass fields, jheels, plantation, hillock, riverine (Karimpuzha river), and the waste dumps.

3.4 OBJECTIVES

The main objective of the present study is;

1. To find out food composition of the adult birds and nestlings,
2. To analyze the habitat-wise foraging repertoire adopted by the individual species,
3. To examine the factors deciding interaction between the Cattle and Cattle Egret in different habitats, and benefits if any, the egrets derive out of this association, and
4. The causes of occasional aggregation of the birds in certain habitats.

3.5 METHODOLOGY

3.5.1 Prey species

Observations on the fishing activities of live birds to collect data on prey items may be subjective (Willard 1977, Mock and Mock 1980, Fasola 1986) and might not give a correct record of prey species. Hence, this method of direct observation was not entirely depended for the data in the present study. Analysis of regurgitated boluses gives reliable information about the prey proportions and the rate of daily food consumption of a bird. The characteristic behaviour of the nestlings to regurgitate when alarmed is also depended to draw information about the prey species in various studies (Kushlan and Kushlan 1975, Rodgers 1976, and Moser 1986).

3.5.2 Food and feeding habits

Three methods are commonly used for collection of data on the food and feeding habits of wading birds, which includes: 1) direct visual observation 2) the analysis of food boluses regurgitated by the nestling when they were alarmed and, 3) the analysis of gut contents. Analysis of food items in the gut examining the stomach contents of dead specimens was done (Kushlan and Kushlan 1975) in pond herons and little egrets. Since cattle egrets were not found breeding in Kerala, collection of regurgitated pellets from nestlings was not possible. Dead birds were used for gut content analysis following the method given by Sodhi (1989) to get adequate number of samples. Basic morphometric measurements were taken on each of the specimens, the results of which are shown (Appendix 3.1 and 3.2).

3.5.3 Gut content analysis

Altogether 52 samples of gut contents were collected for analysis from the three species of birds under study. They belonged to the following categories;

1) Dead specimens (11 samples for Little Egret; 13 for Cattle Egret and 13 for Pond Heron) and
2) Regurgitated food samples from nestling of pond herons and little egrets (13 samples of Little Egrets and 2 of Pond Heron).

3.5.4 Collection of regurgitated food

Methods used for collecting regurgitated food items from pond herons and little egrets were identical to those of Barbraud et al. (2001). Regurgitated samples by chicks were collected from the feeding ground from 0800 h to 1000 h in the heronries and the samples were stored in 70% alcohol for examination. Prey items found in the regurgitates were identified, counted and length measured to the nearest millimeter. Fish were measured from the tip of the snout to the fork of the tail. Prey species found in regurgitates was generally poorly digested and easy to identify.

3.5.5 Foraging Behaviour

Data on foraging behaviour were collected monthly from January 2000 to December 2002 in various habitats like paddy fields, wet grassfields, jheels, riverain habitats and solid waste dump. Prey abundance data were collected monthly from different habitats. All observations of foraging birds were made between 0600 h and 1100h and involved only adult birds. Using a 10x 30 binocular, observations were made in such a way to minimize the chance that the observer's presence did not alter their foraging behaviour (Fasola 1986). The foraging behaviours were obtained by focal sampling method (Altmann 1974, Sodhi and Kerà 1984). Individuals were selected randomly for study. Each month there was a minimum of 20 observations periods for each species. Observation periods were of thirty minutes duration for Pond Herons, Little Egrets and cattle egrets and were measured by a stopwatch and alarm. Only one observation period was recorded for any individual in a day.

3.5.6 Prey Abundance

The Prey abundance in different terrestrial habitats under observation was estimated fortnightly every month using a sweep net of 0.5m diameter. Aquatic organisms were collected using a D-net of 0.5m diameter with metal frame and nylon clothe. The length and number of each species of organisms so collected was measured using a millimeter graduated measuring scale.

3.5.7 Cattle-egret Association

Weekly counts of associated and unassociated cattle egrets were made by spot mapping method explained in chapter-II, walking along a fixed rout in 100x 100m areas. Care was taken to reduce repeat count of the same bird, due to their movement. An 8 x 30 binocular was also used to supplement the bird observation by direct visual count (Altmann 1974). All observations were carried out in five sessions in a day at an interval of 0600 -0900 and 0900 -1200 h in forenoon and 1200 – 0200, 0200 - 0400 and 0400 – 0600 h in the afternoon and the total monthly count was recorded. The criterion for association was that the egret be within one meter of a cow.

Feeding rates of associated and non-associated egrets were compared to evaluate if there is any benefit out of this association. An associated egret was followed through the binoculars and counted the number of successful feeding during a two-minute period and the strike and capture rate per minute was estimated (Heatwole 1965). A prey capture was recorded if a peck at the substrate or blade of grass was followed by the characteristic head jerk-swallowing behavior (Heatwole 1965; Grubb 1976; Scott 1984). If no swallow follows the peck, the event was recorded as a 'strike' (unsuccessful capture attempt). A similar count was made for a non-associated one. The factors such as climatic conditions, time of observation, nature of pasture, vegetation structure, prey availability etc., were the same for a given pair of counts. Since non-associated egrets seemed to be more active than associated egrets during the initial counts, after a few initial paired counts of steps only, the procedure was modified to include the steps taken by each bird while simultaneously recording the number of successful feedings. The number of steps is a measure of energy expenditure in obtaining food. Assuming that the size and quality of food collected by associated and non-associated egret is same, the number of steps

taken by the associated and non-associated birds for successful feeding was counted to evaluate whether associated egret gets more preys with comparatively fewer number of steps than non-associated birds.

3.6 Results

3.6.1 Foraging methods

Foraging methods adopted by different herons (Table1 and 2) and most commonly used techniques in each habitat are also shown (Table-3.3). Both cattle egret and pond heron used least diverse method in riverine system while little egret showed high diversity of method in the same system. In overall Little Egret showed higher variety in the foraging methods than other two species (Table-3.3). There were major differences among species in the relative use of foraging techniques in different habitats. The techniques adopted by the birds varied depending on the nature of habitats (Table-3.4).

Table 3.1. Foraging techniques adopted by Herons

No	Foraging Technique	Definition
1	Stand and Wait (SW)	A heron stands still in water or on land waiting for prey to approach.
2	Walk Slowly (WS)	A heron moves slowly, stalking the prey.
3	Walk Quickly (WQ)	Walks relatively fast
4	Running (RU)	Moves quickly after a specific prey item.
5	Foot Stirring (FS)	Extends one leg forward and vibrates its leg and foot on mud.
6	Foot Paddling (FP)	Move feet up and down on the substrate to disturb prey
7	Probing (PR)	Quickly and repeatedly moves bill into and out of water.
8	Bill Vibrating (BV)	Rapidly opens and closes bill in water
9	Diving (DI)	Dives head first into water from a perch.
10	Leapfrog Feeding (LFF)	Flies from rear of feeding flock to front.
11	Fly catching (FC)	Using stand and wait behaviour catches flying insects

12	Head swaying (HS)	Moves head from side to side, in either slow or rapid sweeps
13	Peering over (PO)	Extends neck and tips of its head so that its bill points straight down towards the ground

Table. 3.2 Foraging methods used by herons in different habitats

Species	Habitat	Methods
Cattle Egret	Paddy Field	6 (RU, LFF, WS, WQ, BV, HS)
Cattle Egret	Grass Field	6 (RU, LFF, WS, WQ, BV,HS)
Cattle Egret	Riverine	3 (RU, WS, WQ)
Cattle Egret	Jheel	6 (RU, WS, PR, WQ, HS, LFF)
Cattle Egret	Waste Dump	4 (RU, WS, WQ, HS)
Pond Heron	Paddy Field	6 (DI, LFF, SW, FC, WS, WQ)
Pond Heron	Grass Field	5 (LFF, SW, FC, WS, WQ)
Pond Heron	Riverine	3 (SW, WS, WQ)
Pond Heron	Jheel	4 (SW, FS, WS, WQ)
Little Egret	Paddy Field	8 (LFF, FC, WS, WQ, RU, FS, FP, PO)
Little Egret	Grass Field	6 (RU, LFF, FS, WS, FC, WQ)
Little Egret	Riverine	8 (RU, FS, FP, FC, WS, PO, WQ, BV)
Little Egret	Jheel	6 (RU, LFF, FS, FP, WS, WQ)

Table-3.3 Commonly used feeding techniques in herons

Species	Commonly used technique*
Pond Heron	SW, WS, WQ, DI, LFF, AF
Little Egret	WS, WQ, RU, FS, BV, FP, LFF, AF, PO
Cattle Egret	WS, WQ, RU, LF, HS, PR, BV

*SW = stand and wait, WS = walk slowly, WQ = walk quickly, DI = diving, LFF = leapfrog feeding, FC = Fly catching, RU= running, FS = foot stirring, BV = bill vibrating, FP = foot paddling, PO = peering over, HS = head swaying, PR = probing

Table-3.4 Different foraging techniques of herons observed in different habitats					
Habitat	Method*	Cattle Egret	Little Egret	Pond Heron	Grand Total
Grass Field	RU	83	36	0	119
	DI	0	0	0	0
	LFF	10	46	30	86
	FS	0	18	0	18
	SW	0	0	104	104
	FP	0	0	0	0
	FC	0	63	8	71
	WS	74	38	26	138
	PR	0	0	0	0
	PO	0	0	0	0
	WQ	53	37	24	114
	BV	26	0	0	26
	HS	8	0	0	8
Jheel	RU	47	28	0	75
	DI	0	0	0	0
	LFF	5	26	0	31
	FS	0	12	0	12
	SW	0	0	105	105
	FP	0	5	0	5
	FC	0	0	10	10
	WS	56	64	61	181
	PR	37	0	0	37
	PO	0	0	0	0
	WQ	61	26	33	120
	BV	0	0	0	0
	HS	18	0	0	18
Paddy Field	RU	104	56	0	160
	DI	0	0	87	87
	LFF	37	32	47	116
	FS	0	30	0	30
	SW	0	0	115	115
	FP	0	16	0	16
	FC	0	24	16	40
	WS	113	66	82	261
	PR	0	0	0	0
	PO	0	16	0	16
	WQ	83	40	51	174
	BV	29	0	0	29
	HS	29	0	0	29
Riverine	RU	28	23	0	51
	DI	0	0	0	0
	LFF	0	0	0	0
	FS	0	69	0	69
	SW	0	0	28	28
	FP	0	18	0	18

	FC	0	12	0	12
	WS	29	94	27	150
	PR	0	0	0	0
	PO	0	32	0	32
	WQ	36	133	23	192
	BV	0	48	0	48
	HS	0	0	0	0
Waste Dump	RU	32	_	_	32
	DI	0	_	_	0
	LFF	0	_	_	0
	FS	0	_	_	0
	SW	0	_	_	0
	FP	0	_	_	0
	FC	0	_	_	0
	WS	622	_	_	622
	PR	0	_	_	0
	PO	0	_	_	0
	WQ	21	_	_	21
	BV	0	_	_	0
	HS	397	_	_	397
	Grand Total	2038	1108	877	4023
*For the abbreviations refer to Table 3.1 and 3.3					

3.6.2 Pond Heron

3.6.2.1 Foraging Behavior

The frequency of foraging technique of *Ardeola grayii* differs with respect to habitats. Each species used more than one feeding technique and this apparently helped the bird to utilise the resource from different zones. Pond Herons utilised the food resources from riverine habitat using three techniques whereas in all other habitats it used four or more repertoires. They are occasionally observed in waste dumpsites scavenging the fresh fish wastes. Pond Heron was observed foraging in terrestrial as well as aquatic habitats both in breeding and non-breeding season. The feeding technique used by these birds in different habitats can be summarised as follows.

3.6.2.1.1 Paddy fields

Pond Herons used six types of foraging techniques in the Paddy fields. They were I) stan*d and wait*, ii) *walk slowly, iii) walk quickly, iv) diving, v) leapfrog feeding and vi) fly catching.* The most common method among them was *stand and wait.* Since its morphology prevents it from wading in deeper waters, this is the most suitable foraging behaviour (Sodhi, 1986). The least common foraging method adopted by pond Heron in

paddy field was *flycatching*. Among the three species under study, Pond Heron alone used *stand and wait* method in paddy fields (Table-3.4). During *stand and wait*, it squatted expecting the arrival of the potential prey to strike. The next frequently used foraging technique was *walk slowly*. The third method of feeding strategy adopted by pond heron in paddy field was *diving*. In this instance, 3-5 birds perched on fencing stones, jumping headfirst into a stream flowing through the margins of paddy field during monsoon season. The fourth method of foraging strategy adopted by pond heron in paddy field was *walk quickly*. At times pond herons are observed adopting *walk quickly* strategy in pursuing the prey items like tadpoles, naiads of dragonflies and especially earthworms and fishes exposed during ploughing. The earthworms and fishes so exposed along with tadpoles and naiads will be chased by *walk quickly* method. The other less common feeding technique that observed in this bird includes *leapfrog feeding* and *fly catching*. Though they are solitary in habit, at some occasions, when paddy field are subjected to ploughing, individual pond herons from the rear end of a feeding flock flies to the front and seizes the prey. Fly catching is primarily observed as a technique used for catching dragonflies.

3.6.2.1.2 Wet grassfields

Pond heron in wet grassfield exhibited five types of feeding strategies. They were, *stand and wait, walk slowly, walk quickly, leapfrog feeding and flycatching*. Of these methods, *walk slowly and leapfrog feeding* is the most common foraging method adopted in the wet grassfield. Among the three species, Pond Heron alone used *stand and wait* strategy in grass fields. The least common foraging technique adopted by Pond Heron was *flycatching*. Occasionally they are observed to use *walk quickly, running, leapfrog feeding, and flycatching*. *Flycatching* is the method used for catching dragonflies that will multiply in large numbers immediately after the southwest monsoon. They were also observed running after crabs and Gryllotalpa.

3.6.2.1.3 Riverine Habitat

Both the freshwater rivers and estuarine habitats were included under this title. Three types of feeding behaviours observed were, *walk slowly, walk quickly, and stand and wait*. Pond herons used both *stand and wait* and *walk quickly* more or less equally in

riverine habitat. *Stand and wait* method was mainly used for catching fishes whereas *walk slowly* and *walk quickly* were used for catching burrowing fishes like *Lepidocephalus thermalis* and insects including naiads of dragonflies respectively.

3.6.2.1.4. Jheels

The jheels covered with weeds, and the shallow waters provide habitat for the foraging herons. Pond herons adopt *stand and wait, walk slowly, walk quickly and flycatching*; among which the most common method is *stand and wait*. Of the three species Pond Heron alone used stand *and wait* strategy in jheels. The least common method of foraging used by Pond Herons in jheels was *flycatching*. Jheels provide habitat for fishes, tadpoles, frogs, naiads of dragonflies and a variety of insects.

3.6.2.1.5 Waste dump

This unnatural habitat rarely supports the pond herons. At times one or two pond herons were observed scavenging among the garbage dumped in the yard. Here, they adopted *walk slowly* method for searching food items along the borders of waste dump having sparse vegetation.

3.6.2.2 Prey Abundance

The aquatic fauna captured during prey sampling belonged to 60 taxonomic groups with notable monthly variation in distribution (Chapter-II). Similarly, the terrestrial organisms collected during prey sampling in different habitats of the foraging areas were of 61 taxonomic groups (Chapter-II) with distinct seasonal variation in their distribution.

3.6.2.3 Food spectrum

The food items observed in the gut contents of both the adults and the nestlings belonged to Phylum Annelida, Arthropoda and Chordata. Earthworms of the Class Oligochaeta represented annelids. Class Insecta, Crustacea and Arachnida represented arthropods. Families such as Apidae, Pyralidae, Tettigoniidae, Acrididae, Tetrigidae, Cicadidae, Elateridae, Gryllidae Lestidae, Aeshnidae, Libellulidae, Gryllotalpidae, Gryllidae and Fulgoridae represented insects. Some larval forms of moths and beetles and naiads of dragonflies were also collected. Few crabs and Arachnid species represented the Classes

Crustacea and Arachnida respectively. Among the Chordates members of Class Pisces (*Puntius amphibius*; *Macropodus cupanus*; *Parluciosoma daniconius and Lepidocephalus thermalis*), Class Amphibia (tadpoles) and Class Reptilia (Calotes spp and Mabuya spp) were seen.

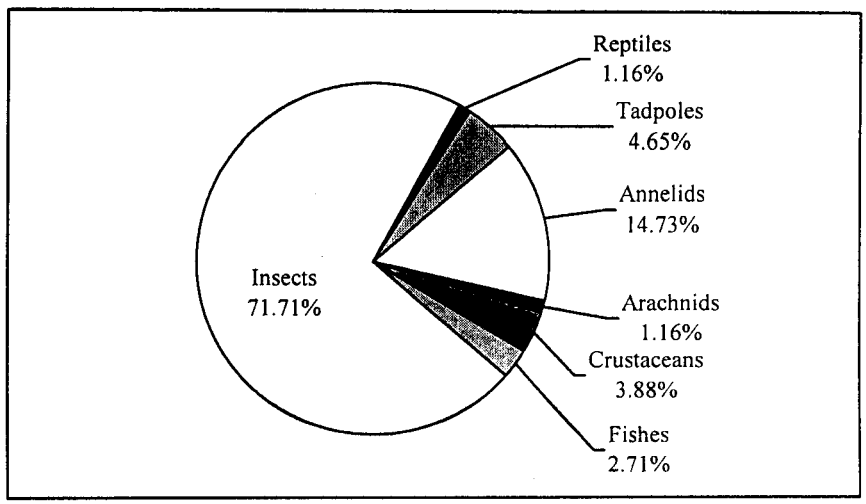


Figure-3.1 Percentage composition of food items in Pond heron

In all, 258 prey items belonging to 26 taxonomic groups were present in the guts of adult Pond Herons collected from 13 samples. The percentage composition of the gut contents of pond heron is shown in Figure-3.1. The food of the adult species consisted of annelids (14.7% of total number), insects (71.7%), Crustaceans (3.88%), Arachnids (1.16 %), Annelids (14.7 %), tadpoles (4.65 %), and fishes (2.7%), and reptiles (1.16%). The most important prey item observed in the adult Pond Heron was the short horned grasshoppers of family Acrididae (116 Numbers) accounting for 45% of the total by number. The next important prey item was *Megascolex spp* (38 Numbers) accounting for 14.7% of the total by number. The Fishes accounted for only 2.7% of total by number.

The comparative abundance of the food items in the gut content samples of Indian Pond Heron is shown in Table-3.5. The aquatic food items present in the regurgitated pellets include Beetle larva (coleoptera), *Macropodus cupanus*, *Aplocheilus lineatus*, *Puntius*

amphibius, *Parluciosoma daniconius* (Pisces), Tadpole, *Rana spp* (Amphibia), crabs (Crustacea), and Dragonfly naiad (Odonata). The terrestrial organisms observed in the pellets regurgitated by the chicks included short horned grasshoppers (Acrididae), and *Arachnid sp.*

Table- 3.5 Abundance of different food items in the gut contents (in parenthesis the number of samples are given)

Food item	Cattle Egret (13)	Little Egret		Pond Heron		Total (52)
		Adult (11)	Nestlings (13)	Adult (13)	Nestlings (2)	
Acrididae	70 (10)	5 (3)	2 (2)	116 (7)	3 (2)	196 (24)
Apidae				1 (1)		1 (1)
Aplocheilus blockii			3 (2)			3 (2)
Aplocheilus lineatus		2 (1)	7 (5)		1 (1)	10 (7)
Arachnid spp	7 (6)			3 (3)	1 (1)	11 (10)
Beetle Larva					2 (1)	2 (1)
Belostomatidae			1 (1)			1 (1)
Blattidae	4 (2)					4 (2)
Calliphoridae	3 (2)					3 (2)
Calotes spp				2 (1)		2 (1)
Carabidae				1 (1)		1 (1)
Centipede	1 (1)					1 (1)
Chrysomelidae	5 (4)					5 (4)
Cicadidae				1 (1)		1 (1)
Coreidae	7 (3)					7 (3)
Danio acquipinnatus			7 (5)			7 (5)
Danio acuipinnatus					1 (1)	1 (1)
Dragonfly Naiad	5 (2)	8 (5)	1 (1)	3 (2)	4 (1)	21 (11)
Elateridae	2 (2)					2 (2)
Esomus danricus			1 (1)			1 (1)
Etroplus maculatus			1 (1)			1 (1)
Fulgoridae				4 (1)		4 (1)
Glossogobius giuris		1 (1)				1 (1)
Gryllidae	1 (1)			21 (4)		22 (5)

Gryllotalpidae		1 (1)		1 (1)		2 (2)
Hydrophilidae	1 (1)		9 (1)			10 (2)
Lepidocephalus thermalis		264 (6)	66 (10)	1 (1)		331 (17)
Lestidae			1 (1)	2 (2)		3 (3)
Libellulidae	4 (2)	5 (3)		6 (4)		15 (9)
Mabuya spp				1 (1)		1 (1)
Macropodus cupanus		109 (6)	126 (11)	4 (2)	8 (2)	247 (21)
Megascolex spp				38 (3)		38 (3)
Meloidae	2 (2)			1 (1)		3 (3)
Moth Larva				1 (1)		1 (1)
Muscidae	20 (4)					20 (4)
Mystus cavasius			1 (1)			1 (1)
Noctuid larva	1 (1)					1 (1)
Fully digested paste	0 (1)			0 (3)		0 (4)
Notonectidae			1 (1)			1 (1)
Paddy Crab			5 (3)	10 (5)	1 (1)	16 (9)
Pangiogoaensis			1 (1)			1 (1)
Parluciosoma daniconius		14 (4)	45 (10)	1 (1)	12 (1)	72 (16)
Puntius amphibius		31 (3)	74 (10)	1 (1)	3 (1)	109 (15)
Puntius vittatus		91 (3)	2 (2)			93 (5)
Pyralididae				1 (1)		1 (1)
Rana spp			1 (1)			1 (1)
Limnonectes limnocharis	15 (2)				1 (1)	16 (3)
Rattus spp	1 (1)					1 (1)
Semi-digested fishes			7 (1)			7 (1)
Tabanidae	2 (2)					2 (2)
Tadpole		1 (1)	4 (2)	12 (1)	4 (1)	21 (5)
Tetrigidae	3 (3)			25 (3)		28 (6)
Tettigoniidae	3 (2)			1 (1)		4 (3)
Unidentifiable particles		0 (1)				0 (1)
Unidentified Larva	9 (2)					9 (2)
Total	166 (22)	532 (13)	366 (22)	258 (26)	41 (12)	1363 (55)

Altogether, 41 prey items belonging to 12 taxonomic groups were present in the regurgitates of nestling collected from two samples. The percentage composition of the

gut contents collected from two samples of nestling-pond herons are shown in Figure-3.2. The food of the nestling consisted of Fishes (62.50% of the total number), Insects (22.50%), Tadpoles (10%), Arachnids (2.50%) and Crustaceans (2.50%). The most important food item was the fish *Parluciosoma daniconius* that accounted for 29.26% of the total by number. The next important food item was the fish *Macropodus cupanus* that accounted for 19.51% of the total by number.

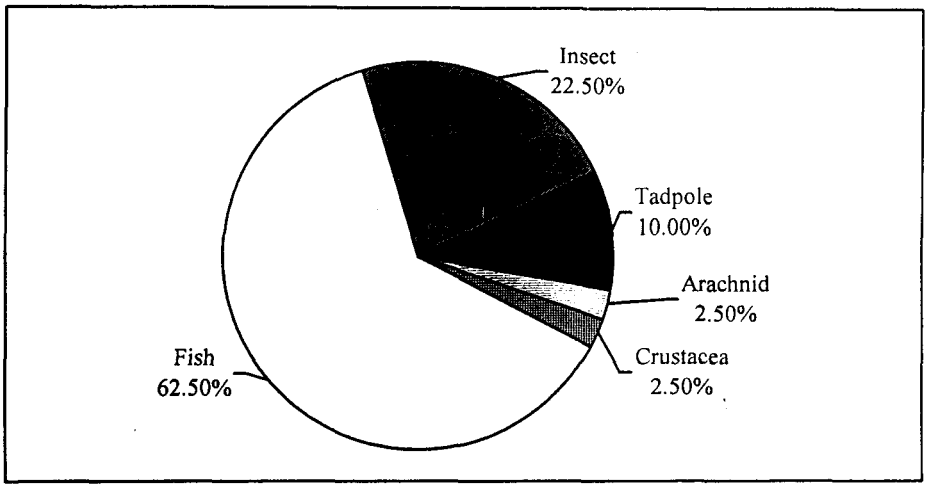


Figure-3.2 Percentage composition of food items in nestlings of pond heron

The food of pond heron consisted mainly of insects and other reptiles during summer season and paddy-crabs, fishes and earthworms during the monsoon seasons. The monsoon foods are seemingly of larger biomass. Hence, the bird has to incur proportionately less energy expenditure in capturing food. Items like fishes, crabs, insects and earthworms were observed in the food during the spring whereas insects, frogs and tadpoles were observed during autumn. Since almost all habitats pond herons foraged is dry in summer, their summer food contained mainly insects. The same habitat gets inundated during the monsoon and a lot of aquatic insects and fishes enter these habitats during heavy rain when the rivers and streams overflow. During monsoon, there is also growth of herbaceous vegetation. The growth and multiplication of the herbaceous vegetation and overall conducive climate bring about an increase in insect population.

3.6.3 Little Egret

3.6.3.1 Foraging behaviour

3.6.3.1.1 Paddy Field

Little egrets use paddy field as an important habitat for foraging as paddy field provides a lot of food species like frogs and their tadpoles, aquatic insects, crabs, naiads of dragon flies, few fishes and some terrestrial insects. The commonly used foraging methods of this bird in this habitat were i) *walk quickly, ii) walk slowly* and iii) *running.* The less frequent method adopted include *leapfrog feeding, foot stirring, aerial feeding, foot paddling* and *peering over.* Among the three species under study Little Egrets alone used *foot stirring, foot paddling and peering over* in paddy fields. However, Little Egrets are comparatively least abundant in Paddy field than the other two species (12.18 %, Chapter- II).

3.6.3.1.2 Wet Grassfield

Little egrets were observed in this habitat throughout the year except during the summer whence they gradually shift their foraging range into certain other wet habitats like marshes, jheels, rivers and estuaries. The most frequently used foraging strategies of this bird in this habitat were *fly catching, walk slowly,* and *leapfrog feeding.* Since paddy field and wet grassland contain more or less similar organisms like frogs and tadpoles, naiads of dragonflies, insects and some fishes, they have to rely upon similar foraging tactics. The less common feeding techniques adopted by the bird was *walk quickly,* and *running,* and *foot stirring* respectively. Among the three species Little Egret had least preference for grass field. Their comparative abundance in grass field was only 3.3% (Chapter-II).

3.6.3.1.3 Riverine

Riverine habitats in the study area were observed overflowing during heavy monsoon, from June to August, and these habitats becomes unsuitable for these birds to forage at least up to October because of the water depth. November onwards the birds use this area and their usage reaches maximum during summer. February onwards their foraging numbers increases and was observed feeding in flocks. The most frequently used foraging technique by these birds in Riverine areas were *walk quickly, walk slowly* and *foot stirring.* The less common foraging technique adopted by this bird include *running,*

foot paddling, bill vibrating, aerial fly catching, and peering over. Among the three species Little Egret is comparatively most abundant both in fresh water and estuarine habitats. Since fresh fishes are their major food and these habitats having a variety of fishes they prefer these habitats to other aquatic areas.

3.6.3.1.4 Jheels

Like riverine habitats, jheels are also flooded during monsoon and the minimum water depth observed from June to October was above 0.5m. Since the length of the tarsus of these birds is less than 15 cm, they could not use such a habitat until October. Thereafter they start appearing in jheels and their number reached highest during summer when most of the other habitats get dried up. This habitat also provides a variety of food species such as *Puntius vittatus*, *Macropodus cupanus*, Naiads of dragonflies, and other aquatic and terrestrial organisms. The commonly used foraging strategy adopted by the bird in this habitat was *walk slowly, walk quickly*, and *running*. The less frequently adopted feeding technique included *foot stirring, leapfrog feeding*, and *foot paddling*. Among the three species Little Egret had comparatively lower abundance in jheels.

3.6.3.1.5 Waste Dump

Not even a single little egret was observed in the waste dumping site, probably because they are highly piscivorous, aquatic and most specific in selecting aquatic preys.

3.6.3.2 Prey Abundance

Of 60 taxonomic groups of aquatic and 61 taxonomic groups of terrestrial prey organisms collected during the entire study period, the food items collected from the gut contents of adult Little Egret belonged to 12 taxa, while that of nestlings belonged to 21 taxa.

3.6.3.3 Food spectrum

The gut content collected from eleven birds showed that the food of this species consisted of fishes (Plate 3c, 96.24 % of total by number), amphibians (0.19 %) and insects (3.57 %). The most important prey item seen in the gut content was the fish *Lepidocephalus thermalis* (264 numbers) accounting 49.6 % of total by number (Figure-3.3). Another important prey item *was Macropodus cupanus* (109 number) accounting 20.5 % of the total by number.

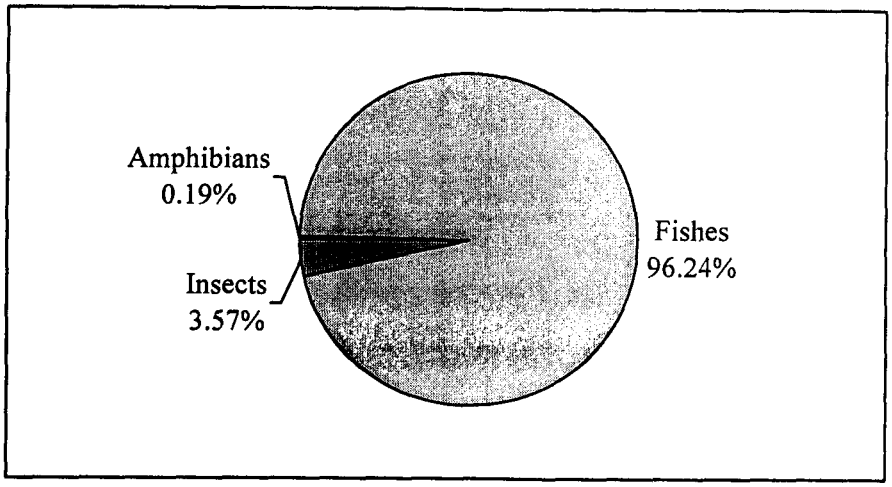


Figure- 3.3 Percentage compositions of food items in Little Egrets

The boluses of regurgitates collected from 13 samples of chicks (Figure-3.4) showed that the food of chicks consisted of fishes (91.3% of total by number), amphibians (1.4%), Crustaceans (1.4%), insects (4.10%), and miscellaneous items (1.9%). The most important prey item was *Macropodus cupanus* (126 by number) accounting 34.4% of total by number. Another important prey item was *Puntius amphibius* (74 by number) accounting 20.2% of the total.

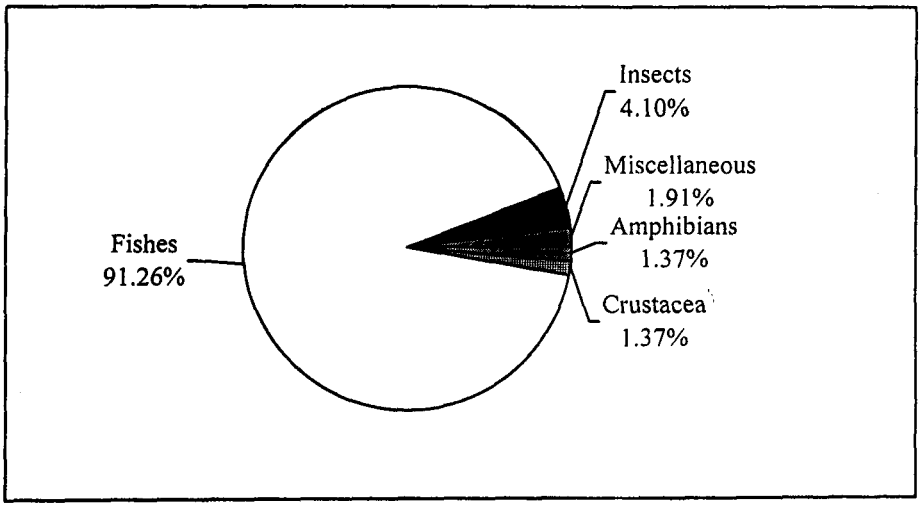


Figure- 3.4 Percentage composition of food items in nestlings of Little egret

3.6.4 Cattle Egret

3.6.4.1 Foraging Behaviour

3.6.4.1.1 Paddy field

When data were pooled for all months, there were significant differences among species in the relative use of each foraging techniques (Table-3.4). Cattle Egrets used mostly the *walk slowly,* the *walk quickly* and *running* methods for foraging. The less frequent foraging strategies used by cattle egrets in paddy fields were *bill vibrating*, *head swaying* and *leapfrog feeding.*

3.6.4.1.2 Grasssfield

Cattle egrets foraging in grassfields were observed to exhibit three types of common feeding strategies. They were *walk slowly*, *running,* and *walk quickly.* The less common method of foraging behaviour adopted by cattle egret in grassfield was *leapfrogfeeding* and *head swaying.* Among the natural habitats grass-field shows highest abundance of the birds. The relative percentage of Cattle Egret in grass field was also highest (58.9%) and similar to that in paddy field with respect to other birds

3.6.4.1.3 Riverine

The most common foraging technique in riverine habitat was *walk quickly*, followed by *walk* slowly and *running.* Cattle Egrets were observed foraging rarely in riverine habitats except during habitat shrinkage wherein they are mostly observed in association with cattle or foraging alone in the vicinity of cattle. In fresh water riverine (Karimpuzha) habitat Cattle Egret was the second abundant bird (31%) while in brackish (Kadalundy) riverine habitat they were totally absent compared to the other two species

3.6.4.1.4 Jheels

The most frequent method of foraging observed in cattle egret in jheels was the so- called *walk quickly.* The other techniques they adopted was *running* and *walk slowly.* Jheels are inundated from June to December. Thereafter it gradually gets drained and water level reaches minimum during April and May. At this time of the year large number of Cattle Egrets aggregate in such jheels. Though the jheels are covered with a lot of weeds, as they dry up during summer the weeds are replaced by grasses, herbs and other shrubs

which harbours a lot of insects, which in turn aid abundance of birds. Moreover, as the water spread area shrink and the depth reduces certain shallow pools only remains. In these pools containing aquatic insects and their larvae cattle egrets forage in flocks. Of the three species birds observed in Jheel Cattle Egret was the second abundant (29.9%) species.

3.6.4.1.4 Waste dump

Apart from the natural habitats, cattle egrets were observed in artificial habitats such as heaps of solid wastes containing fish discarded or parts from markets, remnants of slaughtered or dead animals, chicken wastes, hotel wastes, hospital wastes and other miscellaneous items are dumped. In such waste dumps, a lot of houseflies and blue bottles along with their maggots were observed. This attracted hundreds of cattle egrets into such areas. The foraging techniques adopted by cattle egret in such waste dump included *walk slowly, head swaying, running* and *walk quickly i.e.* methods quite suitable for a prey rich location. The most common methods of foraging strategy observed in cattle egrets in waste dump were *walk slowly* and *head swaying*. The probable reason for this may be the abundance of adult flies and their maggots, which were not common in other natural habitats.

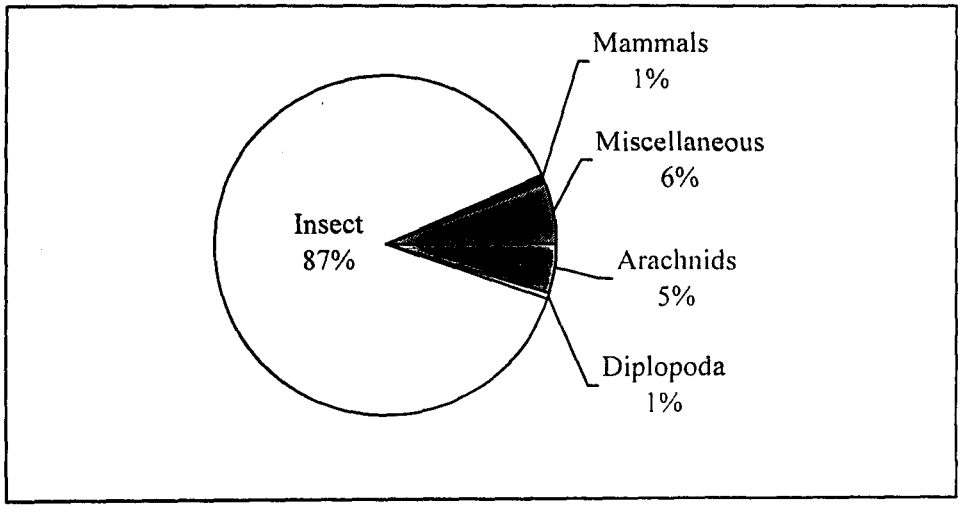


Figure-3.5 Percentage composition of food items in Cattle Egret

3.6.4.3 Prey Abundance

The aquatic fauna captured during prey sampling belonged to 21 taxonomic groups while the terrestrial organisms collected during the study period were of 145 taxonomic groups.

3.6.4.4 Food spectrum

The aquatic organisms analysed from the gut content were of 3 taxonomic groups namely Odonata (dragonfly and damselfly naiad), Hydrophilidae and Amphibia (Frogs). The terrestrial fauna captured during prey sampling belonged to 14 taxonomic groups; Odonata (adult dragonfly), Tettigoniidae (long horned grasshoppers), Acrididae (short horned grasshoppers), Arachnidae, Coreidae, Coleoptera (Chrysomelidae), Blattidae, Gryllidae, Diptera (Muscidae, Calliphoridae, Tabanidae), Hydrophilidae, Hymenoptera, and Centiped and a single Mammalian (*Rattus spp*) individual.

The data on the percentage composition of the food of the adult Cattle Egret (Figure-3.5) shows that the food consisted of insects (87% of the total number), Arachnids (5 %), Diplopods (1%), Mammals (1%) and Miscellaneous items (6%). The most important prey item was short horned grasshoppers of the family Acrididae (70 Numbers) accounting for 42.2% of the total by number. Another important food item was houseflies belonging the insect family Muscidae (20 Numbers) accounting 12.0% of the total by number.

3.6.4.4 Cattle Egret –Cattle Association

From the total of 1118 birds observed to examine the association, 652 (58.3% of the total) were found associated with cattle (Plate 4a) during the year 2000-2001. The association was highest in grassfields than in jheel and paddy fields. The least association was observed in plantation (Figure-3.6). In the waste yard no association could be seen because no cattle is allowed in the compound.

Since cattle egrets shows local movements during breeding season that coincides with heavy monsoon (June to September), they were not observed either associated with cattle or independently grazing in any of the study areas during this period.

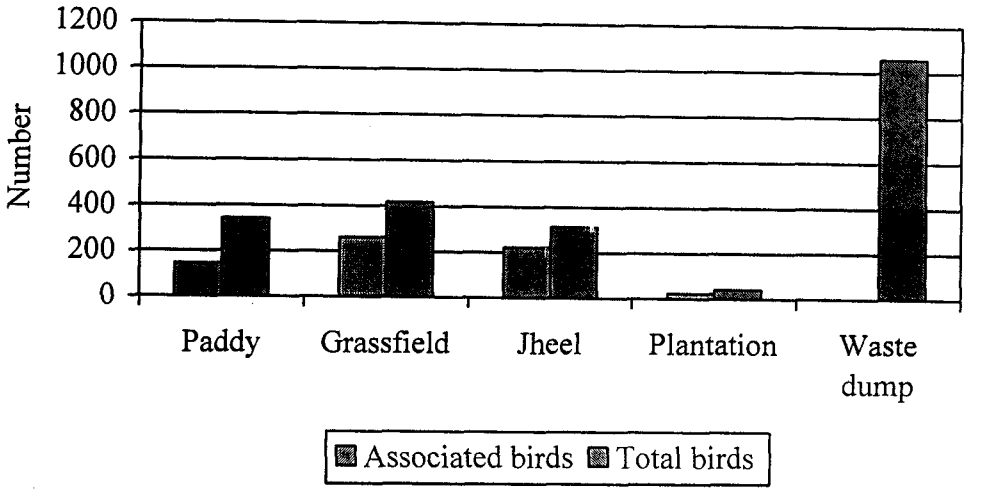


Figure-3.6 Comparative abundance of associated egrets in different habitats

3.6.4.4.1 Associated Feeding

The details of associated and non-associated feeding of Cattle Egrets are shown (Table – 3.6). An associated Cattle Egret had a mean capture (successful feeding) of 1.33 ± 0.86 per minute. The mean steps used by an associated egret were 19.78 ± 2.06 and the mean strikes 4.80 ± 1.77 per minute. One-way ANOVA of capture, steps and strikes between associated and non-associated egrets was highly significant (Table-3.7).

Table-3.6 Comparison of the mean capture, steps and strikes in the associated and non-associated Cattle Egrets

			Mean	Std Deviation	Sum
ASSOC	Associated	CAPTURE	1.33	.86	113.00
		STEPS	19.78	2.06	1681.00
		STRIKES	4.80	1.77	408.00
	Non Associated	CAPTURE	.87	.75	74.00
		STEPS	29.51	2.54	2508.00
		STRIKES	3.55	1.29	302.00

Table-3.7 One way ANOVA of capture, steps and strike rates between associated and non-associated Egrets

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
CAPTURE	Between Groups	8.947	1	8.947	13.621	.000
	Within Groups	110.353	168	.657		
	Total	119.300	169			
STEPS	Between Groups	4023.112	1	4023.112	754.333	.000
	Within Groups	896.000	168	5.333		
	Total	4919.112	169			
STRIKES	Between Groups	66.094	1	66.094	27.579	.000
	Within Groups	402.612	168	2.396		
	Total	468.706	169			

3.6.4.4.2 Non-associated feeding

The non-associated Cattle Egret had capture rate of 0.87 $\pm$ 0.75 per minute. It used 29.51 $\pm$ 2.54 steps and 3.55 $\pm$ 1.29 strikes per minute.

3.6.4.4.3 Diurnal pattern in association

In different study areas of Malabar region, hundreds of Cattle Egrets were observed roosting in Rubber plantations (estates) along with other egrets. They leave the roosts at about 0600h and fly off in small groups to different locations. They return to their roosting site at about 1800–1815h, it can vary in short-day winter and long-day summer. In general the birds starts coming to the roosting site about 30 minutes before sunset. During the day, they may feed either independently or associated with cattle based on the habitat and the presence of cattle. Association of Cattle Egret with cattle was observed maximum from 0900 in the morning till 1200 at the noon and again from 1400 in the afternoon till 1600 in the evening. Association was minimum during early hours of the day and late hours in the evening, i.e., 0600-0900 and 1600-1800 respectively (Figure-3.7).

3.6.4.4.4 Seasonal patterns in Association

The association of cattle and cattle egret shows a seasonal pattern based on the climatic factors, nature of habitats, and availability of food (Figure-3.8). The seasonal pattern in cattle and cattle egret association, in grass field, was highest in December and April whereas in jheel maximum association was during December to March. In the Paddy field highest association was during December; thereafter the association weakens to reach a minimum in May.

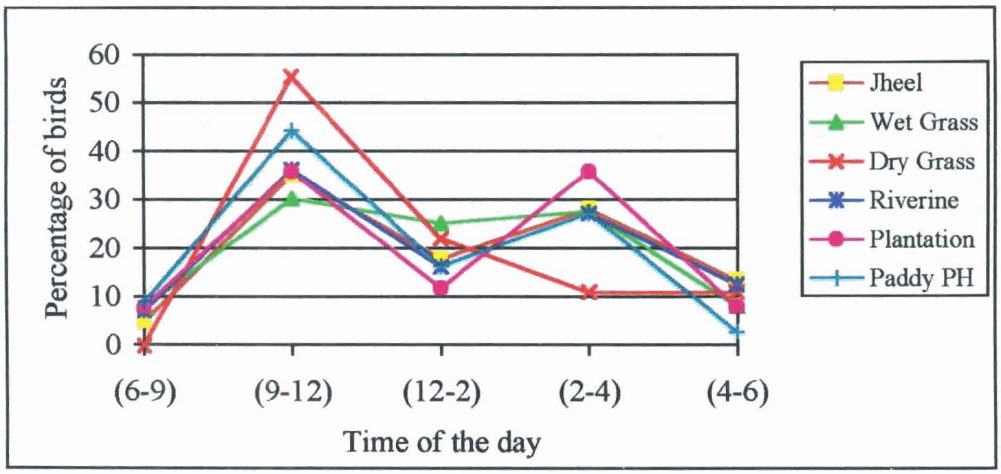


Figure- 3.7 Diurnal patterns in the association of Cattle Egrets in different habitats

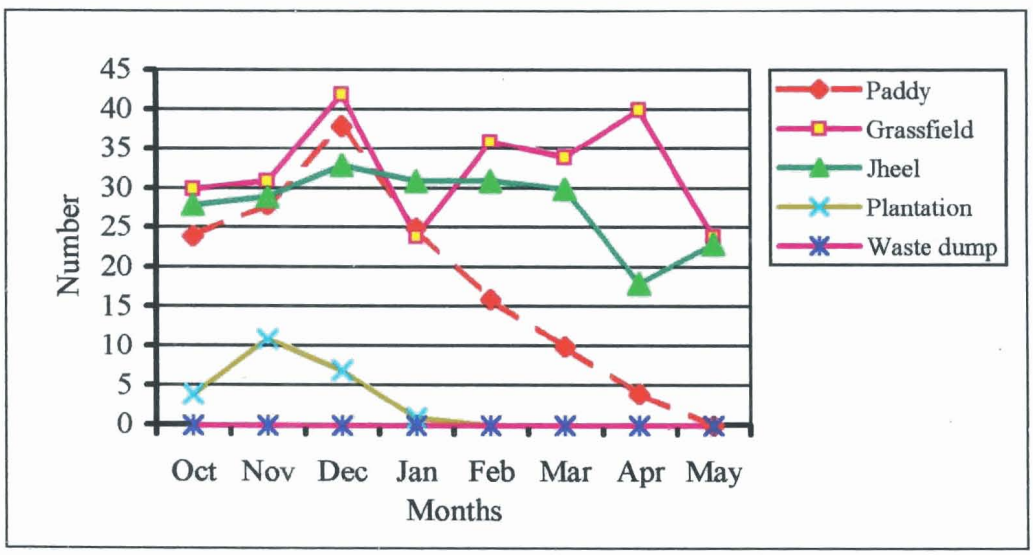


Figure-3.8 Seasonal variation in the association of Cattle Egrets in different habitats

3.7 DISCUSSION

The formalisation of feeding behavior was started by Meyerricks (1962) and continued by Kushlan (1976 a). The environmental determination of food dispersion is complex, but critical to understanding the feeding ecology of wading birds and their study in this respect is very few (Kahl 1964; Vespermeanu 1968; Kushlan and Kushlan 1975; Kushlan 1976 c). The prey selection of these birds was examined by various authors (Siegfried 1971a, 1975; Kushlan and Kushlan 1975; Owen 1955; Willard 1977; Jackson 1984; Mock and Mock 1980; Fasola 1981; Rodger Jr. 1976). Temporal variation in the feeding habits of the Purple Heron *Ardea purpurea* during the breeding season (Campos and Leukona I997) and commensalism in the Little Blue Heron (Kushlan 1978) also have been reported.

Major foraging techniques adopted by wading birds at different habitats in the present study were similar to the other reports. Significant variation in the methods adopted by the bird depending on the nature of habitats and seasons was observed during the present study. All the species under study used only a few foraging methods, which vary among the species, was observed during the present study (Table-3.6). Each method is adopted based on suitability to the habitat and the prey. Even finer aspects such as bobbing the head had their role in successful prey capture (Welty 1979) as it assists in locating the prey better.

The differences in basic foraging techniques of various herons are a strategy to avoid competition, since differences in foraging skill help catch a variety of food items (Willard 1977). The three species of herons, under study, are predominantly aquatic feeders, the depth at which the heron hunts being often related to its size (Meyerrieks 1962; Kushlan 1976; Custer and Osborn 1978). Though these species are largely aquatic in habit, they are also observed sometimes in terrestrial habitats depending on the climatic conditions and food availability. Cattle Egrets are more terrestrial than the other two species since they prefer terrestrial species to aquatic ones in their food. The major observations in food, feeding and foraging behviours of the three species of birds are discussed below.

3.7.1 Pond Heron

Of the six types of foraging techniques used by Pond Herons in paddy fields the most common method was *stand and wait.* In *diving* adopted by pond Herons in paddy fields, 3-5 birds perched on fencing stones jumped headfirst into a stream flowing through the margins of paddy field during monsoon season. Since the breeding season coincides with monsoon, this may be considered as an additional method for collecting fishes and tadpoles observed in abundance in the gut of the chicks during the breeding season. The technique adopted by pond heron in catching fishes while in flight, as described by Kirkpatrick (1953) and Grimwood and Brocklehurst (1984) could not be observed in this study. *Fly catching* method reported by earlier workers (Kirkpatrick 1953; Grimwood and Brocklehurst, 1984) was also recorded in the present study. Among the three species under study, pond herons lie second in paddy field with respect to percentage abundance.

Mostly they were seen in cultivated paddy fields. Occasionally they were observed foraging in dry plots covered with paddy stubbles. When such dry fields were inundated Little Egrets, Pond Herons and Sandpipers frequent such habitats. When inundated paddy fields were ploughed Pond Herons, Crows, Mynas, Brahminy Kites, and Common Snipes gets attracted to such areas in aggregations or flocks (Subramanya 1996; Perennou et al. 2000). Similar observations are also recorded in the present study.

The presence of bees in the diet of Pond Heron is reported in the present study. This is also reported elsewhere (Prasad & Hemanth 1992). Inclusion of earthworms as a food item of this bird was also recorded earlier (Raza 1993). The most preferred foraging habitats of Pond Heron include Jheels, riverine habitats and grass fields. During ploughing operations they were seen in flocks following tractors in paddy fields and pecking up frogs, tadpoles, fishes and earthworms. Rice fields are important breeding sites of frogs (Richardson et al. 2001). Since the food of an adult pond Heron is composed of 71.7% of insects (Figure-3.1) and the remaining annelids, arachnids, crustaceans, fishes, amphibians (tadpoles), and reptiles they prefer an admixture of habitat having both aquatic as well as terrestrial prey organisms. This is shown by their presence in such habitats having all these organisms (Chapter-II Appendix-2.7).

Of the five types of foraging strategies adopted by Pond Herons in wet grassfields, the most common foraging methods were *walk slowly* and *stand and wait.* Wet grassfield had water regime with different species of aquatic organisms and a surrounding vegetation regime with different insects species. Since this habitat contain mostly fishes and short horned grasshoppers, these two foraging techniques are very important because in such habitats, if they move quickly these insects would be disturbed and they may escape. So they evolved a strategy not to disturb the prey species and wait for an opportune moment to have a 'sure shot'. Among the three species with respect to percentage abundance in grass field Pond herons come second (37.8%).

Pond Herons used altogether three types of foraging techniques in riverine habitats. *Stand and wait* method was used for catching swiftly moving fishes like *Macropodus cupanus, Parluciosoma daniconius, Puntius amphibius,* etc., and insects like Acridids, Libellulids and Lestids. W*alk slowly* method was for catching slowly moving prey items such as earthworms and *walk quickly* for naiads of dragonflies and damselflies. Among the three species with respect to percentage abundance Pond herons come first in Karimpuzha (41.2%) and second in Kadalundy (47%) riverine habitats. River Karimpuzha has a variety of prey organisms like fishes, aquatic insects, amphibians, and some insects in around the vegetations at the banks of the river. This gives them easy access to insects and other aquatic organisms. In Kadalundy riverine area, area with notable vegetation is comparatively less that will reduce insect population. In addition, as this area is under tidal influence, access to this habitat is only during low tide.

The shift in foraging habitats in summer may be due to (a) habitat shrinkage, (b) turbidity of water during monsoon season (Kushlan 1981), (c) lack of patience to wait and search for a particular species of prey item since the parent birds have to rush to feed their chicks during breeding season and /or need to scan more habitats due to the increased food demands of the chicks (Sodhi 1986). The third reason quoted above may be debatable as breeding is generally timed at a period when food is available in plenty. As some prey is more frequent than the others in diet, it suggests that the prey item differ in availability or in the ability of an individual to catch them (Kushlan and Kushlan 1975). The length of bill and tarsus of pond heron is comparatively shorter than the other

two species. The mean bill length varies from 50- 75 mm, 55-80 mm, and 85-105 mm in Pond Heron, Cattle Egret, and Little Egret respectively. This has important role in deciding the specific size range of the prey the species can catch and feed on. Accordingly they will have to try different foraging techniques to collect the different preys of their interest within the size range. The tarsus length also has major role in foraging repertoire, since it limits water depth to which the bird can venture into without endangering its own safety. The mean tarsus length varies from 55-70 mm, 60-90 mm, and 100-110 mm (Appendix-3.1) respectively in Pond Heron, Cattle Egret, and Little Egret. This difference in lengths of tarsi corresponds with their mean size (Appendix-3.2). All these factors will limit the nature of the foraging techniques the bird should adopt and the nature of prey the bird can collect. For example, in Pond heron since its morphometric characteristics prevents it from wading in deeper waters, *stand and wait* is the most suitable foraging behaviour (Sodhi 1986) for such locations.

3.7.2 Little Egret

Little Egrets were observed foraging in a variety of habitats such as paddy fields, wet grassfields, jheels, freshwater habitats, estuarine marshes, pools and puddles. Among the three species of birds under study, little egrets when compared to pond herons were more associated with water. Little Egrets are less terrestrial or Cattle egrets are more terrestrial than pond herons and Little Egrets. Among the various foraging techniques, the most common method was *walk quickly* and *walk slowly* and *running*. They were observed using *walk slowly* method to forage in paddy field. Though their food mainly composed of fishes, the dominant fishes in their food were *Lepidocephalus thermalis*, for which they were observed *walking quickly* and sometimes even *running*. At times they use *running* to capture crabs that cannot move faster than egret from paddy field. *Foot Stirring* is observed using to bring out concealed aquatic crabs from among vegetations. Dragonflies were seen captured by *flycatching* technique.

In India, rice fields are exploited by several heron species: Cattle, Little, Intermediate, and Great White egrets; Indian Pond, Little Green and Purple herons, and Yellow and Cinnamon bitterns (Subramanya 1996; Perennou et al. 2000). Rice fields, an integral part of wetland, are often important habitat for some species of water birds particularly in

regions where the availability of natural marshes has diminished (Fasola and Ruiz 1996). Little Egrets remain in Paddy fields until late tillering stage. Following the commencement of southwest monsoon, all the wetlands get inundated and these birds have a variety of habitats. Of these habitats, rivers and jheels are inaccessible during heavy rainfall at least up to October because of the water depth. However these birds are chiefly observed feeding in paddy fields and grassfields, which get supplied with a lot of fishes, and aquatic organisms that come along with rising flood water level in the rivers and streams. Moreover, a lot of frogs start breeding and the tadpoles were observed in these locations during this season. Since the breeding season of these birds coincides with monsoon, from June to September, this provides them additional advantage in terms of resources, probably one of the reasons for coinciding the breeding season. The gut contents, both of the adults and nestlings of Pond Herons and Little Egrets contained a lot of fishes like *Parlusciosoma daniconius, Puntius amphibius, Lepidocephalus thermalis, Puntius vittatus* Day, *and Macropodus cupanus* that are available plenty in suitable sizes.

Among the three species Little Egret has least preference for grass field. They were observed in wet grass field during rainy season during which the species richness of aquatic organisms and fishes in wet grass field was comparatively higher than in other months (Chapter-II). Since their food species are mostly fishes, in all other seasons except monsoon they prefer aquatic habitats such as river Kadalundy, river Karimpuzha, jheels and Paddy fields that are plenty in fishes. Among various habitats, the order of percentage abundance of little egret is Kadalundy river > Karimpuzha river > Jheel >Paddy field > Grass field. This clearly shows their preference towards more aquatic habitats such as rivers and jheels than to less aquatic habitats such as paddy fields and grass fields.

Fishes being the major food of Little Egret and a variety of fishes being present in fresh water (Karimpuzha river) and estuarine (Kadalundy river) habitats they prefer such habitats to other non-riverine areas. This is supported by the observation (Wong et al. 2001) that shallow coastal waters and mudflats were the most important habitats at low tide for Great and Little Egrets (*Egretta garzetta*), and Grey Herons (*Ardea cinerea*), while fishponds were the most important for the Black-crowned Night Herons. In

addition Kadalundy (estuarine) area is daily subjected to the alternate flow and ebb of water due to high and low tides. At high tide, the water depth excluded Great and Little Egrets, and Grey Herons, from most of the shallow coastal waters and mudflats (Wong et al. 1999). During flow the water depth increases and these birds were observed moving towards the adjacent jheels while during ebb the entire area becomes shallow and numerous shallow pools of water trapped with fishes and other aquatic organisms are visible. Fish food trapped in pools during falling tides in summer was a major attraction for egrets and herons. This facilitates their aggregations and flock feeding. Little Egrets are flock feeders (Kushlan 1978) and this mode of flock feeding is highly advantageous for the species (Hafner et al. 1982) as they get maximum food for minimum effort. The flock size depends up on prey availability (Fasola 1982; Fasola and Ghidini 1983; Hafner and Britton 1983). Flocks comprising 10-12 birds were observed in the present study.

Though the jheels are having aquatic organisms and fishes in abundance comparative percentage of Little egrets in Jheels is still behind that of Pond Herons and Cattle Egret. This may be because of the inaccessible water depth of the jheels in most seasons of the year except during the months of March and April (Chapter-II Figures 2.7 and 2.10). The bird is seen applying some strategies during forage such as accompanying Little Cormorant, Reed Cormorant, Sacred ibis, African Spoonbill, Median Egret, Cattle Egret on terrestrial habitat or by even floating bread that attracts fishes (Sodhi 1986). In the present study they were observed foraging in flocks of 6-8 and 8-12 along the margins of the drying jheels and ponds.

3.7.3 Cattle Egret

Previous studies on food habit had shown that this is an insectivorous species. A single specimen taken on Croix, Virgin islands contained 92% Orthopterans by volume (Seaman 1955). Orthopterans, especially grasshoppers of the family Acrididae and Tettigoniidae, crickets (Gryllus sp.) of the family Gryllidae, and flies of the family Tachinidae and Syrphidae were identified from 20 Puerto Rican specimens (Forgarty & Hetrick 1973). From 20 egrets killed in southern Georgia, 59% horse flies, 28% grasshoppers and crickets, 5% tree frogs, 4% spiders, 2% dragonflies, 0.8% caterpillars, 0.5% horn flies, 0.5% stable flies, 0.1% ticks, and 0.1% unidentified organisms were reported.

Cattle Egrets do not compete with native herons and egrets for food since their foraging methods and food items differ (Jenni 1969, 1973 and Burger 1978). The stomach contents from 131 cattle egrets collected near Cairo and 8 from Simbellaween (in the Nile River delta near the Mediterranean coast) contained 37.7% orthopterans and 35.2% dipterans. One specimen collected in Surinam was filled with grasshoppers, dragonflies, beetles of the family Hydrophilidae, and clegs of the family Tabanidae (Haverschmidt 1957).

From the single regurgitated pellets of a 10-12 day old Cattle Egret nestling in a South African colony, 2 grasshoppers, 3 dragonflies, 6 waterbugs, 10 beetles, 1 bee, 22 blowflies (Tachnidae), 12 other flies, 2 snails, and 2 unidentifiable frogs were identified (Middlemiss 1955). The regurgitates from 15 nestlings of South African Cattle Egrets, grasshoppers formed of 84.6% of the predominantly insect diet (Siegfried, 1965).

Egrets were reported to feed on cicadas (Monga and Pandya 1984) and figs of Banyan *Ficus bengalensis* (Chaturvedi 1991). Such instance of feeding on Cicadas and figs of Banyan plant or traces of food item of plant origin was not observed in the present study. In addition to insects belonging to different species, egrets eat frogs and lizards (Ali 1979). Cattle egrets were observed feeding on baby rats (Mathew and Pethani 1997). The role of this bird in biological control of white grubs during ploughing operation has been documented by Parasharya et al. (1984). The egret is known to go after ploughs and tractors with restricted foraging close to the heronry during the breeding season (Kushlan 1978).

Cattle Egrets feed only on insects throughout the season, mostly gleaned from emergent vegetation where terrestrial insects, including Orthoptera, occurred. This sort of prey selection is consistent with the other two studies on cattle egret in Australia. The chick regurgitations at two heronries in New Southwales, showed that cattle egret depend mainly on Orthoptera (Baxter and Fairweather, 1989) and Orthopterans averaged 70% of the total food consumption. Orthopterans were seen in the diets of chicks and adults at a heronry in southeast Queensland (McKilligan 1984). The diet of nestling Cattle Egrets in South Africa resembled that of the independent bird species (Siegfried 1971). Food of

nestlings of cattle egrets collected from 6 heronries in Gujarath showed highest number of Orthoptera and Lepidoptera (Yadav 2000). Orthoptera was the major components in the diet of cattle egrets observed in the present study also. Of 13 food samples analysed in the present study, families Acrididae, Gryllidae, Tetrigidae, and Tettigoniidae of the Order Orthoptera were represented of which Acridids were the highest in number. Cattle Egrets are known to be well adapted to agricultural and disturbed or odd habitats (Lombardini et al. 2001). They remain in paddy fields even after late tillering stage, and forage in areas that possess crops that are in flowering, grain filling and maturity stage. They pick up insects flushed out into air by moving around the densely growing paddy plants.

The use of rice fields by cattle egrets showed a strong seasonal pattern. The maximum use occurred during winter, and was often associated with post harvest ploughing (by tractors), which result in surges of prey availability (Lombardini et al. 2001). They were much more active foragers than the other two species, using almost exclusively the *walk quickly* and *walk slowly* methods even when the rice plants had grown tall and dense (Richardson et al 2001).

The present study revealed that the most preferred feeding habitats of Cattle Egret is grass field and Paddy field among the natural habitats (Chapter-II). Cattle Egrets were well adapted to agricultural and disturbed habitats (Lanes and Fujioka 1998; Lombardini et al. 2001). The order of percentage abundance of Cattle Egret among different natural habitats is Grass field > Paddy field > Karimpuzha river > Jheel. This shows that their food being composed 87% of insects (Figure-3.3). They prefer such aquatic habitats having a terrestrial background to collect maximum number of insects and other fauna (Chapter II, Appendix-2.2 and 2.3). Among artificial habitat their most preferred habitat is solid waste dump. The most common foraging method adopted by cattle egrets in waste dump was *walk slowly, head swaying* probably because of the abundance of maggots, which were very easily pecked at by using this method. Meanwhile the adult flies that were rather difficult to aim at were foraged by *head swaying* strategy.

The opportunistic activity of cattle egret is revealed from the comparison of the gut content analysis of the adult Cattle Egrets. Presence of the prey items such as cicadas,

cattle tick, or green blowfly in some stomachs are most simply explained by clumped dispersions of such species; however, the possibility of variation in food selection among individual cattle egrets, as suggested by Siegfried (1972), cannot be ruled out. Cattle Egrets in South Africa might be of considerable importance as controllers of dipterous pests of cattle (Blaker 1969). In East Africa, Cattle Egrets were reported feeding on flies, which were attracted, to decaying fish wastes (Reynolds 1965). In the present study, I observed cattle egrets foraging in groups of hundreds at the municipal waste dump site in Kundayithode near Kozhikode city feeding on thousands of Dipteran maggots, especially of *Musca domestica* and *Calliphora sp.* developing from the decaying carcasses. This activity of cattle egret helps biological control of these flies that otherwise would multiply and spread in the adjacent residential areas and even cause spread of communicable diseases like cholera and typhoid. The role of this bird in the biological control of white grubs during ploughing operations has been reported by Parasharya et al. (1994). No grubs have been observed in the gut content in the present study. The cattle egrets were also reported feeding on baby rats in the millet fields in Gujarat (Yadav 2000). Adult rat was also observed in the gut contents of cattle egrets in the present study eaten by Cattle Egret. Attempt to feed on Brown Rock Chat (*Cercomela fusca*) was also reported (Kasambe 2003). Minute amounts of meats and ticks were observed in the diet of cattle egret (Gassett et al. 2000).

The guts of Cattle Egrets analysed in the present study contained no fishes. This showed that they prefer insects and other terrestrial organisms to fishes that in turn is the reason for their preference to terrestrial than to aquatic habitat. Out of the 98 boluses regurgitated by nestlings in South Africa, none contained fishes (Siegfried 1971). The popular myth that cattle egrets remove significant numbers of ticks from cattle have been reviewed recently (Jenni 1969, Fogarty and Hetrick 1973). Individual cattle egrets actively feed on ticks in certain special occasions (Skead 1966). However, ticks are extremely rarely reported in systematic studies of feeding biology of cattle egrets (Forgarty and Hetrick 1973, Kadry Bey 1942, Siegfried 1971, Jenni 1973). Even a single tick could not be located from the gut contents of cattle egrets observed in the present study. According to Siegfried (1971) the cattle egret's diet varied seasonally, earthworms

being the main food during the (rainy) winter and spring seasons. However none of the stomach contents analysed in the present study had earthworms.

3.7.3.1 Cattle Egret-Cattle association

Cattle Egret associated with cattle obtains more food per unit time than those of non-associated egrets feeding alone. Associated egrets need only less energy expenditure. The Cattle Egret is considered as an obligate commensal (Rice 1956; Heatwole 1965). The same advantage that the cattle egret makes use of is also received by other types of birds such as Snowy Egrets and they can be considered as facultative commensals in their habit of accompanying cattle (Heatwole 1965). There was an incidence of two Pond Herons foraging in association with grazing cattle, which flushes out grasshoppers in a grass field. For the event of Cattle Egret and Cattle being attracted towards grassfields having fresh grass growth, the main reason is the abundance of grasshoppers (Heatwole 1965).

The yearlong availability of the grass attracts a lot of cattle into this habitat. The presence of grass throughout the year ensures availability of insects especially the grasshoppers, which forms the major food of Cattle Egret. They visit other habitats that have lesser prey items provided the presence of grazing cattle, which serve as beaters of insects in the vicinity. Cattle egrets are present in almost all available habitats during habitat expansion especially after monsoon wherein everywhere there is fresh growth of vegetation.

An associated Cattle egret had a mean capture or successful feeding of 1.33 ± 0.86 per minute while an unassociated Cattle Egret had a mean capture of 0.87 ± 0.75. This means non-associated Cattle egret has to expend more energy for prey capture. This is evident from the fact that an unassociated Cattle Egret had to take more steps per minute (29.51 ± 2.54) and collects only less preys than the associated Egret which made only very few steps per minute (19.78 ± 2.06) to collect food. The association of cattle and cattle egret, showed a pattern that is mainly dependent on the presence of cattle in the grazing field, time of grazing, activity of the grazing cattle and the nature of the habitats. The association had two peaks, from 9-12 in the fore noon session and 2-4 in the after noon. During mid day when the temperature is high cattle tend to take rest. Thus the cattle egrets associate, corresponding the activity of the cattle. As the herd stop grazing at mid

day and the cattle move to the shade and ruminate, the egrets leave them to begin feeding alone or in flocks, groups and /or indulge in activities like preening resting on nearby trees or ground. Usually there is a limit in number of egrets that associate with each grazing cattle. Although it was rarely more than three, the maximum number observed during the present study was seven.

Like the diurnal pattern in association a seasonal pattern is also seen. The pattern is based on seasonal variation in nature of habitats, and availability of food (Figure-3.5). The maximum association in grass field was during December and April. The probable reason for this high association in may be because of the abundant vegetation in Decmber. The high association in April may be due to local movement of the cattle egrets from other adjacent areas into this habitat due to habitat shrinkage. In jheels the maximum association was seen from December to March. Major portions of this area earlier inundated get exposed with the close of December. A variety of grasses and other vegetations along with more egrets also appeared corresponding with this exposure. However, there was not much increase in the rate of association of Cattle Egrets in jheel probably because of the movements of some of these Egrets from jheels in Kozhikode to the adjacent waste dump at Kundayithode, from December 1999 to April 2000. This is substantiated by the simultaneous increase in number of egrets at Kundayithode waste dump from December1999 to 2000 April (Chapter-II).

The plausible reason for the decline in association in paddy fields December onwards may be that some farmers raise paddy only once in a year (June- September) and during the remaining season the land is left fallow. These post-harvest paddy fields have stubbles and scanty vegetations at least up to January. Thereafter the fields gradually dry up. In such fields the Cattle Egrets were often observed associated with cattle through October to February. Paddy fields where paddy is raised twice in a year remain fallow from February onwards till the next monsoon and were very rarely used by grazing cattle because of the scarcity of grasses and other vegetation in that dry season, which in turn have lesser insect abundance and thereby less number of cattle egrets.

In plantations (Rubber estates) vegetation is abundant during the months of September-October, and this normally causes increase of insects, especially grasshoppers. Occasionally cattle are taken into plantation areas for grazing. This attracts Cattle Egrets to associate with cattle, which becomes highest during November and December. This association of cattle and cattle egret in brief may be stated as dependent on three factors namely i) Presence of cattle, ii) Presence of vegetation and iii) availability of prey species.

3.8 Summary and Conclusion

The differences in basic foraging techniques of various herons is a strategy to avoid competition, since differences in foraging skill help catch a variety of food items (Willard 1977). Though these three species are largely aquatic in habit, they are also observed in terrestrial habitats.

Little Egrets are rather purely aquatic in habit as they feed mostly on fishes (96.24%). They were totally absent in two natural (Hillock and Plantation) and one artificial (Waste dump) habitats. Among the natural habitats they preferred estuarine (Kadalundy) habitat at its maximum.

Pond herons are seen both terrestrial and aquatic species but have lesser percentage of insects (71.17%) than in Cattle Egrets and have less preferences to terrestrial and more so for aquatic habitats than in Cattle Egrets. Like Little Egrets they were also absent in Hillock and Plantation (Chapter II). Jheels are their most preferred habitat.

Cattle Egrets are terrestrial than the other two species since they prefer terrestrial species to aquatic species in their food spectrum, which are 87% insects. In the present study, they were not at all present in estuarine (Kadalundy) areas in the present study. Among the three species of birds under study Cattle Egrets were the only one that exploited the Plantations and Hillocks and in association with cattle. They were the only birds utilising the waste dump at its most making a heavy toll of maggots. Cattle Egrets are in a sense 'health officials' performing housefly control enormously.

Cattle Egret feeds on a wide range of invertebrates and small vertebrates including mammals and the few ectoparasites such as ticks or flies taken directly from the bodies of cattle are relatively of no significance in its energy budget (Heatwole 1965). The cattle-cattle egret association is bimodal with two peaks (9-12 h and 2-4 h). Their association is mainly helpful for saving energy expenditure for prey capture, the prey capture rate is increased by this particular association. This is also evident from comparison of the mean capture rates, mean number of steps, mean strike rates of associated and non-associated egrets (Table-3.6).

BREEDING BIOLOGY

Seedikkoya .K “Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality ” Thesis. Department of Zoology , Farook College Calicut ,University of Calicut, 2003

Chapter IV

BREEDING BIOLOGY

4.1 INTRODUCTION

Most of the members belonging to the Ciconiiformes and Pelicaniformes show the habit of colonial nesting (Ali and Ripley 1987; Krebs 1978; Burger 1981). The term heronry is used to designate the nesting colonies of those birds that represent spatial and temporal clustering of nests. Comparatively little information is available on Indian heronries, and such information is restricted to certain specific regions (Subramanya 1996; Mukherjee and Chandra 1973, Mukherjee and Saha 1976 b). The present study attempts to examine the distribution of heronries and the breeding biology of the three species; Cattle Egret, Little Egret and Pond heron. Although reports on these aspects are available from various part of the world it is felt that the present investigation will shed more light on the topic in the environmental set up of Kerala.

4.2 BACKGROUND

Detailed study of breeding biology of many herons has been carried out in different countries. The factors affecting the distribution of heronries in Northern Italy was documented by Fasola et al. (1978). Gawlik et al. (1998) has recorded the population and community features of colonial nesting waterbirds in Galveston Bay Estuary. The breeding aspects of the Grey heron, *Ardea cinerea*, have been studied in detail by Lowe (1954); Owen (1960); Dusi and Dusi (1968) and Milstein et al. (1970). Similar study in Purple heron, *Ardea purpurea*, was carried out by Tomlinson (1974 a, b and 1975). The breeding biology of Great Blue Heron, *Ardea herodias* was also investigated (Vermeer 1969; Parashar and Naik 1988; Werschkul et al. 1977 and Butler 1993). Identification, characteristics of nests, eggs and nestlings of some herons have been studied by Dusi (1966). The studies of breeding and nesting aspects of Great or Large Egret, *Ardea alba* (Teal 1965; Parashar and Naik 1988 Maxwell and Kale 1977), Green Heron, *Butorides virescens* (Dickerman and Gavino 1969) and of Boat-billed Heron, *Cochlearius cochlearius* are also available. Erwin et al. (1996) has studied the reproductive success, growth and

survival of Black-crowned Night Heron, *Nycticorax nycticorax* and Snowy Egret, *Egretta thula*. The nest site characteristics of Great egret, *Casmerodius albus*; Snowy Egret, *Egretta thula*; Cattle Egret, *Bubulcus ibis*; Little Blue Heron, *Florida caerulea* and Louisiana Heron, *Hydranassa tricolor* are also studied (McCrimmon Jr. 1978). Mitchell et al. (1981) has documented reproductive success of Great Blue Herons at Nueces Bay, Corpus Christi, Texas. Breeding biology of Scarlet Ibis on Cajual Island, Northern Brazil has been recorded by Martinez (1999). Incubation behavior of Greater Snow Geese in relation to weather conditions revealed that abiotic factors have a direct effect on heat loss of the clutch (Poussart et al. 2001).

Information available on colonial nesting birds in India include studies on nidification (Ali and Ripley 1968), breeding of egrets in Kerala (Uthaman 1990 a), breeding biology of some Ciconiiformes in Gujarat (Parasharya and Naik 1984), and distribution, status and conservation of Indian heronries (Subramanya, 1996). Mukherjee and Parasharya (2000) reported nests of Purple Heron on water hyacinth *Eichhornia crassipes* from Gujarat. Reports on the breeding biology of Indian Reef Heron, *Egretta gularis* (Naik et al. 1981; Parasharya and Naik 1988; Dharmakumarsinhji 1984) are also available.

4.2.1 POND HERON

There is no detailed study on the breeding biology of Indian pond heron, *Ardeola* grayii, except for information available from some parts of the country. Pandey (1985) and Lamba (1963) attempted documenting certain aspects of the breeding biology of this bird. Some aspects of its breeding biology in Dhaka (West Bengal) and colonial nesting behavior in Sitakunda in West Bengal were worked out by Yesmin et al. (2001) and Begum (2003) respectively. Pairing between Pond heron and Intermediate egret has been reported by Parasharya (1985).

4.2.2 LITTLE EGRET

Parasharya and Naik (1984) has reported a comparative study of the juvenile plumage of Little Egret with that of the white-phase Indian Reef Heron. Breeding biology and postnatal

development of Little Egret is documented by Prasanth et al. (1994, 1996). A brief report on Darters and Little Egret nesting in Gudavi bird sanctuary is reported by Desai, (1998). Uthaman (1990a) has reported breeding of this egret in Kerala and Mahabal (1990) has reported a preliminary survey of heronries of Raigad district of Maharashtra.

4.2.3 CATTLE EGRET

The breeding biology of Cattle Egret, *Bubulcus ibis*, has been studied by several investigators like Skead (1966); Lowe-McConnell (1967); Blaker (1969); Jenni (1969); Dusi and Dusi (1970); Lancaster (1970); Siegfried (1972), Weber (1975); Maxwell and Kale (1977); Burger (1978); Putnam (1978) and Mora and Miller (1998). McKilligan (1990) has reported extrapair copulation studies in Cattle Egrets. In India, information on the breeding biology of this bird includes only scanty documentation from different parts of the country (Gopakumar 1991, 1996; Bhargava et al. 1982; Sodhi 1984; Singh et al. 1985; Parasharya and Naik 1988; Rao 1999 and Yadav 2000).

4.3 OBJECTIVES

The main objectives of the study are:

1. To locate the breeding colonies of the three species of birds under study and
2. To investigate various aspects of breeding, such as nests, nesting colony, clutch size, incubation, and hatching.

4.4 METHODOLOGY

4.4.1 NESTING COLONIES

As a first step attempts were made to identify breeding colonies of the three species in the study area. In case the colonies are not available in the study area attempts were made to find them elsewhere in the State of Kerala. Regular investigations for locating the nesting colonies of Cattle Egrets, Little Egrets and Pond Heron were intensively carried out at

different localities of the study area every year since 1999 to 2002 and in a casual manner even before, i.e., from 1996 onwards. Enquiries were also made with persons of different walks of life from different areas of the state regarding the presence of breeding sites. Since breeding colonies of Cattle Egrets were not found in the entire study area or in Kerala State, salient aspects of this bird recorded in Andhra pradesh by Rao (1999) is cited in the present study; for the purpose of documentation.

4.4.2 NESTING TREES

The nesting trees were numbered and a large number of nests were individually marked by numbered plates. These plates were camouflaged to the best during the nest building stage. The nests were checked by climbing the tree, or the nearest reachable point. The freshly laid eggs were numbered with a felt-tipped pen, measured with vernier calipers and weighed to the nearest 0.5g with a Pesola spring balance, taking care to cause least disturbance; at the opportune occasion when the parent bird would not be alerted.

4.4.3 NESTS

The nests were checked every day during the laying period; at four or five-day intervals during incubation and hatching periods and at weekly intervals from the time chicks are hatched, till they reached the age of 24 days. Observations were also made from the top of a nearest building using 10x30 binoculars. The weight of 2-week-old nestling was taken using a 100 gram capacity Pesola spring balance with the help of a fine net. In addition, some preliminary observations on plumage and colour of various parts of nestlings were done.

4.4.4 SHAPE INDEX

Shape index of eggs was analysed by using the formula explained by Romanoff and Romanoff (1949) and Prasanth et al. (1994).

$$Si = \frac{Bx100}{L}$$

Where Si =shape index, B =breadth and L =length.

4.5 RESULTS

A survey was conducted in early monsoon of 1999 to locate the nesting sites of the three species of birds under study. Accordingly, various roosting sites of these birds in plantations of crops such as rubber and arecanut at Mampad; coconut and arecanut at Kondotty; and teak plantations at Panayi, all of which fall under the Malappuram district were thoroughly searched for the presence of heronries or nests of the birds. As a result of this survey, it is found that none of these birds used their roosting sites as breeding sites other than Pond Herons that were in certain incidences found breeding adjacent to their roosting sites. In that scenario, the study was extended to other neighbouring districts. The district-wise distribution of nesting sites of the different species under study are shown in Figure-4.1.

4.5.1 POND HERON

4.5.1.1 Districts under Study

The nesting colonies of pond heron were found in several places of Malappuram and Kozhikode districts.

Malappuram District:

Although several nesting colonies of pond herons were located in places such as Mampad, Vaniyambalam, Pathapiriyam, Kizhisseri and Melattur in Malappuram District, study was focused in Mampad village of Mampad Panchayath for logistic reasons. Here, both pond herons and little cormorants were nesting on the same trees forming mixed colony.

At Mampad, a small village located in the eastern side of Malppuram about 28 Km from Malappuram district headquarters, two nesting colonies were located approximately within 250sq metres. The other sites where heronries were located were Vaniyambalam, Pathapiriyam, Kizhisseri and Melattur.

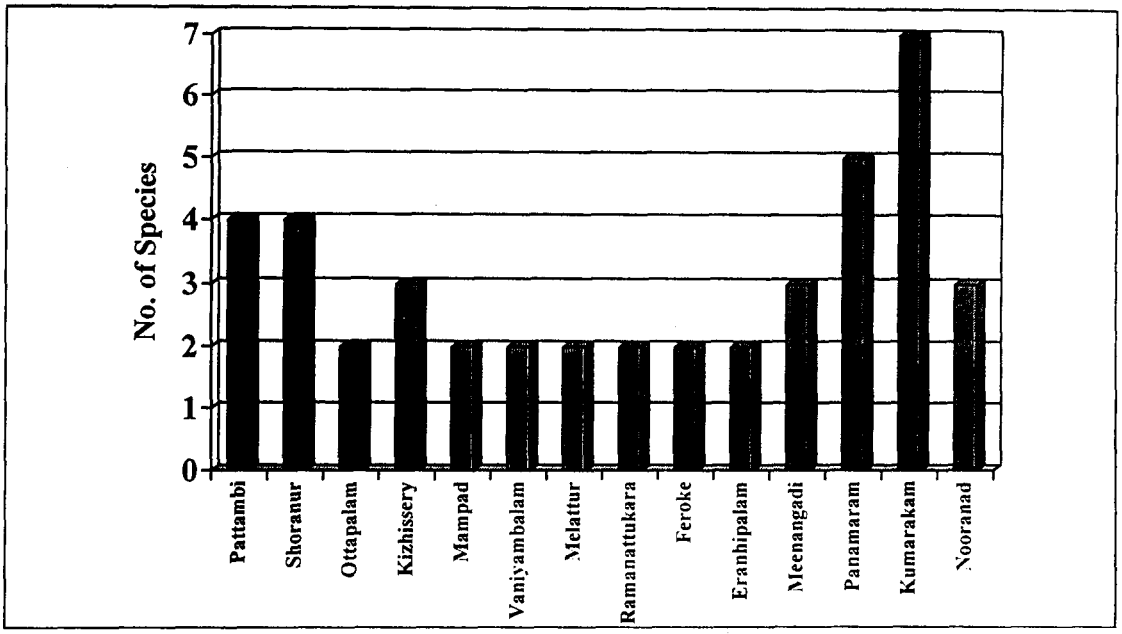


Figure-4.1 Nesting sites of different species of herons

At Vaniyambalam, a small village located at 22 Km away from the main study area towards its southeast direction in Wandoor Panchayath, mixed colonies of both pond herons and little cormorants were seen. At Pathapiriyam, located towards the southern side of the main study site within a range of about 8 Km, little cormorants and pond herons formed a mixed colony. Kizhissery where another breeding colony was seen is small village in Areacode panchayath within a range of about 30 Km located towards the south-west direction from the main study site of Mampad. Melattur, where another colony was located is a Panchayath headquarters located towards the southern direction at about 35 Km away from the main study site.

Kozhikode District

Two nesting colonies of pond herons were located in two places namely Eranhipalam and Ramanattukara in Kozhikode district. Of this Ramanattukara is a small urban site located south of Kozhikode about 12 Km away from Kozhikode city and Eranhipalam, a location 4 Km away from the city centre towards the northwestern side of Kozhikode city.

Nesting season

Pond herons usually breed from May to September corresponding with the onset of southwest monsoon. Occasionally, where rain starts a little early breeding is also accordingly advanced. For example during the 2000 and 2001 there were heavy summer rains in April and the bird commenced breeding in April 1st week. The peak nesting was during June and July. Observation was started at Mampad and Ramanattukara Prior to the onset of monsoon. Large number of pond Herons were observed roosting on some trees like *Tamarindus indicus* and *Mangifera indica* on which they were not normally observed resting or roosting during other seasons.

4.5.1.2 Nesting Colony

Nest site finding

Finding a nest site is a joint effort both by male and female. After selecting a convenient nesting site, the pair remains in that spot for a few hours. Courtship takes place there culminating in copulation. Copulation lasts for about 6-8 seconds. Thereafter the female remains in the vicinity of the nest location and the male flies off to collect nest materials.

Nests building

Males collected more nest materials than females. Female arranged the materials in a crisscross fashion. Some of the nest materials were found falling during the process. Most of the nesting materials were collected from the vicinity of the nesting tree. Some materials were collected from the nesting tree itself. More materials were collected in the morning than in the noon. The activity was brisk during afternoon. Almost a week is

taken to complete nest building. Normal duration for completing a nest is 5-6 days. There was foliage cover over most of the nests. Only a few number of nests were exposed to the open sky.

Location of nests

The nests were usually built on the vertical branches both inside and outside the periphery of the tree crown. Number of nests per the tree depends upon number of forked branches available on the tree. On a big Tamarind tree situated in Ramanattukara 85 nests were seen in 2000 and 78 nests in 2001 at a height of 6- 9 metres (Table-4.1). More than 58 nests of Little Cormorants were also observed on the same tree. Most of the nests were observed on quaternary branches (N=28) and a few (N=18) on the direct sub branch arising from the quaternary branch. The average thickness of the nesting branch was 10.8 $\pm$ 1.91 cm (N=10). This was obtained by measuring 10 nests, among 108 nests observed at Mampad heronries during 2000 and 2001, randomly selected to lessen possible disturbances during measurements (Table-4.2).

Table-4.1 Nesting trees of Pond Heron located in two study areas during 2000 and 2001

No	Nesting tree	Nests (2000)		Nests (2001)		Height (m) (2000)		Height (m) (2001)	
		MP	RN	MP	RN	MP	RN	MP	RN
1	*Acacia sp.*	0	3	0	2	0	3	4-5	0
2	*Albizia lebbek*	3	0	4	0	5-6	0	5-6	0
3	*Ailanthus excelsa*	3	0	2	0	8	0	4-5	0
4	*Artocarpus . heterophyllus*	6	12	5	16	6-9	9-12	7-8	9- 12
5	*Bambusa arundinacea*	2	0	1	0	4 -5	0	4 -5	0
6	*Ficus hispida*	2	0	1	0	3-4	0	3 -4	0
7	*Mangifera indica*	10	4	12	6	7-8	6-7	7-8	7-8
8	*Mimosops elengi*	6	0	4	0	5.5	6-7	0	8-9
9	*Pongamia pinnata*	3	0	2	0	3 -4	0	5 -6	0
10	*Stereospermum colais*	6	0	4	0	9- 10	0	9- 10	0

11	*Strychnos nuxvomica*	1	5	2	6	4 -5	5-6	4 -5	5 –6
12	*Swietenia mahagoni*	3	0	4	0	7-8	0	6-7	0
13	*Sygium cumini*	4	5	3	6	6-7	8-9	5-6	8-9
14	*Tectona grandis*	1	0	0		6			
15	*Tamarindus indicus*	12	85	15	78	6-7	6-9	6-7	6-9
16	*Tetrameles nudiflora*	0	12	0	10	0	18	0	10-15
17	*Terminalia paniculata*	2	0	3	0	9-10	0	8-9	0
(MP= Mampad and RN= Ramanattukara)									

Table-4.2 Details of nest- branch thickness and nest- branch location in Pond Heron			
No of nests studied	Mean thickness of nest-branch (cm)	Total number of nests on quaternary branch	Total number of nests on 1st sub branch on Quaternary
10	10.8 + 1.91	28	18

4.5.1.3 Type of nest

The nests of Pond Herons were of platform type (Plate 4b, c), with a shallow depression in the center made of a network of nest materials such as petioles of leaves, twigs etc.

4.5.1.4 Nest height

The minimum nest height varies between 3-4 m and the maximum height between 10-18 m (Table-4.1). The low nest height was observed on *Pongamia pinnata*, *Ficus hispida* and *Acacia sp.* The nests with maximum height ranging from 9-10 m were observed on *Stereospermum colais* and *Terminalia paniculata* at Mampad whereas nests built at a height of 18 metres were observed on *Tetrameles nudiflora* at Ramanattukara

4.5.1.5 Characteristics of the Colony

The nesting colonies of Pond Herons at Ramanattukara township were within a range of 250 square metres. One of the nesting colonies was located on a big Tamarind tree inside

a compound behind a shopping complex at the heart of Ramanattukara town on the northern side of the Manjeri -Kozhikode road link. This Tamarind tree is under the strict command of nearby shopkeepers and so nobody was allowed to disturb the nest or to climb the tree. For the same reasons, I could also make only intermittent observations on the colony. The little cormorants occupied the top and the inner and outer periphery of the nesting tree whereas the pond herons occupied the outer and inner periphery of the tree crown interspersed with the nests of little egrets. The distance between the nearest nests of pond herons was half a meter and that between the little cormorant and pond heron was ½ -1m but never more than one meter. At Eranhipalam where I observed 18 nests of Pond Herons the nests were placed on *Tetrameles nudiflora*. The tree was tall, about 18- 20 meters high.

At Mampad, totally 84 nests were observed and here observations could be made free of any disturbances or control from the people residing nearby. The nests were built on different plant species, in residential areas. Here, the nests of Pond Herons were either solitary or in colonies with Little Cormorants. Based on the plant species the nest height varied (Table-4.1).

At Vaniyambalam 12 nests of pond herons mixed with 7 nests of little cormorants were observed on a mango tree. This was in a homestead compound situated near a Railway - cross on the Wandoor - Vaniyambalam road. Similarly, at Pathapiriyam 20 nests of Pond Herons were spotted on two mango trees. On the first tree were built 8 nests within a height range of 6 -7 metres and on the second tree 12 nests were built within a height range of 7-8 metres. There were 12 nests each of little cormorants. The nesting site located at Kizhissery had 8nests of pond herons, 4 of little cormorants and 5 of Night Herons on a mango tree in a homestead in a residential area. Tamarindus tree in the same area was site for 5 nests of Pond Herons, 8 of little cormorants and 3 of Night Herons. The nesting site observed at Melattur on a mango tree located in the compound yard of Melattur Police Station, had 12 nests of Little Cormorants, and five of Pond Herons.

4.5.1.6 Nest materials

In Pond Herons, addition of nest materials continued throughout the incubation period but not during hatching. Materials collected from 26 different plant species were used for building the nest (N=12). The average number of materials used for nest building was 91. Out of 12 nests analysed, one was composed of a maximum of 128 materials and other one with only of 54 materials. The mean maximum size of the nest building material used was 29.05 cm and the mean minimum size was 13.46 cm (Table-4.3). The other details of the nests of the three species are given in appendix-4.1.

Table-4.3 Characteristics of the nest materials used by Pond Heron

Pond Heron (26 materials used)			
	Total Materials	Max (Mean)	Min (Mean)
Nest-1	66	31.1	10.8
Nest-2	113	26.6	14.6
Nest-3	128	31.2	15.9
Nest-4	54	25.7	10.9
Nest-5	90	25.8	13.1
Nest-6	120	31.6	14.7
Nest-7	86	27.2	12.4
Nest-8	105	29.1	15.6
Nest-9	90	26.9	13.0
Nest-10	72	27.2	14.2
Nest-11	87	30.0	15.0
Nest-12	81	36.2	11.2
Mean	91	29.05	13.46

4.5.1.7 Eggs

4.5.1.7.1 Shape

The eggs are broad, oval and medium in size. In total number 58 eggs were examined for shape index. The longer and thinner eggs showed lower shape index while shorter and thicker eggs showed higher shape index (Appendix-4.2). There is no correlation between the weight and the shape index of the eggs (Table-4.4).

Table-4.4 Correlation between Egg Weight and Shape Index in Pond Heron

		Shape Index	Egg Weight
Pearson Correlation	Shape Index	1.000	-.059
	Egg weight	-. 059	1.000
Significance (2 –tailed)	Shape Index	-	.658
	Egg Weight	.658	-
N	Shape Index	58	58
	Egg Weight	58	58

4.5.1.7.2 Colour, weight, size and clutch size

The egg is of sea green colour without any markings or spots. Of the 58 eggs examined the maximum weight was 17.8 gm, the minimum 11.2 gm and the average was 15.51 ± 1.87 gm. The eggs were generally laid during night or early in the morning. The minimum length of egg was 33.3 mm and breadth 24.1 mm. The maximum egg length was 48.0 mm and breadth 32.0 mm. The mean length was 37.36 ± 1.91mm and the breadth 28.34 ± 1.44mm (Table-4.5). Average size of one hundred eggs reported earlier was 38.0 x 28.5 mm (. Ali and Ripley, 1968). The common clutch size was 3 that had a percentage frequency of 87. Clutches of 5 were very rare (Figure-4.2). 58 eggs that were examined belonged to 19 clutches.

Table-4.5 Length and breadth variations in the eggs of pond Heron (N=58)		
	Length of Egg (mm)	Breadth of Egg (mm)
Mean	37.36	28.34
Standard Deviation	1.91	1.44
Minimum	33.3	24.1
Maximum	48	32

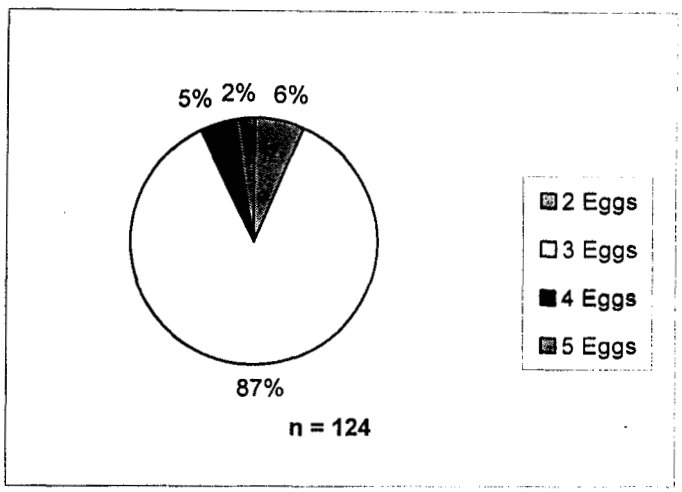


Figure-4.2 Percentage frequency of clutch size variation in Pond Heron

4.5.1.7.3 Egg mortality

One of the major causes for the egg loss was nest falling. During heavy monsoon sometimes rain and strong wind affects the stability of the nests and some of the nests built on comparatively weak branches at the periphery of the tree shake strongly causing the eggs to fall off. 5 such eggs were seen fallen under the Tamarind tree at Ramanattukara during heavy monsoon. Rarely when somebody climbs up the tree carelessly the parent bird spurt out of the nest causing the eggs to role out of the nest.

4.5.1.8 Incubation

The first egg was laid within 5-6 days after the beginning of the nest building. Incubation started with laying of the first egg. Once the egg was laid the nest was never left

unattended except when disturbed. The incubation period, of 62 eggs that were observed in the present study, ranged from 18- 24 days. The mean incubation period was 20.9 ± 1.66 (Figure-4.3).

Both the parents incubate the eggs. Usually there was 3-4 changeover of duty within 12 hours of daytime. It took about 3-4 hours for each change over. In some observations (N=15) while one sat on the eggs the other remained very close to the nest in another branch within the reach watching over the nest. The eggs that failed to hatch were those that surpassed incubation period but failed to hatch either because they were not fertilized or due to the death of embryo before completing development. In one nest 2 eggs were found unhatched for about 15 days after completing the incubation period. Afterwards the nest was found missing.

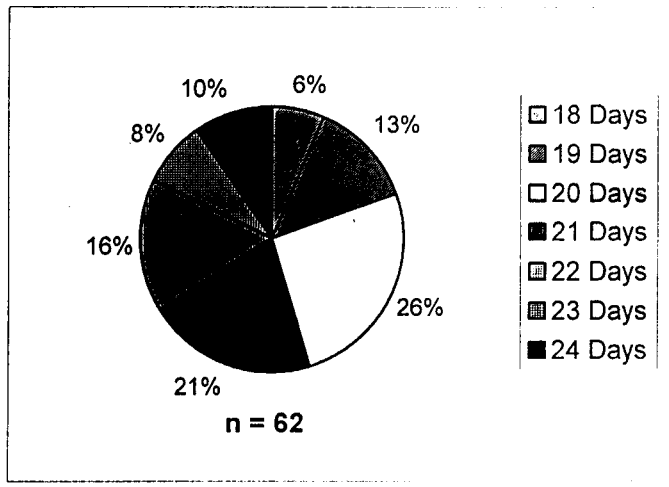


Figure-4.3 Frequency distribution of incubation period of Pond Heron

4.5.1.9 Hatching

In pond Herons hatching was asynchronous. The freshly hatched (0 days) chick weighs about 13.6grams (N= 10). The chicks were almost naked and eyes closed. They had a bulging abdomen that is almost transparent. The body was fleshy light in colour. The natal plumage was prominent on the head. The nestligs did not take food for 1-3 days after hatching. Food of the nestlings was mainly fishes. Both the parents took part in feeding the nestlings. At one occasion, the parent bird was seen regurgitating into the nest

and it contained the head of a sardine, which was broken into pieces by the parent bird. The eyes of nestlings opened their eyes during third to fifth day after hatching.

4.5.1.10 Hatching Success

Out of 85 eggs laid, 70 hatched. Of the remaining eggs, 5 were lost due to nest loss, 3 by falling from the nest and 7 were unhatched. The hatching success was 82% (Table-4.6).

Table-4.6 Hatching success of Pond Heron		
Pond Heron	Mean	Std Deviation
Clutch Size	2.58	0.50
Eggs Hatched	2.12	1.02
Hatchlings successfully left	1.67	1.05
Hatching Success	0.82	0.36

4.5.2 LITTLE EGRET

4.5.2..1 Districts under study

The nesting colonies and nests of little egrets were located in several places in Palghat and Wayanad Districts.

Palghat District:

The nesting colonies of Little Egret were seen at Shoranur, Ottapalam and Pattambi. Of the three localities in the district, the study was concentrated only in one locality due to logistic reasons.

At Shoranur, the nesting sites of Little Egrets were on the trees located near Railway platform in Shoranur Junction. Due to high-voltage electricity cables carrying about 25000 V, passing close above the nesting trees, permission was not granted to climb the tree and observe the birds. No other suitable vantage point was also seen to closely

observe the activities in these nesting colonies. A few nests were located near Ottapalam railway station on some trees located on the way to Bharathapuzha. Some nests were seen on mango trees located in the compound of a house in the nearby area. For collecting data on breeding biology of Little Egrets the main study site was at Pattambi. Four nesting colonies of little egrets were seen in a residential area of Pattambi town along the banks of the river Bharathapuzha. The entire study area occupies about 250 square metres. Within this stretch, four small areas each of approximately 50 square metres were located; one in a temple premise and the other three close to human residences.

Wayanad District

Panamaram

At Wayanad, the nesting colony of little egrets was observed among the other egrets in Panamaram, (11° 44′ 22.8″ N, 076° 04′ 26.4″ E,) about 30 Km from Kalpetta, the district headquarters. The river Kabani, a tributary of river Cauvery flows through Panamaram. At Panamaram on the main road, nearby the bridge, a small patch of elevated area covered with bamboo clumps and encircled by the river make it almost an island giving protection to the breeding colony. The entire area covering about 100 square metres have a mixed colony of about 50 nests of Median Egrets, 2 of Great egrets, 10 of Black crowned night herons and 10 of Little Egrets.

4.5.2..2 Nesting season

Courting (Plate 5a) and the nesting season starts with the onset of southwest monsoon from June and extends up to September. Nesting was started by June and was at its peak in August. The last batch of fledglings left the nest by middle of October. At Pattambi and Shoranur with the approach of the nesting season an increasing number of Little Egrets started roosting on some trees on which they were not seen roosting in other seasons.

4.5.2.3 Nest Building and nesting colony

The nests were usually built on the vertical forks of two to five branches both inside and the periphery of the tree crown. There was foliage cover over the nests and the nests were not exposed to the sky. Number of nests per tree depends upon branched forks available on the tree. On a big Tamarind tree 12 nests of little egrets (Table-4.7) and more than 50 nests of Little Cormorants were observed, as there were plenty of forks available for constructing nests. The nests of little egrets were of platform type, made of a loose network of twigs, compact at the base and loose at the periphery. Males collected the nest material while the females built the nest.

After selecting a convenient nesting place, the pair remains at that place for a few hours. They court each other and copulate. Copulation lasted for about 8-10 seconds. Thereafter the female remained in the vicinity of the nest location and the male flew off to collect nest materials. The male after collecting nest materials passed it on to the female who arranged it on the nesting branch. Some nest materials were seen falling to ground during the process. The birds do not care for the falling twigs. After building up the platform, some thinner twigs were placed inside as lining. Most of the nest materials were collected from the adjacent areas. Twigs from the nesting tree was also collected and used, but rarely.

The nests were built at a height of about 4–8 meters from the ground; Of the 63 nests counted on different tree species at Pattambi, the highest nest was built on *Cocos nucifera* and *Thespesia populnea* while the lowest was on *Azadiracta indica, Bambusa arundinacea* and *Pongamia pinnata* (Table-4.7). Fifteen different species of trees were used for nesting. Most of the nests were either on quaternary or smaller branches. The average thickness of the branches on which nests were made was 18.3cm (N= 10).

Table-4.7 Location of the nests of Little Egrets in Pattambi during 2000-2001

Nesting Tree	Number of Nest	Height (m)
Cocos nucifera	1	8
Syzygium cumini	1	7
Azadiracta indica	2	4

Terminalia cattapa	2	5
Areca catechu	2	5
Bambusa arundinacea	3	4
Pongamia pinnata	3	4.5
Strychnos nuxvomica	3	5
Cipadessa baccifera	3	5
Artrocarpus heterophylla	3	5
Erythrina sp	4	6
Mangifera indica	6	6.5
Thespesia populna	8	8
Aegle marmelos	10	6-7
Tamarindus indicus	12	6-7

One of the nesting colonies located at the heart of Pattambi town in a Temple compound was on a tree *Aegle marmelos* facing towards the Pattambi - Trichur road. This tree contained 10 nests of Little Egrets, 5 of Median Egrets, 3 of Large Egrets and 14 of little egrets. The Large Egrets occupied the top of the nesting tree where as the nests of Median Egrets, Little Egrets and little cormorants were observed just below them interspersed with one another. The distance between the adjacent nests of the same species was within 1m whereas that of the different species was between 1-2metres. On a mango tree in the same temple premise 12 nests of Great Egrets, 6 of Median Egrets, 22 of Little Cormorants and 2 of Little Egrets were also observed. Here too, the Great Egrets took the topmost position below which Median Egrets, Little Cormorants and Little Egrets built nest in an interspersed manner.

The other places that were searched for locating the nesting colonies of Little Egret include, Ottapalam of Palakkad district, where about 8 nests each on two mango trees were seen in a compound of a house near Ottapalam railway station. There these birds nested among the Little Cormorants in a colony. The proximity of this place to the banks of the river Bharathapuzha might be a reason for attracting a lot of little egrets to nest here. Moreover the abundance of the fishes in different habitats in these areas during

monsoon when the river gets flooded may also attract these piscivorous birds to this sites Here the little egrets were observed associated with little cormorants.

Apart from Ottaplam of Palakkad district, nesting colonies of little egrets in association with Little Cormorants were observed at Shoranur railway station. Here 40 nests of little egrets, 52 of little cormorants and 1 of Great Egret were seen in the monsoon. As in the case of the nesting colony at Ottapalam this location also is situated at the banks of Bharathapuzha, which may act as a source of food supply to the nestlings. Here, the nests are located on *Pongamia pinnata*, *Thespesia populna* and *Azadiracta indica*. Since the nests were built on the railway platform, some chicks, which fell from the nesting trees, were fatally injured and /or killed as they fall directly on the cemented platform.

The little egrets were also observed nesting in Meenangadi town, Wayanad district associated with little cormorants. Here 15 nests of egrets and 22 of cormorants were seen. The nests of Little Egrets were also observed at Panamaram in Wayanad district (page 16). Only since 2001 this heronry was seen here. However, the presence of this area as a heronry was reported earlier (Uthaman, 1988), but was discontinued for some years for unknown reasons.

4.5.2.4 Nest materials

The outer diameter, inner diameter and depth of the nests were measured using a tape taking care to minimize disturbance (Appendix-4.1). The birds used materials collected from 35 different plant species for building nest (N=12) and the average number of materials used for building a nest was 89 (Table-4.8). Out of 12 nests analysed, one was composed of a maximum of 101 nest materials and another had the minimum of 61 materials. The mean maximum size of the nest building material was of 36.33 cm and mean minimum size 19.18 cm.

4.5.2.5 Shape of Eggs

Out of 82 eggs that were examined for shape index, longer and thinner eggs showed lower shape index while shorter and thicker eggs showed high shape index (Appendix-4.2). Most of the eggs had the index ranging between 73-75.9 (Figure-4.4). A positive

correlation between the weight and the shape index of the eggs ($P < 0.01$) could be seen (Figure-4.5), indicating that as the weight increases the eggs become more rounded and thicker.

Table-4.8 Characteristics of nest materials in Little Egret

Nest No.	Total material	Maximum size (Mean)	Minimum size (Mean)
Nest-1	61	29.6	18.5
Nest-2	88	36.7	25.7
Nest-3	91	35.1	17.5
Nest-4	81	37.4	15.3
Nest-5	93	36.1	19.3
Nest-6	98	33.6	12.8
Nest-7	100	37.5	15.4
Nest-8	77	40.8	17.0
Nest-9	93	37.8	13.4
Nest-10	94	36.0	12.5
Nest-11	101	39.7	32.6
Nest-12	95	39.4	30.2
Mean	89.33	36.63	19.18

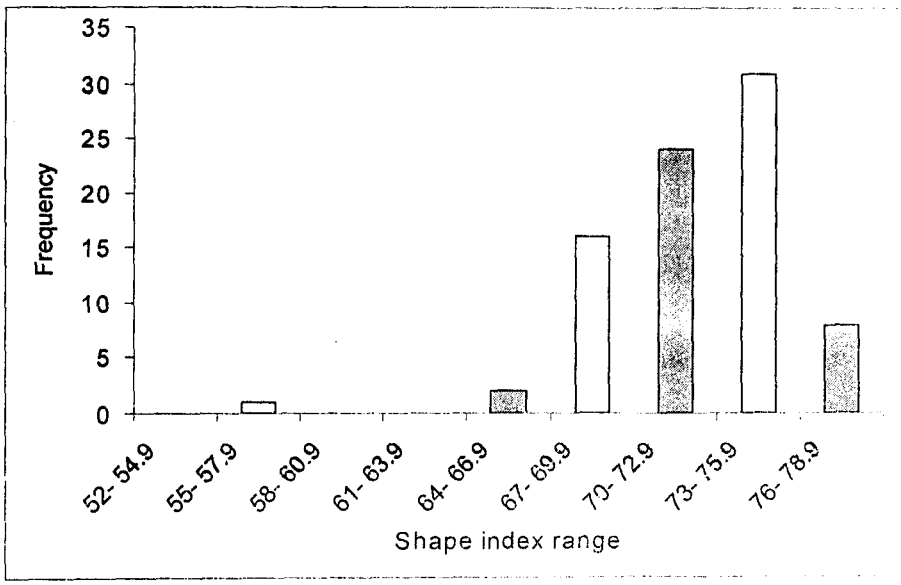


Figure-4.4 Frequency distribution of Shape index of the eggs of Little Egret (n= 82)

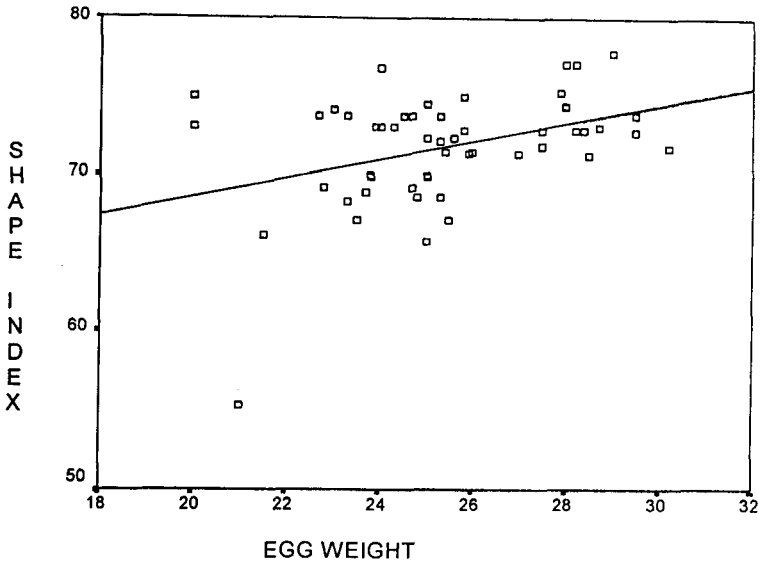


Figure-4.5 Egg weight Vs Shape Index (r=0.390; P<0.01)

4.5.2.6 Colour and Weight of Eggs

The colour of eggs is generally light sea green. The weights of 52 eggs were examined and the maximum was 30.2 gm and the minimum 20 gm. The average weight of 52 eggs was 25.37 gm. The eggs were generally laid in night or early in the morning.

4.5.2.7 Clutch and Egg Size

Clutch size is defined as the sum of eggs known to have been laid in a nest in an uninterrupted series. The clutches of 3 and 4 eggs are very common and had the percentage frequency of 31 and 34 respectively. Clutches containing 6 eggs were also occasionally observed. The data on the size of 48 clutches are summarised in Figure-4.6.

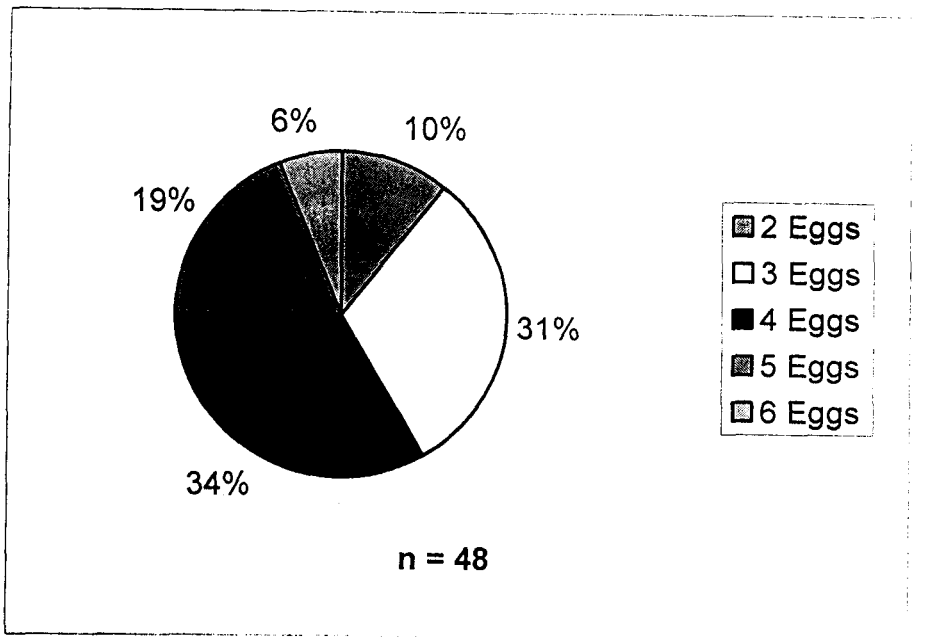


Figure-4.6 Percentage frequency of clutch sizes in Little Egret

A total of 82 eggs were observed in 23 clutches. The minimum length was 42.6mm and breadth 29 mm. The maximum egg length was 52.5 mm and breadth 35 mm. The mean length was 45.34 $\pm$ 1.82 mm and the breadth was 32.7 $\pm$ 1.03 mm (Tables 4.9 and 4.10). About 48% of the eggs had a length range between 44 mm and 45.9 mm and 57% of eggs had breadth range 31- 32.9mm. Average size of 60 eggs was 44.4 x 31.7 mm.

Table-4.9 Frequency distribution of length of egg in a sample of 82

Class interval (mm)	Frequency	% Frequency
40-41.9	0	0
42-43.9	17	20.73
44-45.9	39	47.56
46-47.9	21	25.61
48-49.9	4	4.88
50 - 51.9	0	0
52-53.9	1	1.22
Mean length = 45.34$\pm$1.82		

Table-4.10 Frequency distribution of width of eggs in a sample of 82		
Class interval (mm)	Frequency	% Frequency
29-30.9	2	2.44
31-32.9	47	57.32
33-34.9	30	36.59
35-36.9	3	3.66
Mean	32.70	
Standard Deviation	± 1.03	

4.5.2.8 Incubation

The first egg was laid within 5- 6 days after the initiation of nest building. The incubation (Plate 5b) started with the laying of the first egg. After the egg was laid the nest was never left unattended except on severe disturbance. The incubation periods of 60 eggs were recorded in the present study. It ranges from 19- 24 days and the mean incubation period is 21.8 ± 1.5 days (Figure-4.7).

Both the parents incubate the eggs and usually there were four changes over of duty within 12 hours of the daytime. For each change over the parent birds took about 2.5- 3 hours. During incubation the bird changes its sitting position every 30- 45 minutes. It also kept its feathers fully depressed or partially raised to conserve its body heat and kept them fully raised for passage of air for dissipating the heat. They also kept their neck straight in such a way that their head rested on the rim of the nest.

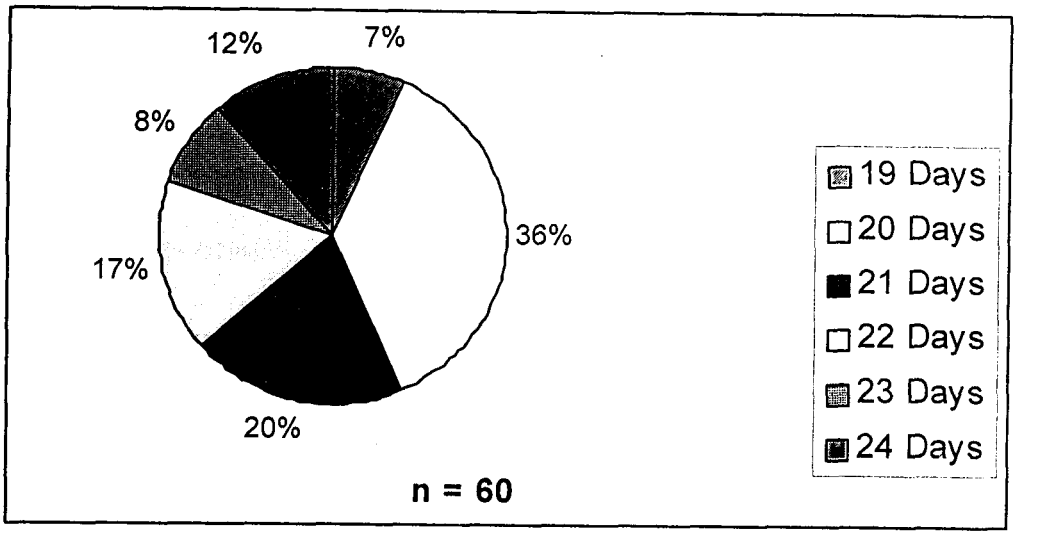


Figure-4.7 Frequency distribution of incubation period of Little Egret (mean = 21.8 days; S.D = ± 1.48)

4.5.2.9 Egg mortality

The eggs that failed to hatch were those that survived the incubation period, but failed to hatch either because they were not fertilized or due to the death of embryo before completing development or any other such causes. The egg mortality is the number of eggs lost plus that did not hatch per total number of eggs laid. An important reason for the loss of eggs and thereby the chicks was fall from the nest. During heavy wind and rain some of the nests fell down and the eggs broken. Disturbance due to careless human approach to the nest tree also caused the bird to fly off in a hurry, leading to the fall of eggs. In some such occasions, when the birds leave the nest in haste, crows were observed raiding the nest and preying up on the eggs.

4.5.2.10 Hatching

Asynchronous hatching was observed in Little Egret. The freshly hatched (0 days) chick weighs about 21.76 gm (N=10). The nestlings (0-14 days) had down feathers all over the body. The neck region, dorsal tract, ventral tract, femoral tract and retrices were still attached with pin contours having down feathers. The beak, tarsus, and toes were slaty.

The empty eggshell was removed from the nest by the attending parent. In the fledging stage (15-30 days), first seven primaries were well developed whereas those from 8-10 were still growing. The secondaries were full-grown in fledglings. In the sub adults (3- 4 months) most of the feather tracts was clear and had full-grown feathers. The beak and tarsus were greyish black and had bluish green lore. The feet of the bird were yellow up to the distal end of tarsus. The growth rate of the chicks differed with respect to their size and weight.

The newly hatched chicks were very weak and they had a bulging abdomen. For first few days the adults regurgitated the food on the nest floor. The parents also assisted the chicks in feeding if the food items are not manageable by the chick itself. As the chicks grew older they begged for food grabbing the beak of the parents forcibly at its base and pulled it down causing the parent to regurgitate. The food items directly entered into its beak of the chick. A few food items were seen falling down from the mouth of the parent bird during the begging-regurgitation process.

The older chicks got food quicker than the younger ones. Even when the chicks started fledging the parents continued to come to the original nest site to feed the fledglings. Parent birds were seen sometimes avoiding the older chicks aged 24 days or more. This probably would increase the survival chance of the chicks that had still not left the nest. It may help the chicks to leave the nest and fly around and ultimately to leave the colony. Some of the chicks, i.e., fledglings which could fly freely but had still not left the colony, were observed sitting on some adjacent trees in the nesting territory aiming some insects and houseflies to feed on.

4.5.2.11 Hatching success

Of the 84 eggs laid under observation, 62 hatched. The remaining 22 eggs were lost for different reasons such as predation by crows, falling from nests and nest desertion. The hatching success is the number of eggs hatched per total number of eggs laid. The hatching success in the present study was 74% (Table-4.11).

4.5.2.12. Parental care

The chicks are guarded by one of the parents until they reach the age of 18-20 days. Afterwards the parent bird was seen perching at some distance and guarding the chicks for another four to five days. Thereafter the chicks were left unattended and they come back to the nest only to feed them and to roost with them during night.

Table-4.11 Mean clutch size and hatching success of Little Egret		
Little Egret	Mean	Std Deviation
Clutch Size	4.42	0.84
Eggs Hatched	3.26	0.93
Chicks lost	0.95	0.71
Eggs lost	1.16	0.69
Hatchlings successfully left	2.32	0.75
Hatching success	0.74	0.16

Any kind of intruder, let it be a predator, a conspecific that inadvertently come to perch close to the nest, or even a human individual would be threatened by 'forward display'. It has been observed that when somebody climbs up the nesting tree the parent bird immediately leaves the nest and hovers around the vicinity of the nest watching the movement of the intruder and giving alarm calls. A guarding heron did not allow any individual bird be it of the same species or of different species to come and perch close to its nest. Such intruders were chased away immediately showing forward display. Chicks fallen from the nest were not at all cared by the parents.

4.5.3 CATTLE EGRET

4.5.3.1 Search for nest site location

As part of the attempt to locate the nesting colony of Cattle Egret in the study area, all the nesting colonies of Little Egrets and Pond Herons and its adjacent areas were subjected to a thorough combing for locating nests of cattle egret. Apart from this, other localities surrounded by water such as Nedumkayam of Malappuram District, Kadalundy of

Kozhikode District, in and around Palghat district especially at the margins of the river Bharathapuzha were also kept under observation.

4.5.3.2 Nesting season

The Cattle Egret breeds from June to August in North India and November to February in South India (Ali and Ripley, 1968). An attempt to locate their breeding site in Kerala failed and no breeding site could be located. In Kerala the breeding of Little Egrets and Pond Herons coincide with the South West monsoon during which a number of nests of Pond Herons and Little Egrets were located at various places but not even a single nest of Cattle Egret could be spotted.

4.5.3.3 Survey for breeding locations in other districts of Kerala

Since the effort to locate the nesting sites of Cattle Egrets in the study areas was in vain, the study was expanded to other districts of Kerala. The three commonly known heronries in Kerala are at Kumarakam in Kottayam district, Nooranad in Alleppy district and Periyar in Idukki district. None of these heronries were reported to contain breeding colonies of Cattle Egret (Subramanya, 1996; Jeyson, E.A, Pers. communication).

As a part of this study the heronries at Kumarakam in Kottayam, Nooranad in Alapuzha and Akulam in Thiruvananthapuram were examined but no nest could be located. In addition, the observation was extended to several places in Wayanad, Kannur, Trichur and Ernakulam districts but to find no breeding site.

4.5.3.4 Breeding Plumage

The Cattle Egrets in breeding plumage in the study areas of Malabar were observed either towards the end of March or during the first week of April. In 1999 towards the last week of March the first batch of Cattle Egrets in their breeding plumage was seen feeding in a paddy field. In the years 2000 and 2001 the species in their breeding plumage was located only in the first week of April in a grass field.

4.5.3.5 Local Movements

By the start of June almost all the Egrets in their breeding plumage disappeared from the State of Kerala. The first batch of egrets returns after their breeding (migration) only during the first week of October. By this time south–west monsoon would be almost over.

4.5.3.6 Search for breeding sites outside Kerala

The States mainly of Tamil Nadu, Karnataka and Andhra Pradesh were combed to trace the nesting site of Cattle Egrets.

Tamil Nadu

In August 2000, Tamil Nadu, particularly Vedanthangal bird sanctuary, was visited in search of the breeding colonies of Cattle Egrets. But neither a nest nor a bird in breeding plumage could be seen anywhere in that locality or Tamilnadu. The egrets of Peninsular India may be moving toward North/Central India for breeding. The intensity of Southwest monsoon is not so heavy in Tamil Nadu as in Kerala. But North East monsoon is rather heavy in this eastern side of Western Ghat. The bird seems to have a certain threshold level of rainfall (i.e., around 1000 mm.) beyond which it is unable to withstand as the other egrets can, and hence they resort to short distance migration.

Karnataka

A visit to Karnataka especially Ranganthittu Bird Sanctuary, to search for the breeding colonies of cattle egrets (Plate 5c) during July and August 1999 and 2000 revealed about 10 nests. In a quick survey conducted in other areas of Mysore and other adjacent areas of the city no such colonies could be located.

A visit to Mandagaddy, 25 Km south of Shimoga, in NH-13 connecting Shimoga and Mangalore showed the presence of 150 nests of Median Egrets, 10 of Little Cormorants and 1 of Little Egret at the banks of the river Thunga adjacent to Shettyhalli forest. Most

of these nests were observed on trees like *Bambusa arundinacea, Acacia sp., Pongamia pinnata* etc., No nest of Cattle Egret was observed here too.

In Gudavi Bird sanctuary 90 km north of Shimoga, Karnataka more than a thousand nests of White ibis, more than 100 nests each of Little Egret and Median Egret and more than 50 nests of Night Heron but not a nest of Cattle Egret.

Andhra Pradesh

The breeding biology of Cattle Egret has been worked out in Andhra pradesh (Rao et al. 1999). According to them Cattle Egrets nest in different localities including the heart of the cities in the districts of Hyderabad, Rangareddy, Mehaboobnagar and Madak in Southern Telengana Zone and Warangal and Karimnagar in Northern Telengana zone of Andhra pradesh from June to September. This clearly shows that in Andhra pradesh the conditions are more favourable for breeding cattle egrets. I had also observed a lot of Cattle Egrets in breeding plumage in various agricultural fields between Vijayawada and Hyderabad during my surveys from Kerala to Hyderabad in August 2001 (breeding season of Cattle Egret, Rao 1999).

Since the nests and breeding colonies of Cattle Egrets were not observed in the entire State of Kerala, extracts of the studies conducted (Rao 1999) in Andhra Pradesh is referred to here for the purpose of comparison and documentation.

4.5.3.7 Breeding Colonies

The studies on breeding ecology (Rao, 1999) were conducted in two agricultural zones namely Southern Telengana Zone (STZ) and Northern Telengana Zone (NTZ). It covered four districts in STZ and identified 56 locations with a total population of 24,251 Cattle Egrets and a total of 100 colonies with 11,639 nests. The largest congregation of Cattle Egret was recorded at Yellareddy of Medak district (Table-4.12), while 13 colonies with 936 nests were recorded at NTZ covering the districts of Karimnagar and Warangal. All the colonies observed were in and around human habitations (Table- 4.13).

Cattle Egret breed in small to medium sized colonies often mixed with cormorants, night herons, egrets etc., (Ali and Ripley, 1968). Studies conducted in New Jersey revealed that Cattle Egrets tend to breed later than native North American Ardeids thus eliminating competition for nest sites (Dusi 1966; Dusi & Dusi 1968; Jenni 1969; Burger 1978).

Table-4.12 Details of Cattle Egret nest and their feeding range in different locations

District	Location	No of Trees	No of Cattle Egrets	No of Nests	Feeding range from the nesting colony
Rangareddy	Shamshabad (SHB)	12	1298	556	0.5- 2 Sq. km
	Nagulapally (NP)	9	1852	801	0.5- 1 Sq. km
Medak	Yellareddy (YR)	38	4898	4021	0.5- 3 Sq. km.
Warangal	Ganapur (GP)	7	958	421	0.5- 1 Sq. km.

Source: Rao (1999)

4.5.3.8 Nest building

Both sexes take part in nest building and the nest is an untidy platform made of twigs. Generally the nests were built of sticks of nearly uniform size on shorter trees (Rao Pers. communication).

4.5.3.9 Nesting Trees

In all the four locations the most preferred nesting tree of Cattle Egrets was *Prosopis* (71.5%) followed by *Acacia* sp. (16.0%) and *Tamarindus indica* (11.1%) (Table-4.13). They nest on neem trees (*Azadiracta indica*), Sheesham (*Dalbergia sisso*), Sares (*Albizia lebbek*), Palm (*Phoenix sylvestris*) and Paras Pipal (*Ficus drupacea*).

Table-4.13 Percentage preference of trees for nesting by Cattle Egret

No	Name of the plant species	Study Area				Total
		SHB	NP	YR	GP	
1	*Prosopis* spp.	57.6	64.4	78.5	37.5	71.5
2	*Acacia* spp.	25.2	20.0	14.0	15.4	16.0
3	*Tamarindus indica*	12.6	15.6	6.2	47.1	11.1
4	*Azadiracta indica*	5.6	-	1.1	-	1.3
5	*Ficus* spp.	-	-	0.2	-	0.0

Source: Rao (1999)

4.5.3.10 Clutch size and incubation

The Clutch size varies from 1-4 and clutches of 3 had maximum frequency. The mean clutch size varied from 3.50 to 4.00 (Table-4.14). The mean clutch varies with locations and had a maximum 4.00 and a minimum 3.50 in Yellareddy and Shamshabad locations respectively. The incubation period also varies from 19 – 24 days. The mean incubation period and the frequency distribution for 85 eggs at Ganapur are shown (Figure-4.8).

Table- 4.14 Mean Clutch Size of Cattle Egret in different agro-ecological regions

Name of the District	Locations	No of Clutches studied	Clutch of eggs				Mean Clutch of eggs
			1	2	3	4	
Rangareddy	Shamshabad	63	9	20	28	6	3.50
Rangareddy	Nagulapally	72	6	22	32	12	3.70
Medak	Yellareddy	126	9	20	62	35	4.00
Warangal	Ganapur	54	5	18	27	4	3.60

Source: Rao (1999)

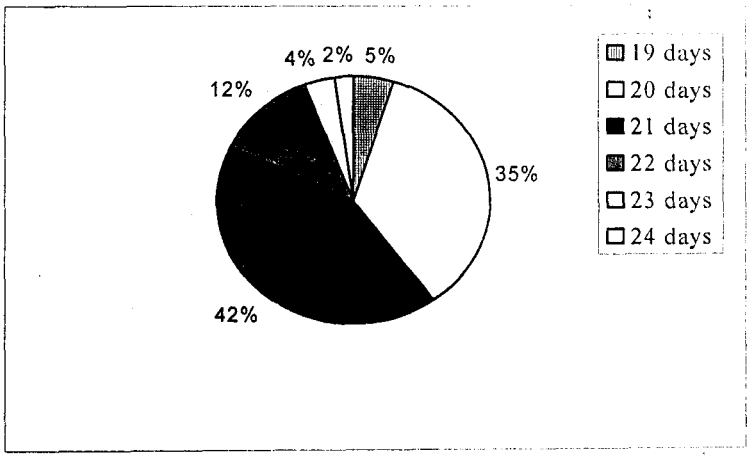


Figure- 4.8 Frequency distribution of incubation period (Mean = 20.8 days) in Cattle Egret (N= 85) (Source: Rao 1999)

4.5.3.11 Egg mortality

The crows are the main egg robbers who prey upon the eggs and small chicks when the parents were not around.

4.5.3.12 Hatching

The hatching success was compared in four localities of the study area (Table-4.15). The highest hatching success of 95.9% was observed at Yellareddy in Medak district while minimum was 87.4% at Ganapur inWarangal district. The Cattle Egret nestlings fledged in 2 months i.e., the time the eggs hatched until they left the nest.

Table-4.15 Hatching success of Cattle Egret in different agro-ecological locations

District	Location	No of Nests	No of eggs laid	Hatching success
Rangareddy	Shamshabad	33	115	87.8
	Nagulapally	22	82	89.0
Medak	Yellareddy	105	380	95.9
Warangal	Ganapur	34	122	87.4

4.6 DISCUSSION

4.6.1 POND HERON

The breeding season of Pond Heron in most part of the continent is May to September; in South India and Ceylon it is November to February (Ali and Ripley 1968). They breed from April to September depending on the monsoon. If southwest monsoon started earlier, they started breeding early.

In Pond heron, the nest site was also used for roosting. For example in Ramanattukara, Kozhikode district, a large Tamarindus tree, which had on it, 85 nests of Pond Herons and 58 nests of Little Cormorants was also used as roosting site by Pond Herons. Similar observations were also reported by Parasharya et al. (1988).

The nests of Pond Herons were small and made of dry soft twigs loosely arranged and almost looks like the nest of a Crow. The nest was rather flat and devoid of inner lining and was reported as an untidy platform of twigs (Henry 1971). According to Ali and Ripley (1968) the nest of Pond Heron was 'an untidy structure of twigs slightly more substantial than a dove's nest'. Pond Herons used dry small branches and petiole of

leaves of different trees (Yesmin et al. 2001). In the present study it is noticed that they used dry small twigs of 26 plant species for 12 nests; mostly of plants of the neighbourhood areas.

During the nest building the male collected the material and the female built the nest (Hancock and Elliot 1978). Both sexes took part in nest building; apparently the male is chiefly responsible for collecting the material which the female puts together (Ali and Ripley 1968). The rate of gathering nest material was comparatively higher in the morning than in the noon hours (Yesmin et al. 2001). In the present study also it is observed that most of the nest materials are collected by the male during the morning and is passed on to the female for building the nest.

The nest was located at some height from the ground (Baker 1929). The nest was built in isolated large trees and was located at a height of two and four metres above surface (Ali and Ripley 1968). The nest height may vary between two to ten metres (Hancock and Elliott 1978). In the study conducted by Yesmine et al. (2001), the nest-height ranged from 0.12-3.35 m, the average being 1.95 m. The nests were built more frequently between 9 and 10m above the ground (Begum 2003). In the present study Pond Heron was seen to nest solitary as well as in colony. Generally they are less colonial than the Little and Cattle Egrets. The nest height varied from 3 metres in *Acacia* and *Pongamia pinnata* to about 10 and 18 metres in *Stereospermum colais* and *Tetrameles nudiflora* respectively. It is felt that nest height varied with the regions of the nest and the height of the tree species available. Coloniality in herons is not an adaptation for exploiting food (Jenni 1969), but Krebs (1974, 1978) considers that coloniality in the Ciconiiformes is an adaptation concerned with food exploitation.

The clutch size varied from 3-5 to five (Ali and Ripley 1968). 4-5 eggs per clutch were also reported. Clutches of 4-6 was most common in Burma (Smythies 1953). The clutch size varied from 1-4 according to Yesmin et al. (2001). In the present study clutch size varied from 2 to 5 and the percentage frequency of nests having clutch size 3 was 86.3.

The average size of the 100 Pond Heron egg was 30.0 x 28.5 mm (Baker, 1929). A comparable size was reported by Ali and Ripley (1968). The measurement results in three

or four eggs were 39.5x 29.5 mm (Henry 1971). The average size of the 76 eggs observed by Yesmin et al. (2001) was 36.38 x 29.87 mm and the average weight 19.27 gm. In the present study the average length of 58 eggs was 37.36 $\pm$ 1.91 and breadth 28.34 $\pm$ 1.42 and the average weight was 15.51 $\pm$1.87 gm.

The incubation period of Pond Heron (38eggs) was reported to be ranging from 21 to 24 days, the average being 23.02 days (Yesmin et al. 2001). In the present study the incubation period varied from 18 to 24 days the average being 20.9 $\pm$ 1.7 days. Addition of nest materials i.e., repair and maintenance continued throughout the incubation period, but stopped almost completely when the chicks hatched. Similar observation was also reported in Cattle Egrets by Blaker (1969).

Earlier workers except Yesmin et al. (2001) did not mention the loss of eggs of Pond Heron. The following were the causes of egg loss (Yesmin, et al. 2001): human interference (9), Loss during handling (2), and infertility (21). In the present study human interference and infertility were identified as the major causes behind the egg loss. According to Yesmin et al. (2001), the hatching success of the pond Heron was 46.05%. In the present study, the hatching success was observed to be 82%.

Both the parents took part in feeding the nestling (Ali and Ripley 1968). Similar was the observation made in the present study. The weight of nestlings was found to increase up to two weeks after hatching. Thereafter, the weight dropped until the birds finally left the nest (Yesmin et al. 2001). Similar observation was made in the present study. In the present study the average weight of newly hatched (0 days) chick was observed to be 13.6 gm (N = 10).

The food of nestlings is mainly composed of fishes (62.50%). Other items include insects (22.50%), Tadpoles (10%), Arachnids (2.50%) and Crustaceans (2.50%, Chapter-III Figure-3.2). A major reason for the coincidence of the breeding season of this bird with monsoon may be due to the heavy and growing demand of the chicks for substantial quantity of fishes and other aquatic organisms.

Observation regarding the loss of nestlings of pond heron showed that 8.5% of the nestlings were lost due to natural calamities, 5.71% succumbed to ectoparasitic disease, and 2.85% died of starvation (Yesmin et al. 2001). In the present study, the loss of nestlings although noticed was not quantified. The carcasses of three nestling pond herons were observed under the nesting tree, *Tamarindus indicus*, which harboured more than 100 nests in a season. All of these three dead specimens were observed on the days following heavy rain and strong wind.

4.6.2 LITTLE EGRET

The starting of the breeding season with the onset of southwest monsoon may be helpful for getting sufficient food for the nestligs during their growth and development. The amount of food delivered per day was 385gm as chicks of age 10- 20 days (Hafner et al. 1993). A lot of fishes and other required food items are usually available in the study areas in all sorts of wetland habitats during the monsoon. As a result of heavy rain during the southwest monsoon in Kerala the rivers and other aquatic habitats get frequent floods. The floodwater along with various aquatic organisms enters different wetlands. Moreover the breeding season of dragonflies and amphibians also coincides with the beginning of the monsoon season. Usually during heavy monsoon breeding egrets are observed in paddy fields and jheels where the water depth will be usually suitable for wading.

Nest site selection always depended on getting maximum food to the nestlings and also security and safety of the young as well as the parents. This may be the reason why they select proximity to aquatic habitat especially the river for locating their nest. For example, the egrets breeding at Panamaram, Wayanad district, were found nesting at the banks of the river Kabani on an elevated area, which is surrounded by water on all its sides. Such location offers probably maximum protection to the young ones. Nesting of Little Egrets at Shoranur Railway Station premises may also indicate the security aspect. However, such locations give maximum protection from human direct disturbances but do not offer as much protection from other predators.

Regarding the preference of nesting trees these birds prefer those trees, which possess a lot of forked branches. In *Tamarindus* trees the twigs are strong and branched and at the same time non brittle. So the nests can be built on small and slender branches located towards the periphery of the tree. Nest building on quaternary branch or branches of the next in the sequence may ensure security from large predators and human interference. Both sexes were found taking part in nest building. Male collects the material and female builds nest. Such types of division of labour have been reported both in Indian Reef Heron and Cattle Egret (Blaker 1969). Observations on the roosting sites of Little Egrets show that the roosting sites are not used for nesting. In Reef Herons, some times roosting tree was also used for nesting whenever the trees provide safety and sufficient food during nesting season (Parasharya et al. 1988).

In the present study, Little Egrets were found breeding only one breeding season, that is, during southwest monsoon while Prasanth et al. (1994) reported breeding in other season also. They also reported that the nests of Little Egret breeding in southwest monsoon had lesser length and depth than those that bred in other season. The mean incubation period (for 60 eggs) in the present study was 21.18 $\pm$ 1.48 days. The incubation period may vary from region to region in response to temperature fluctuations (Prasanth et al. 1994). The amount of energy incorporated in the egg also varies mainly because of the relative size of the yolk which, being more in precocial than in altricial species (Perrins 1996). The chicks of Little Egret were semi altricial, naked and blind and completely depended on their parents (Gill 1990).

Parental care and active defense of nest is very active as there is always threat to the chicks and therefore it is on part of their parents to protect their young. Owing nest, egg and nestling defense they always makes "Waku- Waku "vocalisation and aggressive postures as a warning to the predator. But the bird normally would not attack the predator until it comes directly to the nest or shows some clear sign of attack. House crows generally prey upon eggs and sometimes on small chicks exploiting unusual situations such as all guarding parents moving away for some sudden disturbance. The crows utilised this chance and devoured the eggs from the nest. However, predation is not a serious cause for chick mortality according to Hafner (1978) and Hafner et al. (1993).

Older chicks are sometimes stabbed to death by the parents from the adjacent nest (Hafner et al.1993). This was also reported in the case of Grey heron (Owen 1960) and the Cattle Egret (Blaker 1969). However, such incidence is not observed in the present study. This could not have happened if there were permanent brood guarding until the chicks left the nest entirely. In the early nestling stage, risk rate is very little since one of the parents permanently guards the nest until the nestlings fledged. But when the chick fledged to hop around the nesting branch, the parent would already start foraging leaving the chick alone and prone to attack by a neighbour. Hence it seems that the function of brood guarding is not likely related with the chick-defense against neighbours.

4.6.3 CATTLE EGRET

The observation in some of the oldest 22 heronries distributed through out 10 states of India revealed that none of these heronries except the one in Karnataka, Ranganthittu bird sanctuary, have breeding colonies of Cattle Egret. Of 19 traditional nesting sites distributed throughout India in 19 districts over 8 states Cattle egrets bred only in four sites. They were Ghoga town in Bhavnagar district of Gujarath; Ranganthittu Bird Sanctuary in Mysore district of Karnataka; Koeladeo National Park in Bharathpur district of Rajasthan and Chithrangudi heronry in Ramanathapuram district of Tamilnadu (Subramanya 1996). The breeding colonies of Cattle Egrets in Bharathpur were also documented by Sivasubramanian (1992).

Ornithologists have opined long before that bird species select nesting habitats only in some selected localities (Lack 1933; McCrimmon Jr 1978). Cattle Egrets nest commonly in colonies with other egrets like Night Herons, Cormorants, Ibises and Storks. At Ranganthittu Bird Sanctuary they were nesting along with white ibises, Painted storks, Pond Herons, Whitenecked Storks and Openbilled Storks on shorter trees. In Andhra Pradesh also they nest on small short trees (Rao Pers. Communication). This probably may give protection from avian predators (Lowe-McConnell 1967) but at the same time such nests may be vulnerable for human interference. The vertical stratification of nests was reported in Cattle Egrets (Jenni 1969). In a study on the nest site characteristics of five species of herons, McCrimmon (1978) found that Cattle Egrets selects sites farther

from the edge of the heronry. No such observations could be made during this study in Ranganthittu bird sanctuary during 1999 and 2000.

The most common nesting species in Indian heronries was the little egret, which nests in about 150 sites. The Glossy Ibis, Spotbilled Pelican, Lesser Adjutants and Greater Adjutant were the most abundant nesting species (Mahabal 1990; Subramanya 1996). The occurrence of heronries in a particular region is dependent on the availability of suitable feeding conditions for waterbirds (Bancroft et al. 1988; Gibbs et al. 1987). Intraspecific and interspecific aggression was reported in Cattle Egrets but intraspecific aggression was more common (Weber 1975; Lowe-McConnell 1967; Burger 1978). Vegetation having diversified substrates for nest building helped in minimising competition among nesting species. Thorny species of vegetation like *Prosopis* species helps accommodating number of nesting species (Rao 1999). Trees having more forked branches may also help accommodating more nests, which in turn helped reduction in intra and interspecific competition among nesting members. 85 nests of pond herons and a few nests of Littlle Cormorants on a Tamarind tree at Ramanattukara in Malappuram district of Kerala, despite of a number of other trees in the immediate vicinities, indicated probably their preference for trees having forked branches.

The Cattle Egrets showed two-peak nesting in a year in Guyana, in the main rains between April and August, and again in the rains at the end of the year, November-December. Similar observations have also been reported in studies conducted in Andhra Pradesh (Rao Pers. Communication). Studies conducted in New Jersey revealed that cattle egrets tend to breed later than native North American Ardeids, eliminating competition for nest sites (Dusi 1966; Dusi and Dusi 1968; Jenni 1969; Burger 1978). The Cattle Egrets breeding both in Guyana of South America and in East African latitude had 1-3 eggs, whereas those breeding further away from the equatorial region of East Africa had 3-5 eggs (Lowe-McConnell 1967). The number of eggs in clutches studied at different locations in Andhra predesh also found varying from 1-4 (Rao 1999). The tendency for birds to have more eggs in higher latitudes may be a function of the day length and time available for food gathering for the chicks (Lack 1954).

4.6.3.1 Breeding colonies of Cattle Egrets in some States of India

4.6.3.1.1 Andhra pradesh

In Andhra Pradesh the two oldest heronries reported were Telineelapuram and Ethirapattu in Srikakulam and Nellore districts respectively. No nests of Cattle Egrets were reported from these heronries as early as 1983 (Subramanya 1996). Another top heronry known as Telikunchi village heronry in Andhra pradesh was also devoid of the breeding colonies of Cattle Egrets (Subramanya 1996)

The breeding biology of Cattle Egret has been worked out in Andhrapradesh (Rao 1999). According to their report Cattle Egrets were observed nesting in the cities in several localities like Yellareddy, Mehaboob Nagar, Madak, Warangal in Andhra pradesh from June to September. In this study a lot of Cattle Egrets could be observed in breeding plumage feeding in various agricultural fields in Andhra Pradesh and Maharashtra in July and August when they are totally absent in Kerala. Nevertheless presence of a lot of cattle egrets in breeding plumage in a particular locality does not make sure that all those egrets breed there. During the months of heavy Southwest monsoon rain in Kerala, there is less rain in Andhra Pradesh (northeast of Western Ghat) and Maharashtra where the ghats are of low heights. There is a strong possibility that the Cattle Egrets migrate to those states for breeding is a strong possibility cannot be ruled out. For confirming the breeding migration of cattle egrets from Kerala to Andhra Pradesh or Maharashtra ringing studies are necessary.

4.6.3.1.2 Maharastra

Mahabal (1990) had recorded heronries at 13 places in Raigad district while Pande (2002) added 11 more heronries to the list. Some of these nests were reported from Konkan area. In addition, a number of heronries and breeding populations of little cormorants, Pond Herons, Median Egrets, Cattle Egrets and Night Herons were noticed at various places of the district. These heronries were either on a single tree or on widely scattered ones. This indicates the possibility that egrets and other herons may selectively move to breeding places in Maharashtra.

4.6.3.1.3 Kerala

By the start of June almost all the Egrets disappeared from the entire State of Kerala first from southern parts where early rains are usual followed by from northern parts (Shukkur pers. Communication). During this period they appear high in Maharashtra and Andhra Pradesh. Their total absence from Kerala in the breeding season and the breeding colonies in Andhra Pradesh and Maharashtra hints at the possible migration. The first batch of egrets returns to Kerala only during the first week of October. The start of southwest monsoon in Maharashtra and Andhra Pradesh is more or less simultaneous with that in Kerala. Since these birds totally disappeared from the entire State of Kerala after developing breeding plumage, they may be moving to the neighbouring Maharashtra and Andhra Pradesh for breeding. Now there exist some questions as to what exactly prevents them from breeding in Kerala. The probable reason may be a lesser tolerance for a higher rainfall threshold and the shortage of food, which should be made available in plenty for the developing nestlings. As per my observation prey species was least in almost all habitats during summer. Then it gradually increased from June to September, during which the abundance of food species was in a medium range (See Chapter-II Figure-2.1). Maximum abundance of prey species was observed during the months of October to December. From this it can be inferred that during their breeding season (June-September), though the food is available, probably heavy rain may reduce time available for searching food. When they return prey items were plenty since all sorts of habitats are covered with a variety of vegetation. Scarcity of nesting trees may also be major reasons for the breeding migrations in Cattle Egrets. The trees like *Prosopis* species have a lot of forked branches are plenty in the states of Maharashtra and Andhra Pradesh than in Kerala. In addition, large scale felling of trees as a part of industrialisation and urbanisation also have caused declining available nesting sites for these birds in Kerala. But migration might have started millions of years back along with their evolution.

4.6.3.2 Threats to heronries in Kerala

Developmental activities are always against nesting birds. A number of heronries have disappeared due to removal of large nesting trees or disturbances as a result of developmental activities. The absence of breeding sites (trees) near the wetlands is a deterrent for all trees nesting waterbirds like storks, Spoonbills, Larger Egret, Little Egret, Cattle Egret, Grey Heron and Night Heron (Vyas 1993d). Destruction of nesting tree species is an important factor leading to the loss of heronries. As part of social forestry program, the foreshore stands of *Acacia nilotica* were harvested to distribute benefits to the people (Wilson 1986; Subramanya 1996). Heronries in different parts of Madras (Subramanya 1996) seem to have disappeared due to development of the city (Subramanya, 1996). Similar is the case with the Salt Lake Colony of Purple Herons in Calcutta (Saha 1969).

The nesting of waterbirds in large colonies often causes fowl smell due to defaecation and decaying of fish remnants fallen from the nests. The resulting pungent smell is offensive to locals living near by. At Ulloor, Trivandrum, the unbearable smell of heronry instigated its owner to cut down the nesting tree (Subramanya 1996). Again for the same reason the Vattappara Heronry in Trivandrum was also destroyed and the heronry near KTC bus stop in Palakkad is threatened. The same reason is attributed to the loss of once abundant nesting sites of wetland birds in Nooranad of Alleppy district. The locals whom I contacted were of the opinion that about two to three years back the area was covered with a lot of wetland birds which nested on big trees in the nearby area especially on trees adjacent to shopping complexes and taxi stand. Due to the offensive smell and disturbance due to their excrement the people of the area especially drivers and shop owners drive them away by ringing bells and using crackers quite frequently.

4.7 SUMMARY AND CONCLUSION

4.7.1 POND HERON

In Pond herons breeding started along with the first rains that heralded the onset of monsoon. Nests are built on different plant species, usually very close to aquatic habitats especially paddy fields. Altogether 17 plant species were used to build the nests. The nests were platform types, with a loose 'cup' in the centre and made of materials such as small petioles of plants, small branches of trees etc. Nest materials were collected from 26 different plant species and 91 nest materials were used on an average for nest building. The mean maximum size of the nest material used was 29.05 cm. and the mean minimum size was 13.46 cm.

The eggs were green in colour broad, oval in shape and medium in size, without any markings or spots. The longer and thinner the eggs the lower the shape index, the shorter and thicker eggs the higher the shape index. The average weight of egg was 15.51 gm while the maximum and minimum weight was 17.8 gm and 11.2 gm respectively. Clutch size varied from 2-5 in which clutches of 3 were very common.

Both sexes take part in incubation. The first egg was laid within 5-6 days after the initiation of the nest building. The incubation period ranged from 18-24 days and the mean incubation period was 20.9 $\pm$ 1.66 days. During incubation, usually the parents change duties 3-4 times within 12 hours of the daytime.

One of the major causes for the egg loss was nest falling. Heavy rain and strong wind also resulted in the loss of eggs. Hatching was asynchronous. The hatching success was 82%. The chicks were almost naked and eyes closed, semi altricial or semi precocial. The food of the nestlings was mainly fishes. Both parents took part in feeding the nestlings.

4.7.2 LITTLE EGRET

Little Egrets started the breeding along with the onset of southwest monsoon, usually in the middle of June or during the first week of July. In Pond Herons breeding starts earlier, i.e., at the end of April or middle of May depending on the first few summer rains before the onset of southwest monsoon. The nests of Little Egrets were not so common as of pond heron and were mostly on riversides and built in safer areas such as in temple premises, platforms at railway junctions, island like locations.

The nests were platform type and usually built on the vertical forks of 2-5 branches both inside and outside the periphery of the tree crown. The nests were not exposed to the sky. Male collected the nest material and the female lined it up inside the nest. The nest height ranged from 4-8 m from the ground. Altogether 15 different plant species were used for nesting. Totally 35 plant species were used for nest building.

Of the 82 eggs examined, longer and thinner eggs showed lower shape index while shorter and thicker eggs showed high shape index. The eggs were generally light sea green and had a maximum and minimum weight of 30.2gm and 20gm (N=52) respectively. Average size of 60 eggs was 44.4 x 31.7 mm. The clutch size varied from two to six.

Both parents took part in incubation. Incubation period varies from 19-24 days and the mean incubation period was 21.18+1.478 days. Fall of the nests containing eggs during heavy rain and strong winds caused egg mortality. Hatching was asynchronous and the freshly hatched (0 days) chicks had a weight of 21.76 gm. The hatching success was 74%.

4.7.3 CATTLE EGRET

The nests of Cattle Egrets were located nowhere in the study area during the entire study period. Hence the survey was extended to the entire State of Kerala. But no nests could be located. The important breeding aspects of Cattle Egrets presented in this chapter are

based on studies conducted elsewhere (Ali and Ripley 1968; Rao 1999 and Bhargava et al. 1982).

The nests of Cattle Egrets are also of platform type and both sexes take part in nest building (Ali 1979). The nests are made of twigs of uniform size and in some cases lined with grassy petioles of neem leaves (Bhargava et al. 1982) and had a mean nest width of 35.8 cm (Burger 1978). Cattle Egrets usually nested on shorter trees like *Prosopis* (Rao Pers. Comm.).

The eggs were pale sea green and the average size was 44.1 x 36.5 mm. (N=80 Ali and Ripley 1986). Clutch size varied from 1-4 and clutches of 3 had maximum frequency. The incubation period also varied from 19-24 days and the mean incubation period for 85 eggs was 21 days (Rao 1999).

Crows caused egg mortality by preying on the eggs when the parents were out in search of food.

Despite many survey no breeding colony of Cattle Egret was seen in the state. The reasons for the absence of their breeding sites in Kerala may be as mentioned below; i) Lack of enough nesting sites, especially the thorny species of vegetation. ii) Lack of protection to the eggs and nestlings. iii) Heavy rain may interrupt the time- length for searching food, which should be made available in plenty for the developing nestlings. iv) Since their breeding season coincides with the close of summer and the onset of monsoon, the availability of insects that forms the major source of food for nestlings becomes comparatively less due to drying of vegetation. This may lead to a southeast or southwest local movement (which should be confirmed by ringing) during breeding season, and 5) Anthropogenic pressure such as nest destruction, shooting etc. also may force them to move in search of better breeding grounds.

PESTICIDE CONTAMINATION

Seedikkoya .K “Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality ” Thesis. Department of Zoology , Farook College Calicut ,University of Calicut, 2003

Chapter V

PESTICIDE CONTAMINATION

5.1 INTRODUCTION

The Organochlorine compound known as Dichlorodiphenyl trichloroethane (DDT) was synthesized in1874 (Carson 1962) and it came into wide agricultural use in late 1940s. Significant declines in the population of some raptors, and related eggshell thinning were reported after 1946, the period associated with the widespread use of DDT and other organochlorine insecticides (Ratcliffe 1967; Hicky and Anderson 1968). Dieldrin another more toxic organochlorine insecticides came into wide use in the mid-1950s (Stickel et al. 1984). Polychlorinated biphenyls (PCB), another serious chemicals of environmental and ecological concern, are a group of synthetic chlorinated aromatic hydrocarbons that were first synthesized in 1881. They are present in commercial products such as lubricants, dielectric agents, flame-retardants, plasticizers, waterproofing materials and heat transfer materials (Beyer et al. 1996).

The senseless use of organochlorine pesticides for the human welfare and agriculture and public health purpose has triggered lot of ecological problems on piscivorous water birds, marine mammals, resident birds, migratory birds, bats, wild animals and man (Senthilkumar et al. 2001). In birds, biomagnification of DDTs and PCBs was supposed to be much higher than those of some other organochlorines (Guruge et al. 2001). Among the birds, like the raptors, piscivorous birds hold a very sensitive position in terms of their vulnerability to pesticides. World over a number of cases of herons and other piscivorous birds getting affected by pesticides are reported (Custer 2000; Van Wyk et al. 2001; Albanis et al. 1996; Niethammer 1984). In the countries of the west a large number of studies are conducted on ecological impacts of the agrochemicals and pesticides. In spite of their continuous use, comparatively little is known about the impacts of such chemicals and their residues in developing countries like India, which is one of the major producer and consumer of agrochemicals. The present chapter attempts to document the pesticide residue levels in the select species of ardeids collected from the study area.

5.2 BACKGROUND

5.2.1 Pesticide residues in tissues

Tissue concentration of organochlorine pesticides in living systems is helpful for determining the spatial distribution of environmental contamination and identifying their sources (Ohlendorf 1981). Organochlorines (OC) being highly fat-soluble, their residues accumulate in adipose tissues. The extent of this concentration depends upon the exposure and the physiological condition of the organism determined by biological demands such as migration, feeding activity, and reproduction (White 1980). Birds being important components of ecosystem occupy different trophic levels and get exposed to a wide range of environmental contaminants through their food (Ankeley et al. 1993) and also other means. The levels of persistent organochlorine pesticides in avian species have been widely documented (Ohlendorf 1981).

Studies specifically dealing with Pond Heron, Little or Cattle Egret and pesticides are comparatively rare in the country. The whole-body homogenates of two Pond Herons from in South India (Senthilkumar 2001) have detected notable levels of organochlorine pesticides, Poly chlorinated biphenyls (PCB) and Dchloro diphynyl trichloroethane (DDT). Breast muscle of birds analysed for organochlorines in South India had notable levels of DDT and its metabolites (Ramesh et al. 1992, Jayakumar 1999). Residues of Little Egret nestlings collected in wetlands of Thermaikos Gulf, Macedonia, Greece showed relatively low DDE concentrations (Albanis et al. 1996).

5.2.2 PESTICIDE RESIDUES IN EGGS

Members of the Order Ciconiiformes are reported to be highly sensitive to DDE (o, p'-dichloro diphenyl dichloroethylene) induced eggshell thinning. Eggshell thinning in herons was describeed for the first time in Grey herons. In 1967 in Britain egg breaking was observed in a colony of incubating Grey herons by Custer (2000). Herons showing most eggshell thinning were species that rely heavily on fish in their diet (Niethammer et al. 1984). It is generally accepted that p,p'-DDE is a major factor in causing birds to lay thinner eggs, although the mechanism is yet to be completely understood (Dirksen et

al.1995). In 13 species of fish-eating birds eggshell thinning was correlated with p,p'-DDE (Cooper 1991). Organochlorine pesticides in the eggs and nestlings of Squacco Herons collected at Thermaikos Gulf, Macedonia, Greece was reported by Albanis (1996) and Custer (2000). The shell thinning in Great Egret eggs collected from the Eastern United States in 1972 and 1973 in relation with organochlorine pesticide residues was examined by Ohlendorf (1979a).

Organochlorines and heavy metals were determined in shorebirds in Texas by White et al. (1980) and in the chicks of Great Blue Herons (*Ardea herodias*) from upper Mississipi River, Wincosin, by Ohlendorf, et al. (1979 b). The incidence of organochlorine residues in Black-crowned Night Herons (*Nycticorax nycticorax*), White-faced Ibis (*Plegadis chihi*), Black-necked stilts (*Himantopus mexicanus*) and Snowy Egrets (*Egretta thula*) were discussed by Henny et al. (1985).

Studies on DDE concentrations in the eggs of Night Herons collected from Salton Sea, California, USA (Ohlendorf and Marois 1990) and Green-backed Herons from Tennessee Valley, USA (Fleming et al. 1984) have been reported. Low concentrations of DDE were found in eggs of two Purple Herons collected from Southwest Spain, in Little Egret eggs collected from Donana National park, Spain, from Israel, and from Northern Italy (Custer 2000). The eggs of Cattle Egrets from the United States, Mexico, Spain, Israel and Egypt also had low levels of DDE residues. The only organochlorine residues found at detectable levels in Cattle Egrets nesting in a residential area of Bryan, Texas were DDE and PCBs (Mora and Miller 1998).

Eggshell changes in 25 species of birds found in North America have been associated in 11 cases with DDE or DDT-family residues in eggs (Anderson and Hickey 1972). The Anhingas seem to be more sensitive to DDE than Green Backed Herons; shell thinning in Anhingas averaged 14% with a geometric mean of only 2 ppm DDE in the eggs. According to Blus et al. (1974) and White et al. (1988) Brown pelicans (*Pelecanus occidentalis*) suffer nest failure if their eggs contain more than 25ppm DDE. Increased absence from the nest site in individual glaucous gulls with high blood concentrations of OC suggests effects on reproductive behaviour (Bustnes et al. 2001). Cormorants

(*Phalacrocorax carbo sinensis*) breeding in the heavily contaminated sedimentation area of the rivers have an extremely reduced breeding success compared to other colonies (Dirksen et al. 1995). Incidence of eggshell breakage and change in eggshell characteristics has been studied in the Grey Heron, *Ardea cinerea* in Eastern England by Cook et al. (1976). They report that shell breakage was positively related to the residue levels of pp'-DDE or dieldrin in intact eggs.

Correlation analyses showed that the eggshell thickness was inversely proportional to residues of DDE in eggs (Beyer et al. 1996). In Bald Eagles an increase in eggshell thickness and reproductive success was accompanied by decrease in DDE residues (Ohlendorf and Fleming 1988). The reproductive success was evaluated in colonial water birds nesting in the Rio Grande Valley, Texas, and correlated success with concentrations of contaminants in eggs (Wainwright et al. 2001).

In India, the studies on organochlorine pesticide contamination in the eggs are scanty. Organochlorine residues in the eggs of eight species of colonial birds in Keoladeo National Park were documented by Muralidharan et al (1992). Senthilkumar et al. (2001) documents accumulation of organochlorine pesticides and polychlorinated biphenyls in bird eggs, collected from South India.

5.3 OBJECTIVES

The objectives of the present study were;

1. To examine accumulation of select organochlorine pesticides, Aldrin, BHC, Chlordane, DDT, Dieldrin, Endrin, Endosulfan, Heptachlor and Methoxychlor in heart,,liver and muscle of Little Egret, Cattle Egret and Pond Heron, and

2. To determine concentrations of organochlorines BHC, Dieldrin, Endosulfan, Heptachlor, pp-DDD, pp-DDT and pp-DDE in the eggs of Little Egrets and Pond Herons.

5.4 METHODOLOGY

5.4.1 Tissue Sample collection

No attempts were made to sacrifice live birds to assess pesticide residues in the tissue. Tissues from three dead specimens of Cattle Egret, Little Egret and Pond Heron were collected nearby their roosting sites in a Rubber plantation at Mampad, Malappuram district, over a period of 3 years. Tissue samples each of heart, muscles and liver were dissected out from the carcasses, stored in clean polyethylene vials, labeled and transported to Ecotoxicology laboratory at SACON where analysis of metals and pesticides were carried out.

5.4.2 Egg Sample collection

The egg samples of Little Egrets for pesticide and heavy metal analysis were collected from breeding colonies located at Pattambi, Palakkad district while that of Pond Herons were collected from Mampad, Malappuram district. One egg each from 5 clutches of Little Egret and pond herons were collected. The eggs were stored in a refrigerator until they were weighed, volume estimated and length and breadth measured. Each egg was opened at the equator and its contents poured into a chemically cleaned jar. The samples were stored in a freezer until they were analysed. Shells of all eggs were rinsed in tap water and dried. Eggshell thickness (including membranes) was measured at three sites on the equator with a micrometer graduated in units of 0.01mm: an average of four measurements was taken to represent shell thickness.

5.4.3 Organochlorine pesticides included in the present study

Heart, liver and muscle tissues of pond herons, little egrets, and cattle egrets were analysed for residues of the pesticides namely, Aldrin, BHC, Chlordane, DDT, Dieldrin, Endrin, Endosulfan, Heptachlor, Methoxychlor. The eggs of Pond Herons and Little Egrets were analysed for the presence of the following pesticides, BHC, Dieldrin, Endosulfan, Heptachlor, pp-DDD, pp-DDT and pp-DDE.

5.4.4 Tissue sample processing

All tissue samples were analysed for organochlorine pesticides and their metabolites mentioned earlier. The sample was ground with anhydrous sodium sulphate to remove moisture content in the sample. The same was packed in a thimble, vacuumised and kept overnight for complete drying. The packed thimble was loaded in a soxhlet apparatus where the sample was extracted using organic solvent hexane (250 ml) for 6 hours. After extraction was completed, the extracted solvent was condensed in a Rotary Flask Evaporator to 5 ml volume. The condensed sample was then cleaned up and separated by silica gel column chromatography, eluted with 250 ml of acetone and hexane in the ratio 1:4 to ensure maximum recovery. The collected eluent was again condensed to 3 ml, by using Rotary Flask Evaporator. The condensed samples were analysed on a Hewlett-Packard Model 5890 Series II Gas Chromatography equipped with a linearised Ni^{63} Electron Capture Detector.

Column:

HP5, 25 m long x 0.25 mm ID, with the thickness of 0.33 μm, packed with 5% of Biphenyl and 95% methylsiloxane.

Temperature:

Column: 160 ^{0} c/3 min -2^0 c/one min -220^{0}c/5 min

Injector: 250^{0}c

Detector: 300^{0}c

Carrier gas:

Nitrogen 45 ml/ min.

5.4.5 Egg sample processing

The whole contents of each egg sample were homogenized and a known quantity was taken and ground with anhydrous sodium sulphate (1:1 to 1:4 w/w) until a fine dry powder was obtained. Celite (1:1) was added and mixed thoroughly. The resultant powder was loaded in a clean glass column for extraction using 250 ml pesticide grade n-hexane. The eluent from the column was collected, condensed to specific volume (3 ml) using Rotary Flask Evaporator. The condensed sample was then injected to Gas chromatography equipped with an Electron Capture Detector for the organochlorine residues of BHC, Heptachlor, Dieldrin, Endosulfan, pp-DDE, pp-DDD and pp-DDT. The samples were analysed using the same Hewlett-Packard Model 5890 Series 11 Gas Chromatography with the parameters as mentioned earlier for tissue processing.

5.5 RESULTS

5.5.1 Organochlorine residues in tissues

Organochlorine residues in different tissues of Pond Heron, Little Egret and Cattle Egret are given in Figure 5.1-5.3.

5.5.1.1 Pond Heron

Heart: In Pond Heron the heart showed highest level of BHC (mean 0.25±0.11 ppm) and DDT (mean 0.25±0.05 ppm). Other pesticides that were seen in lower concentrations were Endrin (0.19±0.01ppm) and Aldrin (0.16±0.06ppm), Endosulfan sulphate (0.07±0.01ppm) and Heptachlor (0.08 ± 0.01 ppm). Dieldrin was the lowest in concentration of the detected OCs (mean 0.01 ± 0.02 ppm, Appendix-5.1).

Liver: In the liver of Pond Heron BHC (mean 0.11± 0.10 ppm) and Endosulfan (mean 0.11 ± 0.15 ppm) had the highest concentrations. Other pesticides that followed them were Aldrin (0.08 ± 0.05 ppm) and Chlordane (0.06 ± 0.05 ppm). Dieldrin had the lowest mean concentration (0.01 ± 0.02 ppm).

Muscle: In the muscle DDT had the highest concentration (mean 0.16 ± 0.03 ppm). Dieldrin was seen almost around the BDL value. Endrin (0.12 ± 0.03 ppm) and BHC (0.08 ± 0.05 ppm) followed DDT. Endosulfan sulphate (0.02 ± 0.02_ppm), Heptachlor (0.02 ± 0.01 ppm) and Methoxychlor were also present in the samples.

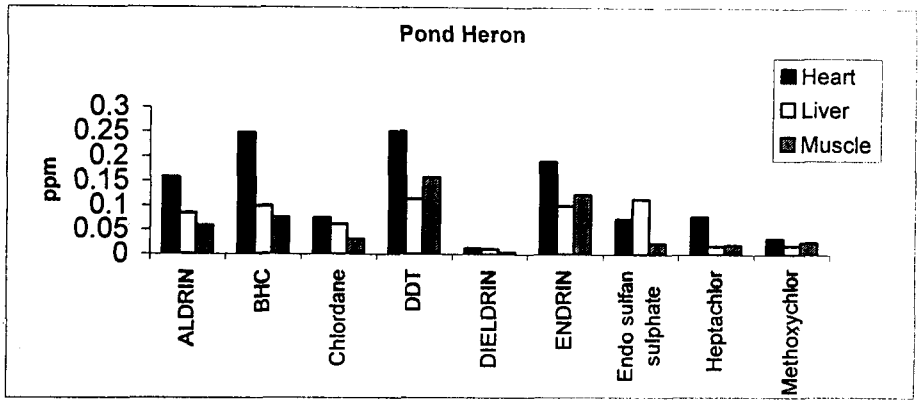


Figure 5.1. Organochlorine residues in the tissues of Pond Heron

5.5.1.2 Little Egret

Heart: Liver had the highest concentration of DDT (mean 0.34 ± 0.14 ppm) in the heart. Heptachlor (mean 0.03 ± 0.02ppm) and Methoxychlor (mean 0.03 ± 0.03 ppm) were present equally in lowest concentrations. Endosulfan sulphate (0.20 ± 0.17 ppm) and BHC (0.20 ± 0.11 ppm) were almost equal in their concentrations. Aldrin, Endrin, Chlordane and dieldrin followed Endosulfan sulphate and BHC.

Liver: Endrin had the highest concentration in liver (mean 0.30 ± 0.41 ppm). The lowest concentration was that of Heptachlor (mean 0.02 ± 0.03 ppm). DDT (0.22 ± 0.23 ppm) followed heptachlor in concentration. BHC and Aldrin were present more or less in equal amounts. Endosulfan sulphate, Chlordane and Dieldrin and Methoxychlor were also present but in lower in amounts.

Muscle: The muscle accumulated the highest concentration of Endosulfan (mean 0.09 ± 0.11 ppm) and the lowest was Dieldrin the concentration of which was around the BDL.

Aldrin (0.06 ± 0.06 ppm) and DDT (0.06 ± 0.02 ppm) were present in equal amounts and they followed Endosulfan sulphate. BHC, Chlordane and Endrin lie next to Aldrin and DDT, both present in almost identical concentration.

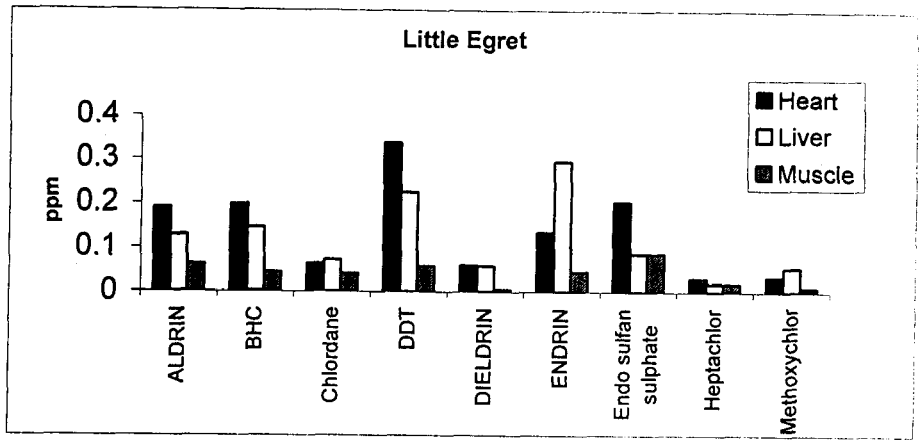


Figure 5.2. Organochlorine residues in the tissues of Little Egret

5.5.1.3 Cattle Egret

Heart: Heart accumulated the highest concentration of Endrin (mean 0.11 ± 0.02 ppm) and the lowest concentration of Methoxychlor (mean 0.00 ± 0.01 ppm). Endosulfan sulphate (0.10 ± 0.10 ppm) followed Endrin in residue levels. DDT and BHC were present more or less equally. Aldrin and Chlordane followed them and were present in almost equal amounts. The amount of Dieldrin and Heptachlor was lower.

Liver: The liver contained the highest level of BHC (mean 0.19 ± 0.11 ppm) while the lowest was in the case of Methoxychlor (mean 0.02 ± 0.02 ppm). Dieldrin. Endrin (0.17 ± 0.14 ppm) and DDT (0.15 ± 0.12 ppm) respectively followed BHC in concentration. Aldrin and Chlordane were present more or less equally. Endosulfan sulphate and Heptachlor were also present but lower in concentration.

Muscle: The muscle accumulated the highest concentration of Aldrin (mean 0.39 ± 0.22 ppm) and BHC (mean 0.35 ± 0.43 ppm) and DDT (0.34 ± 0.41ppm) respectively. The lowest concentration was represented by Methoxychlor (mean 0.05 ± 0.06 ppm). Dieldrin

and Chlordane were also present more or less in equal concentrations. They were followed by Heptachlor and Endosulfan sulphate.

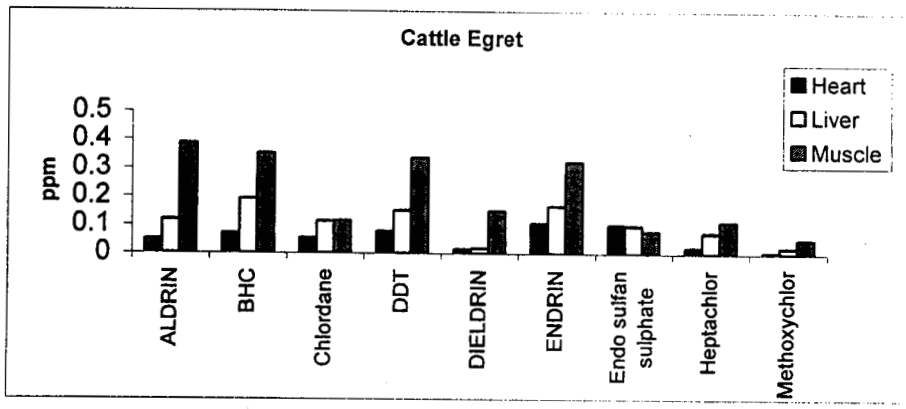


Figure 5.3. Organochlorine residues in the tissues of Cattle Egret

5.5.2 Organochlorine residues in eggs

5.5.2.1 Pond Heron

Organochlorine residues in different eggs tissues of Pond heron and Little Egret are given in Figure 5.4, 5.5 and Appendix-5.2. The eggs of Pond Herons had very low Organochlorine pesticides. Among the seven pesticides for which analysis was done BHC (mean=0.107 ±0.22 ppm), DDT (mean=0.064 ±0.070 ppm) and DDD (mean=0.042 ±0.087 ppm) had slightly higher concentration than the other pesticides. DDE was nearly below detectable level (mean=0.0001±0.0001ppm). Other pesticides that were present in the egg included Heptachlor (mean=0.013±0.026 ppm), Endosulfan (mean=0.015±0.029 ppm) and Dieldrin (mean=0.006 ± 0.011ppm).

5.5.2.2 Little Egret

The Little Egret had comparatively high concentration of Endosulfan (mean=0.016± 0.021ppm), DDD (mean=0.009±0.012 ppm) and DDT (mean=0.008±0.007 ppm) was present in comparatively equal concentrations. Heptachlor (mean=0.002±0.003 ppm) and Dieldrin (mean=0.002±0.003 ppm) was lowest and in equal concentrations. Other

pesticides present in the egg include pp-DDE (mean=0.003± 0.005 ppm), (mean=0.05±0.10 ppm) and Heptachlor (mean=0.03 ± 0.07 ppm).

This result shows that the variation in the concentration of the total organochlorine residues in the species of birds where in the order - Pond Heron > Little Egret.

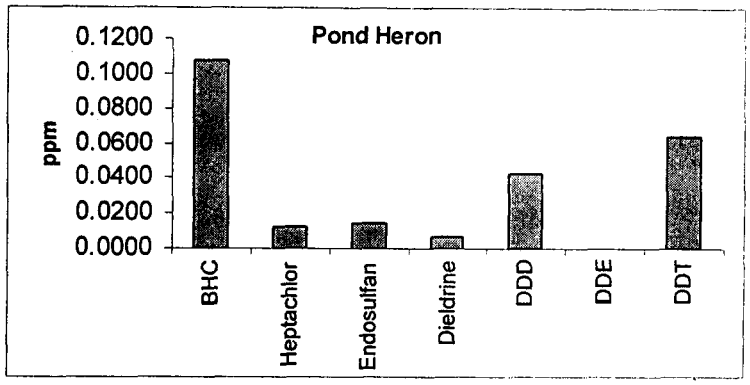


Figure 5.4. Organochlorine residues in the eggs of Pond Herons

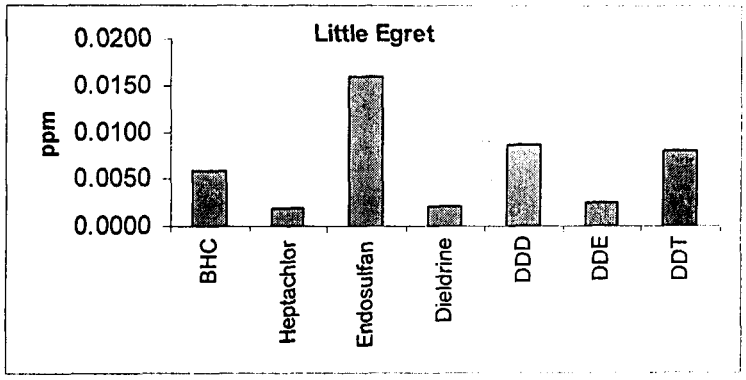


Figure 5.5 Organochlorine residues in the eggs of Little Egret

5.5.3 Organochlorine residues and egg shell thickness

Among the species under study there was no significant correlation between pesticide concentration and eggshell thickness.

5.5.3.1 Pond Heron

No significant correlation could be found between the concentration of pesticides and shell thickness in the case of the eggs of Pond Heron examined in the present study.

5.5.3.2 Little Egret

Similar to the eggs of Little Egrets, in the case of Pond Heron eggs also no significant correlation between the concentration of pesticides and shell thickness could be found.

5.6 DISCUSSION

5.6.1 Pesticides in organs

The tissue samples from breast muscles of pond Heron and Cattle Egrets from south India had average 0.5ppm DDT together with its metabolites (Ramesh et al. 1992). The concentration of DDT on an average in the breast muscles of Cattle Egret in the present study (0.34ppm) was lower than the above value. The concentration of that in the breast muscles of Pond Herons (0.16 ppm) was yet lower. In the present study the concentration of dieldrin in Little Egret was highest in the liver followed by heart and muscle. In Pond Heron the concentration was highest in muscle followed by liver and heart. In the case of Cattle Egret the concentration of dieldrin is highest in heart followed by muscle and liver.

Liver tissues of three piscivorous African cormorants (*Phalacrocorax africanus*) contained dieldrin levels ranging between 10 and 20.1 μg / kg (Van Wyk et al.2001). The same workers have reported 690 μg /kg dieldrin in a dead African fish eagle (*Haliaeetus vocifer*. Organochlorine and heavy metal residues examined in 103 shorebirds belonging to seven species in Texas revealed that the geometric means on a wet weight basis ranged from 0.25 to 4.76 ppm for DDE and residues of other compounds averaged less than 1 ppm in all instances (White et al. 1980). Chicks of Great Blue Herons (*Ardea herodias*) from four heronries of upper Mississippi River, Wisconsin showed highest mean wet-weight concentrations, 6.43 ppm PCBs, 1.31 ppm DDE, and 1.90 ppm Σ DDT (the average total burden of DDT) in one locality (Ohlendorf et al. 1979b).

5.6.2 Pesticides in eggs

Residues of pesticides such as DDE, DDT, Endosulfan, BHC and dieldrin in the eggs of bird species indicate exposure of the mother bird to these contaminants. Studies conducted on organic contamination of Little Egret (*Egretta garzetta*) eggs laid in the Camargue area, in the Mediterranean region showed that DDE were usually below 1μg/g wet weight (Berny et al.2002). The mean concentration of p,p'-DDE in Great Blue Heron eggs collected from Indiana Dunes National Lakeshore, Indiana was 1.6 μg (Custer et al. 1998). The study conducted by Perry et al. (1990) found comparatively higher concentrations (mean= 1.6 ppm) of DDE in the eggs of Little Egrets from Israel.

The concentration of DDT in the eggs of Little Egret in the present study (0.008 ppm) is comparatively lower than that of Large Egret (0.16 ppm) reported earlier by Muralidharan et al. (1992). Similarly the levels recorded in the present study was much less than the levels recorded in Great Egret (23.24 ppm), Olivaceous Cormorant (6.22 ppm), Roseate Spoonbill (3.85 ppm), Snowy Egret (3.26 ppm) and Black-crowned Night Heron (1.76 ppm) of Texas, where nevertheless no adverse effect was reported (King et al. 1978). The eggs of Pond Herons analysed for the presence of pesticides in the present study had considerably low amount of DDE and Heptachlor (0.002 ppm) in equal amounts. In the two species of birds under study there was no significant correlation between the pesticides and shell thickness.

Custer (2000) states that cattle Egret eggs generally had low concentration of DDE, except some rare instances of high levels from his study of 16 Atlantic colonies. Low concentrations of DDE were recorded in eggs of two Purple Herons collected in southwest Spain (2.0–2.1 ppm; Custer 2000). Eggs of Green-backed herons collected from Tennessee Valley, USA also had high concentration of DDE (mean = 3.9 ppm; Fleming et al. 1984). High concentrations of DDE (geometric mean = 8.6 ppm) were found in Night Heron eggs collected from Salton Sea, California, USA in 1985 (Ohlendorf and Marois 1990; Custer 2000). Little Egret eggs collected from Spain, in 1983-1984 were low in concentration than those from Israel (mean = 1.6 ppm; Perry et al. 1990). Relatively high concentrations of DDE (mean = 4.2 and 4.8 ppm) were detected in

Snowy Egret Colonies in Idaho (Custer 2000). Members of the order Ciconiiformes were classified by Peakall (1975) as highly sensitive to DDE-induced eggshell thinning. This classification was based on 1970 data demonstrating up to 16% eggshell thinning (25% decrease in thickness index) in several heron species after the use of DDT (Faber and Hicky 1973).

The mean pp-DDE concentration detected in the eggs of Little Egrets and Pond Herons in the present study was 0.003 ppm and 0.0001 ppm respectively. This value was considerably lower than that reported in the eggs of Black-crowned Night Herons in 1972-1976 along eastern Lake Ontario, Canada where the mean DDE concentrations were high in the range from 4.5-12.4 ppm. DDE concentrations in Black-crowned Night herons, Ontario, Canada also showed 14-17% shell thinning, low hatching success (36-54%), and low fledging success (less than 1 per pair, Custer 2000). But in Night herons studied in the St. Lawrence Estuary, Canada had relatively low mean concentrations of DDE (2.2 ppm). The level of DDE recorded in the present study was again lower than the levels detected in the eggs of European Kestrel where the levels were in the range of 0.11 to 17.9ppm (Mateo, et al. 2000, Scjwarzbach et al. 2001). The detailed survey conducted in Black-Crowned Night Heron eggs in the Eastern United States in 1972 and 1973 revealed higher organochlorine concentrations in the northern Atlantic coast Colonies than in southern colonies and there were significant decreases in egg shell thickness compared to pre-1947 eggs (Ohlendorf et al 1979a). In the eggs of Great Blue Herons from Nucces Bay, Texas, organochlorine residues was analysed in two consecutive years of 1978 and 1979. This analysis showed that the residues were low both in 1978 and 1979 except for DDE. The high levels of DDE that was 49 ppm in 12% of eggs in 1978 could not be established when re-sampled and examined in 1979. The eggshell thickness in these eggs averaged 0.37 mm and 0.40 mm in 1978 and 1979. The relationship, generally negative, between DDE concentrations and shell thickness was well documented by Custer (2000).

Widespread application of agrochemicals such as insecticides, pesticides, herbicides, and fungicides are very common in Kerala. The insecticides commonly used contain organic sulphurous acid esters, Carbamates and Organophosphorous compounds. The common

fungicides contain copper and sulphur based products, Carbamates, organophosphorous compounds, chlorinated nitrobenzene compounds, heterocyclic nitrogen compounds, systemic fungicides and herbicides. The herbicides used are both selective and non-selective types. The commonly available agrochemicals sold through the markets in the study areas are shown in Appendix-5.3. A list of agrochemicals and their formulations distributed throughout the agricultural office depots of Kerala is shown in Appendix-5.4. In addition, some of the banned products such as DDT and BHC are said to be available in the market via unauthorized routes. The analysis of tissues of the three birds in the present study show that all of them are exposed to organochlorine pesticides such as DDT, BHC, Chlordane, Aldrin, Dieldrin, Endrin, Endosulfan, Heptachlor and Methoxychlor. Therefore their eggs are also not likely to be free from such contaminants.

The present study shows that there is not much variation in concentration of organochlorine residues in the three species of herons. But the concentration recorded for DDT was comparatively higher both in Pond Heron and Little Egret tissues than in cattle egret. The accumulation of DDT in the tissues shows that Cattle Egret has less contamination than Pond Herons and Little Egrets. Cattle Egret being more terrestrial, its food is mainly insects especially grasshoppers, which they gather from a variety of habitats such as Paddy fields, grass fields, jheels, riverine habitats, waste dumps, or from hillocks and plantations. The grass fields, jheels, hillocks and riverine habitats being left fallow and uncultivated, are less exposed to pollutants than paddy fields and plantations which are put under cultivation and exposed to agrochemicals. In addition, Paddy fields are made available for egrets only for a short period, as paddy is cultivated only once or twice in a year, due to water shortage. Most of the grass fields and jheels are also wet throughout the year. Such habitats were used by Cattle Egrets, which forage in association with cattle preying up on grasshoppers and other insects. This ultimately results in relatively low exposure of these birds to chemicals such as DDT. Contamination of DDT is comparatively more among Pond Herons and Little Egrets than in Cattle Egret, due to their different habitat preferences as their food contains both insects and fishes.

In the present study, very low concentration of Heptachlor (0.002 ppm) was detected in the eggs of Little Egret whereas DDE was very low in Pond Heron (0.0001ppm). This level was comparatively lower than that reported (Muralidharan et al. 1992) in Large Cormorant (1.54 ppm), Indian Shag (2.94 ppm), Darter (1.52 ppm), Grey Heron (5.95 ppm), Cattle Egret (0.86 ppm), Large Egret (2.52 ppm), Painted Stork (5.78 ppm) and Spoonbill (1.3 ppm). However, the presence of these pesticides although in trace amounts in the eggs of these two species of birds point out their bioaccumulation and the contamination of the habitats consequent to the rampant use of chemicals in agriculture or similar other activities.

5.7 SUMMARY AND CONCLUSION

There is not much variation in the concentration of organochlorine residues in the tissues of three species of herons. But the concentration recorded for DDT was comparatively higher both in Pond Heron and Little Egret tissues than in cattle egret. Organochlorine pesticide residues recorded in the eggs of Pond Heron was slightly higher than that of Little Egret but following a uniform pattern, except for BHC and Endosulfan in Pond Heron and Little Egrets respectively. The concentration of DDE, which has a major role in shell thinning, was not significantly high in any of these species. In the two species there was no significant correlation between pesticide concentration and eggshell thickness.

HEAVY METALS

Seedikkoya .K “Comparative Ecology of Certain Paddy Field Birds with Emphasis on the Habitat Quality ” Thesis. Department of Zoology , Farook College Calicut ,University of Calicut, 2003

Chapter VI
HEAVY METALS

6.1 INTRODUCTION

Accumulation of heavy metals in the body due to metal pollutants in food, water or air has been considered dangerous for reproduction and survival of birds (Leonizo et al. 1986). In ecotoxicological terms, "heavy metal" is generally applied to refer to metals, such as mercury, zinc, copper, nickel, chromium, cadmium, lead, vanadium, selenium and arsenic (Abbasi et al. 1998). They are either not essential for growth and development of organisms or their function in the biological systems have not been so far established. Experimental studies have demonstrated that heavy metals induce changes in metabolism and behaviour. Heavy metals are derived primarily from the underlying soil and bedrock, volcanism, natural erosion and biogeochemical cycles. Due to growing industrial activity and motor traffic as well as from agricultural run off, industrial effluent, storm-water run off, the environment is being contaminated by heavy metals (Kaur 1987).

There is ample evidence that on a global scale human activities have contaminated the environment with heavy metals and other pollutants from the polar region to the tropics and from mountains to abyssal zones of ocean (Depledge et al. 1994). These pollutants, on entry to aquatic system above certain levels persist in the environment and undergo environmental transformation into toxic substances; it brings about toxic effects in plants; causes biomagnification and bioaccumulation; and also chronic and sublethal effects to living organisms. Heavy metals accumulation in different tissues depend on the intensity and timing of exposure, the form or species of metal, and a variety of other factors such as feeding habits, growth or age, reproduction, molting and migration of the species concerned (Burger and Gochfeld 1985, Honda et al. 1986).

Accumulation and magnification of heavy metals in the tissues of animals have recently received considerable attention due to increasing detection of their lethal and sub-lethal effects. There have been many cases wherein serious environmental and human health implication heavy metal contamination had been reported (e.g., Minamata episode). Wild

bird populations are susceptible to dangers derived from the environmental presence of toxic elements and substances especially those that are non-degradable and that in many occasions tend to concentrate through the food chain. Monitoring such elements and substances in select bird species from a delimited area could be useful not only to evaluate the health condition of the species involved but also to assess the degree of contamination in the ecosystem where they live (Guitart et al. 1994). Heavy metal accumulation in vital organs is a well-documented phenomenon whose affinity to a particular organ depends on the number of the intracellular binding sites (Osborn et al. 1979), metal binding proteins (metallothioneins, Azeez et al. 1985) and metal binding amino acids (Cosson 1989). Comparatively little is known about heavy metal contamination in wild birds such as ardeids in the country. Because of their status in the trophic web in the ecosystem they have high potential to function as indicators to environmental contaminations and as an early warning system.

6.2 BACKGROUND

6.2.1 Heavy Metals in Tissues

Generally birds get exposed to environmental contaminants like heavy metals through air, food and water. The contaminants either accumulates in tissues, get metabolized or / and excreted from the organism. If organisms are unable to eliminate a metal contaminant it may reach dangerous concentrations (Hulse et al. 1980) in their body in due course or as it passes on to the higher trophic levels in the food web. Wading birds act as good bioindicators of environmental contamination (Custer et al. 1991; Kushlan 1993 and Bryan et al. 2001). They are usually predators consuming animals, such as fishes, insects, molluscs and annelids, near the top of the aquatic food web and susceptible to bioaccumulation of contamination.

Lead is a non-essential, highly toxic heavy metal that affects all body systems. The lead accumulation level in the liver is an indicator of lead poisoning (Kingsford et al. 1989). Waterfowl are directly exposed to high lead concentrations through ingestion of spent lead gunshot (Pain 1996; Blus et al. 1993). The laying mallards dosed with one shot

(196mg) accumulated significantly higher liver, Kidney and bone lead concentrations than did males (Pain 1996). High lead accumulation results from consumption of sediments and food that are contaminated. In Californian Condor, blood samples showed accumulation of lead in considerable level. The concentration of copper was much high in the liver and kidney when compared with that of the Turkey Vultures and Common Ravens. The accumulation of zinc and chromium observed in the livers and kidneys of both the Turkey Vultures and Common Ravens were similar (Wiemeyer et al. 1988).

Studies on Grey Herons along the Atlantic coast, USA in Netherlands (Custer 2000), Great Blue Herons in Washington and Idaho, USA (Blus et al. 1985), Black-crowned Night Herons along the Atlantic coast, USA (Custer and Mulhern 1983), Little Egret from Camargue, France (Cosson et al. 1988), Tricoloured Herons and Cattle Egrets from Texas, USA (Hulse et al. 1980), Eastern Great White Egret from Central Korea (Honda et al. 1985) and Great Blue Herons, Snowy Egrets, from South Florida (Custer 2000), showed that lead accumulated in livers of these herons although their levels were within the range of background concentrations (<6.7ppm dw).

Cadmium is a known teratogen and carcinogen, and also a mutagen. Its concentrations may increase comparatively higher in the tissues of some estuarine and marine birds. Lesions have been observed in the kidneys of some pelagic seabirds having high levels of cadmium accumulations in their tissues (Custer 2000). Cadmium contamination is severe in the vicinity of smelters and industrialized areas (Eisler 1985a). Cadmium accumulation is generally absent in herons. Cattle Egrets from India (Husain and Kaphalia 1990), Cattle Egrets from Baja California, Mexico (Mora and Anderson 1995), Black-crowned Night Herons along the Atlantic Coast, USA (Custer and Mulhern 1983) were <3 ppm dry weight in the liver and <8 ppm dry weight in the kidney, all within background Cd concentrations. The levels of five metals namely Al, Cu, Zn, Cd and Pb in feathers of six species of birds analysed in Southern Finland (Solonen et al. 1999) revealed that Cu and Pb levels were highest in samples near urban areas.

In a study on three passerine bird species, Great Tit (*Parus major*), Rock Bunting (*Emberiza cia*) and Blackbird (*Turdus merula*) subjected to air pollution from a coal-fired

power plant analysed in Spain found significantly higher levels of Cr in feathers of Great Tits than those from unpolluted area (Llacuna et al.1995). Rock Buntings from the polluted zone had higher levels of Cr in feathers and Al in bone and lower levels of Mn in muscle whereas Blackbird showed no significant difference between sites.

The concentrations of Pb, Hg, and Cd in the liver, kidney and the whole body of the Japanese Quail was comparatively higher than that in the muscle, brain, and egg. The eggs were found to be the least sensitive biological indicator of metal exposure. The results of external applications of various toxicants to eggs were reviewed by Wiemeyer (1996). Lead, cadmium and mercury analysed in the kidney and liver of 61 white tailed eagles showed low cadmium value in all samples, but highest values and widest ranges were detected for lead in liver and mercury in kidney (Kenntner et al. 2001). Concentration of lead, mercury, and cadmium in the liver, kidney, and muscle of four Steller's sea eagles (*Haliaeetus pelagicus*) and one white-tailed sea *eagle (Haliaeetus albicilla*) in Japan showed high lead levels (> 70μg/g dry weight) whereas mercury and cadmium in the tissues of these raptors were low (Kim et al. 1999).

Mercury contamination was determined from 393 blood and 164 growing scapular feathers from 252 great egret nestlings (*Ardea albus*) from Southern Florida USA (Sepulveda et al. 1999). Reports of mercury contamination in nestlings of wading birds in Florida and Costa Rica were made by Burger et al. (1993). In a study of fish-eating birds nesting along the lower Carson River, Nevada adult double-crested Cormorants (*Phalacrocorax auritus*), Snowy Egrets (*Egretta thula*) and black-crowned night herons (*Nycticorax nycticorax*) contained high concentrations of total mercury in their livers and kidneys (Henny et al. 2002). Eggs and chick feathers of Ospreys (*Pandion haliaetus*) collected for Hg analysis from North American Great Lakes showed less Hg levels in the chick feathers than eggs. However Hg levels in eggs, chick feathers and adult feathers did not approach levels associated with toxic reproductive effects (Hughes et al. 1997).

Studies on tissue metal contamination in Pond Herons are scanty, except for reports such as Jayakumar (1999) who has analysed 10 Pond Herons collected from Nilgiri district of Tamil Nadu. Mercury, Cadmium, Selenium and lead accumulation in the tissues of Little

Egrets have been documented from the Camargue, France (Cosson et al. 1988) but all the detected levels were within background concentration limit. Documentation on heavy metal contamination in Cattle Egret is also very limited. Some available studies include that on lead accumulation in Cattle Egrets from Lucknow (Husain and Kaphalia 1990), on cadmium from Texas, USA (Hulse et al. 1980, Cheney et al. 1981) and on mercury from Puerto Rico (Burger et al. 1992 a).

Documentation of heavy metal contamination in India remains inadequate, notwithstanding some all India coordinated projects (Krishnamurti and Viswanathan 1991). Though the problem of contamination exists in varying dimensions it has not been sufficiently explored. Contamination by heavy metals and its implications on environment demands higher level of attention from researchers. The varying magnitude of metal accumulation in wildlife especially birds remains a great deal unexplored. Some information on aquatic birds in Keoladeo National Park, Bharathpur (Muralidharan 1995), in urban area of Jaipur (Bakre and Sharma 1995), in Nilgiris (Vishnu, 2001, Jayakumar 1999), and Coimbatore (Manickam 2002) is available.

6.2.2 Heavy metals in eggs

Metal contaminants occurring in very small concentrations may not bring any measurable impact on adult birds. However it may bring about serious effects in embryos that are more sensitive than the adults to contaminants. Species-specific variations in sensitivity to heavy metal are common. Exposure to lead at levels low to have any measurable impact, (such as weight gain or loss and feeding) results in a reduction of 50% in egg hatching success in Ring Doves (*Streptopelia risoria*: Scheuhammer, 1987). Toxic metals such as Cr, Mn, and Pb are channeled to eggs in rock dove, *Columba livia* (Gochfeld 1997; Hui 2002). In heron eggs mercury concentrations and its association with reproductive failure (Ohlendorf et al. 1978b; Custer 2000) have been reported. Mercury concentrations were measured in blood, down and feather samples collected from 20 post-fledging Wood Storks (*Mycteria americana*) captured in the coastal zone of Georgia (Bryan et al. 2001). However, critical Hg level in eggs has not been measured for any heron species and further studies are highly required in this line.

Generally birds such as raptors that are higher on the food chain are exposed to higher levels of lead in their food (Burger 1995 and Garcia-Fernandez et al. 1997). Herons and egrets are not generally at risk from lead because they do not generally ingest spent lead shots from environment. Forms of the metal other than shots do not generally enter the body in sufficient concentrations to cause clinical signs of Pb poisoning in birds (Custer 2000). Burger and Gochfeld (1993) have reported air-borne Pb accumulated in the body getting transferred from hen to the eggs. Hui (2002) also states that Chromium, manganese and lead can be passed from mother bird to her eggs. Chromium inhibiting bone growth in embryos, and Cr-IV reducing egg hatchability is reported by Kanti and Smith (1997) and Hui (2002).

Selenium is a naturally occurring trace element that is an essential animal nutrition, but the range between dietary requirements and toxic levels is relatively narrow. High selenium concentrations have not been documented in herons. Normal Se concentrations in the eggs of fresh water bird species were 0.4-0.8 ppm (1-3 ppm dw; Custer 2000). Selenium concentrations within acceptable background level were reported in eggs and livers of Great Blue Herons from Lake Erie, USA by the same author, and in the eggs of five colonies of Black-crowned Night Herons and one colony of Great egrets from California, USA by Ohlendorf and Marois (1990).

In brief it is felt that documentation on the heavy metal contamination in the tissues and eggs of Cattle Egrets, Little Egrets and Pond Herons remains insufficient. In this study an attempt is made to document this aspect.

6.3 OBJECTIVES

The objectives of this study are;

1) To make quantitative assessment of select heavy metal levels in the three species of birds under study,

2) To document the magnitude of heavy metal contaminants in the eggs of the two species under study.

6.4 METHODOLOGY

6.4.1 Tissue Sample Collection

No attempt was made to capture and sacrifice live birds for the study. Tissues from dead specimens of Cattle Egret, Little Egret and Pond Heron were collected from the study area over a period of 3 years. The samples of heart, muscles and liver of the birds were dissected out from the carcass, stored under refrigeration in clean polyethylene vials, labeled and transported to Ecotoxicology laboratory at SACON where analysis of five heavy metals namely copper, zinc, lead, cadmium and chromium were carried out using Atomic Absorption Spectroscopy (Model: Perkin Elmer 3300, double beam).

6.4.2 Egg Sample collection

The egg samples of Little Egrets for heavy metal analysis were collected from breeding colonies at Pattambi, Palakkad district while that of Pond Herons were collected from Mampad, Malappuram district. Since Cattle egret was not breeding in Kerala, its eggs could not be collected and included in the present study. One egg each from 13 clutches of Little Egret, and one egg each from 9 clutches of pond herons were collected. The eggs were stored in a refrigerator until they were weighed, volume is estimated and length and breadth measured. Each egg was opened at the equator and its contents poured into a chemically cleaned jar. The samples were stored in a freezer until they were analysed for the presence of metals. Shells of all eggs were rinsed in tap water and dried. Eggshell thickness (including the membranes) was measured at four sites on the equator with a micrometer graduated in units of 0.01mm; an average of three measurements represented shell thickness. The analysis was performed in Ecotoxicology laboratory at SACON using Perkin Elmer AAS for five heavy metals namely copper, zinc, lead, cadmium and chromium.

6.4.3 Sample Digestion

Various techniques for digesting biological samples including Aquaregia heating, nitric acid digestion, wet-ashing and dry-ashing are available to estimate concentration of

heavy metals. Microwave assisted digestion has been one such methods commonly used to digest samples for heavy metal analysis. Microwave Digestion System (MDS), Milestone Model MLS 1200 and Exhaust module (EM45) was used for the current study. The digestion proceeds as follows.

6.4.3.1 Stage I

Preserved tissue samples were weighed (approximately 1 gm) using a top loading balance. Mettler AE 240, and transferred into digestion vessels. 10 ml of concentrated nitric acid was added, loaded on to the Microwave Digestion System and digested at 250W power for 10 minutes.

6.4.3.2 Stage II

After cooling, 1 ml of Perchloric acid was added to the digested samples, loaded again to MDS and digested for 5 minutes at the same magnetron power.

6.4.3.3 Stage III

Subsequent to cooling the vessels, 7 ml of hydrogen peroxide was added to the same material and loaded to the MDS and run for 10 minutes at the same power settings.

After ensuring complete digestion, the solutions were filtered using Whatmann No.1 filter paper, transferred to volumetric flasks and made up to 25 ml with metal free doubled distilled water. The contents were transferred to clean good quality polyethylene bottles and stored in refrigerator till Atomic Absorption Spectrometer analysis.

6.5 RESULTS

6.5.1 Tissue Samples

Totally 27 tissue samples comprising 3 each of heart, liver and muscle from Pond heron, Cattle Egret and Little Egret were analysed for heavy metals copper, lead, zinc, cadmium and chromium. The variation of metal contamination among the species and accumulation of heavy metals among various organs are shown in Figures 6.1 and

Appendix-6.1. One-way ANOVA was applied to assess variation of metals among species (within groups) and among organs (between groups, Tables-6.1-6.5).

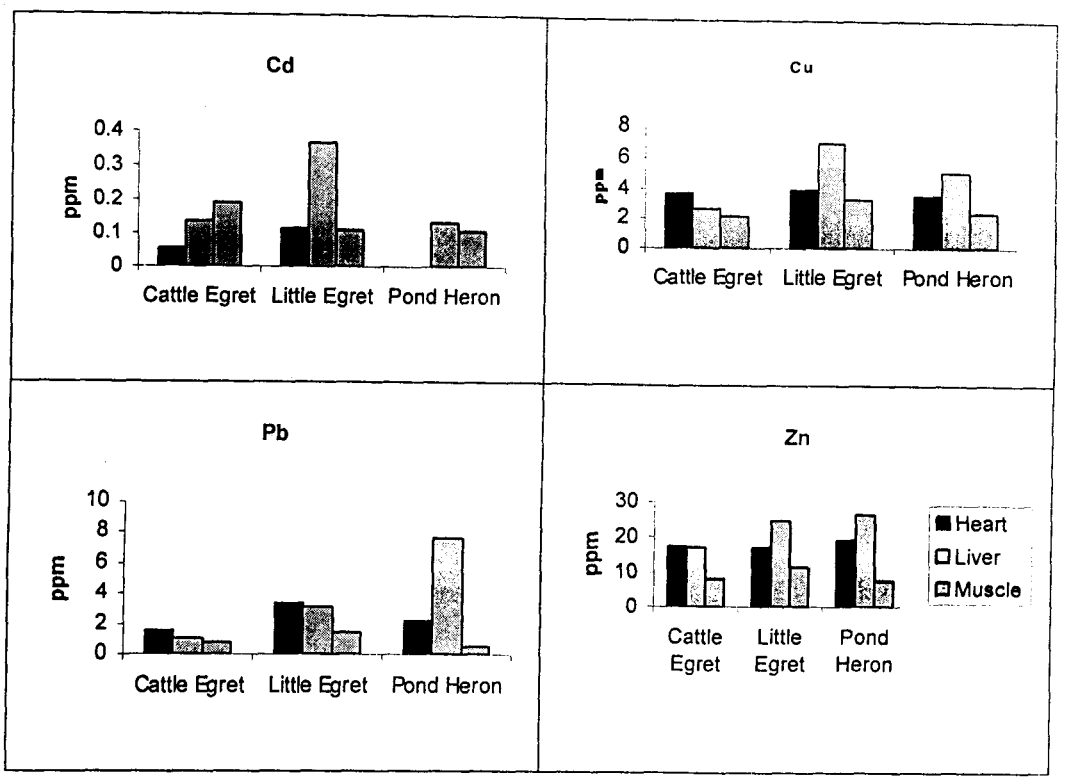


Figure 6.1. Concentration of heavy metals in tissues of the birds

6.5.1.1 Pond Heron

Among the five metals the heart had high concentration of Zinc (mean = 19.27 ± 4.00 ppm) and low concentrations of Lead (mean = 2.25 ± 1.72 ppm). Cadmium and Chromium were below detectable levels in the heart tissue. Among the three tissues the liver accumulated the highest concentration of Zinc (mean = 26.38 + 11.91 ppm). Of the detectable metals in the liver Cd was lowest in concentration (mean = 0.13 ± 0.17 ppm) and Chromium was below detectable level. Muscle also accumulated high concentration of Zinc (mean= 7.59 ± 2.90 ppm) and low concentration of Cadmium (mean= 0.11 ± 0.18 ppm). Chromium was BDL level. Only zinc showed statistically significant variation between tissues in Pond Heron (Table-6.3) while for all other metals the variation was insignificant.

6.5.1.2 Little Egret

Heart accumulated high concentration of Zinc (mean = 17.06 ± 1.95 ppm), while the concentration of Cadmium in heart tissue was low (mean= 0.11 ± 0.10 ppm). Chromium was below detectable level. Among the three tissues liver accumulated the highest concentration of Zinc (mean= 24.62 ± 8.05 ppm). Cadmium had the lowest concentration (mean = 0.37 ± 0.34 ppm). Muscle had high concentration of Zinc (mean = 11.61 ± 2.52 ppm) and low concentration of Cadmium (mean= 0.11 ± 0.13 ppm). As in the case of Pond Heron, in the case of Little Egret also Cr was below detectable level. Among the four metals that were present above detectable level only zinc showed statistically significant variation among tissues (P=0.05) (Table-6.4). Zinc accumulation was highest in liver followed by heart and muscles.

6.5.1.3 Cattle Egret

Heart had the highest concentration of Zinc (mean = 17.33 + 2.65 ppm). Among those metals that were detected Cadmium was seen in the lowest concentration (mean= 0.05 ± 0.09 ppm). Liver had high concentration of Zinc (mean= 17.14 ± 7.25 ppm) and low concentration of Cadmium (mean= 0.14 ± 0.15 ppm). Muscle had high accumulation of Zinc (mean = 8.28 ± 5.16 ppm) and low concentration of Cadmium (mean = 0.19 ± 0.33 ppm). In none of the tissues Cr could not be detected. No statistically significant variations between tissues were seen in Cattle Egrets (P >0.05) (Table-6.5).

6.5.2 Egg Samples

Totally 22 eggs comprising of 9 eggs from Pond Heron and 13 eggs from Little Egrets were analysed (Figure 6.2 and Appendix-6.2 and 6.3).

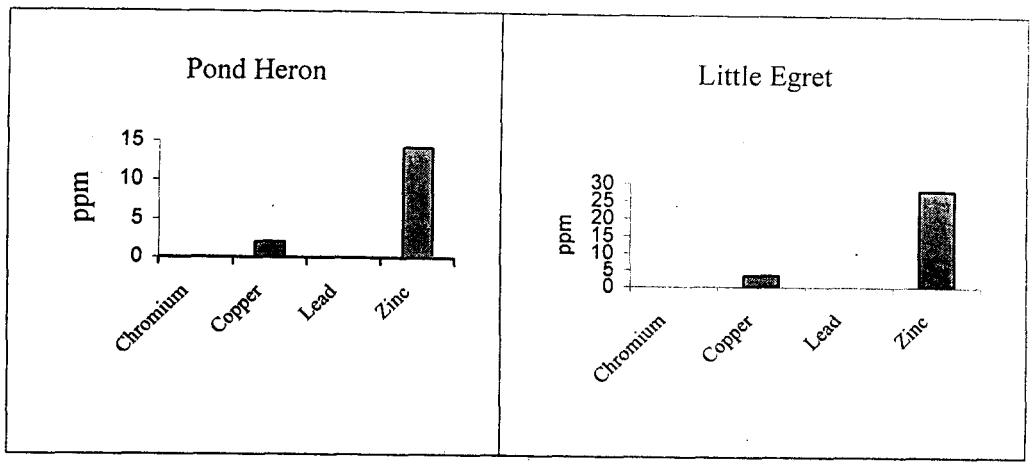


Figure 6.2. Heavy metal accumulation in the eggs of the birds

The concentration of Copper and Zinc was comparatively low in the eggs of Pond heron (mean = 2.05 ± 1.51 ppm & 14.24 ± 11.08 ppm respectively) than that in Little Egrets (mean = 3.41 ± 2.81ppm & 28.20 ± 28.69 ppm respectively).

Table 6.1. ANOVA of metals among the tissues of all three species

		Sum of Squares	df	Mean Square	F	Sig.
Cd	Between Groups	.109	2	5.453E-02	1.566	.229
	Within Groups	.836	24	3.482E-02		
	Total	.945	26			
Cu	Between Groups	22.459	2	11.230	3.213	.058
	Within Groups	83.890	24	3.495		
	Total	106.349	26			
Pb	Between Groups	42.334	2	21.167	1.152	.333
	Within Groups	440.849	24	18.369		
	Total	483.182	26			
Zn	Between Groups	849.545	2	424.772	12.193	.000
	Within Groups	836.071	24	34.836		
	Total	1685.615	26			

Table 6.2. ANOVA of metals among three species in all the tissues						
		Sum of Squares	df	Mean Square	F	Sig.
Cd	Between Groups	6.256E-02	2	3.128E-02	.851	.439
	Within Groups	.882	24	3.676E-02		
	Total	.945	26			
Cu	Between Groups	16.050	2	8.025	2.133	.140
	Within Groups	90.299	24	3.762		
	Total	106.349	26			
Pb	Between Groups	26.079	2	13.039	.685	.514
	Within Groups	457.104	24	19.046		
	Total	483.182	26			
Zn	Between Groups	73.670	2	36.835	.548	.585
	Within Groups	1611.946	24	67.164		
	Total	1685.615	26			

Table 6.3. ANOVA of metals among tissues of pond heron						
		Sum of Squares	df	Mean Square	F	Sig.
Cd	Between groups	2.989E-02	2	1.495E-02	.718	.525
	Within Groups	.125	6	2.081E-02		
	Total	.155	8			
Cu	Between groups	10.405	2	5.203	2.189	.193
	Within Groups	14.257	6	2.376		
	Total	24.662	8			
Pb	Between groups	84.144	2	42.072	.796	.494
	Within Groups	317.229	6	52.872		
	Total	401.373	8			
Zn	Between groups	540.409	2	270.205	4.871	.055
	Within Groups	332.816	6	55.469		
	Total	873.226	8			

Table 6.4. ANOVA of metals among tissues of Little Egret						
		Sum of Squares	df	Mean Square	F	Sig.
Cd	Between Groups	.130	2	6.491E-02	1.341	.330
	Within Groups	.290	6	4.841E-02		
	Total	.420	8			
Cu	Between Groups	23.437	2	11.718	3.212	.113
	Within Groups	21.888	6	3.648		
	Total	45.325	8			
Pb	Between Groups	6.862	2	3.431	.483	.639
	Within Groups	42.638	6	7.106		
	Total	49.500	8			
Zn	Between Groups	255.976	2	127.988	5.126	.050
	Within Groups	149.801	6	24.967		
	Total	405.777	8			

Table 6.5. ANOVA of metals among tissues of Cattle Egret						
		Sum of Squares	df	Mean Square	F	Sig.
Cd	Between groups	2.808E-02	2	1.404E-02	.302	.750
	Within Groups	.279	6	4.651E-02		
	Total	.307	8			
Cu	Between groups	3.720	2	1.860	.673	.545
	Within Groups	16.592	6	2.765		
	Total	20.312	8			
Pb	Between groups	.881	2	.441	.494	.633
	Within Groups	5.350	6	.892		
	Total	6.231	8			
Zn	Between groups	160.467	2	80.233	2.791	.139
	Within Groups	172.476	6	28.746		
	Total	332.943	8			

6.6 DISCUSSION

6.6.1 Metals in Organs

Liver has a major role in detoxification of poisonous substances. High concentrations of all metals in liver point toward to this role. It also indicates to the path taken by contaminants in the body of organisms, before reaching any target organs, getting sequestered or excreted. Muscles accumulated the least metal concentration. Statistically significant variation of copper and zinc concentrations among liver and muscles ($p<0.05$) was observed (Table-6.1). Significant levels of copper lead and zinc ($p < 0.05$) among muscles and heart were also reported by Beyer et al. (1988). Heart is the major pumping centre. Blood from the digestive system loaded with materials assimilated in the digestive system enters the heart from which it is pumped to various organs of the body. Being the main organ involved in transportation of materials and contaminants via blood heart has a chance to accumulate the contaminants that are present in the blood. Moreover the heart tissue may accumulate more metals by way of its special blood supply. The heavy metal residues in heart do not denote heart is a target organ of accumulation.

Among the three species, Little Egret and Pond Heron accumulated nearly similar concentrations of all metals and Cattle Egret recorded the minimum level. Nevertheless, the variation of heavy metals was not statistically significant ($p>0.05$) among bird species (Table-6.2). The levels recorded of any of the metals in these birds were comparably

lower than the levels recorded elsewhere. Significance of Organochlorine and heavy metal residues in wintering shorebirds like Avocet, Dunlin, Greater Yellowlegs, Least Sandpiper, Lesser Yellow Legs, Sanderling and Western Sandpiper at Corpus Christi, was studied by White et al. (1980). Previous works reports that the lead concentrations ranging between 6 and 20 ppm should be considered as an indication of recent acute lead exposure and of lead intoxication (Longcore et al. 1974; Kingsford et al. 1989; Leonzio and Massi 1989). In the present study, lead concentration was comparatively high in the liver (mean = 7.70 $\pm$ 12.47ppm) of Pond Heron than in the other two species. Apparently healthy Cattle Egrets (*Bubulcus ibis*) collected in industrialized area had liver lead concentrations of 0.07 to 1.3ppm and kidney concentration of 0.08 to 3.5 ppm wet weight (Franson 1996). The mean lead concentration in the liver of Cattle Egret was 1.09 $\pm$ 0.32 ppm in the present study. This was slightly higher than that reported by Franson (1996). Earlier works by Muralidharan (1995) reported levels ranging from 0.13 to 58 ppm for copper and 0.8 to 93.38 ppm for zinc in 16 species of birds in Keoladeo National Park and the levels were considered not toxic. Jayakumar (1999) recorded copper in the range of BDL to 13.71 ppm and zinc BDL to 26.34 ppm in Little Egret, Cattle Egret and Pond Heron. Thus in the present study it may be stated that in the three species of birds under study the level of copper contamination was comparatively less than that reported in the previous studies. There are also reports recording copper toxicity, but not mortality, with high concentration in the range of above 1000 ppm (Frank and Borg 1979). Cadmium levels found in the present study is low compared to the levels recorded by Mochizuki et al. (2002) in the kidney and liver of 85 wild birds of Japan. The levels recorded in the study (Mochizuki et al. 2002) ranged from non-detectable level (ND) to 17.4μ g/g dry weight and ND-21.2 μg/g dry weight respectively. Reports varies widely regarding the tissue levels that have notable toxic effects or cause serious morbidity or mortality.

Lead sulphide or galena (PbS) is the main source of lead. Its use is wide; in batteries, cables, paints, pesticides containing lead arsenate, PVC plastics, glazing ceramics and automobile fuels. The main source of lead contamination in the aquatic environment is run off from contaminated land areas and sewage effluents. Lead accumulation in the tissues of the three species of birds under study supports this view. Lead levels ranging

from 30-40μ g/100gm bloods are considered to be within normal limits (Omkar Undated). The main source of aquatic contamination of zinc is metal production units, paints and fungicides factories. Zinc present in Carbamate fungicides is marketed in formulations such as Indofil M-45 and Dithame M-45, which are used as foliar fungicides (Chapter-V, Appendix-5.3). This may be one of the reasons for high zinc accumulation in different tissues of the bird species under study. The maximum permissible limit of zinc in drinking water is 5 ppm (Trivedy 1996). The potential sources of chromium in aquatic environment are effluents from tanneries and textile mills. The maximum permissible limit of chromium in drinking water is 0.05 ppm. The main source of copper contamination in the aquatic environment is copper salts used as algicides and fungicides. Copper oxychloride containing fungicides are commonly used by farmers as for foliar spray in different formulations such as Bliotox 50 W, Fytolan 50 W and Blue Copper 50 W (Chapter-V, Appendix 5.2 and 5.3). Bordeaux mixture (a formulation of $CuSO_4$ and $CaCO_3$) is also commonly used as a fungicide. This will explain the reason for copper concentration in different tissues of the birds species under study. The copper level in the sediment of Periyar river is reported to vary from 1-107 ppm as against 0.05 ppm maximum permissible limit (Omkar Undated). In nature cadmium is always associated with zinc ores (ZnS) due its similarity with zinc. The main source of contamination of water is from zinc smelters and discharges from electroplating units. Cominco Binani Zinc Limited near Alwaye, Kerala produces cadmium and zinc. The factory effluents are discharged in the Periyar River. The cadmium concentration in Periyar river water, sediments and organisms has been reported to range from 0.002 -0.2 ppm, 0.75- 18 ppm and 0.04- 2.2 ppm respectively (Omkar Undated).

The accumulation of heavy metals in the tissues of the three bird species under study shows that Cattle Egret has less contamination with respect to Pond Herons and Little Egrets. Cattle Egret being more terrestrial its food is mainly formed of insects especially grasshoppers, which they collect from a variety of habitats such as Paddy fields, grass fields, jheels, riverine habitats, waste dumps, or even from hillocks and plantations. The grass fields, jheels, hillocks and riverine habitats being abandoned and uncultivated, are less exposed to pollutants with respect to paddy fields and plantations which are put

under cultivation and are exposed to various heavy metals. In addition, Paddy fields are made available for egrets only for a short period, as paddy is cultivated only once or twice in a year, due to scarcity water. Most of the grass fields and jheels that are wet throughout the year and are left uncultivated are free from application of agrochemicals. Cattle Egrets are frequent in such habitats foraging mostly in association with cattle preying on the grasshoppers and other insects. This ultimately results in their relatively low exposure and bioaccumulation of metals.

Among Pond Herons and Little Egrets contamination is slightly more in Pond Heron. Little Egrets are piscivorous. Due to their this habit they are confined to aquatic habitats such as estuarine, riverine, wet grass fields and jheels. Pond herons being both piscivorous and insectivorous feed on insects (mostly) and fish and may visit a variety of habitats with varying degrees of contamination. This may result in the accumulation of more contaminants in Pond Herons than in Little Egret.

It is very interesting to mention that no detectable levels of chromium were recorded in the organs of all the species. This indicates that the habitats of these herons are not exposed to any sources of the metal.

6.6.2 Metals in eggs

Between the two species, Little Egret had more concentrations of copper and zinc in their eggs. The concentrations of lead, cadmium and Chromium were BDL in the eggs of the above two species. Information regarding the accumulations of copper and zinc in the eggs of herons is scanty. Concentration of Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn estimated in the water and sediments in Kuttanad Wetland Ecosystem showed that in water, all heavy metals except Cr and Cu had higher concentrations during the pre-monsoon period (George et al. 1999). This shows the chance for accumulating these metals in the birds by way of their food. The maximum permissible limit of Cd, Cr, Cu, Fe, Mn, Pb, and Zn in water was reported to be 0.01, 0.05, 0.05, 0.3, 0.1, 0.1, and 5.0 ppm respectively (George et al. 1999, Trivedy 1996).

Heavy metal residues in bald eagle eggs collected from Winconsin, Florida showed that the wet weight residues of copper varied from 0.3-1.2 ppm, that of iron from 4.7- 18.3 ppm and of zinc from 3.7- 8.2 ppm (Krantz et al. 1970). The result of the present study shows that the values for all these metals stands above the values that are reported for bald eagle. The studies conducted in Brown Pelicans showed the accumulation (μg/g fresh ww) of Cd, Cu, Zn, Ni, Hg, and Pb in their eggs being 0.004, 1.15, 5.9, 0.024, 0.08 and 0.016 respectively (Blus, 1975). The cadmium concentration, along with Pb and Cr, were found BDL in the present study. So far, no specific limit, either in the permissible or deleterious range of accumulation of metals in eggs has been demarcated. As noted earlier the levels of metals that may cause notable toxic effects vary widely. Moreover in long-term period the insidious effects of metal may harm the survival of species. However, it may be stated that the level of contamination of metals recorded in the present study would not be significant enough to cause any mortality in any of these birds.

6.7 Summary and Conclusion

The order of metal accumulation in the organs was Liver > Heart > Muscle, which is substantiated by the metabolic role of liver in detoxifying and excreting the pollutants. The metal contamination among species was in the order of Little Egret > Pond Heron > Cattle Egret. The metals levels in the species were insignificant to induce any mortality. However, other possible implications such as metabolic disorders cannot be ruled out without further study. In addition to the dietary preferences, age, sex, migration characteristics, exposure period and physiological aspects are to be considered for prediction of the extent of metal toxicity. In order to evaluate any instance of metal poisoning normal levels of these metals for the species must be known and the abnormal levels, which tend to produce either harm or no apparent harmful effects must be recognized (Bagley and Lock 1969). In India, no such levels of metals are identified that is essential for establishing the levels of concern. Between the eggs of the two species of birds, the eggs of Little Egret had highest mean concentration of copper and zinc than in Pond Heron. This may be because the birds more piscivorous.

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Plate 1 a: Pond Herons, in breeding plumage, at the nest

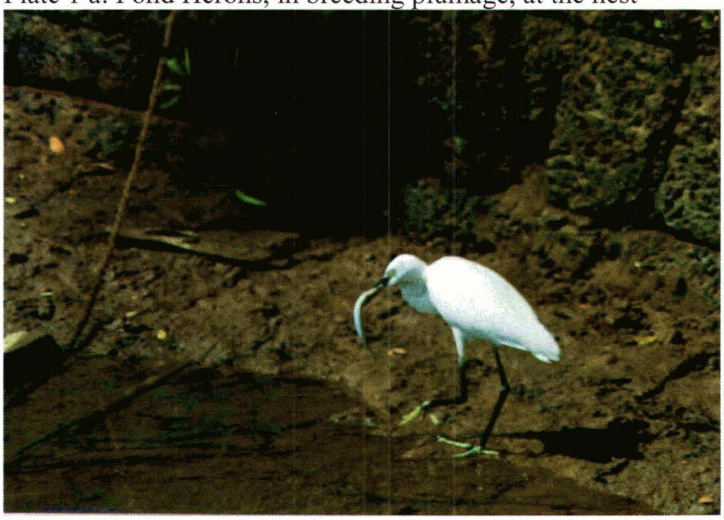

Plate 1. b. Little Egret feeding on fish

Plate 1c: Cattle Egret in breeding plumage

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Plate 2a. Azhinjilam jheel, a study area

Plate 2b: Little egrets in Feroke Jheel, a study area, during habitat shrinkage

Plate 2c. Karimpuzha river – a study site

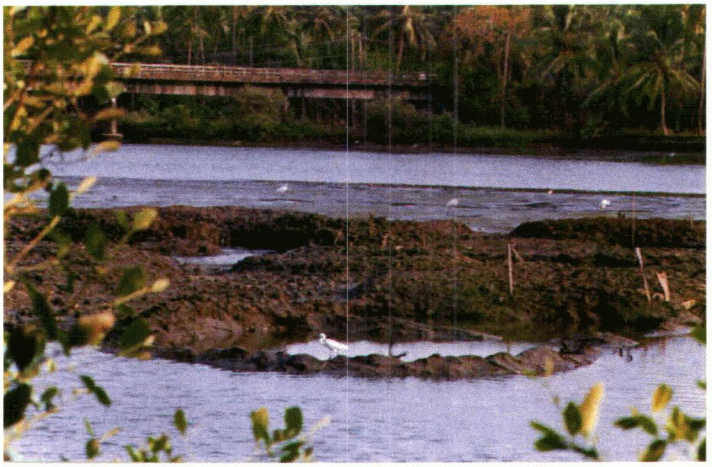

Plate 3a: Kadalundy (Kallampara) river – a study site

Plate 3.b. Cattle Egrets, in breeding plumage, Kadalundy study site

Plate 3c: Little egrets peering over and capturing prey

Plate 4 a: Egrets associated with cattle

Plate 4.b. Pond Heron, nest with hatchling

Plate 4c: Pond Heron, guarding eggs

Plate 5a: Little Egrets in breeding plumage showing courtship behaviour

Plate 5.b. Little Egret in the nest at Pattambi study site

Plate 5c: Cattle Egrets in the nest, Ranganthittu bird sanctuary

APPENDICES

Appendix-1.1 Co-ordinates of the study sites				
No	General study sites	Co-ordinates	Nesting sites	Co-ordinates
1	Azhinjilam Jheel	11° 12′ 01.7″ N, 075° 48′ 59.8″ E	Panamaram	11°44′ 22.8″ N, 076 ° 04′ 26.4″ E
2	Calicut Jheel	11° 15′ 32.8″ N, 075° 47′ 22.4″ E	Ramanattukara	11°10′ 32.8″ N, 075° 52′ 04.8″ E
3	Feroke Jheel	11° 10′ 52.9″ N, 075° 50′ 48.5″ E	Eranhipalam	11° 16′ 39.5″ N, 075° 47′ 05.7″ E
4	Waste dump	11°11′55.8″N, 075°52′ 04.5″ E	Kizhissery	11° 10′ 28.5″ N, 076° 00′ 00.3″ E
5	Kadalundy River	11° 09′ 25.5″ N, 075° 51′ 02.0″ E	Melattur	11° 03′ 02.7″ N, 076° 16′ 37.2″ E
6	Paddy field	11° 14′ 23.5″ N, 076° 11′ 46.8″ E	Vaniyambalam	11° 11′ 20.0″ N, 076°15′ 35.4″ E
7	Hillock	11° 14′01.1″ N, 076° 10′20.0″ E	Mampad	11°14′ 16.8″ N, 076° 11′ 47.2″ E
8	Plantation	11°14′06.1″N, 076°10′ 23.9″ E	Pathapiriyam	11° 11′ 33.4″ N, 076° 08′ 03.2″ E
9	Dry Grass field	11°14′ 16.8″ N, 076° 11′ 47.2″ E	Ottapalam	10° 46′ 14.7″ N, 076° 22′ 40.8″ E
10	Wet Grass field	11°15′21.4″N, 076°11′ 58.0″ E	Shoranur	10° 45′ 27.7″ N, 076°16′ 23.2″ E
11	Karimpuzha River	11° 18′ 20.2″ N, 076° 15′ 17.8″ E	Pattambi	10° 48′ 11.0″ N, 076° 11′ 00.3″ E

Appendix 2.1 Monthly percentage Composition of birds in different habitats				
Habitats	Bird Species			
	Month	Cattle Egret	Little Egret	Pond Heron
		%	%	%
Paddy field	October	57.14	16.88	25.97
	November	43.75	21.43	34.82
	December	73.63	10.99	15.38
	January	67.07	4.88	28.05
	February	60.94	4.69	34.38
	March	51.92	1.92	46.15
	April	85.00	0.00	15.00
	May	12.50	37.50	50.00
Grass field	October	58.46	6.15	35.38
	November	60.26	6.41	33.33
	December	61.11	1.85	37.04
	January	58.54	3.66	37.80
	February	63.51	1.35	35.14
	March	58.06	3.23	38.71
	April	63.16	1.75	35.09
	May	43.14	1.96	54.90
Jheel	October	37.04	7.41	55.56
	November	33.68	8.42	57.89
	December	35.24	7.62	57.14
	January	38.05	10.62	51.33
	February	30.88	16.18	52.94
	March	32.56	17.05	50.39
	April	25.95	25.41	48.65
	May	19.32	29.95	50.72
Karimpuzha river	October	0.00	11.11	88.89
	November	0.00	27.27	72.73
	December	5.88	29.41	64.71
	January	6.90	34.48	58.62
	February	36.59	24.39	39.02
	March	46.81	19.15	34.04
	April	44.44	25.93	29.63
	May	32.65	38.78	28.57
Hillock	October	100.00	0.00	0.00
	November	100.00	0.00	0.00
	December	100.00	0.00	0.00
	January	100.00	0.00	0.00
	February	100.00	0.00	0.00

	March	.	.	.
	April	.	.	.
	May	.	.	.
Plantation	October	100.00	0.00	0.00
	November	100.00	0.00	0.00
	December	100.00	0.00	0.00
	January	100.00	0.00	0.00
	February	.	.	.
	March	.	.	.
	April	.	.	.
	May	.	.	.
Kadalundy river	October	0.00	44.44	55.56
	November	0.00	44.44	55.56
	December	0.00	45.00	55.00
	January	0.00	51.72	48.28
	February	0.00	52.94	47.06
	March	0.00	57.89	42.11
	April	0.00	61.54	38.46
	May	0.00	51.85	48.15
Waste dump	October	98.48	0.00	1.52
	November	98.46	0.00	1.54
	December	98.96	0.00	1.04
	January	99.51	0.00	0.49
	February	99.10	0.00	0.90
	March	100.00	0.00	0.00
	April	99.34	0.00	0.66
	May	97.83	0.00	2.17

Appendix-2.2 Abundance of prey organisms in different habitats

Species	Azhinjilam Jheel	Dry Grassfield	Paddy Field	Hillock	Wet Grass field	Total
Acrididae	192	175	235	162	292	1056
Aeschnidae	25				18	43
Apidae	77	101		142	43	363
Apionidae			19	30		49
Arachnid spp	45		42		97	184
Arctiidae			2		5	7
Asilidae	2	14		32	27	75
Blattidae				10		10
Calliphoridae					4	4

Carabidae		17			1	18
Cassididae	5			46	2	53
Cercopidae		5		22		27
Chrysomelid larva					2	2
Chrysomelidae	83	32	62	110	52	339
Cicadellidae	131	49	141	42	91	454
Cicadidae				42		42
Coccinellidae	51	20	35		68	174
Coreidae	53	13	127	52	59	304
Crambidae			80			80
Culicidae					1	1
Danaidae				47		47
Delphacidae			136			136
Formicidae	60	184	155	134	103	636
Fulgoridae		2		11		13
Geometrid Larva	1					1
Gryllidae	24	6	105		168	303
Hesperiidae	2			18	1	21
Hispidae	10		72	19		101
Jassidae			93		5	98
Lestidae	98		118		135	351
Libellulidae	54		82	38	35	209
Lygaeidae		12				12
Lymantridae			28			28
Megachillidae				25		25
Meloidae		29	62	48	7	146
Membracidae		17		25		42
Muscidae	59		47		39	145
Noctuiid Larva	1		3		4	8
Noctuiidae	1		107		22	130
Nymphalidae	3			54	4	61
Papilionidae	1			95		96
Pentatomidae	2		36			38
Phasmatidae					1	1
Pieridae	2			81	5	88
Pseudococcidae			59			59
Pyralidae	70				113	183
Pyraustidae			223			223
Pyrrhocoreidae		8			3	11
Rana spp			17		24	41
Rhagionidae					2	2
Satyridae	1		66		22	89
Scoliidae					1	1
Sphingidae	1			10	12	23

Staphylinidae	6		2			8
Syrphidae					3	3
Tabanidae					2	2
Tetrigidae	68	53	139	65	69	394
Tettigoniidae	63	29	93	69	77	331
Tipulidae		1		15	8	24
Vespidae				32		32
Xylocopidae				45		45
Grand Total	1191	767	2386	1521	1627	7492

Appendix-2.3 Abundance of Aquatic organisms in different habitats

Species	Location						
	Azhinjilam jheel	Calicut Jheel	Feroke Jheel	Kadalundy river	Karimpuzha river	Vadapuram Grass field	Total
Ambasis gymnocephalus				5			5
Ambassis nalua				5			5
Amblypharyngodon sp.			1		4		5
Anabas sp.			2				2
Anabas testudineus					7		7
Aplocheilus blockii	95	26	138	159	46	34	498
Aplocheilus lineatus	66	12	44	42	11	7	182
Arachnid sp.	22	59	24	8		21	134
Beetle Larva	47	6	16				69
Belostomatidae	25	395	55				475
Cattle Leech	2		2				4
Channa orientalis		2					2
Chela(Neochela) dadyburjori						1	1
Chironomidae		36	14				50
Corixidae						1	1
Damselfly Naiad	82	155	39	2	40	36	354
Danio acquipinnatus	101	19	447	94	88	180	929
Dragonfly Naiad	181	154	138	32	66	132	703
Dytiscid Larva			2				2
Dytiscidae	12	1					13
Eleotris sp.				2			2
Etroplus maculatus				26	58		84
Fresh water mussel	1						1
Gerridae		3		4	20	33	60
Glossogobius giuris					1		1
Gyrinidae	2	4					6
Hydrometridae	88	16	65		20		189
Hydrophilidae	57		26			87	170
Lepidocephalus thermalis					15	10	25

Lymnidae	8	11	82		11	72	184
Macrobrachium sp.				243			243
Macropodus cupanus	277	205	91	17	13	74	677
Mastacembelus armatus					16		16
Mystus cavasius						6	6
Naucoridae	28	6	2				36
Nereis sp.				1			1
Notonectidae		93	23			114	230
Oreochromis mossambica		1		1	3		5
Unidentified crab			3			18	21
Palaemon sp.	192	46	236		518	101	1093
Parluciosoma daniconius	2		25	5	13	45	90
Penaeus sp.				376			376
Pila globosa	7		27				34
Planorbidae	84	24	158		14	8	288
Pleiidae		214	2				216
Puntius amphibius	11		3	74	145	15	248
Puntius denisonii					4		4
Puntius fasciatus fasciatus					10		10
Puntius filamentosus			1		14		15
Puntius ticto					4	7	11
Puntius vittatus	151	54	254	21	50	58	588
Rana hexadactyla	3				1	3	7
Rana sp.	13		9		6	19	47
Tadpole	34	5	2	5	2	3	51
Tetraodon travancoricus					95		95
Thiaridae		26			3	68	97
Unidentified fish					4		4
Unidentified Larva	2	8			1		11
Viviparidae			16		25		41
Xenentedon cancila					7		7
Grand Total	1593	1581	1947	1122	1335	1153	8731

Appendix-2.4 Percentage composition of vegetation at Kadalundy River		
	Plants	%
1	*Enteromorpha sp.*	20.41
2	*Avicennia marina*	19.09
3	*Acanthes ilicifolius*	16.15
4	*Sphaeranthus indica*	15.56
5	*Vegetation Free Area*	13.18
6	*Salvinia molusta*	6.54
7	*Cyperus sp.*	4.88

8	*Fimbristylis milliaceae*	1.33
9	*Mimosa pudica*	0.56
10	*Desmodium triflorum*	0.51
11	*Excoeccaria agallocha*	0.26
12	*Ageratum conyzoides*	0.23
13	*Cyrtococcum trigonum*	0.23
14	*Eragrostis unioloides*	0.15
15	*Paspalum conjugatum*	0.15
16	*Sida rhombifolia*	0.15
17	*Connarus monocarpus*	0.13
18	*Derris trifoliata*	0.13
19	*Oldenlandia auricularia*	0.13
20	*Scoparia dulcis*	0.13
21	*Paspalum scrobiculatum*	0.1
Total		100.00

Appendix-2.5 Aquatic organisms recorded during the present study			
No	Name	Family	Class
1	*Ambasis gymnocephalus*	Ambassidae	Pisces
2	*Ambassis nalua*	Ambassidae	Pisces
3	*Amblypharyngodon sp.*	Cyprinidae	Pisces
4	Anabas sp.	Anabantidae	Pisces
5	*Anabas testudineus*	Anabantidae	Pisces
6	*Aplocheilus blockii*	Aplocheilidae	Pisces
7	*Aplocheilus lineatus*	Aplocheilidae	Pisces
8	Arachnid sp.	Araneidae	Arachnida
9	Beetle Larva	Dytiscidae	Insecta
10	Belostomatidae	Belostomatidae	Insecta
11	Cattle Leech	Hirudinidae	Hirudinea
12	Channa orientalis	Channidae	Pisces
13	*Chela(Neochela) dady burjori*	Cyprinidae	Pisces
14	Chironomidae	Chironomidae	Insecta
15	Corixidae	Corixidae	Insecta
16	Damselfly Naiad	Lestidae	Insecta
17	*Danio malabaricus (acquipinnatus)*	Cyprinidae	Pisces
18	Dragonfly naiad	Libellulidae	Insecta
19	Dytiscid larva	Dytiscidae	Insecta
20	Dytiscidae	Dytiscidae	Insecta
21	Eleotris sp.	Eleotridae	Pisces

22	*Etroplus maculatus*	Cichlidae	Pisces
23	Fresh water mussel	Unionidae	Pelecypoda
24	Gerridae	Gerridae	Insecta
25	*Glossogobius giuris*	Gobiidae	Pisces
27	Hydrometridae	Hydrometridae	Insecta
28	Hydrophilidae	Hydrophilidae	Insecta
29	*Lepidocephalus thermalis*	Cobitidae	Pisces
30	Lymnidae	Lymnidae	Gastropoda
31	*Macrobrachium sp.*	Palaemonidae	Crustacea
32	*Macropodus cupanus*	Belontiidae	Pisces
33	*Mastacembelus armatus*	Mastacembelidae	Pisces
34	*Mystus cavasius*	Bagridae	Pisces
35	Naucoridae	Naucoridae	Insecta
36	Nereis sp.	Nereididae	Polychaeta
37	Notonectidae	Notonectidae	Insecta
38	*Oreochromis mossambica*	Cichlidae	Pisces
39	Unidentified crab	-	Crustacea
40	*Palaemon sp.*	Palaemonidae	Crustacea
41	*Parluciosoma(Rasbora) daniconius*	Cyprinidae	Pisces
42	*Penaeus sp.*	Penaeidae	Crustacea
43	*Pila globosa*	Pilidae	Gastropoda
44	Planorbidae	Planorbidae	Gastropoda
45	Pleiidae	Pleiidae	Insecta
46	*Puntius amphibius*	Cyprinidae	Pisces
47	*Puntius denisonii*	Cyprinidae	Pisces
48	*Puntius fasciatus fasciatus*	Cyprinidae	Pisces
49	*Puntius filamentosus*	Cyprinidae	Pisces
50	*Puntius ticto*	Cyprinidae	Pisces
51	*Puntius vittatus*	Cyprinidae	Pisces
52	*Rana hexadactyla*	Ranidae	Amphibia
53	Rana sp.	Ranidae	Amphibia
54	Tadpole	Ranidae	Amphibia
55	*Tetraodon travancoricus*	Tetraonidae	Pisces
56	Thiaridae	Thiaridae	Gastropoda
57	Unidentified fish	-	Pisces
58	Unidentified larva	-	Insecta
59	Viviparidae	Viviparidae	Gastropoda
60	*Xenentedon cancila*	Beloniidae	Pisces

Appendix-2.6 Percentage composition of vegetation in Azhinjilam Jheel		
No	Plant species	%
1	*Salvinia molusta*	23.06
2	*Oryza sp.*	17.59
3	*Cynodon dactylon*	13.56
4	*Hydrilla verticillata*	10.54
5	*Nymphoides hydrophylla*	9.42
6	*Nymphaea stellata*	4.43
7	*Ludwigia adscendens*	3.56
8	*Desmodium triflorum*	2.95
9	*Ischaemum sp.*	2.43
10	*Heteropogon contortus*	2.11
11	*Polygonum glabrum*	1.77
12	*Cyperus sp.*	0.87
13	*Digitaria bicornis*	0.85
14	*Sporobolus diander*	0.77
15	*Fimbrystylis milliaceae*	0.76
16	*Kyllinga sp.*	0.76
17	*Mimosa pudica*	0.75
18	*Desmodium heterophyllum*	0.64
19	*Paspalum scrobiculatum*	0.49
20	*Nymphaea nouchali*	0.39
21	*Paspalum conjugatum*	0.38
22	*Sacciolepis indica*	0.35
23	*Fimbristylis sp.*	0.32
24	*Eragrostis viscosa*	0.27
25	*Eragrostis unioloides*	0.18
26	*Kyllinga brevifolia*	0.18
27	*Scoparia dulcis*	0.15
28	*Ludwigia hyssopifolia*	0.09
29	*Centella asiatica*	0.08
30	*Vernonia cineria*	0.07
31	*Oldenlandia auricularia*	0.05
32	*Cyrtococcum trigonum*	0.03
33	*Lindernia pusilla*	0.03
34	*Lindernia rotundifolia*	0.02
35	*Pycreus spp.*	0.02
36	*Sphaeranthus indica*	0.02
37	*Dentella repens*	0.01
38	*Hygrophila schullii*	0.01
39	*Justicia chelenoides*	0.01
40	*Lindernia antipoda*	0.01
41	*Smithia sensitiva*	0.01

42	*Blumea oxyodonta*	0
43	*Hygrophila octovalvis*	0
44	*Ischaemum indicum*	0
45	*Oldenlandia brachypoda*	0
46	*Triumfetta rhomboidea*	0
Total		100

Appendix-2.7 Mean size (cm) of prey organisms in different habitats

Species	Azhinjilam Jheel	Dry Grassfield	Paddy field	Hillock	Wet Grass field	Total
Acrididae	1.66	1.64	2.05	1.74	1.62	1.74
Aeschnidae	3.52				3.77	3.64
Apidae	0.68	0.71		0.71	0.73	0.71
Apionidae			0.82	0.78		0.80
Arachnid spp	0.85		0.68		0.83	0.79
Arctiidae			0.90		0.90	0.90
Asilidae	1.80	1.30		1.24	1.33	1.42
Blattidae				3.69		3.69
Calliphoridae					0.48	0.48
Carabidae		1.55			0.80	1.17
Cassididae	0.50			0.65	0.50	0.55
Cercopidae		0.70		0.70		0.70
Chrysomelid larva					0.65	0.65
Chrysomelidae	0.67	0.63	0.71	0.70	0.69	0.69
Cicadellidae	0.64	0.61	0.75	0.62	0.77	0.69
Cicadidae				2.08		2.08
Coccinellidae	0.61	0.46	0.66		0.57	0.57
Coreidae	0.74	1.38	0.99	1.14	0.76	1.00
Crambidae			0.96			0.96
Culicidae					0.70	0.70
Danaidae				9.26		9.26
Delphacidae			0.67			0.67
Formicidae	0.73	0.88	0.81	0.76	0.77	0.79
Fulgoridae		0.70		0.67		0.68
Geometrid Larva	3.80					3.80
Gryllidae	1.49	1.50	1.49		1.13	1.40
Hesperiidae	1.45			2.83	1.60	1.96
Hispidae	0.53		0.56	0.57		0.56
Jassidae			0.75		0.77	0.76
Lestidae	2.82		2.67		2.33	2.61
Libellulidae	4.23		3.68	3.75	3.94	3.90
Lygaeidae		0.83				0.83

Lymantridae			1.11			1.11
Megachillidae				0.91		0.91
Meloidae		1.30	1.09	1.12	0.78	1.07
Membracidae		0.60		0.58		0.59
Muscidae	0.77		0.73		0.74	0.75
Noctuiid Larva	1.80		1.30		1.80	1.63
Noctuiidae	1.00		1.32		1.44	1.25
Nymphalidae	2.00			4.93	1.87	2.93
Papilionidae	2.50			7.87		5.18
Pentatomidae	0.95		1.01			0.98
Phasmatidae					3.50	3.50
Pieridae	1.35			3.68	1.47	2.16
Pseudococcidae			0.63			0.63
Pyralidae	0.91				0.90	0.91
Pyraustidae			0.92			0.92
Pyrrhocoreidae		1.37			0.80	1.09
Rana spp			2.04		1.96	2.00
Rhagionidae					0.60	0.60
Satyridae	1.60		1.45		1.79	1.61
Scoliidae					0.90	0.90
Sphingidae	2.40			5.63	1.93	3.32
Staphylinidae	0.64		1.00			0.82
Syrphidae					0.73	0.73
Tabanidae					2.20	2.20
Tetrigidae	1.06					1.06
Tettigoniidae	1.79	1.16	1.60	1.31	1.35	1.45
Tipulidae		1.60		1.45	1.09	1.38
Vespidae				1.60		1.60
Xylocopidae				1.52		1.52
Grand Total	1.38	1.03	1.21	2.23	1.32	1.43

Appendix-2.8 Bird species recorded in different habitats under study

Common name	Scientific name	Family	AJ	B	C	D	E	F	G	H	I	J	K
Black headed Munia	*Lonchura malacca*	Ploceidae	-	-	-	-	-	-	+	-	-	-	-
Spotted Munia	*Lonchura punctulata*	Ploceidae	-	-	-	-	-	-	+	-	-	-	-
White backed Munia	*Lonchura striata*	Ploceidae	-	-	-	-	-	-	+	-	-	-	-
Purple rumped Sunbird	*Nectarinia zeylonica*	Nectariniidae	-	-	-	-	-	-	+	+	-	-	-
Indian Robin	*Saxicoloides fulicata*	Muscicapidae	-	-	-	-	-	-	-	+	-	+	-
Magpie Robin	*Copsychus saularis*	Muscicapidae	-	-	+	+	-	+	+	+	+	+	-
Paddy field Pipit	*Anthus novaeseelandiae*	Motacillidae	-	-	-		-	+	+	-	-	-	-
Tailor Bird	*Orthotomus sutorius*	Muscicapidae	-	-	-	-	-	-	+	-	-	-	-

Greenish leaf Warbler	*Phylloscopus trochiloides*	Muscicapidae	-	-	-	-	-	-	+	+	-	-	-
Blyth's Reed Warbler	*Acrocephalus dumetorum*	Muscicapidae	-	-	-	-	-	-	+	-	-	-	-
Paddy field Warbler	*Acrocephalus agricola*	Muscicapidae	-	-	-	-	-	+	+	-	-	-	-
Paradise Flycatcher	*Terpsiphone paradisi*	Muscicapidae	-	-	-	-	-	-	+	-	-	-	-
Common Babbler	*Turdoides caudatus*	Muscicapidae	-	-	-	-	-	-	+	+	+	+	-
Jungle Babbler	*Turdoides striatus*	Muscicapidae	-	-	-	-	-	+	+	-	-	-	-
Red vented Bulbul	*Pycnonotus cafer*	Pycnonotidae	-	-	-	-	-	-	+	+	-	-	-
Red whiskered Bulbul	*Pycnonotus jocosus*	Pycnonotidae	-	-	-	-	-	-	+	+	-	-	-
House Crow	*Corvus splendens*	Corvidae	-	+	+	+	+	+	+	+	+	-	+
Jungle Crow	*Corvus macrorhynchos*	Corvidae	-	+	+	+	+	+	+	+	+	-	+
Pond Heron	*Ardeola grayii*	Ardeidae	+	+	+	+	+	+	+	-	-	-	+
Cattle Egret	*Bubulcus ibis*	Ardeidae	+	+	+	+	-	+	+	+	+	-	+
Great Egret	*Egretta alba*	Ardeidae	-	-	-	-	+	-	-	-	-	-	-
Median Egret	*Egretta intermedia*	Ardeidae	-	+	+	+	+	+	+	-	-	-	-
Little Egret	*Egretta garzetta*	Ardeidae	+	+	+	+	+	+	+	-	-	-	-
Little Cormorant	*Phalacrocorax niger*	Phalacrocoracidae	-	+	+	+	+	+	+	-	-	-	-
White breasted Kingfisher	*Halcyon smyrnensis*	Alcedinidae	+	+	+	+	+	+	+	-	+	-	-
Storkbilled Kingfisher	*Pelargopsis capensis*	Alcedinidae	-	-	-	-	-	-	+	-	-	-	-
Small Blue Kingfisher	*Alcedo atthis*	Alcedinidae	-	+	+	+	+	+	+	-	-	-	-
Blackcapped Kingfisher	*Halcyon pileata*	Alcedinidae	-	-	-	+	+	+	+	-	-	-	-
Pied Kingfisher	*Ceryle rudis*	Alcedinidae	-	-	-	+	+	+	+	-	-	-	-
Crow pheasant	*Centropus sinensis*	Cuculidae	-	+	-	-	-	+	+	+	+	-	-
Koel	*Eudynamis scolopacea*	Cuculidae	-	-	-	-	-	-	+	-	-	-	-
Blossom headed Parakeet	*Psittacula cyanocephala*	Psittacidae	-	-	-	-	-	-	+	-	-	-	-
Roseringed Parakeet	*Psittacula krameri*	Psittacidae	-	-	-	-	-	-	+	+	-	-	-
Little Brown Dove	*Streptopelia benegalensis*	Columbidae	-	-	-	-	-	-	-	+	-	-	-
Spotted Dove	*Streptopelia chinensis*	Columbidae	-	-	-	-	-	-	+	-	-	-	-
Blue Rock Pigeon	*Columbia livia*	Columbidae	-	-	-	-	-	-	+	-	-	-	-
Fantail snipe	*Gallinago gallinago*	Charadriidae	-	-	-	-	+	+	+	-	-	-	-
white breasted waterhen	*Amaurornis phoenicurus*	Rallidae	-	+	+	+	-	+	+	-	-	-	-
Green Bee-eater	*Merops orientalis*	Meropidae	-	+	+	-	-	+	+	-	-	-	-

Blue-tailed Bee-eater	*Merops philippinus*	Meropidae	-	+	+	-	-	+	+	-	-	-	-
Indian Tree Pie	*Dendrocitta vagabunda*	Corvidae	-	-	-	-	-	-	+	-	+	-	-
Common Myna	*Acridotheres tristis*	Sturnidae	+	+	+	-	-	+	+	+	+	+	+
Jungle Myna	*Acridotheres fuscus*	Sturnidae	-	-	-	-	-	-	+	-	-	-	-
Black Drongo	*Dicrurus adsimilis*	Dicruridae	+	+	+	-	+	+	+	-	+	-	-
Racket tailed Drongo	*Dicrurus paradiseus*	Dicruridae	-	-	-	-	-	-	+	+	+	-	-
Ashy Swallow Shrike	*Artamus fuscus*	Artamidae	-	-	-	-	-	-	+	-	-	-	-
Brown Shrike	*Lanius cristatus*	Laniidae	-	-	-	-	-	-	+	-	-	-	-
Black headed Oriole	*Oriolus xanthorus*	Oriolidae	-	-	-	-	-	-	+	-	+	-	-
Indian Roller	*Coracias benghalensis*	Coraciidae	-	-	-	-	-	-	+	-	-	-	-
Small Green Barbet	*Magalaima viridis*	Capitonidae	-	-	-	-	-	-	+	-	-	-	-
Lesser Goldenbacked Woodpecker	*Dinopium benghalensis*	Picidae	-	-	-	-	-	-	+	+	+	-	-
Palm Swift	*Cypsiurus parvus*	Apodidae	-	+	-	-	-	-	+	-	-	-	-
Indian Small Skylark	*Alauda gulgula*	Alaudidae	-	-	-	-	-	-	+	-	-	-	-
Redrumped Swallow	*Hirundo daurica*	Hirundinidae	-	-	-	-	-	-	+	-	-	-	-
Grey Heron	*Ardea cinerea*	Ardeidae	+	-	-	-	+	-	-	-	-	-	-
Little ringed Plover	*Charadrius dubius scopoli*	Charadriidae	-	-	-	+	+	-	-	-	-	-	-
Indian Whiskered tern	*Chlidonias hybrida*	Laridae	-	-	-	-	+	-	-	-	-	-	-
Curlew	*Numenius arquata*	Scolopacidae	-	-	-	-	+	-	-	-	-	-	-
Wood or Spotted Sandpiper	*Tringa glareola*	Scolopacidae	-	-	-	-	+	-	-	-	-	-	-
Common Sandpiper	*Actitis hypoleucos*	Scolopacidae	+	-	+	+	+	+	+	-	-	-	-
Red shank	*Tringa totanus*	Scolopacidae	-	-	-	-	+	-	-	-	-	-	-
Little Stint	*Calidris minuta*	Scolopacidae	-	-	-	-	+	-	-	-	-	-	-
Purple Heron	*Ardea purpurea*	Ardeidae	+	-	-	-	+	-	-	-	-	-	-
Great Stone Plover	*Esacus magnirostris*	Charadriidae	-	-	-	-	+	-	-	-	-	-	-
Purple Moorhen	*Porphyrio porphyrio*	Rallidae	+	-	-	-	-	-	-	-	-	-	-
Bronzewinged Jacana	*Metopidius indicus*	Jacanidae	+	-	+	-	-	-	-	-	-	-	-
Red wattled Lapwing	*Vanellus indicus*	Charadriidae	+	-	+	+	-	+	+	-	-	-	-
Yellow wattled Lapwing	*Vanellus malabaricus*	Charadriidae	+	-	+	+	-	+	+	-	-	-	-
Yellow wagtail	*Motacilla flava*	Motacillidae	+	+	+	-	+	-	+	-	-	-	-
Large Pied Wagtail	*Motacilla maderaspatensis*	Motacillidae	+	+	+	+	+	+	+	-	-	-	-

Goldmantled Chloropis	*Chloropis cochinchinensis*	Muscicapidae	-	-	-	-	-	-	+	-	+	-	-
Common Pariah Kite	*Milvus migrans*	Accipitridae	+	+	+	-	+	-	+	-	-	-	+
Brahminy Kite	*Haliastur indus*	Accipitridae	+	+	+	-	+	+	+	-	-	-	+

(-) = Absent, (+) = Present, Habitats: AJ = Azhinjilam Jheel, B = Calicut Jheel, C = Feroke Jheel, D = Karimpuzha (Riverine), E =Kadalundy (Riverine), F =Wet Grass field, G = Paddy field, H = Hillock, I = Plantation, J = Dry land Grass (Grass in dry area) and K = Waste dump

Appendix-2.9 Percentage composition of vegetation in Calicut Jheel

No	Plant species	%
1	*Ipomea aquatica*	32.25
2	*Alternanthera philoceroides*	29.63
3	*Eichhornia crassipes*	18.86
4	*Salvinia molusta*	11.14
5	*Lemna sp.*	4.07
6	*Cyperus sp.*	2.65
7	*Nymphoides indica*	0.34
8	*Eragrostis unioloides*	0.24
9	*Nymphaea stellata*	0.18
10	*Fimbristylis milliaceae*	0.17
11	*Digitaria bicornis*	0.1
12	*Wedelia trilobata*	0.09
13	*Ludwigia hyssopifolia*	0.06
14	*Sphaeranthus africanus*	0.06
15	*Desmodium triflorum*	0.05
16	*Kyllinga sp.*	0.03
17	*Scoparia dulcis*	0.03
18	*Corchorus tiliaceae*	0.01
19	*Heliotropium indicum*	0.01
20	*Ischaemum sp.*	0.01
21	*Mimosa pudica*	0.01
22	*Pycreus spp.*	0.01
23	*Adiantum philippensis*	0
24	*Centella asiatica*	0
25	*Heliotropium keralens*	0
26	*Lindernia rotundifolia*	0
27	*Ludwigia perenis*	0
28	*Mariscus sp.*	0
29	*Paspalum conjugatum*	0

30	*Paspalum scrobiculatum*	0
31	*Piperomia pellucida*	0
	Total	100

Appendix-2.10 Percentage composition of vegetation in Feroke Jheel		
	Plant species	%
1	*Ipomea carnea*	28.11
2	*Hydrilla verticillata*	22.59
3	*Oryza sp.*	19.34
4	*Nymphaea stellata*	9.85
5	*Digitaria bicornis*	5.7
6	*Cynodon dactylon*	5.67
7	*Nymphoides hydrophylla*	3.78
8	*Salvinia molusta*	2.17
9	*Paspalum conjugatum*	1.91
10	*Eragrostis unioloides*	0.22
11	*Cyperus sp.*	0.19
12	*Blyxa auberti*	0.18
13	*Eragrostis viscosa*	0.12
14	*Mimosa pudica*	0.09
15	*Paspalum scrobiculatum*	0.03
16	*Desmodium triflorum*	0.02
17	*Ludwigia adscendens*	0.01
18	*Ludwigia hyssopifolia*	0.01
19	*Hewitschia scandens*	0
20	Grand Total	100

Appendix-2.11 Percentage composition of vegetation in Vadapuram grass field		
	Plant species	%
1	*Cyrtococcum trigonum*	20.49
2	*Ischaemum sp.*	12.61
3	*Sporobolus diander*	11.44
4	*Fimbristylis milliaceae*	10.15
5	*Eragrostis viscosa*	7.75
6	*Digitaria bicornis*	7.46
7	*Paspalum conjugatum*	4.63
8	*Desmodium triflorum*	4.29
9	*Paspalum scrobiculatum*	4.08
10	*Kyllinga monocephala*	3.41
11	*Eragrostis unioloides*	3.17

12	*Cyperus sp.*	2.43
13	*Oryza sp.*	2.18
14	*Colocasia esculenta*	1.44
15	*Perotis indicum*	0.94
16	*Mimosa pudica*	0.84
17	*Monochoria vaginalis*	0.54
18	*Oldenlandia auricularia*	0.44
19	*Hygrophila octovalvis*	0.26
20	*Lindernia rotundifolia*	0.15
21	*Ludwigia hyssopifolia*	0.15
22	*Ludwigia perenis*	0.13
23	*Scoparia dulcis*	0.13
24	*Eupatorium odoratum*	0.12
25	*Christella sp.*	0.08
26	*Triumfetta rhomboidea*	0.07
27	*Centella asiatica*	0.06
28	*Pycreus spp*	0.06
29	*Blumea oxyodonta*	0.05
30	*Centrosema virginiana*	0.05
31	*Cyperus cyperinus*	0.05
32	*Desmodium heterophyllum*	0.05
33	*Sida acuta*	0.05
34	*Dentella repens*	0.04
35	*Polygonum glabrum*	0.03
36	*Ageratum conyzoides*	0.02
37	*Cassia occidentalis*	0.02
38	*Dactyloctenium aegyptium*	0.02
39	*Selaginella philippensis*	0.02
40	*Stemodia verticillata*	0.02
41	*Adiantum philippensis*	0.01
42	*Atylosia scarabaeoides*	0.01
43	*Impatiens klenii*	0.01
44	*Lindernia pusilla*	0.01
45	*Mukia maderaspatna*	0.01
46	*Vernonia cineria*	0.01
47	*Achyranthes aspera*	0
48	*Alternanthera sessilis*	0
49	*Cheilanthus tenuifolia*	0
50	*Commelina bengalensis*	0
51	*Emilia sonchifolia*	0
52	*Hemidesmus indica*	0
53	*Hyptis capitata*	0
54	*Lantana camara*	0
55	*Pouzolzia zeylanica*	0

56	*Synedrella nodiflora*	0
57	*Urena lobata*	0
	Total	100.00

Appendix-2.12 Percentage composition of vegetation in the Paddy field		
	Plant species	%
1	*Oryza sativa*	64.17
2	*Paddy Stubbles*	13.06
3	*Vegetation Free Area*	9.44
4	*Ischaemum sp.*	2.75
5	*Desmodium triflorum*	1.71
6	*Eriocaulon quinquangulare*	1.5
7	*Echinochloa colonum*	1.32
8	*Fimbristylis milliaceae*	1.11
9	*Heteropogon contortus*	0.81
10	*Digitaria bicornis*	0.68
11	*Desmodium heterophyllum*	0.55
12	*Mimosa pudica*	0.5
13	*Paspalum conjugatum*	0.31
14	*Paspalum scrobiculatum*	0.31
15	*Eragrostis uniloides*	0.25
16	*Sporobolus diander*	0.19
17	*Eragrostis viscosa*	0.16
18	*Scoparia dulcis*	0.13
19	*Oldenlandia auricularia*	0.1
20	*Ageratum conyzoides*	0.09
21	*Centella asiatica*	0.09
22	*Cyperus sp.*	0.09
23	*Cyrtococcum trigonum*	0.08
24	*Lindernia antipoda*	0.07
25	*Polygonium glabrum*	0.06
26	*Sida acuta*	0.06
27	*Vernonia cineria*	0.06
28	*Heliotropium keralens*	0.05
29	*Hygrophila octovalvis*	0.05
30	*Ludwigia hyssopifolia*	0.05
31	*Imperata sp.*	0.04
32	*Blumea oxydonta*	0.03
33	*Hemidesmus indica*	0.03
34	*Dentella repens*	0.02
35	*Sida alnifolia*	0.02
36	*Stemodia verticillata*	0.02
37	*Triumfelta rhomboidea*	0.02

38	*Adiantum philippensis*	0.01
39	*Christella sp.*	0.01
40	*Lindernia rotundifolia*	0.01
41	*Aerva lanata*	0
42	*Bridelia scandens*	0
43	*Cymbopogon citratus*	0
44	*Pouzolzia zeylanica*	0
45	*Sida rhombifolia*	0
	Total	100

Appendix-2.13 Percentage composition of vegetation in Hillock

No	Plant species	%
1	*Lantana camara*	24.39
2	*Anacardium occidentale*	14.05
3	*Vegetation Free Area*	9.25
4	*Terminalia paniculata*	8.27
5	*Clerodendrum viscosum*	7.18
6	*Hyptis suaveolens*	5.00
7	*Heteropogon contortus*	3.80
8	*Stachytarpheta jamaicense*	3.22
9	*Ischaemum indicum*	3.20
10	*Zizyphus oenoplia*	3.07
11	*Dimeria hohenackeri*	2.97
12	*Canthium parviflorum*	2.45
13	*Mimosa pudica*	2.25
14	*Sida rhombifolia*	1.65
15	*Sida acuta*	1.63
16	*Justicia simplex*	1.23
17	*Desmodium triflorum*	1.13
18	*Mirtacarpus verticillatus*	0.93
19	*Ichnocarpus frutescens*	0.90
20	*Callicarpa lanata*	0.75
21	*Oldenlandia auricularia*	0.70
22	*Eupatorium odoratum*	0.68
23	*Calycopteris floribunda*	0.58
24	*Ageratum conyzoides*	0.25
25	*Vernonia cineria*	0.25
26	*Eragrostis unioloides*	0.18
27	*Scoparia dulcis*	0.08
Total		100

Appendix-2.14 Percentage composition of vegetation in Plantation		
No	Plant species	%
1	*Hevea braziliensis*	41.00
2	Vegetation Free Area	30.06
3	*Ipomea sp.*	11.28
4	*Eupatorium odoratum*	2.34
5	*Sida rhombifolia*	1.84
6	*Gloriosa superba*	1.82
7	*Heteropogon contortus*	1.70
8	*Muraya exotica*	1.58
9	*Lantana camara*	1.42
10	*Sida acuta*	1.40
11	*Oldenlandia auricularia*	1.16
12	*Ageratum conyzoides*	1.02
13	*Calycopteris floribunda*	0.92
14	*Leucas aspera*	0.84
15	*Clerodendrum infortunatum*	0.76
16	*Macaranga peltata*	0.50
17	*Clerodendrum sp.*	0.36
Total		100.00

Appendix-3.1 Mean Length of Bill and Tarsus (mm) in different herons				
Species	Bill (Ali and Ripley)	Bill (Present study)	Tarsus (Ali and Ripley)	Tarsus (present study)
Cattle Egrets	50 – 66	55-80	82-92	60-90
Little Egrets	79 – 91	85-105	99-110	100-110
Pond Heron	60 – 67	50-75	60-64	55-70

Appendix-3.2 Mean weight of different heron species			
Species	Weight (gms)	Number of birds analysed	Mean weight (gm)
Cattle Egret	240-260	11	331.8
Little Egret	335-485	11	384.09
Pond Heron	150-280	12	222.5

Appendix 4.1 Nest size details of among 3 Ardeids					
Nest No	Bird	Outer diameter	Inner diameter	Depth	Index
Nest-1	Little Egret	29.8	12.5	5.3	17.79
Nest-2	Little Egret	33.6	12	6.8	20.24
Nest-3	Little Egret	32.6	7	7.2	22.09
Nest-4	Little Egret	46	7.5	8.5	18.48
Nest-5	Little Egret	45	7.3	9	20
Nest-6	Little Egret	33.5	7.2	4.8	14.33
Nest-7	Little Egret	34.5	16	5.5	15.94
Nest-8	Little Egret	29.6	15	4.5	15.2
Nest-9	Little Egret	42.5	15.5	6.5	15.29
Nest-10	Little Egret	30.5	17	7.8	25.57
Nest-11	Little Egret	40.5	15	6.2	15.31
Nest-12	Little Egret	31.5	15	5.5	17.46
Nest-13	Little Egret	27.8	14.5	8	28.78
Nest-14	Little Egret	26.4	12.5	8.4	31.82
Nest-15	Little Egret	24	13	5.6	23.33
Nest-16	Little Egret	28.5	12.5	6.5	22.81
Nest-17	Little Egret	27.5	11.5	5.5	20
Nest-18	Little Egret	25.2	15.5	6	23.81
Nest-19	Little Egret	36	15	7	19.44
Nest-20	Little Egret	27.5	12.5	5	18.18
Nest-21	Little Egret	26.5	15.2	4.5	16.98
Nest-22	Little Egret	36.5	12.5	6.5	17.81
Nest-23	Little Egret	34	12	5	14.71
Nest-24	Little Egret	36.5	12.8	7	19.18
Nest-25	Little Egret	32.5	12.6	6.5	20
Nest-26	Little Egret	29.5	12.7	5.5	18.64
Nest-27	Little Egret	46	12.5	6	13.04
Nest-28	Little Egret	44	12.4	5	11.36
Nest-29	Little Egret	38.5	12.6	4.8	12.47
Nest-30	Little Egret	35.5	12.3	4.6	12.96
Nest-31	Little Egret	33.2	7.8	5	15.06
Nest-32	Little Egret	41	15.6	5	12.2
Nest-33	Little Egret	31	7.5	4.5	14.52
Nest-34	Little Egret	23.5	12.5	6	25.53
Nest-35	Little Egret	33	11.5	7	21.21
Nest-36	Little Egret	26	11.8	4.5	17.31

Nest-37	Little Egret	25	15	5.5	22
Nest-38	Little Egret	28.5	13	5	17.54
Nest-39	Little Egret	28	13.5	4.5	16.07
Nest-40	Little Egret	29	13	5	17.24
Nest-41	Little Egret	41	15.5	5.5	13.41
Nest-42	Little Egret	34	15.5	5	14.71
Nest-43	Little Egret	25	15.1	4.8	19.2
Nest-44	Little Egret	19	15	4.5	23.68
Nest-45	Little Egret	23	15	3.8	16.52
Nest-46	Little Egret	32.5	16.8	4	12.31
Nest-47	Little Egret	32	16.4	5	15.63
Nest-48	Little Egret	34	15.8	4.4	12.94
Nest-49	Little Egret	39	15.5	6	15.38
Nest-50	Little Egret	34	15.5	5	14.71
Nest-51	Little Egret	37	21	7	18.92
Nest-52	Little Egret	23	17	7	30.43
Nest-1	Pond Heron	23	9	3.5	15.22
Nest-2	Pond Heron	38	17	6.5	17.11
Nest-3	Pond Heron	26	7	3.5	13.46
Nest-4	Pond Heron	37	16.5	5.5	14.86
Nest-5	Pond Heron	23	9	3.5	15.22
Nest-6	Pond Heron	23	8.5	4	17.39
Nest-7	Pond Heron	30.5	20.5	5	16.39
Nest-8	Pond Heron	26	7	3.5	13.46
Nest-9	Pond Heron	23.5	9.5	3.5	14.89
Nest-10	Pond Heron	34	14.5	8	23.53
Nest-11	Pond Heron	42	20	9	21.43
Nest-12	Pond Heron	24	15	8.5	35.42
Nest-13	Pond Heron	43	23	12	27.91
Nest-14	Pond Heron	44	22	14	31.82
Nest-15	Pond Heron	34	17	9.5	27.94
Nest-16	Pond Heron	33	15.5	9	27.27
Nest-17	Pond Heron	30	20	4.5	15
Nest-18	Pond Heron	28	7.5	4	14.29
Nest-19	Pond Heron	24	10	4	16.67
Nest-20	Pond Heron	34	15	8	23.53
Nest-21	Pond Heron	42	20.5	9	21.43
Nest-22	Pond Heron	25	15.5	9	36
Nest-23	Pond Heron	43	23	12.5	29.07

Nest-24	Pond Heron	44.5	22	14.5	32.58
Nest-25	Pond Heron	34	17.5	10	29.41
Nest-26	Pond Heron	33	15	9	27.27
Nest-27	Pond Heron	24	9.5	4	16.67
Nest-28	Pond Heron	38.5	17	7	18.18
Nest-29	Pond Heron	26	7.5	4.5	17.31
Nest-30	Pond Heron	37	17	6	16.22
Nest-31	Pond Heron	23	9	3.5	15.22
Nest-32	Pond Heron	23	8.5	4	17.39
Nest-33	Pond Heron	24	9.2	3.6	15
Nest-34	Pond Heron	39	17.3	6.4	16.41
Nest-35	Pond Heron	25	9.6	5	20
Nest-36	Pond Heron	24	9	5	20.83
Nest-37	Pond Heron	45	25	13	28.89
Nest-38	Pond Heron	42	22	11	26.19
Nest-39	Pond Heron	32	21	6	18.75
Nest-40	Pond Heron	27	7	4	14.81
Nest-41	Pond Heron	24	9	4	16.67
Nest-42	Pond Heron	34	14.5	8	23.53
Nest-43	Pond Heron	24	9.5	4	16.67
Nest-44	Pond Heron	31	21	5	16.13
Nest-45	Pond Heron	26	7	4	15.38
Nest-46	Pond Heron	34	15	8	23.53
Nest-47	Pond Heron	42	20	9	21.43
Nest-48	Pond Heron	43	23	12	27.91
Nest-49	Pond Heron	34	17	10	29.41
Nest-50	Pond Heron	33	15	9	27.27

Appendix 4.2 The details of egg measurements and shape index among three species of birds

Bird	Egg length (mm)	Egg breadth (mm)	Egg weight (gm)	Shape index
Little Egret	44.2	34.1	28	77.15
Little Egret	46.5	31.9	24.8	68.6
Little Egret	45.6	33.2	25.8	72.81
Little Egret	44.1	32.5	25.3	73.7
Little Egret	48.9	32.8	25.5	67.08
Little Egret	43	31.7	24.7	73.72
Little Egret	46.5	33.2	25.9	71.4
Little Egret	45.5	32.5	25.4	71.43
Little Egret	44.2	32	25	72.4
Little Egret	42.6	31.1	24.3	73

Little Egret	45.7	31.6	24.7	69.15
Little Egret	44	33	25.8	75
Little Egret	45.8	32	25	69.87
Little Egret	47.5	31.4	21.5	66.11
Little Egret	48.7	32	25	65.71
Little Egret	45.3	31.2	23.7	68.87
Little Egret	43.8	32.3	24.5	73.74
Little Egret	44.3	33	25	74.49
Little Egret	43	31.9	23	74.19
Little Egret	45.2	32.6	25.3	72.12
Little Egret	47	32.9	25	70
Little Egret	47.1	32.9	25	69.85
Little Egret	45.2	33	24	73.01
Little Egret	52.5	29	21	55.24
Little Egret	47.3	32.3	23.3	68.29
Little Egret	43.2	33.2	24	76.85
Little Egret	47	32.9	23.8	70
Little Egret	47.1	32.9	23.8	69.85
Little Egret	45.2	33	23.9	73.01
Little Egret	44.2	34.1	28.2	77.15
Little Egret	46.5	31.9	25.3	68.6
Little Egret	45.6	33.2	27.5	72.81
Little Egret	44.1	32.5	23.3	73.7
Little Egret	48.9	32.8	23.5	67.08
Little Egret	43	31.7	22.7	73.72
Little Egret	46.5	33.2	27	71.4
Little Egret	45.5	32.5	26	71.43
Little Egret	44.2	32	25.6	72.4
Little Egret	42.6	31.1	20	73
Little Egret	45.7	31.6	22.8	69.15
Little Egret	44	33	20	75
Little Egret	43.8	32.3	.	73.74
Little Egret	44.3	33	.	74.49
Little Egret	43	31.9	.	74.19
Little Egret	45.7	32.4	.	70.9
Little Egret	46.4	32.3	.	69.61
Little Egret	44.6	33.6	27.9	75.34
Little Egret	45	35	29	77.78
Little Egret	47.2	34.5	28.7	73.09
Little Egret	46.2	33.2	27.5	71.86
Little Egret	45.2	32.6	.	72.12
Little Egret	44.8	30.8	.	68.75
Little Egret	42.6	31.1	.	73
Little Egret	43	31.9	.	74.19
Little Egret	43	31.7	.	73.72
Little Egret	45.7	31.6	.	69.15
Little Egret	43	31.9	.	74.19
Little Egret	44.1	32.6	.	73.92
Little Egret	47.1	32.9	.	69.85

Little Egret	47	32.9	.	70
Little Egret	45.5	32.5	.	71.43
Little Egret	45.8	32.8	.	71.62
Little Egret	44.2	32.5	.	73.53
Little Egret	44.2	32	.	72.4
Little Egret	45.7	32.4	.	70.9
Little Egret	46.5	32.3	.	69.46
Little Egret	44.3	33.8	.	76.3
Little Egret	44.6	33.2	.	74.44
Little Egret	44.7	33.2	.	74.27
Little Egret	44.3	33	.	74.49
Little Egret	43.2	33	.	76.39
Little Egret	43.8	33.2	.	75.8
Little Egret	43.2	33.8	.	78.24
Little Egret	43.1	33.5	.	77.73
Little Egret	45	33.2	.	73.78
Little Egret	45.7	34	28	74.4
Little Egret	46.8	34.1	28.4	72.86
Little Egret	47.4	34.5	29.5	72.78
Little Egret	47.5	34.6	28.2	72.84
Little Egret	47.7	34	28.5	71.28
Little Egret	47.4	35	29.5	73.84
Little Egret	48.8	35	30.2	71.72
Pond Heron	37.9	32	16	84.43
Pond Heron	39	28.3	17	72.56
Pond Heron	38.8	29.4	16.3	75.77
Pond Heron	48	29.2	17.7	60.83
Pond Heron	38.9	29.3	17.7	75.32
Pond Heron	37	29	17.3	78.38
Pond Heron	38	29.5	17.3	77.63
Pond Heron	39	29.4	17.5	75.38
Pond Heron	35.5	28.6	14.5	80.56
Pond Heron	36.5	29	14.5	79.45
Pond Heron	36	27.4	14.2	76.11
Pond Heron	37	28	16.5	75.68
Pond Heron	37.6	27.9	15.5	74.2
Pond Heron	38	29.5	17.8	77.63
Pond Heron	36.7	27.9	14	76.02
Pond Heron	37.3	29	17.2	77.75
Pond Heron	35	30	12	85.71
Pond Heron	37	26	12.72	70.27
Pond Heron	37	26	12.8	70.27
Pond Heron	37	28.7	17	77.57
Pond Heron	36.8	28.1	16.9	76.36
Pond Heron	36.5	28.4	14.5	77.81
Pond Heron	37.9	24.1	15.8	63.59
Pond Heron	39.5	29.4	17.5	74.43
Pond Heron	39	29	16.8	74.36
Pond Heron	37.2	28.7	16.8	77.15

Pond Heron	38	29.4	17.2	77.37
Pond Heron	36	27.5	14.4	76.39
Pond Heron	37	29.2	17.4	78.92
Pond Heron	38	29.4	17.5	77.37
Pond Heron	36.4	28.5	14.6	78.3
Pond Heron	38.8	29.4	17.6	75.77
Pond Heron	36	29.5	17.2	81.94
Pond Heron	38.5	29	17.4	75.32
Pond Heron	38.9	29	17.3	74.55
Pond Heron	37.5	28	15.5	74.67
Pond Heron	38	29.5	17.8	77.63
Pond Heron	35.5	32	13.5	90.14
Pond Heron	37	28	16.5	75.68
Pond Heron	36	27.4	14.1	76.11
Pond Heron	38.8	29.4	16.4	75.77
Pond Heron	37.5	27.8	15.1	74.13
Pond Heron	38	29	17.1	76.32
Pond Heron	37.9	24.1	15.8	63.59
Pond Heron	36.4	28.4	14.5	78.02
Pond Heron	35.5	28.6	14.5	80.56
Pond Heron	36	27.5	14.4	76.39
Pond Heron	36	27.4	14.2	76.11
Pond Heron	36.8	27.9	16.2	75.82
Pond Heron	39	28.3	17	72.56
Pond Heron	36.7	27.3	11.9	74.39
Pond Heron	33.3	26.2	14.2	78.68
Pond Heron	35	28	14.7	80
Pond Heron	38.5	27.8	12.72	72.21
Pond Heron	36	25.3	11.4	70.28
Pond Heron	35.1	27	13.9	76.92
Pond Heron	37.9	28.1	12.1	74.14
Pond Heron	36.7	27.9	11.5	76.02

Appendix 5.1 Organochlorine residues in different tissues of the bird species

Bird species	Pesticides	TISSUE						Group Total	
		Heart		Liver		Muscle		Mean	Std Deviation
		Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation		
Cattle Egret	ALDRIN	.05	.02	.12	.11	.39	.22	.18	.20
	BHC	.07	.05	.19	.11	.35	.43	.21	.25
	Chlordane	.05	.03	.11	.09	.12	.10	.09	.08
	DDT	.08	.04	.15	.12	.34	.41	.19	.24
	DIELDRIN	.02	.01	.02	.02	.15	.20	.06	.12
	ENDRIN	.11	.02	.17	.14	.32	.36	.20	.21
	Endosulfan sulphate	.10	.10	.10	.10	.08	.05	.09	.07
	Heptachlor	.02	.02	.07	.06	.11	.16	.07	.09

	Methoxychlor	.00	.01	.02	.02	.05	.06	.02	.04
Little Egret	ALDRIN	.19	.20	.13	.19	.06	.06	.13	.15
	BHC	.20	.11	.14	.15	.04	.04	.13	.12
	Chlordane	.06	.04	.07	.08	.04	.01	.06	.04
	DDT	.34	.14	.22	.23	.06	.02	.21	.18
	DIELDRIN	.06	.06	.06	.04	.00	.01	.04	.04
	ENDRIN	.13	.09	.30	.41	.04	.02	.16	.24
	Endosulfan sulphate	.20	.17	.09	.06	.09	.11	.13	.12
	Heptachlor	.03	.02	.02	.03	.02	.02	.02	.02
	Methoxychlor	.03	.03	.05	.08	.01	.01	.03	.05
Pond Heron	ALDRIN	.16	.06	.08	.05	.06	.05	.10	.06
	BHC	.25	.11	.10	.05	.08	.05	.14	.10
	Chlordane	.07	.00	.06	.05	.03	.01	.06	.03
	DDT	.25	.05	.11	.11	.16	.03	.17	.09
	DIELDRIN	.01	.02	.01	.02	.00	.01	.01	.01
	ENDRIN	.19	.01	.10	.10	.12	.03	.14	.07
	Endosulfan sulphate	.07	.01	.11	.15	.02	.02	.07	.08
	Heptachlor	.08	.01	.02	.01	.02	.01	.04	.03
	Methoxychlor	.03	.02	.02	.02	.02	.01	.03	.02
Group Total									
ALDRIN		.13	.12	.11	.11	.17	.20	.14	.15
BHC		.17	.11	.15	.10	.16	.26	.16	.17
Chlordane		.06	.03	.08	.07	.06	.06	.07	.06
DDT		.22	.14	.16	.15	.18	.24	.19	.18
Dieldrin		.03	.04	.03	.03	.05	.12	.04	.07
Endrin		.14	.06	.19	.24	.16	.22	.17	.18
Endosulfan sulphate		.13	.12	.10	.09	.06	.07	.10	.10
Heptachlor		.04	.03	.04	.04	.05	.09	.04	.06
Methoxychlor		.02	.02	.03	.04	.03	.03	.03	.03

Appendix 5.2 Organochlorine pesticide (ppm) in the eggs of Little Egret and Pond Heron

Bird	Pesticide	Mean	Std deviation
Pond Heron	BHC	0.107	0.223
	Heptachlor	0.013	0.026
	Endosulfan	0.015	0.030
	Dieldrine	0.006	0.011
	DDD	0.042	0.087
	DDE	0.000	0.000
	DDT	0.064	0.070
Little Egret	BHC	0.006	0.000
	Heptachlor	0.002	0.003
	Endosulfan	0.016	0.021

	Dieldrine	0.002	0.003
	pp-DDD	0.009	0.012
	pp-DDE	0.003	0.005
	pp-DDT	0.008	0.007

Appendix-5.3 Agrochemicals frequently sold in the market			
No	Common name	Formulation	Remark
1	Furadan-3G	Carbofuran 3%	Insecticide
2	Ekalux	Quinalphos Ec 25%	Insecticide
3	Dim ecron	Monocrotophos 36% SL (Rc pos)	Insecticide
4	Fenval 20Ec	Fenvalerate 20%Ec	Insecticide
5		Lambda-cyhalothrin 5% Ec	Insecticide
6	Tata fen	Fenvalerate 20% Ec	Pesticide
7	Radar 20 Ec	Chloropyrifos 20% Ec	Pesticide
8	Polytrin	Profenophos (40% Ec) + Cyper methrin(4% Ec)	Broad spectrum insecticide
9	Brassinolides	–	Crop yield enhancer
10	Rogor 30 E	Dimethoate 30%Ec	Insecticide
11	Fytolan	Copper oxychloride 88%ww	Fungicide
12	Sevin	Carbaryl 50%Wpp	Insecticide
13	Thiram 75% ws	Thiram technical 78.2%	Insecticide
14	Pyarry sulfan	Endosulfan	Insecticide
15	Indophyl-M 45	Mancozeb- 75%	Fungicide
16	Dilhana- M 45	Mancozeb- 75%	Fungicide
17	Parathion	Methyl parathion	Termiticide
18	Ratol	Bromadiolone 0.0005%	Rodenticide
19	Gamaxone	Paraquat dichloride 24%SL	Weedicide

Appendix 5.4 Insecticides, fungicides and herbicides used in agro-ecosystems in the entire state of Kerala (* indicates the agrochemicals used in the study areas, Source:Kerala agricultural department)		
Generic name	Formulation	Remark
Insecticides Organic sulphurous acid ester		
*Endosulfan	Thiodan 35% EC/AF Starsulfan 35% EC/AF Hildan 35% EC/AF Haxasulfan 35% EC/AF Endocoel 35% EC/AF *Parrysulfan 35% EC/AF Corosulfan 35% EC/AF Thiokill 35% EC/AF	Broad-spectrum action. Relatively safer to beneficial insects and pollinators

	Hexasulfan 4% DP Parrysulfan 4% DP Thiotox 4% DP	For controlling pests infesting vegetables

Carbamates		
*Carbaryl	*Sevin 5% DP *Sevin 10% DP Carvint 10% DP Hexavin 5% DP *Sevin 50% WP Killex Carbaryl 50% WP Killex Carbaryl 85% WP Carvint 85% WP	Broad-spectrum insecticidal action. Effective against a wide range of pests. Not recommended for control of mites. Should not be sprayed in crops at flowering.
Carbaryl+ Lindane granules	Sevidol 8%	For broad spectrum pest control in rice
Carbofuran	*Furadan 3G Hexafuran 3G	For pest control in rice
Aldicarb	Temik 10% G	For control of rice cyst nematode, dip seedlings in 0.02% solution of aidicarb. Also for control of burrowing nematodes in pepper at 1 g ai per vine and for nematode control in banana.

Organophosphorous compounds		
*Methyl Parathion	*Metacid 50% EC/AF *Metacid 2% DP Parament M 50% EC/AF Parataf 2% DP Ekatox 2% DP Parataf 50% EC/AF	Rapid knock down action. Not to be used against pests supporting a wide spectrum of natural enemies. Avoid use of sub-optimal quantities. Avoid use of sub-optimal quantities. Restricted in crops where honeybees are not pollinators
*Fenitrothion	Folithion 50% EC/AF Sumithion 50% EC/AF Sumithion 5% DP Accothion EC/AF	Contact and stomach action toxicity broad spectrum

*Mercaptothion	*Malathion 25% WP *Malathion 50% EC/AF Malamar 50% EC/AF *Cythion 50% EC/AF Star Mal 50% EC/AF Cythion 5% DP Malatox 50% EC	Safe insecticide for controlling pests of vegetables and storage pests. For control of pests of vegetables.
*DDVP	Vapona 76% EC/AF, Divap 100% EC/AF, *Nuvan 100% EC/AF, Marvex Super 100% EC/AF	Contact and fumigant: less residual: toxicity lasts for only 24 hours; safer to applied on vegetables.
*Quinalphos	*Ekalux 25% EC/AF Kinalux 25% EC/AF *Quinalphos 25% EC/AF Quinalphos 5% Quinalphos 1.5%	Broad-spectrum toxicity; particularly effective against mealy bugs and scale insects For rice pests control For control of cardamom thrips.
Phosalone	Zolone 35% EC/AF	Broad spectrum insecticide cum acaricide
Fenthion	Lebaycid 50% EC/AF	For effective control of rice stem borer and other pests of rice.
*Dimethoate	*Tara 909 30% EC/AF Killex-Dimethoate 30%EC/AF Corothioate 30% EC/AF Nugor 30% EC/AF Hilthoate 30% EC/AF	Systemic insecticides cum nematicide
Methyl demeton	Metasystox 25% EC/AF	Strongly systemic; effective against sucking insects.
Formothion	Anthio 25% EC/AF	Systemic insecticide cum acaricide
*Monocrotophos	*Nuvacron 40% EC/AF *Monocil 40% EC/AF Corphos 36% EC/AF Monophos 40% EC/AF JK Mono 36% Kadett 36% *Phoskill 36% Hillcron 36%	Systemic, persistent; long residual action; has ovicidal action. Under review by expert committee.
*Phosphamidon	*Dimecron 86% EC/AF Umecron 85% EC/AF JK Midon 85% EC/AF	Systemic with week contact toxicity; insecticide cum acaricide. Under review by expert committee.

*Phorate	*Timet 10% G *Phorate 10% G JK Phorate 10% G Umet 10% G	Systemic granular insecticide cum nematicide; for pest control in rice and banana.
*Trichlorfon	Dipterex 50% EC/AF	Useful only against chewing insects; contact action feeble.
Thiometon	Ekatin 25% EC/AF	Systematic; effective against sap sucking insects. Under review by experts committee.
*Chlorphyrifos	*Dursban 20% EC/AF	Effective against stem borers and gallfly. Useful for root dipping.
Phenthoate	Phendal 50% EC/AF Elsan 50% EC/AF Phendal 2% DP	Broad spectrum with ovicidal and larvicidal action.
Triazophos	Hostathion 40% Ec/AF	Effective against rice leaf folder Under review by expert committee
Acephate	Asataf 75 SP Starthene 75 SP	Effective against rice leaf folders

Chloronicotinyl		
Imidacloprid	Confidor 200 SL	Effective against brown plant hopper
Fungicides -Copper based products		
*Copper oxychloride	*Bliotox *Blue Copper 50 W Cuparmar Esso Fungicide Copper Fungimar Copper 50 W *Fytolan 50 W Starcop 50 W Killex Copper Fungicide 50 W	Foliar spray
Sulphur based products		
*Sulphur	Cosan *Esso Wetable Sulphur Thiovit 80 WP *Microsul 80% W	For foliar spray against powdery mildew. Also effective against mites.

Carbamates and others		
Ziram (zinc dimethyl dithio carbamate)	Cuman-Z 27% JK Ziram	Residual acting protective fungicide for foliar application. Under review of expert committee.
Zineb (zincethylene bisdithio-carbamate)	Dithance Z-78 Sandoz Zineb Zineb 75 Hexathane 75 W	Under review of expert committee.
*Thiram (tetramethyl thiuram disulphide)	*Thiride 75 WP Hexathir 75 W JK Thiram 75 W	For foliar spray, soil and seed treatment.
*Mancozeb (zinc ions and manganese ethylene bisdithiocarbamate)	*Dithame M-45 *Indofil M-45 Manzeb 75% WP Hilthane M-45 Uthane- M-45	Foliar fungicide

Organophosphorus compounds		
*Ediphenphos	*Hinosan H-Phos 50% EC	For control of blast and sheath blight, high volume spray recommended. To be reviewed by expert committee.
Chlorinated nitrobenzene		
Dinoocap	Karathane 25% WP 48 EC	For foliar spray for powdery mildew control of cucurbits and rose.
Heterocyclic nitrogen compounds		
*Captan	*Captan 75% WP Hexacap 75%WP	For seed treatment at 1.5 g per Kg seed
*Captafol	*Difolatan 80% Wp *Foltaf 80% WP	Shall be used only for seed dressing

Systemic fungicides

*Carbendazim	*Bavistin 50% WP B-Stin Bengard 50% WP JK Stein 50% WP *Zoom 50% WP	Effective against powdery mildew diseases in ornamental plants; and blast, sheath blight and sheath rot of rice.
Benamyl	Benlate 50%	Foliar fungicide for blast control in rice. Under review by expert committee.
Cabexin	Vitavax 80% WP Vitavax 75%	For seed treatment and for foliar application.
*Kitazin	*Kitazin-P 48 EC	For foliar spray against rice blast
Pyroquilon	Fongorene 50 WP	For seed treatment
Tricyclazole	Beam 75 WP	For seed treatment
*Hexaconazole	*Contaf 5 EC	For foliar spray against sheath blight
*Propeconazole	*Tilt 25 EC	For foliar spray against sheath blight
Potassium phosphopate	Akomin	Effective against phytophthora foot rot of pepper
*Tridmorph	*Calaxin 5%	Coconut stem bleeding
Antibiotics		
Antifungal materials	Aureofungin sol	For foliar spray
Antibacterial material	Agrimycin-100 Plantomycin Paushamycin Streptocycline	For foliar spray
Validacin 3L	Validamycin A 3%	Control sheath blight

Herbicides		
Selective herbicides		
*2,4 D sodium salt	*Femoxone 80% WSP	Rice- for control of broad leaved weeds
2,4 D amine	Agrodar 96-58% WSL	Do
2,4-D ethyl ester	Agrodon 34-48% EC	Do
Thiobencarb	Saturn 50% EC	Rice-dry sown and transplanted
Pendimethalin	Stomp 30% EC	Rice-dry sown and vegetables

Butachlor	Machete 50% EC Butachlor 50% EC	Rice-dry sown Rice-wet sown Rice transplanted
	Machete 5% G	Rice wet sown and transplanted
Oxyflourfen	Goal 23.5%	Rice-dry sown banana.
*Pretiachlor	*Refit 50% EC	Rice dry sown
*Pretilachlor + safener	*Sofit 30%	Rice- wet sown
Cyhalofop butyl	Clincher 10% EC	Rice-for control of *Echinochloa* sp.
Anilofos	Arozin 30% EC Aniloguard 30% EC	Rice transplanted
Diuron	Klass 80% WP	Banana Pineapple
Atrazine	Atrazine 50% WP	Sugarcane
Non-selective herbicides		
*Paraquat	*Gramoxone 20% EC	Rice-land preparation Plantation crops, pineapple and banana
*Glyphosate	*Roundup 41% SL Glycel 41% SL Weed all 41% SL Weed all 41% SL.	Rice-land preparation Plantation crops, pineapple and banana
(* = Pesticides used in the study areas), SP = Soluble powder; Dp = Dustable powder; G = Granules; EC = Emulsifiable concentrate; Af = Aqua flowable; W = wettable; WP = Wettable powder; S = Soluble concentrate; SL = Soluble liquid; WSP = Water soluble powder and WSL=Water soluble liquid).		

Appendix- 6.1 Heavy metal accumulation (ppm) in the tissues of different bird species							
Bird Species		Heart		Liver		Muscle	
	Metal	Mean	Std Deviation	Mean	Std Deviation	Mean	Std Deviation
Cattle Egret	Cadmium	.05	.09	.14	.15	.19	.33
	Chromium	.00	.00	.00	.00	.00	.00
	Copper	3.74	.47	2.62	2.14	2.22	1.87
	Lead	1.52	1.46	1.09	.32	.75	.66
	Zinc	17.33	2.65	17.14	7.25	8.28	5.16
Little Egret	Cadmium	.11	.10	.37	.34	.11	.13
	Chromium	.00	.00	.00	.00	.00	.00
	Copper	3.90	.40	7.01	3.25	3.34	.44
	Lead	3.42	2.87	3.12	3.56	1.44	.62
	Zinc	17.06	1.95	24.62	8.05	11.61	2.52
Pond Heron	Cadmium	.00	.00	.13	.17	.11	.18
	Chromium	.00	.00	.00	.00	.00	.00
	Copper	3.61	1.58	5.08	2.07	2.45	.59
	Lead	2.25	1.72	7.70	12.47	.53	.31
	Zinc	19.27	4.00	26.38	11.91	7.59	2.90

Appendix-6.2 Heavy metal accumulation (ppm) in the eggs of different bird species (Cd is BDL)					
Bird Species	Metal	Mean	Std Deviation	Maximum	Minimum
Pond Heron	Chromium	.00	.00	.00	.00
	Copper	2.05	1.51	4.83	.06
	Lead	.00	.00	.00	.00
	Zinc	14.24	11.08	35.12	1.85
Little Egret	Chromium	.00	.00	.00	.00
	Copper	3.41	2.81	10.00	.51
	Lead	.00	.00	.00	.00
	Zinc	28.20	28.69	90.91	.00

Appendix-6.3 Heavy metal accumulation in the eggs (ppm) of different bird species				
IDNo	Species	Cu	Zn	Pb
1	Pond Heron	0.06	1.85	.00
4	Little Egret	0.66	7.97	.00
5	Little Egret	3.24	28.17	.00
6	Little Egret	2.98	0.00	.00
7	Little Egret	6.68	58.53	.00
9	Pond Heron	4.83	35.12	.00

10	Pond Heron	2.54	17.60	.00
11	Pond Heron	2.06	20.50	.00
12	Pond Heron	0.86	7.66	.00
13	Pond Heron	0.71	6.69	.00
14	Pond Heron	1.28	3.66	.00
15	Pond Heron	2.49	10.21	.00
16	Pond Heron	3.58	24.88	.00
17	Little Egret	1.88	26.97	.00
18	Little Egret	4.15	17.21	.00
19	Little Egret	2.27	27.00	.00
20	Little Egret	10.00	73.08	.00
21	Little Egret	1.30	90.91	.00
22	Little Egret	0.51	10.83	.00
23	Little Egret	3.80	5.10	.00
24	Little Egret	0.00	20.88	.00
25	Little Egret	0.00	0.00	.00
* Value for Cd and Cr is also BDL				