BEHAVIOUR AND ADAPTATIONS OF LITTLE CORMORANT PHALACROCORAX NIGER AND DARTER ANHINGA MELANOGASTER

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IN ZOOLOGY

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CERTIFICATE

This is to certify that, this thesis entitled **"Behaviour and Adaptations of Little Cormorant *Phalacrocorax niger* and Darter *Anhinga melanogaster*"** is an authentic record of the research work carried out by Mrs. Zeenath Chozhiyattel, M.Sc., M.Phil., under the supervision and guidance of Dr. V.J. Zacharias and myself in partial fulfilment of the requirements for the degree of Doctor of Philosophy, under the Faculty of Science of the University of Calicut. Neither this thesis nor any part of the same has been presented before for the award of any degree or diploma.

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DECLARATION

I, **Zeenath Chozhiyattel**, hereby declare that this thesis entitled **"Behaviour and Adaptations of Little Cormorant *Phalacrocorax niger* and Darter *Anhinga melanogaster*"** submitted by me to the University of Calicut, in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Zoology is an authentic record of original research work done by me. The research was carried out under the supervision and guidance of Dr. V.J. Zacharias, (Rtd.) Head, Dept. of Zoology, St. Joseph's College, Devagiri and Dr. Sabu K. Thomas, Reader, Dept. of Zoology, St. Joseph's College, Devagiri, Calicut. It is further declared that this has not previously formed the basis for the award of any degree or diploma in any University.

Devagiri (Calicut),
14.01.2009.

Zeenath Chozhiyattel

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Chapter 1

GENERAL INTRODUCTION

GENERAL INTRODUCTION

Cormorants and Darters are diving birds with similarities in behaviour patterns. Both the groups feed mostly on fishes. Cormorants chase and capture the prey often solitarily, but occasionally in flocks also. Darters are individualistic in catching their prey (Ali, 1968) and does not hunt in co-operative bands (Ali and Ripley, 1983). A well known characteristic of these two groups is their habit of spreading their wings to the sun or breeze after a period in the water, a feature commonly referred to as "wing drying" (Rijke, 1968) or spread-winged behaviour (Henneman, 1984). Peters (1931) placed them in separate families: darters come under Anhingidae and cormorants belong to Phalacrocoracidae – both under the order Pelecaniformes (Van Tets, 1965; Grzimek, 1990).

Members of both Anhingidae and Phalacrocoracidae are characterized by long necks and mandibles, totipalmate feet, largely black and are found in similar habitats (Owre, 1967). Cormorants exhibit a far greater degree of specialization for active pursuit of fish than Anhingas. Further, their pelvic appendages are modified for powerful and rapid swimming and the skull is adapted for powerful prehension. Darters are adapted for slow prowling progression under water. Prey is approached by stealth and pierced with a thrust of the mandibles.

Cormorants have a cosmopolitan distribution all over the world while Darters are confined to South and Southeast Asia, Africa, America and Australia (Grzimek, 1990). The family Phalacrocoracidae consists of thirty seven species and Anhingidae four species (Kumar *et al*., 2005). There are three species of cormorants in the Indian Peninsula, the Little Cormorant, *Phalacrocorax niger* (Vieillot), the Indian Cormorant, *P. fuscicollis* (Stephens) and the Great Cormorant, *P. carbo* (Linnaeus) (Grimmet *et al*., 1998). Of these the first two species occur in tanks and rivers with sand banks, deep pools and rocks (Ali and Ripley, 1983) and the latter in coastal waters, reservoirs and large inland lakes and rivers. Little Cormorant, one of the most common aquatic birds in Kerala also occur in most of the wetland habitats including paddy fields. Darter, *Anhinga melanogaster* (Pennant) is the only representative of the group in India. It inhabits open placid streams, village tanks and dammed reservoirs (Ali, 1968). It also inhabits shallow inland wetlands including lakes, rivers, swamps, and reservoirs as well as estuaries, tidal inlets, mangroves and coastal lagoons (Kumar *et al*., 2005). The species has been declining in numbers in Kerala.

In his classical work, Owre (1967) has attempted to relate the morphology of the Double-crested Cormorant, *P. auritus* and American Darter, *Anhinga anhinga* to the function and ecology of the two species. Feeding ecology and buoyancy constraints of Darter, *A. melanogaster* have been documented by Donnelly and Hustler (1986) and Hustler (1992).

The important works on various cormorant species include the behaviour of Double-crested Cormorant, *Phalacrocorax auritus* and Flightless Cormorant, *P. harrisi* (Hennemann, 1984), the activity pattern of Blue eyed Shag, *P. atriceps bransfieldensis* (Berstein and Maxson, 1984), the energy requirements of Great Cormorant, *P. carbo sinensis* (Gremillet *et al*., 2001), and daily food requirements of Great Cormorant (Gremillet *et al*., 2003). Many studies have been carried out on the foraging behaviour of cormorants. They include comparative account of diving and recovery periods (Williams and Cooper, 1983), comparison of diving periods of different species (Cooper, 1986), foraging behaviour of Rock Shag *P. magellanicus* (Quintana, 2001), diving patterns of Antarctic Shag, *P. bransfieldensis* (Croxall *et al*., 1991), feeding performance of Red-legged Cormorant, *P. gaimardi* (Gandini *et al*., 2005), foraging behaviour of Imperial Cormorant, *P. atriceps* (Sapoznikow and Quintana, 2003), diving behaviour of Red-legged Cormorant, *P. gaimardi* (Frere *et al*., 2002), foraging location and site fidelity of Double-crested Cormorant, *P. auritus* (Coleman *et al*., 2005) and foraging behaviour of Japanese Cormorant, *P. filamentosus* (Watanuki *et al*., 2004).

Influence of environmental variables upon the diving behaviour of Red-legged Cormorants are also documented (Frere *et al*., 2002; Gandini *et al*., 2005). Solitary and flock feeding of cormorants were reported by Bernstein and Maxson (1985), Watanuki *et al*. (2004) and Casaux (2004).

Recent studies show flexibility in the foraging behaviour of cormorants and they may use different foraging tactics to exploit the prey to the maximum (Wanless *et al*., 1998; Watanuki *et al*., 2004).

Anhinga melanogaster is a near threatened species of wetland birds. It is primarily threatened due to habitat loss, disturbances, hunting and pollution at feeding grounds and nesting sites (Birdlife International, 2001; Grewal *et al*., 2002; Pande, 2003). The species is generally uncommon and declining throughout Asia with an estimated number of 4000 for South Asia (Kumar *et al*., 2005). According to Asian Waterbird Census report, only 482 Darters (*A. melanogaster*) have been recorded from India (Rahmani, 2002). Earlier, Darters, *A. melanogaster* were common in all freshwater lakes of Kerala (Whistler and Kinnear, 1938). However, in recent years their number is decreasing while that of the Little and Great Cormorants have been increasing (Jafer *et al*., 1997; Zacharias and Gaston, 2004).

The information available about Little Cormorant, *P. niger* and Darter, *A. melanogaster* are from the natural history notes of earlier observers like Baker (1923), Whistler and Kinnear (1938) and Ali and Ripley (1983). In addition, short accounts on the food habits of Little Cormorant during breeding season is also documented (Sengupta and Brahmachary, 1968). Forbes (1882) has described certain aspects of the anatomy of Darter, *A. melanogaster*.

Neelakantan (1958) had reported the occurrence of Darters, *A. melanogaster,* but no cormorants around the Malampuzha reservoir in the Palakkad District of Kerala in 1950s. However, recent years the number of Darters, *A. melanogaster* have decreased considerably and Little and Great Cormorants are also there in and around the reservoir (Zacharias pers. com.). The recovery of Russian-ringed Large Cormorant at Calcutta (Abdulali, 1976) provides valuable information on the migratory movement of the species. This behaviour is an interesting problem for further investigation. The Little and Great Cormorants have been increasing all over Kerala. Both these species are found colonizing new areas and are in conflict with human beings in some parts of South India (Balakrishnan and Thomas, 2004). The cormorants are blamed for stealing fishes from fish farms. Around their roost and nest sites in rubber plantations, the droppings of Little Cormorants are known to damage rubber latex (Dr. Zacharias pers. comm.).

In many parts of Asia and Africa, cormorants are used for sport fishing as well as to meet human food requirements. They are kept in cages and the tamed birds are used to catch fishes. They are fitted with a collar to prevent them from swallowing their prey and are forced to deliver it to their masters (Grzimek, 1990). Stonor (1948) has narrated an interesting incident of a party of 12 men carrying tamed Darters, *A. melanoagster* on bamboo yokes on shoulders in North Assam, for catching fish. He has also mentioned that

Little Cormorants and Darters were used to catch fish in Logtak Lake in Manipur State.

No detailed studies have been conducted so far on cormorants and darters in the Indian subcontinent and no information is available on the biology, ecology and behaviour of Little Cormorant, *P. niger* and Darter, *A. melanogaster*. A comparative study is hence undertaken on these two species of aquatic birds.

1.1 Objectives

Present study has been undertaken with the objectives of analysing the following aspects of Little Cormorant, *P. niger* and Darter, *A. melanogster*.

1. Analysis of the population trend during premonsoon, monsoon and postmonsoon seasons.

2. Documentation of the general habits and activity pattern.

3. Study of the foraging behaviour and diving pattern.

4. Understanding the breeding biology and associated behaviours.

5. Comparison of the thermoregulatory adaptations of the birds and the morphological and functional adaptation of the feather.

Data generated by the current effort is expected to provide a broad idea about the general behaviour patterns and adaptations to seasonal variations and climatic conditions. The study also aims to reveal the structural and functional adaptations of the feathers. The findings would be helpful to plan the management programme for both the species and their habitats.

Chapter 2

STUDY AREA

STUDY AREA

2.1 Introduction

A preliminary survey of waterbirds of North Kerala wetlands initiated by the Kerala Forest and Wildlife Department and the Malabar Natural History Society revealed the abundance of birds in the Kadalundy estuary and Kalpally-Palliyol wetland (Sashikumar, 2005). Kallampara river near Kadalundy Bird Sanctuary also supports a notable population of Little Cormorant and other wetland birds. Similarly Kalpally-Palliyol wetland is home for about 58 species of wetland birds (Sashikumar, 2005) including migratory birds and globally threatened species like Darter. Since the above mentioned areas have a notable population of Little Cormorants and Darters, those sites were selected for intensive study.

During breeding season wetland birds including common as well as threatened forms usually establish their nesting colonies in and around human habitation (Subramanya, 1996). The heronry of Ramanattukara town, Kozhikode district is a mixed breeding colony where Night Heron, Pond Heron and Little Cormorant co-exist. It is an appropriate nesting site to study breeding behaviour of Little Cormorant. Mangalavanam mangrove of Ernakulam district is a protected area where Darters, *A. melanogaster* and other wetland birds breed (Jayson, 2001). In this context Ramanattukara heronry and Mangalavanam mangrove were selected for studying the breeding behaviour of Little Cormorant and Darter.

Wetland habitats near Ramanattukara, that act as feeding grounds for the nesting birds were also studied. Heronries in the nearby areas were also visited to collect information on the breeding activities (Appendix I).

2.2 Climate and rainfall

Climatic data of Kozhikode and Kochi was collected from India Meteorological Department, Thiruvananthapuram.

Kozhikode

As evident from Table 2.1 & Fig. 2.1 during the study period (2004-2006) maximal temperature was recorded during March to May while it was minimum during December.

The study area obtained heavy rainfall during Southwest Monsoon (Table 2.3). During the study period, the study sites received rain from April onwards. Maximum rain (864.6 mm) was in May during 2004, in June during both 2005 (697.7 mm) and 2006 (98.46 mm). Northeast Monsoon occurs from October to January.

Kochi

The temperature was maximum during April and May while the minimum temperature was recorded in December and January (Table 2.2, Fig. 2.2).

Southwest Monsoon was the heaviest (884.6 mm) in May during 2004, in June during 2005 (792.5 mm) and 2006 (671.8ºC) (Table 2.3).

2.3 Depth profile

Depth profiles of two feeding locations of each of the two study area (Kallampara & Kalpally-Palliyol) were taken every month during 2005 and 2006. The mean values are presented in Table 2.4. At Kallampara site, the water level was highest (400 cm) in June and (435 cm) July during 2005 and 2006 respectively and lowest (110, 130 cm) in March during both the years. At Kalpally-Palliyol wetland, maximum depth was recorded in June (440 cm and 480 cm) and minimum in March (150 cm and 185 cm) during 2005 and 2006 respectively (Fig. 2.3).

2.4 Study sites

2.4.1 Kallampara river site

Kallampara river (11º09' 25.5" N, 075º 51' 02.0"E) near Kadalundy Bird Sanctuary is a tributary of Chaliyar river that joins the Arabian Sea near

Beypore. It is located in the Feroke Panchayat of Kozhikode District, Kerala, South India (Plate I & II). It is also connected to Kadalundy river on the western side and is subjected to regular tidal influx and attracts a wide variety of wetland birds. Mangroves of the river bank act as perching site for foraging birds. The river bed gets exposed during low tide and serves as an ideal habitat for waders. The area under study extends upto 15 hectares.

Vegetation

The bank of Kallampara river is covered with scattered patches of mangroves (Plate V). A large stretch of mangrove is present near the middle of the river. The major mangrove species are *Avicennia officinalis, Excoecaria agallocha* and *Acanthus ilicifolius*. The floating vegetation include *Salvinia molesta*. An algal species *Enteromorpha* is also present in large numbers. The other plant species recorded from Kallampara include *Connarus monocarpus, Sphaeranthus indica, Derris trifoliata, Eclipta prostrata, Hibiscus tiliaceus, Mariscus javanicus, Ipomoea pescapra* and *Premna latifolia* (Table 2.5).

Avifauna

The birds recorded from this region are Redshank, Common Sandpiper, Little Ringed Plover, Little Egret, Large Egret, Cattle Egret, Pond Heron, Grey heron, Little Cormorant, Brahminy Kite, Pariah Kite, White breasted Waterhen, Night Heron, Pied Kingfisher, White-breasted Kingfisher and Little Blue Kingfisher (Appendix II A). Birds were identified, following Ali (2002) and Grimmett *et al*. (1998).

Fish fauna

Fish diversity of Kallampara river was high during the study period (Table 2.7). About 27 species of fishes were sampled and identified from the river. Fish samples were collected every month and the data were analysed for seasonal abundance (represented as monthly percentage). Maximum fish abundance was recorded during November in 2004 (12.67%) and 2006 (12.03%) and during December in 2005 (12.14%). Minimum value was recorded during April in 2004 (3.31%) and 2006 (3.51%) and during May in 2005 (3.47%) (Table 2.8). Fish abundance was greater in 2006 (total 399) than in 2004 (total 363) and in 2005 (total 346). During the premonsoon season, fish abundance was lesser compared to the monsoon and postmonsoon (Fig. 2.4). Fishes were identified following Kottelat *et al*. (1993).

Other aquatic organisms

Among crustaceans the *Penaeus* sps. was maximum (Family Penaeidae). Prawn samples were collected every month. The data were pooled and seasonal abundance was calculated. Prawn (*Penaeus* sps.) abundance was maximum during March in 2004 (22.31%), 2005 (23.32%) and 2006 (24.91%) (Table 2.9). Minimum number was found in July and

August. *Macrobrachium* sps. (about 159) could also be collected. Others included neries (Phylum Annelida) and a few crab species. *Penaeus* species was abundant during premonsoon season than monsoon and postmonsoon (Fig. 2.5).

2.4.2 Kalpally-Palliyol wetland (Mavoor Vayal)

Kalpally-Palliyol wetland (11º15'36.24"N 75º56'26.12"E) is located towards the North-West side of Mavoor town in the Mavoor Grama Panchayat, Kozhikode district, Kerala, South India (Plate I & II). It is a large wetland that attracts both migratory and resident birds. It is also called Mavoor Vayal and was a paddy field till 2000. When Kavanakkallu Regulator cum Bridge was built across Chaliyar, the paddy fields of Kalpally-Palliyol region got inundated and water logged. Now it is permanently water-logged with muddy banks and vegetation. The wetland is transected by Kozhikode-Mavoor Road. Mavoor-Kunnamangalam Road passes across the Western border and Kanniparamba Road across the Eastern border. Towards the Northern side, the wetland is crossed by a pipeline road. The area under study extends upto 50 hectares.

Vegetation

The wetland is endowed with rich diversity of plants which include floating, submerged and emergent vegetation (Table 2.10). Abundance of vegetation reduces open water available for diving birds. The free floating plants are *Eichornia crassipes, Salvinia molesta* and *Azolla pinnata*. The important submerged plants are *Vallisneria nattans, Hygrophila salcifolia, Eclipta prostrata* and *Potamogeteon pectinatus*. The rooted floating plants provide substratum for certain groups of waterbirds like jacanas. The important rooted floating plants are *Nymphaea nouchali, Nymphaea amarana* and *Nymphoides hydrophilla*. Emergent group include about 5 species. Amphibious grasses grow heavily just after rainy season and reduce open water availability (Plate VI).

Avifauna

Kalpally-Palliyol wetland is the home for large number of bird species including both migratory and resident birds (Appendix II B). The important migratory birds belong to the Family Anatidae. They were Garganey, Cotton Teal and Common Teal. Sandpipers and plovers were also observed. Open-billed stork was found almost throughout the year except June and July. Darter, *A. melanogaster* - a globally threatened species, was frequently found. Wetland dependent species belonging to the families Alcedinidae (Kingfishers), Meropidae (Bee-eaters), Hirundinidae (Swallows), Motacillidae (Wagtails and Pipits) and Ploceinae (Weavers) were also well represented in this wetland. Waders are also well represented.

Fish fauna

The major fishes recorded from Kalpally-Palliyol wetland were *Aplocheilus blochii, Aplocheilus lineatus, Macropodus cupanus, Puntius mahecola, Puntius vittatus* and *Channa orientalis* (Table 2.11). The wetland act as a breeding ground for these fishes during monsoon season.

Other aquatic organisms

Frogs, mainly belonging to *Hoplobatrachus* species breed here during monsoon season. Tadpoles contribute to the food of carnivorous birds like Cormorants and Darters. Invertebrates include aquatic insects, crabs, prawns (*Palaemon* species) and snails. Different species of Dragon flies and Damsel flies and their larvae were also present. Snails include *Bellamya*, *Indoplanorbis*, *Gyralis* and *Limnae* species.

2.4.3 Ramanattukara heronry

Ramanattukara town (11º10'38.06" N 75º52'1.97"E) is located in Kozhikode District, Kerala, South India (Plate I & II). The heronry was situated in the middle of Ramanattukara town, on either side of National Highway in a grove of trees (Table 2.12). The nesting species were Little Cormorant, Pond Heron and Night Heron. Nests were built on 12 trees and the height of which ranged between 10 to 20 metres. The major trees used for nest building were *Samanea saman, Artocarpus heterophyllus, Mangifera* *indica, Alstonia scholaris, Ficus religiosa, Tamarindus indica, Terminalia catappa, Syzygium cumini, Bombax ceiba, Delonix regia, Peltophorum pterocarpum, Lagerstroemia speciosa* and *Careya arborea*.

The trees which were utilized as source of nest materials include *Strychnos nuxvomica, Mimusops ilanchi, Anacardium occidentale, Acacia auriculiformis, Tectona grandis* etc. The heronry was located close to human habitation (Plate VII) and extends upto one kilometre.

Feeding locations near Ramanattukara heronry

Wetlands near Ramanattukara heronry was utilized by the nesting birds as feeding sites during the breeding season. The major wetlands are Azhinjilam (30 hectares), Thottungal Kadavu, inundated paddy fields at Pulikkal, inundated lowlands at Ayikkarappadi and Chellipadam, Muttiara canal and Jheel at Feroke Chungam.

2.4.4 Mangalavanam mangrove

Mangalavanam is situated in Ernakulam district (Plate III & IV) of Kerala (9°59'15.15"N 76°16'25.51"E). The study area is in Ernakulam city and the total extent is 8.44 hectares and it is declared as a Bird Sanctuary in 2004 (Plate VII). The northern and eastern part is bordered by Bharath Petroleum Company, south by Ernakulam Railway goods station, west by Salim Ali road and Central Marine Fisheries Research Institute.

Mangalavanam is a small mangrove area comprising of a shallow tidal lake in the centre with its edges covered with thick vegetation. This water body is connected with backwaters by a canal. In the middle of the lake, there is a small island with mangrove growth. Mangalavanam gained importance due to the mangrove vegetation and congregation of communally breeding birds. Prominent species of mangroves are *Avicennia officinalis*, *Rhizophora mucronata* and *Acanthus ilicifolius*. Exotic species like Eucalyptus is also planted in the area. Other plant species are *Samanea saman*, *Terminalia catappa*, *Alstonia scholaris* and *Caryota urens* (Table 2.6).

Table 2.1. Monthly mean minimum and maximum temperature (ºC) in Kozhikode (2004, 2005 & 2006)

Month	Monthly mean temperature (ºC)					
	2004		2005		2006	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Jan	23.0	32.6	23.6	32.5	23.3	32.8
Feb	24.1	33.2	23.9	33.0	23.0	33.0
Mar	26.2	34.0	25.8	33.7	25.3	33.9
Apr	26.4	34.0	26.0	33.8	27.0	34.2
May	24.7	31.1	27.3	34.1	25.7	32.2
Jun	24.2	30.6	24.6	31.0	24.4	30.5
Jul	24.0	29.7	24.1	29.2	23.9	30.3
Aug	23.6	29.5	24.2	30.1	23.9	30.0
Sep	24.2	30.7	24.2	30.1	23.9	29.8
Oct	24.4	31.4	24.3	31.2	24.4	31.5
Nov	24.1	32.6	24.1	31.5	24.5	31.7
Dec	22.3	32.8	23.4	32.0	22.3	32.6

Fig. 2.1. Monthly minimum and maximum temperature (mean) in Kozhikode

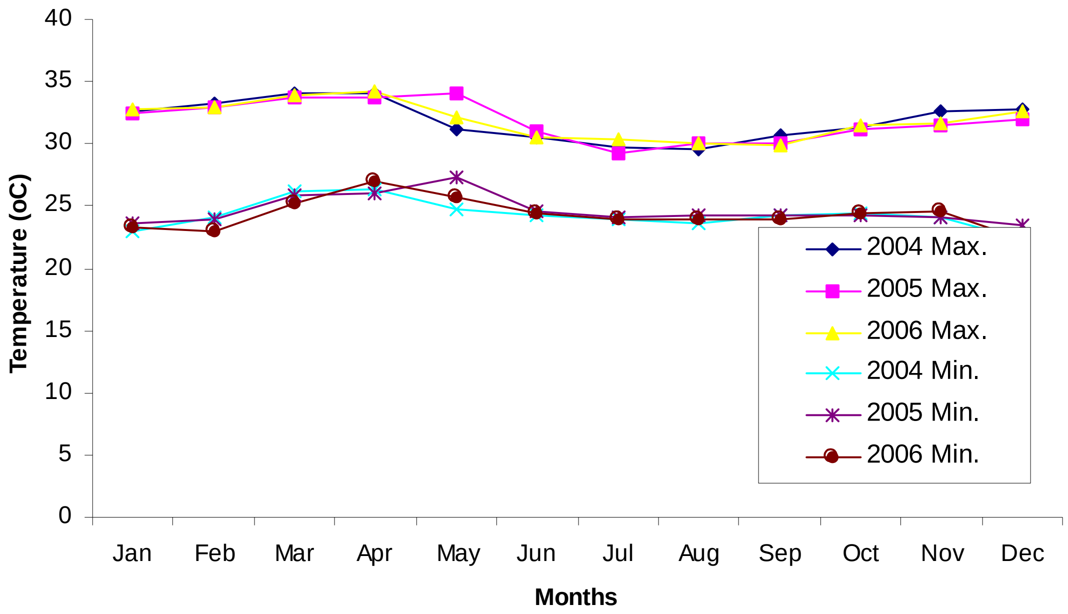


Table 2.2. Monthly mean minimum and maximum temperature (ºC) in Kochi (2004, 2005 & 2006)

Month	Monthly mean temperature (ºC)					
	2004		2005		2006	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Jan	23.3	31.6	23.7	31.5	23.5	31.2
Feb	24.6	32.1	24.2	32.0	23.4	31.8
Mar	26.3	33.1	26.1	32.7	25.3	32.3
Apr	26.4	33.6	25.7	32.7	26.4	32.7
May	24.7	30.7	26.2	32.9	25.3	31.8
Jun	24.7	30.0	24.2	30.2	24.6	30.7
Jul	24.2	29.4	23.9	29.4	24.2	30.1
Aug	24.3	29.3	24.4	30.3	23.8	29.6
Sep	24.5	30.1	24.4	29.6	23.8	29.8
Oct	24.5	31.0	24.4	30.6	23.9	30.4
Nov	24.1	31.7	24.2	30.4	23.8	31.2
Dec	22.9	31.7	23.9	30.7	23.0	32.4

Fig. 2.2. Monthly minimum and maximum temperature (mean) in Kochi

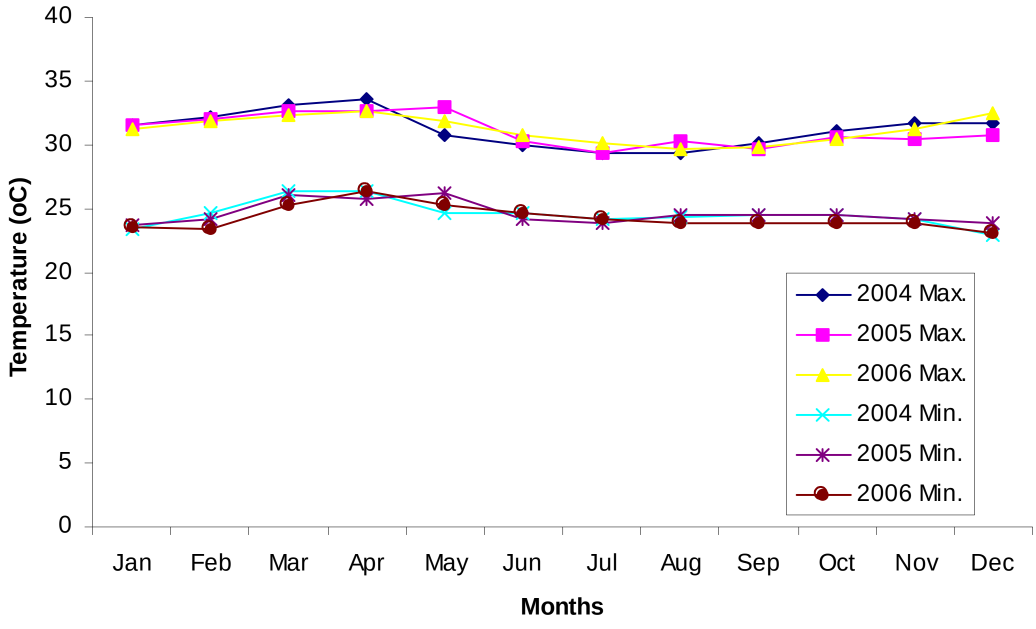


Table 2.3. Monthly rainfall (mm) recorded at Kozhikode and Kochi during 2004, 2005 & 2006

Month	Kozhikode			Kochi		
	2004	2005	2006	2004	2050	2006
January	1.8	18.3	0.0	9.6	93.7	4.7
February	0.4	0.0	0.0	29.0	1.4	0.0
March	2.8	0.0	14.5	12.3	17.0	87.9
April	97.6	56.3	20.8	85.3	254.4	52.7
May	864.6	56.1	636.7	884.6	156.5	576.4
June	850.6	697.7	984.6	556.9	792.5	671.8
July	370.9	610.9	600.7	421.5	550.2	596.8
August	428.8	207.6	531.9	276.7	281.6	475.5
September	125.8	334.9	707.0	202.0	390.7	449.8
October	309.9	190.7	331.6	623.2	448.7	545.5
November	131.0	180.0	99.6	198.8	230.7	198.6
December	0.4	17.7	0.0	0.0	38.5	0.0

Source: India Meteorological Department, Thiruvananthapuram.

Table 2.4. Monthly Fluctuations in Water Depth

Month	Water depth (cm)			
	Kalpally		Kallampara	
	2005	**2006**	**2005**	**2006**
January	290	255	175	215
February	165	195	165	150
March	150	185	110	130
April	200	280	215	230
May	250	400	280	320
June	440	480	400	425
July	435	465	385	435
August	415	425	360	400
September	400	415	350	395
October	395	375	315	325
November	390	350	300	300
December	340	300	265	285

Fig. 2.3. Monthly fluctuations in water depth

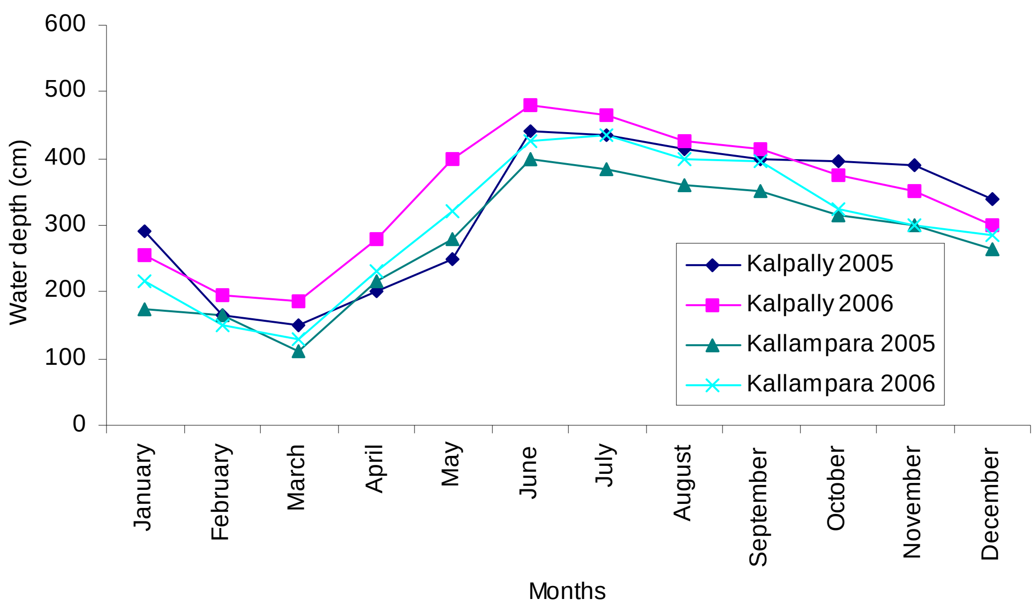


Table 2.5. Prominent Vegetation of Kallampara river site

Sl. No.	Family	Scientific name	Category
1.	Avicenniaceae	*Avicennia officinalis*	Mangrove
2.	Euphorbiaceae	*Excoecaria agallocha*	Mangrove
3.	Acanthaceae	*Acanthus ilicifolius*	Mangrove
4.	Connaraceae	*Connarus monocarpus*	Wetland herb
5.	Asteraceae	*Sphaeranthus indicus*	Woody climber
6.	Fabaceae	*Derris trifoliata*	Mangrove associate
7.	Compositae	*Eclipta prostrata*	"
8.	Malvaceae	*Hibiscus tiliaceus*	"
9.	Cyperaceae	*Mariscus javanicus*	Emergent grass
10.	Convolvulaceae	*Ipomoea pescaprae*	Grass
11.	Verbenaceae	*Premna latifolia*	Mangrove associate

Table 2.6. Prominent plants of Mangalavanam

Sl. No.	Family	Scientific name	Common local name
1.	Avicenniaceae	*Avicennia officinalis*	Uppatti
2.	Rhizophoraceae	*Rhizophora mucronata*	Pranthan kandal
3.	Acanthaceae	*Acanthus ilicifolius*	Chullikandal
4.	Mimosaceae	*Samanea saman*	Rain tree
5.	Combretaceae	*Terminalia catappa*	Badam
6.	Apocynaceae	*Alstonia scholaris*	Ezhilampala
7.	Palmaceae	*Caryota urens*	Toddy palm
8.	Mimosaceae	*Acacia auriculiformis*	Acacia

Table 2.7. Fish fauna of Kallampara river

Sl. No.	Scientific name	Common malayalam name	Family	Order
1.	*Etroplus maculatus* (Bloch)	Pallathi	Cichlidae	Perciformes
2.	*Etroplus suratensis* (Bloch)	Karimeen	Cichlidae	"
3.	*Scatophagus argus* (Linnaeus)	Chutichi	Scatophagidae	"
4.	*Terapon jarbua*	Keechan	Teraponidae	"
5.	*Gerres filamentosus* (Cuvier)	Pranjil	Gerreidae	"
6.	*Gerres acinaces* (Cuvier)	Pranjil	Gerreidae	"
7.	*Glossogobius giuris* (Hamilton Buchanan)	Poolon	Gobiidae	"
8.	*Ambassis commersoni* (Cuvier)	--	Ambassidae	"
9.	*Ambassis dussumeri*	--	Ambassidae	"
10.	*Lutjanus argentimaculatus*	--	Lutjanidae	"
11.	*Siganus guttatus*		Siganidae	"
12.	*Mystus gulio (Hamilton – Buchanan)*	Chillankoori	Bagridae	Siluriformes
13.	*Mystus oculatus* (Valenciennes)	Chillankoori	Bagridae	Siluriformes
14.	*Arius arius*	Etta	Ariidae	"
15.	*Triachanthus blochii* (Schiegel)	--	Triacanthidae	Tetradontiformes
16.	*Chelonodon patoca* (Hamilton – Buchanan)	--	Tetradontidae	Tetradontiformes

Sl. No.	Scientific name	Common malayalam name	Family	Order
17.	*Puntius mahecola* (Valenciennes)	Paral	Cyprinidae	Cypriniformes
18.	*Aplocheilus lineatus* (Valenciennes)	Manathukanni	Aplocheilidae	Cyprinodontiformes
19.	*Cyanoglossus punticeps* (Richardson)	Nangu	Bothidae	Pleuronectiformes
20.	*Thryssa hamiltoni*	--	Eugrolidae	Clupeiformes
21.	*Amblypharyngodon melettina* (Valenciennes)	Vayambu	Cyprinidae	Cypriniformes
22.	*Euryglossa orientalis* (Bloch & Schneider)	--	Solidae	Pleuronectiformes
23.	*Monodactylus argenteus*	--	Monodactylidae	Perciformes
24.	*Strongylura strongylura*	Koli	Belonidae	Cyprinodontiformes
25.	*Aplocheilus blockii*	Manathukanni	Aplocheilidae	Cyprinodontiformes
26.	*Mugil cephalus (Linnaeus)*	Thirutha	Mugilidae	Perciformes
27.	*Danio malabricus* (Jerdon)	--	Cyprinidae	Cypriniformes

Table 2.8. Seasonal abundance of fish during 2004, 2005 and 2006 at Kallampara river

Month	Fish abundance of Kallampara river (%)		
	2004	2005	2006
January	7.16	6.36	8.02
February	6.34	5.20	7.02
March	7.99	6.94	7.77
April	3.31	5.20	3.51
May	4.41	3.47	4.76
June	8.26	8.09	8.02
July	8.82	8.96	9.02
August	9.64	9.83	9.77
September	11.02	10.98	10.53
October	12.12	11.27	11.53
November	12.67	11.56	12.03
December	8.26	12.14	8.02

Fig. 2.4. Seasonal abundance (%) of fish at Kallampara river

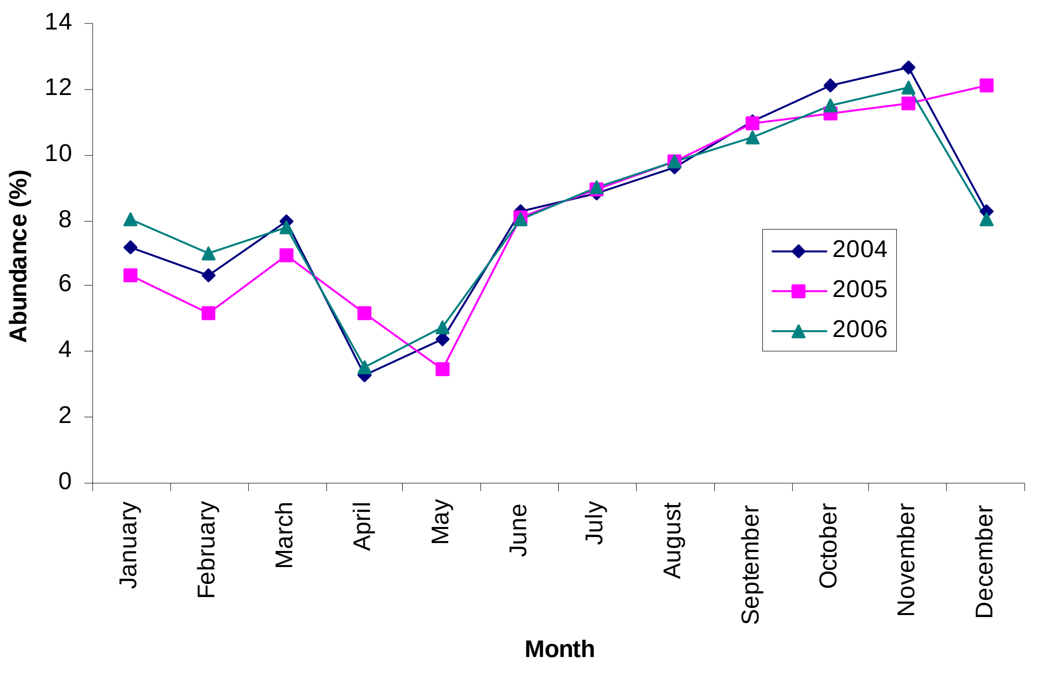


Table 2.9. Seasonal abundance of prawn during 2004, 2005 and 2006 at Kallampara river

Month	Prawn abundance of Kallampara River (%)		
	2004	**2005**	**2006**
January	10.76	9.44	11.36
February	13.85	14.59	15.38
March	22.31	22.32	24.91
April	18.46	18.88	18.68
May	10.00	10.30	9.16
June	3.85	3.43	2.93
July	1.15	1.29	1.09
August	1.54	1.72	1.47
September	1.92	3.00	2.20
October	5.00	5.15	4.40
November	5.38	3.86	3.30
December	5.77	6.00	5.13

Fig. 2.5. Seasonal abundance (%) of prawn at Kallampara river

Table 2.10. Major Plants of Kalpally-Palliyol wetland

Sl.. No.	Family	Scientific name	Category
1.	Pontederiaceae	*Eichhornia crassipes*	Floating
2.	Salviniaceae	*Salvinia molusta*	"
3.	Hydrocharitaceae	*Hydrilla verticellata*	Submerged
4.	Hydrocharitaceae	*Vallisneria natans*	Submerged
5.	Acanthaceae	*Hygrophila salcifolia*	"
6.	Asteraceae	*Eclipta prostrata*	"
7.	Potamogetonaceae	*Potamogeton pectinatus*	Submerged
8.	Lentibularaceae	*Utricularia gibba*	Rooted floating
9.	Nymphaeaceae	*Nymphaea nouchali*	"
10.	Nymphaeaceae	*Nymphaea omarana*	"
11.	Menyanthaceae	*Nymphoides hydrophylla*	"
12.	Cyperaceae	*Cyperus exaltatus*	Emergent
13.	"	*Fimbristylis mileacea*	Emergent
14.	Poaceae	*Panicum ripens*	"
15.	Poaceae	*Oryza granulata*	"
16.	Poaceae	*Hygroryza aristata*	"
17.	Poaceae	*Paspalum scrobiculatum*	Amphibious grass
18.	Poaceae	*Ischaemum indicum*	Grass
19.	Poaceae	*Ipomoea aquatica*	Amphibious grass
20.	Azollaceae	*Azolla pinnata*	Floating

Table 2.11. Fish fauna of Kalpally-Palliyol wetland

Sl. No.	Scientific name	Common malayalam name	Family	Order
1.	*Aplocheilus blockii*	Manathukanni	Aplocheilidae	Cyprinodontiformes
2.	*Aplocheilus lineatus* (Valenciennes)	Manathukanni	Aplocheilidae	Cyprinodontiformes
3.	*Macropodus cupanus* (Valenciennes)	--	Belontidae	Perciformes
4.	*Puntius mahecola* (Valenciennes)	Paral	Cyprinidae	Cypriniformes
5.	*Puntius vittatus*	Paral	Cyprinidae	Cypriniformes
6.	*Channa orientalis*	Murrel	Channidae	Perciformes
7.	*Heteropneustis fossilis*	Mushi	Heteropneustidae	Cyluriformes

Table 2.12. Major trees of Ramanattukara heronry

Sl. No.	Family	Scientific name	Common name
1.	Mimosaceae	*Samanea saman*	Rain tree
2.	Sapotaceae	*Mimusops ilanchi*	Ilanchi
3.	Euphorbiaceae	*Bombax ceiba*	Red cotton silk tree
4.	Anacardiaceae	*Anacardium occidentale*	Cashew
5.	Anacardiaceae	*Mangifera indica*	Mango tree
6.	Caesalpineaceae	*Tamarindus indica*	Tamarind
7.	Mystaceae	*Syzgium cumini*	Njaval
8.	Mimosaceae	*Acacia auriculiformis*	Acacia
9.	Verbenaceae	*Tectona grandis*	Teak
10.	Moraceae	*Artocarpus heterophyllus*	Jack tree
11.	Loranthaceae	*Loranthus intermedius*	Loranthus
12.	Caesalpineaceae	*Delonix regia*	Gulmohar
13.	Lythraceae	*Lagerstroemia speciosa*	Manimaruthu
14.	Apocynaceae	*Alstonia scholaris*	Ezhilampala
15.	Caesalpineaceae	*Peltophorum pterocarpum*	Copper pod
16.	Moraceae	*Ficus religiosa*	Banyan tree
17.	Combretaceae	*Terminalia catappa*	Badam
18.	Loganiaceae	*Strychnos nuxvomica*	Kanhiram
19.	Lecythidaceae	*Careya arborea*	Pezhu

Chapter 3

ABUNDANCE AND SEASONALITY OF LITTLE CORMORANT AND DARTER

ABUNDANCE AND SEASONALITY OF LITTLE CORMORANT AND DARTER

3.1 Introduction

Study of population trends is vital for conservation programmes in the case of both rare as well as common species. This helps in identifying the potential problems. Wetland birds have been cited as important indicators of the health of the wetland environment itself (Kushlan, 1993). Long term declines in the wetland bird numbers may be symptomatic of changes in the food supply, pollution, interspecific interactions or other environmental problems (Furness and Camphuysen, 1997). Population fluctuations can have important conservation implications. Estimation of population is a prime requisite for ascertaining the status of threatened / endangered species from time to time. Increase of common species is often problematic, especially if the species is considered a health hazard or an economic threat. In North America, for instance, the rapid increase of the Double-crested Cormorants have created problems to commercial fisheries and aquaculture (Hatch, 1970; Milton *et al*., 1995). Thus long term monitoring of population is important for conservation (Wiens *et al*., 1986; Wiens, 1989; Coulter and Frederick, 1997).

Little Cormorant is one of the commonest aquatic birds of Kerala and occupies most of the wetland habitats (Neelakantan, 1958). Darter, *A. melanogaster* is a globally threatened species and once enjoyed a wide distribution in the wetlands of Kerala (Whistler and Kinnear, 1938) but recently their number has declined all over the state (Zacharias and Gaston, 2004). Kallampara backwaters supports a large population of Little Cormorants in comparison to Kalpally-Palliyol wetland. Fishermen complain of the fish stealing habit of Little Cormorant on large scale from the fishes gathered in the gill nets spread across the river. At Kalpally-Palliyol wetland, though in smaller numbers, both Little Cormorant and Darter co-exist. Ali and Ripley (1983) had reported that these two species make local movements related to water conditions. The data on the population dynamics of Little Cormorant and Darter is scanty. Hence a preliminary survey has been conducted to know the population trend and local movements according to changing seasons.

The breeding sites of Little Cormorant and Darter are located outside the wetland territories and close to human habitation. So they are often in conflict with human beings. Nest site tenacity is very strong among darters and cormorants, quite characteristic of colonial nesting waterbirds (Newton and Wyllie, 1992). In this context it is also quite relevant to study the breeding population at the heronries.

3.2 Objectives

The major objectives of the present study are:

1. to understand the population fluctuation of Little Cormorant, *P. niger* and Darter, *A. melanogaster* during the different seasons in the years: 2004, 2005 and 2006 at Kallampara river site and Kalpally-Palliyol wetlands.

2. to estimate the breeding population of Little Cormorant at Ramanattukara heronry in the years: 2004, 2005 and 2006, and Darter at Mangalavanam during 2006.

3.3 Methodology

Total count method (Gaston, 1973) was employed to estimate the population of Little Cormorant and Darter. The study area was divided into different blocks and each block was searched for birds. The count was taken during 7 to 10 am. Binoculars (8x40) and a monocular spotting scope (32X) were used for counting the birds.

In the main study areas viz., Kallampara river and Kalpally-Palliyol wetlands, two counts were taken every month for a period of three years during 2004, 2005 and 2006 and monthly average was calculated. From the monthly data, seasonal variations were calculated. The months in a year were categorized into 3 seasons viz., Premonsoon (February to May), Monsoon (June to September) and Postmonsoon (October to January).

Survey of the breeding populations of Little Cormorants, *P. niger* and Darters, *A. melanogaster* were also carried out since the breeding sites are located outside the wetland territories. The population of Little Cormorants feeding in the jheels, inundated lowlands, paddy fields and canals close to Ramanattukara heronry (breeding site) was also recorded.

Two-way ANOVA and Scheffe test were used to test significance of seasonal changes. P-value < 0.05 is considered significant.

3.4 Results

3.4.1 Little Cormorant

Population of Little Cormorant showed a trend of monthly fluctuation during the years: 2004, 2005 and 2006 (Table 3.1). The fluctuation was almost similar throughout the study period at Kallampara wetland (Appendix IIIa). The birds were most abundant in April 2004 and 2006 ($\bar{X}$ = 210.5 in 2004 and $\bar{X}$ = 231.5 in 2006), but in 2005, the highest number was found in March ($\bar{X}$ = 199.5). The least number of birds were recorded in July during 2004 and 2006 ($\bar{X}$ = 7.5 in 2004 and $\bar{X}$ = 7 in 2006), but in 2005 the least value was found in June ($\bar{X}$ = 6.5). There was an increasing trend for the population of Little Cormorant from January to May and a decreasing trend in June and July. When monthly fluctuation was examined, in 2004 a mean value of 60 was recorded in January and a mean of 210.5 in April. But in June the value was very low ($\overline{X}$ = 10) and in July it was the least ($\overline{X}$ = 7.5). Again from August onwards the population gradually increased, reached the highest value in April. A sudden decrease was observed in June and July. Almost a similar pattern was recorded in 2005 and 2006.

Monthly fluctuation of population was very evident (Appendix IIIb) for Little Cormorant at Kalpally-Palliyol wetland also (Table 3.2). Population of birds increased gradually from January ($\overline{X}$ = 11) to April ($\overline{X}$ = 29.5). In May there was a slight decrease ($\overline{X}$ = 26). Again lower values were observed in June ($\overline{X}$ = 7.5), July ($\overline{X}$ = 11) and August ($\overline{X}$ = 10). Then there was an increasing trend till December ($\overline{X}$ = 20). The maximum population was observed from February to May (Fig. 3.2).

At Kallampara wetland, the population of Little Cormorant showed maximum abundance during premonsoon season of all the three years under study ($\overline{X}$ = 760.5 in 2004, $\overline{X}$ = 707 in 2005 and $\overline{X}$ = 867.5 in 2006). The least values were observed during monsoon season ($\overline{X}$ = 96.5 in 2004, $\overline{X}$ = 89 in 2005 and $\overline{X}$ = 90.5 in 2006). An intermediate trend was observed during postmonsoon season ($\overline{X}$ = 201.5 in 2004, $\overline{X}$ = 239.5 in 2005 and $\overline{X}$ =

265.5 in 2006). The percentages of the above values are presented in Table 3.3 (Fig. 3.1).

At Kalpally-Palliyol wetland the population showed an almost similar trend as at Kallampara with the most abundant population during premonsoon season ($\overline{X}$ = 119 in 2005 and $\overline{X}$ = 133 in 2006). The lowest population trend was observed in the monsoon season ($\overline{X}$ = 44.5 in 2005 and $\overline{X}$ = 37 in 2006). Slightly higher values were recorded in the postmonsoon season ($\overline{X}$ = 55 in 2005 and $\overline{X}$ = 66 in 2006). Percentage of seasonal abundance is presented in Table 3.4 (Fig. 3.3)

Survey of the heronry at Ramanattukara indicated a gradual increase in the number of nesting Little Cormorants from 2004 to 2006 (Table 3.5). The breeding season was found to be lengthy and it extended from April to November. In 2004, the highest number of breeding birds was recorded in July ($\overline{X}$ = 166.33) and the lowest value ($\overline{X}$ = 7) in April. The same pattern was observed in 2005 and 2006. During all the three years the breeding population decreased from July onwards. The highest number of breeding birds ($\overline{X}$ = 514.33) was recorded in July 2006, compared to 2004 and 2005. The breeding period ended in November during 2006, but breeding was completed in October during 2004 and 2005.

The breeding population of Little Cormorant at Ramanttukara heronry was observed to feed in the nearby jheels, inundated lowlands and paddy fields and also canals. In these feeding sites maximum population was observed in June, July and August, which was the peak breeding period of Little Cormorant. Highest population ($\overline{X}$ = 159.01) was recorded from Azhinjilam jheel, the main feeding habitat of the breeding group. The lowest population count was recorded from paddy fields of Ayikkarappadi (Table 3.6).

3.4.2 Darter

Abundance of Darter population was low at Kalpally-Palliyol wetland during the study period (Table 3.7). During 2005, maximum number was observed in January ($\overline{X}$ = 13.5) and the lowest number ($\overline{X}$ = 1) was found in August. In 2006 also the maximum number was seen in January ($\overline{X}$ = 17), but the least number in June ($\overline{X}$ = 1) (Fig. 3.5). When seasonal variation (Appendix IIIc) was considered, minimum values were recorded in the monsoon season ($\overline{X}$ = 9 in 2005 and $\overline{X}$ = 11.5 in 2006). During the premonsoon season the population trend was static in 2005 and 2006 ($\overline{X}$ = 42 in 2005 and $\overline{X}$ = 41 in 2006). The postmonsoon values were 42 ($\overline{X}$) in 2005 and 39 ($\overline{X}$) in 2006. Seasonal abundance (% values) is given in Table 3.4 (Fig. 3.4).

At Mangalavanam mangroves, sixteen breeding adults of Darters were observed on May 19th 2006. Maximum breeding population of 24 adult birds were noticed in June. The birds started to disperse in July after breeding. By the second week of August the birds left the breeding ground (Table 3.8). The breeding of Darter was from May to August during the study.

3.5 Discussion

3.5.1 Little Cormorant

The population of Little Cormorant was highly dynamic and showed local movements depending upon water conditions available for foraging. The population abundance was also controlled by the availability of preferable sites for breeding with adequate food and protection. Present study shows that population of Little Cormorant was very low in June and July during all the three years in the main study areas. The probable reason might be that the birds congregated at the breeding site, foraged at the feeding habitats close to the heronries. The inundated paddy fields and lowlands provided suitable food resources like fish larvae, frogs, tadpoles and crustaceans needed for feeding the nestlings. Due to heavy monsoon rain, Kallampara river system was flooded and the depth increased making the habitat unsuitable for feeding of Little Cormorant in June and July. Cormorants prefer to forage in shallow water (Cooper, 1986; Quintana *et al*., 2004). Consequently the number of

Little Cormorants foraging at Kallampara river system decreased to low numbers in June and July.

From September onwards the number of birds increased at Kallampara river as the birds gradually return to their feeding habitats when monsoon rain ended. Another reason may be the increase in fish population during post monsoon months. When water depth decreased, more and more birds congregated the river during tidal cycles. Towards the end of November the fields and low lands get dried and birds returned to their feeding habitats like larger wetlands. In 2006 January, the number of birds were high at Kallampara, the reason may be decrease in rainfall in December that make the paddy fields dry earlier.

Premonsoon months (February, March, April and May) were the most suitable period for the feeding of Little Cormorants at Kallampara river site because the water level decreases and the tidal cycles bring more and more prawns into the river. In summer months the population shifted their feeding habitat to larger water bodies where they have enough space and food available as the alternative habitats dry up. Ali and Ripley (1983) reported that Little Cormorants showed local movements depending upon water conditions. Seasonal switches in foraging sites are related to prey depletion and seasonal changes in the physical environment (Dugan *et al.*, 1986).

Shifting of foraging area in the present study could also be related to seasonal changes and prey depletion.

Water depth increased at Kalpally-Palliyol wetland with the advent of rain in June. As the rain brought sufficient water, the floral growth also increased. This resulted in an unfavourable condition for the foraging of Little Cormorants, and the birds were less in June, July, August and September. Foraging behaviour of piscivorous birds can be affected by prey density, water depth and water clarity (Nocera and Burgess, 2002). Presence of floating and submerged vegetation was also not preferable for diving birds. Shallow water near the coast was heavily infested with vegetation. Open stretch of water towards the centre of the wetland became deeper as monsoon progressed. Thick vegetation inhibited the free diving of Little Cormorants. Due to all these reason, the number of birds were very few at Kalpally-Palliyol wetland during monsoon season. Monsoon months are the breeding season of these birds, so that they congregated at their nest site usually away from large wetlands. This was another cause for the decrease in the number of Little Cormorants during monsoon season.

In the postmonsoon season the emergent grass-like vegetation increased and made the shallow water near the bank unfavourable for the diving birds. As the water depth slowly decreased with the end of monsoon, the number of birds increased.

Generally, most of the heronry nesting birds are fish eating, their breeding season coincides with breeding of fishes during monsoon season endorsing the "food availability–breeding time" concept (Lack, 1968). This is further illustrated by the present study. The commencement of rain in April stimulated the breeding of Little Cormorants and they started arriving at the heronry of Ramanattukara. In April, the number was very low but it gradually increased and the peak breeding was noticed in July. Subsequently, gradual decline was observed in bird number as they dispersed and flew away after completing their breeding and parental care. The least number of birds were observed in October in 2004 and 2005, but in November during 2006.

The occurrence of heronries in a particular region is dependent on the availability of suitable feeding conditions for waterbirds (Gibbs *et al*., 1987; Bacroft *et al*., 1988; Carrascal *et al*., 1993). Little Cormorant, one of the most abundant heronry nesting species (Subramanya, 1996) breed close to fresh waterbodies and human habitations. The heronry at Ramanattukara occurs on either side of the highway in the town near fish market and Thottungal Kadavu. The birds were found to feed in the nearby jheels of Azhinjilam, canals of Muttiara and Thottungal and inundated paddy fields and lowlands of Chellippadam and Ayikkarappadi during breeding season. Affinity to previous nesting sites, appears to be very strong among colonial nesting waterbirds (Newton and Wyllie, 1992). Little Cormorants have been nesting at Ramanattukara for last 10 years since 1999.

3.5.2 Darter

Studies conducted in Kalpally-Palliyol wetland shows that Darter population is very low in this area as compared to wetlands of South Kerala. Though Darters were observed during all the seasons, their number was very low during monsoon – the breeding season. About 600 Darters were recorded from Kumarakam and Pathiramanal Island and around 65 from Thattekadu Bird Sanctuary in a decade back study (Sugathan, 1997). Darters were also recorded from Mangalavanam mangroves (Jayson, 2001) and were seen nesting along with Little Cormorants.

Darters used to breed in the heronries at Kallettinkara Polytechnic, Thrissur District, Trivandrum Zoo Compound (Raju and Rajasree, 2007), Nooranad, Alleppey District (Balakrishnan and Thomas, 2004) and Malabar Special Police Camp, Malappuram District (Sashikumar and Jayarajan, 2008).

During the present study, 12 pairs of Darters were found to nest at Mangalavanam mangroves during 2006.

Table 3.1. Relative abundance of Little Cormorant during the years: 2004, 2005 & 2006 at Kallampara

Month	2004		2005		2006	
	No. of birds (Mean)	Relative abundance (%)	No. of birds (Mean)	Relative abundance (%)	No. of birds (Mean)	Relative abundance (%)
January	60.00	5.67	66.5	6.42	80	6.54
February	187.50	17.72	201	19.42	222.5	18.19
March	198.50	18.76	199.5	19.27	214.5	17.54
April	210.50	19.89	197.5	19.07	231.5	18.93
May	164.00	15.49	109	10.53	199	16.27
June	10.00	0.94	6.50	0.63	8.0	0.47
July	7.50	0.71	9.0	0.87	7.0	0.57
August	38.50	3.64	31.0	2.99	30.0	2.45
September	40.50	3.83	42.5	4.10	45.5	3.72
October	38.00	3.59	51.0	4.93	53.0	4.33
November	47.00	4.44	64.5	5.79	60.0	4.91
December	56.50	5.34	57.5	5.55	72.5	6.21

Fig. 3.1. Seasonal abundance of Little Cormorant during 2006 at Kallampara

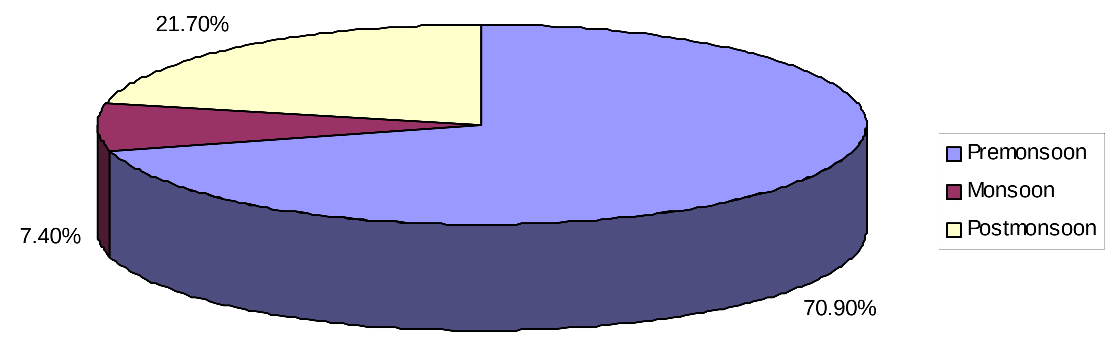


Table 3.2. Relative abundance of Little Cormorant during the years 2005 & 2006 at Kalpally-Palliyol Wetland

Month	2005		2006	
	No. of birds (Mean)	Relative abundance (%)	No. of birds (Mean)	Relative abundance (%)
January	11.0	5.03	15.5	6.57
February	28.0	12.81	37.5	15.89
March	35.5	16.25	33.0	13.98
April	29.5	13.50	35.0	14.83
May	26.0	11.90	27.5	11.65
June	7.5	3.43	10.5	4.45
July	11.0	5.03	6.0	2.54
August	10.0	4.58	6.0	2.54
September	16.0	7.32	14.5	6.14
October	12.0	5.49	13.0	5.95
November	12.0	5.49	13.5	5.72
December	20.0	9.15	24	10.17

Fig. 3.2. Relative abundance (%) of Little Cormorant at Kalpally-Palliyol wetland

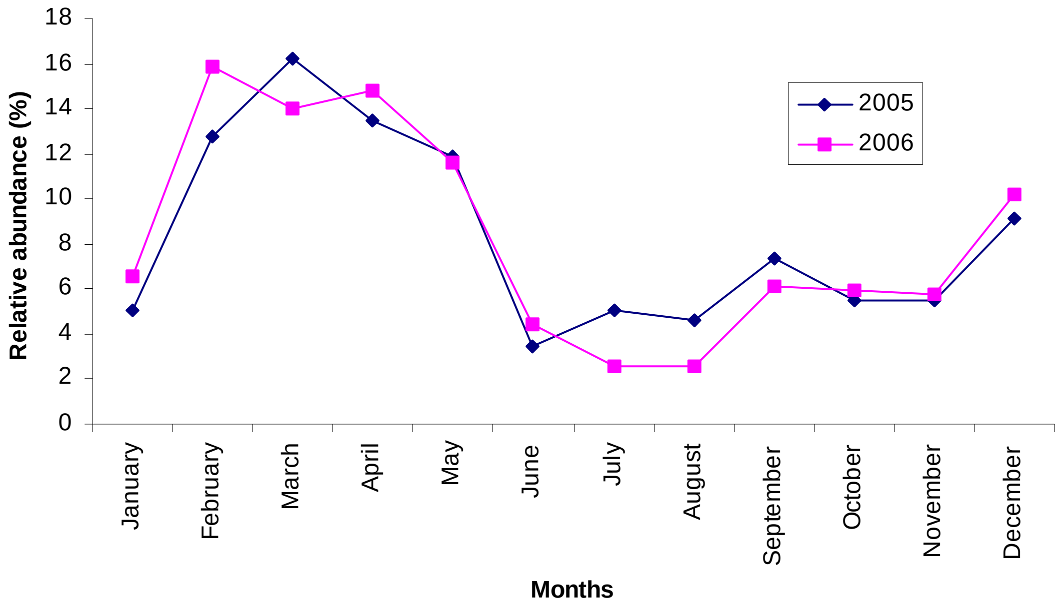


Table 3.3. Seasonal abundance (%) of Little Cormorant in the years: 2004, 2005 & 2006 at Kallampara

Year	Premonsoon	Monsoon	Postmonsoon
2004	71.85	9.12	19.04
2005	68.31	8.60	23.13
2006	70.90	7.40	21.70

Table 3.4. Seasonal abundance (%) of Little Cormorant and Darter during 2005 & 2006 at Kalpally-Palliyol wetland

Year	Darter			Little Cormorant		
	Pre monsoon	Monsoon	Post monsoon	Pre monsoon	Monsoon	Post monsoon
2005	45.16	9.68	45.16	54.46	20.37	25.17
2006	44.81	12.57	42.62	56.36	15.68	27.97

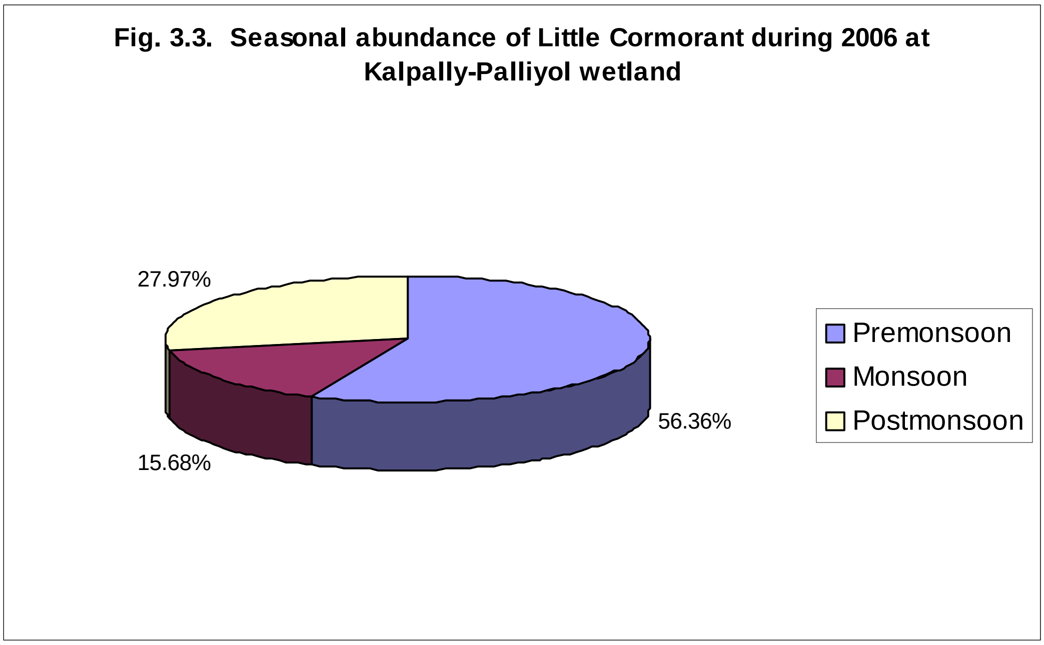


Fig. 3.3. Seasonal abundance of Little Cormorant during 2006 at Kalpally-Palliyol wetland
27.97%
56.36%
15.68%
Premonsoon
Monsoon
Postmonsoon

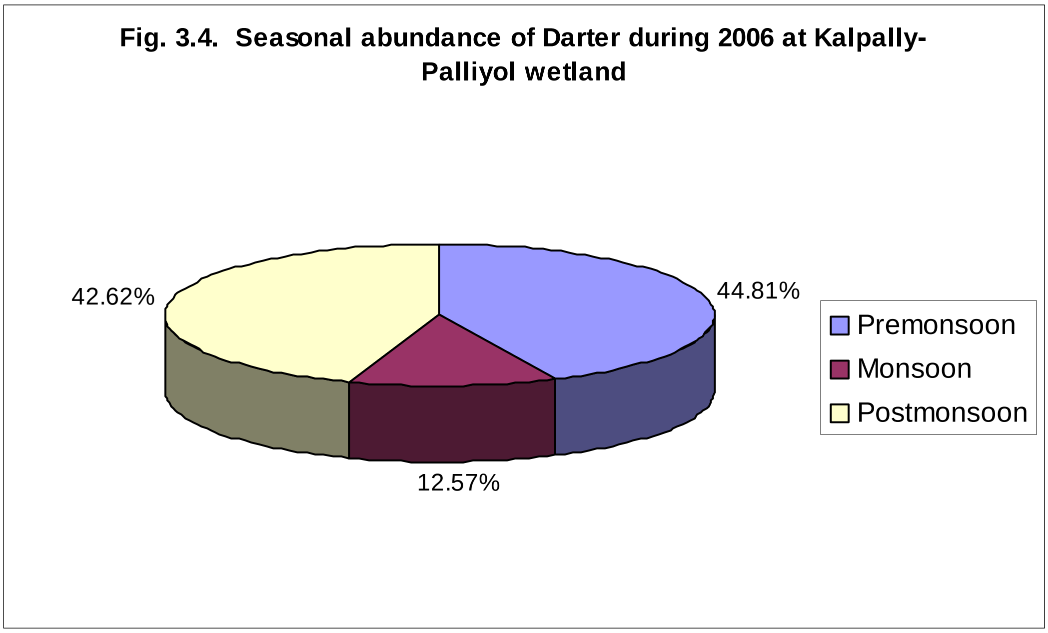


Fig. 3.4. Seasonal abundance of Darter during 2006 at Kalpally-Palliyol wetland
42.62%
44.81%
12.57%
Premonsoon
Monsoon
Postmonsoon

Table 3.5. Breeding Population of Little Cormorant during the years: 2004, 2005 & 2006 at Ramanattukara heronry (mean values)

Year	April	May	June	July	August	September	October	November
2004	7.00	27	136.67	166.33	158	102.67	46.33	--
2005	7.33	161.33	304	371	300.33	132.33	93	--
2006	16.67	104	342	514.33	245	184	68	15

Table 3.6. Population of Little Cormorant in the feeding habitats close to the breeding site at Ramanattukara (Mean values)

Name of places	April	May	June	July	August	Septe-mber	Octo-ber	Nove-mber	Dece-mber	Total
Azhinjilam	2.67	5.67	22.33	34	26	25	13.67	14	15.67	159.01
Thottungal	1.33	3.67	5.33	11.67	9	4	7.33	4.33	1.33	47.99
Pulikkal	--	--	7.33	12.33	9	6	2	--	--	36.66
Ayikkarapadi	--	--	9.67	9	10	1.67	5	--	--	35.34
Chellipadam	--	--	10	30	16.67	9.67	5	--	--	71.34
Muttiara	2	5	27.33	49	24.67	15	8.33	4	33	136.66
Feroke Chungam	--	--	22.33	25	34.33	12.33	12.67	--	--	106.66

Table 3.7. Relative abundance of Darter during the years: 2005 & 2006 at Kallpally-Palliyol Wetland

Month	2005		2006	
	No. of birds (Mean)	Relative abundance (%)	No. of birds (Mean)	Relative abundance (%)
January	13.5	14.59	17.0	20.36
February	10.5	11.35	16.5	19.76
March	11.5	12.43	8.5	10.18
April	10.5	11.35	8.0	9.58
May	9.0	9.73	8.0	9.58
June	1.5	1.62	1.0	1.20
July	2.0	2.16	2.0	2.40
August	1.0	1.08	3.0	3.59
September	4.5	4.86	5.5	6.59
October	4.5	4.86	3.5	4.19
November	12.0	12.97	8.5	10.18
December	12.0	12.97	10.0	11.98

Fig. 3.5. Relative abundance (%) of Darter at Kalpally-Palliyol wetland

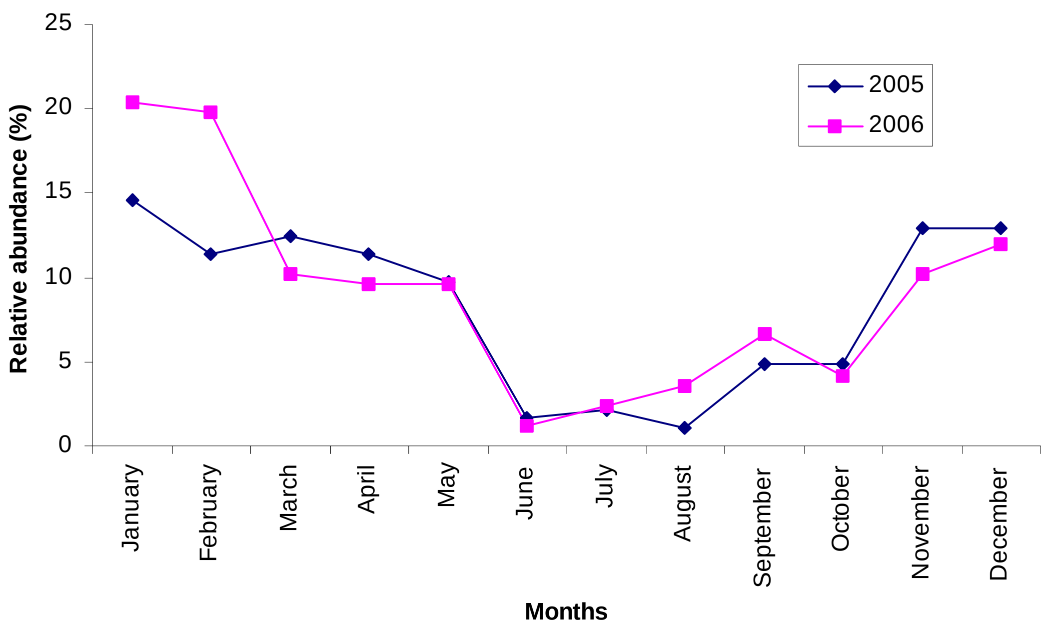


Table 3.8. Breeding population of Darters at Mangalavanam mangrove (2006)

Month	Visits to the heronry	No. of birds
May	1st	16
	2nd	24
June	1st	24
	2nd	24
July	1st	8
	2nd	8
August	1st	8
	2nd	Nil

Chapter 4

GENERAL HABITS

GENERAL HABITS

4.1 Introduction

Scientific study of bird behaviour has great importance. Every species has its own unique behaviours. The learning ability of a bird is comparable to most mammals. Behaviour is what a bird does; it is always adaptive to the environment and it includes the process by which a bird perceives the environment through its senses and responds to its surroundings (Pettingill, 1970).

In response to both intrinsic and extrinsic stimuli, birds show various activities. The intrinsic stimuli are closely related to the physiological conditions of the bird where as the biotic and abiotic factors of the habitat are the extrinsic stimuli. Normally many of the behavioural activities occur in specific patterns. But they need not be always constant, since the activities could be modified by the changes in the physiology of the birds and the spatio-temporal conditions of the surroundings. Certain activities need more energy and time than others. Further, activities of the birds are confined to the most opportune time (Smith, 1976). Time budget is a quantitative description of how animals apportion their time for various activities (Baldassarre and Bolen, 1994). Ecological factors influence the behaviour and activity pattern of the bird. The study of activity pattern enables us to understand the above relationship (Boeltcher and Haig, 1994). However, the allotment of time for an activity is determined by natural selection to maximize the chance of survival (Fagen, 1974; Macfar Land, 1977).

Courtship displays of birds facilitate the successful completion of the reproductive cycle. Physical display (posture) is one of the several means of animal communication and birds use visual signals effectively (Butcher and Rower, 1989). Visual signals include movement of head, body, tail, wings and body feathers (Maler and Hamilton, 1966). Many signals may act as stimuli to which members of the same species or other species respond instinctively (Krebs and Devies, 1987).

Auditory signals are also important means of communication. Calls are vocal displays of birds in which one or more sounds are consistently repeated in a specific pattern (Pettingill, 1970). Willingness to mate, threat, hunger and fright can be effectively communicated through calls. Calls proclaim territory and warns conspecific intruders. They also advertise the species and sex of the singer and invite attention of the opposite sex of the same species. Thorough understanding and analysis of the behaviour of a species is required for developing effective conservation strategies (Sutherland, 1998). Description and categorization of individual behaviour by function is necessary to interpret the gross behaviour of a species (Craig, 1977). The gross behaviour of birds has been investigated by Allee (1936), Tinbergen (1948), Lorenz (1950), Emlen (1952), Andrew (1961), Brown (1964) and Manning (1980). The activity pattern of water birds have mainly been studied by Burton and Hudson (1978) on geese, Baldessare and Bolen (1994) on ducks, Paulus (1988) on non breeding Anatidae, Pedroli (1982) on tufted ducks and Muzaffar (2004) on Ferruginous Porchad.

Activity pattern of cormorants has been studied by many workers outside India. The reported works include the activity pattern of Blue eyed Shags (Bernstein and Maxson, 1984), energy requirements of Great Cormorants (Gremillet *et al*., 2001), daily food requirements of Great Cormorants (Gremillet *et al*., 2003), energetics of Anhingas (Hennemann, 1982) and behaviour of Double-crested cormorants and Flightless Cormorants (Hennemann, 1984).

However, the studies of activity patterns and behaviour of Indian birds are relatively lesser. The available reports include studies on Coot (*Fulica atra*) by Jayaraman (1985) and Pheasant tailed (*Hydrophasianus chirurgus*) and Bronze winged Jacanas (*Metopidius indicus*) by Ramachandran (1998). Ali and Ripley (1983) have briefly described the behaviour of several water birds.

Only a few reports are available on the behaviour of Little Cormorant and Darter from India. Abdulali (1948) and Stonor (1948) have given brief notes on *Anhinga*. Pandey (1958), Ripley (1962) and Sengupta and

Brahmachary (1968) have provided short accounts on Little Cormorant. Dick and Wurdinger (2001) have given a brief note on the fan-drying behaviour of Little Cormorant and Darter.

4.2 Objectives

1. To study various behavioural activities of Little Cormorant and Darter, and to assess the timing of various diurnal activities.

2. To study seasonal variations in the activities among the birds.

4.3 Methodology

General habits and the activity pattern of Little Cormorant and Darter were studied at Kallampara river site and Kalpally-Palliyol wetland respectively.

Focal animal sampling (Altmann, 1974) was adopted to study the behavioural activities of Little Cormorant and Darter. The birds were observed with binoculars (8 x 40) and a spotting scope (32 X). Various behavioural activities like awakening, roosting, movements, maintenance, agonistic behaviour, postures and displays, body orientation, vocalization, feeding and gular fluttering were studied by direct observation.

To study the timing of behavioural activities, a particular bird was followed and its activities recorded. When the bird under observation was out of sight another bird was focused. The observation was carried out in phases: for two hours every day, to collect the data for the whole daytime (from 6.30 to 18.30 hours). The sampling was repeated for three seasons (premonsoon, monsoon and postmonsoon). Fifteen samples each were collected for every hour of the day per season. The timing of feeding, spread-winged behaviour, spread-winged preening, preening, gular fluttering, flying, fan-drying, alert, paddling and perching were recorded.

The hourly time (%) spent for each activity per day was calculated. The mean and standard deviation for each activity per hour of the day was also calculated. Scheffe multiple test was used to find significance of seasonal variations in feeding, spread-winged behaviour, spread-winged preening, preening, gular flutter, fan-drying and perching. It was also used to find the significance between different behavioural activities of Little Cormorant and Darter. P-value < 0.05 is considered significant.

4.4 Results

4.4.1 Behaviour

Various behavioural activities were recorded by direct observations.

4.4.1.1 Little Cormorant

Awakening and roosting

Little Cormorants woke up 5-10 minutes before sunrise. However the first sighting of the bird in the feeding habitat was usually 20-30 minutes after sunrise. They roosted 10-20 minutes after sunset and left the foraging ground 10-20 minutes earlier than sun set, while other birds were still feeding.

Movements and locomotion

Flying

The flight of Little Cormorants were marked by uninterrupted rapid wing flapping. Usually they flew low over the surface of the water. When alighting on water, the long stiff tail was first to break the surface and helped to check momentum. After feeding the bird rose up flapping its wings heavily along the surface to get air-borne.

Swimming

At water surface, Little Cormorants swam with back and shoulders exposed. They swam under water using the wings and large powerful webbed feet, with wings held tightly close to their bodies to improve streamlining.

Paddling

Paddling is the swimming on the water surface using feet as paddles. Little cormorants swam on the water surface with the help of webbed feet. The water-logged feathers help to keep a low profile (Plate VIII.D).

Hopping

The birds hopped from one branch to another on the perching tree. While hopping, the wings are temporarily extended.

Walking

Little Cormorants walked on the mud flats close to the water and slowly dropped into water for swimming. During walking, the neck and head were held in a slanting position.

Flocking

The flocking pattern of Little Cormorant consisted of flying in lines, settling on the water surface and gathering in a tight bunch. The flock swam about for 2-3 minutes. After this, one bird dived followed by others. Flocks of these birds locate shoals of fish, swam around them in decreasing circles to concentrate the fishes. Once they finished feeding, they perched in flocks. They form flocks at the roosting and nesting sites also.

Maintenance behaviour

Preening

By perching on rocks, stakes or trees, the bird preened elaborately (Plate VIII.F). It was the most frequent activity in plumage care performed by the bill. A cormorant preened its neck first followed by the back, then the wings, breast, flank and tail. At intervals the bird nibbled the oil gland. While preening, the bird fluffed its feathers.

Preening was done to clean the feathers, to remove any debris or ectoparasites larking under the surface of feathers or to rearrange the barbules.

Spread-winged behaviour

This behaviour is similar to sunbath observed in other birds. The bird was seen perching on rocks, stakes or trees with the wings held fully outspread (Plate VIII.B). The open wing posture is very characteristic to cormorants and darters. After prolonged feeding in water, Little Cormorant adopted an upright posture with wings held outstretched.

Fan-drying

Fan-drying behaviour was observed commonly among Little Cormorants. Active shaking of wings at a higher frequency was a mechanism to improve evaporation of water.

Bathing and ruffling

After the final dive of a feeding bout, the bird shook its plumage vigorously with head dipping in water and wings extended and body feathers ruffled. This displaced water from the feather and increased buoyancy.

Spread - winged preening

Preening was performed by the bird while in spread-winged posture (Plate VIII.C). This behaviour enhanced drying of feathers and easy take off to the perching site.

Perching

The bird perched upright on rocks, stakes, trees or mud flats with the long neck held in 'S' shape exhibiting the streamlined body (Plate VIII.A).

Agonistic behaviour

Fighting

Intraspecific interactions involve aggressive displays with the bill pointing at the opponent. The owner of the territory pecked the intruder with widely opened bills. When fighting, the birds spread their wings and pecked at their opponent's bill. Mild fight was noticed during courtship, among the males. If the threat was serious, the forehead crest was raised. Tail and wings were also raised. Fight was less frequent among Little Cormorants.

Postures and displays

Alert posture

In alert posture, the bill gaped and the bird stretched its neck and turned its head in all directions. Erection of the crest was an effective way of signaling to the intruder that the sitting bird was not simply occupying the nest or the perching site, instead guarding the nest and will defend it.

Wing position

The wings were kept folded while the bird was perching and walking. During sunbathing and fanning, wings were fully opened and outstretched. During courtship display wings were raised up.

Tail position

While perching in the normal posture, tail was kept downwards. In squatting, tail was held horizontally. In appeasement display, the tail was held downwards.

Body orientation

In the normal body posture during perching the neck assumed a characteristic "S" bend and the bird appeared relaxed even when it moved its head to scan the surroundings. The angle that the body makes with the substrate ranges from near vertical in calm conditions, to near horizontal in very strong winds. In appeasement display, the bill was directed away from the intruder and in aggressive display the bill was pointed towards the opponent. Body adopted a horizontal position in threat display and vertically oriented in appeasement display.

Vocalization

The vocal repertoire of the Little Cormorant was very limited. Calls were produced during breeding season when chicks were present in the colony. Croaking sound was produced by adults during chick rearing and parental care when intruders were present. When nestlings were frightened they produced repeated croaking sound. Begging calls Coo ... Coo were produced by the juveniles while the parents approached with food.

Feeding

Underwater foraging activity was performed by the bird by conducting a series of dives and surface pauses.

Gular fluttering

It is a non-ventilatory expansion and compression of the buccal cavity (gular area) that contribute to evaporative cooling (Plate VIII E).

4.4.1.2 Darter

Awakening and roosting

The first sighting of the bird in the feeding habitat was usually 30-40 minutes after sunrise. After awakening it flew all the way from the roosting site to the feeding site. It left the feeding location 5-15 minutes earlier than sun set.

Movements and locomotion

Flying

The flight of Anhinga is characterised by a regular re-setting of its wings at intervals. It can soar to great heights. The bird becomes airborne by diving into flight from trees, bushes or banks. The Darter appeared to drop down into water on its belly and breast after a short flight or walk from a nearby perch. During flight the tail feathers were spread in a fanned manner. It 'crawled' out of water after a long feeding bout.

Swimming

Darters are good swimmers as well as divers. They swam at the water surface with only head and part of neck raised above water. They swam long distances horizontally below water surface till they could locate a prey.

Paddling

Darters swam at the water surface using webbed feet as paddles.

Walking

The gait was clumsy on land with wings kept close to body. The tail was dragged along the land while walking.

Hopping

Darter hopped from one branch to another using the webbed feet, during which the wings were raised for balancing.

Flocking

Flock feeding was not found among darters, but they congregate during breeding season. They also breed in mixed colonies and in groups.

Maintenance behaviour

Preening

The preening behaviour of Darter was almost similar to that of Little Cormorant. The bird started preening from the neck region, but intermittently nibbled the oil gland. It was followed by the back, the wings, breast, flank and tail. While preening the tail and back, it stretched the neck and held it in different positions (Plate IX.E & F).

Spread-winged behaviour

In this posture the bird was extremely alert. Darters adopted an upright posture with wings held outstretched (Plate IX.A & B). The tail was lowered and kept downwards close to the substratum. The head and neck were directed forward and raised a little.

Fan-drying

Shaking of feathers with high frequency wing flapping will enhance evaporation of water from the wings and the body feathers. Darters fanned the wings at a low frequency when compared to Little Cormorant.

Bathing and ruffling

This behaviour was not found in Darter. After feeding it 'crawled' to the nearby perch without bathing and ruffling.

Spread-winged preening

Preening of various body parts by the Darter while in the spread-winged posture, promotes drying of feathers at a faster rate.

Perching

In Darters perching was noticed during resting hours. It perched in an upright posture on rocks, stakes, trees, or mud flats with the long neck held in

'S' shape exhibiting its streamlined body (Plate IX.C & D). Tail is held downwards. The bird was vigilant and alert about its surroundings while perching.

Agonistic behaviour

Fighting

Darters were less agonistic during non breeding reason, but they were highly territorial during breeding time. Agonistic interactions were common among males. Competition for nest site, nest material, and mates was found in a breeding colony of Darter. Nest material stealing and related aggressive behaviour was also observed. The males "peck threat" at the neighbour by raising the wings. Both males and females kept an alert posture towards the intruders for defending the territory while brooding.

Postures and displays

Alert posture

With a gesture of alertness in the eyes the brooding bird turned its head to all directions. Gular fluttering was observed in the brooding birds, especially during hot days.

Wing position

During spread-winged posture, wings were out-stretched and held in a peculiar manner, so that the entire wing was exposed to sunlight or air current. While perching wings were kept folded close to the body. Wings were also kept folded during walking and preening. Wing waving was found in courtship display.

Tail position

In Darters, the tail was kept slantingly downwards during perching. In squatting in the nest, tail was held horizontally. Tail was fanned during flight.

Body orientation

During perching, the neck assumes a characteristic 'S' bend and the bird was almost relaxed. The body was kept in a slanting posture, while resting. Head and bill were kept in a horizontal position while perching. Body adopted a horizontal posture in aggressive display and was vertically oriented in pair bonding display.

Vocalization

While flying, a clicking sound was made by adults. It is similar to Tliki....Tliki calls. These were shrill and sharp calls of high frequency. Breeding adults produced caw.....caw.....caw......calls like the calls of crow. Juveniles made shrill calls of Kee....Kee....which were sharp and of high frequency. The clicking calls of adult were believed to be contact calls, which can be heard only if we listen carefully.

Feeding

Darters conducted foraging trips to shallow water and performed a series of dives and surface pauses to capture the prey.

Gular fluttering

It is a behavioural activity that aid in thermoregulation through evaporative cooling.

4.4.2 Time budget and activity pattern

The data analysed by Scheffe Test (Appendix IV) shows significant seasonal variations in the activities. The activity patterns of both the birds also vary significantly.

4.4.2.1 Little Cormorant

Premonsoon

Overall, Little Cormorant spent about half of daytime for maintenance behaviour (50.96%) with less time spent for feeding (37.79%) (Fig. 4.1). There were two peaks of feeding, one in the morning (44.38%) between 8.30 and 9.30 hours and another in the afternoon (46.05%) between 15.30 and 16.30 hrs. The feeding activity was low in the noon hours. The least time (26.27%) was spent between 13.30 and 14.30 hours. After 14.30 hours it gradually increased in the afternoon.

Spread-winged behaviour gradually increased in frequency from 6.30 till 16.30 hours (Fig. 4.7). Then it showed a decrease in frequency. It was low between 6.30 to 7.30 hours (1.98%). The maximum activity was found between 15.30 and 16.30 hours (11.44%). There was only one peak (11.44%)

which was observed between 15.30-16.30 hours. In the early morning hours, gular flutter was very low (1.32%) and it increased in frequency till 16.30 hours (9.17%) and thereafter it decreased. The time budget for gular flutter was almost similar to spread-winged behaviour. Fan drying was observed between 6.30 to 10.30 hours and it ranged between 0.32% and 0.95%. Again it was found from 16.30 to 18.30 hours and ranged between 1.07% and 1.85%. Fan drying was not at all observed between 10.30 and 16.30 hours (Fig. 4.8).

The bird allotted considerable time in preening during noon hours between 12.30-13.30 hours (19.29%) and 13.30-14.30 hours (19.68%). Another peak was found between 14.30-15.30 (20.22%) and between 15.30-16.30 hours (20.99%). In the morning and late evening preening was very low.

Perching was high (42.4%) at 6.30 to 7.30 hours. It was very low (7.65%) between 15.30 and 16.30 hours when other activities like feeding, gular flutter and spread-winged behaviour were with peak values.

The bird was alert during the morning hours with a peak of 4.27% activity between 7.30 and 8.30 hours. It did not appear alert between 13.30 to 16.30 hours when human disturbances were less in the habitat. Again a peak (3.80%) was observed between 16.30-17.30 hours. Most of the time the bird was found sitting and doing some maintenance activity. Very short flights were observed between other activities. The frequency of flying ranged between 1.28% to 3.05%.

The bird was paddling considerably in the noon hours (4.72%) between 10.30 and 11.30 hours and 4.44% between 13.30 and 14.30 hours. During the other times of the day paddling was less. The bird preened while in spread-winged posture only for very little time and it ranged between 2.5% to 2.72% from 6.30 to 18.30 hours.

Bathing and ruffling was more frequent in the morning hours with a peak between 8.30 and 9.30 hours. The activity was less in the noon. Again it increased in the afternoon.

In the premonsoon season the bird spent major share of time for feeding than for other activities (Fig. 4.4). The maintenance activity, it was higher than feeding (Fig. 4.5).

Monsoon

During monsoon season feeding was less (23.08%) and maintenance was more (69.29%) (Fig. 4.2). As in other seasons there was one peak (29.98%) in the morning between 8.30 and 9.30, another peak (35.85%) was observed in the afternoon between 15.30 and 16.30. Lowest feeding was observed at noon.

Spread-winged behaviour showed a reduced rate when compared to the other seasons. The least rate (0.78%) was observed between 6.30 and 7.30 hours and the maximum rate (6.62%) was found between 15.30 and 16.30 hours. Gular flutter was also very low during monsoon season (Fig. 4.9). During morning hours it was absent and between 14.30 and 15.30 it was 7.86%. Fan drying considerably increased during monsoon season and the maximum rate was 2.40% between 16.30 and 17.30 hours.

The bird was perching for increased duration during monsoon season. The peak value (71.33%) was found between 13.30 and 14.30 hours. The rate of perching decreased (33.59%) between 15.30 and 16.30 hours. The bird was not found alert till 8.30 in the morning hours. It was maximum vigilant (3.98%) during 13.30 to 14.30. The movement of the bird was less in the monsoon season because the feeding and other activities were less. Flight ranged between 0.85 to 2.55%. Paddling was less during the monsoon and highest value was 3%. The bird spent less time for bathing and ruffling. The peak value (3.96%) was found between 15.30 and 16.30 and the least value was 0.74%. Fighting was very rarely seen during monsoon season. Spread-winged preening was less in duration. The bird was almost less active during monsoon compared to other seasons.

Postmonsoon

The time allocation of feeding in the postmonsoon season showed some similarities with that of pre monsoon. The bird spent more time in the morning and afternoon for feeding than at noon. There was one peak 38.92% in the morning (8.30 to 9.30) and another one (46.02%) in the afternoon (15.30-16.30). The rate of feeding was least (16.61%) in between 10.30 and 11.30 (Fig. 4.3). Maintenance behaviour was higher (58.84%) than feeding (32.56%).

Spread-winged behaviour showed a similar pattern which was observed in the premonsoon season. The lowest rate (1.04%) was observed between 6.30 and 7.30 hours. The highest rate (9.24%) was observed between 15.30 and 16.30. The frequency of spread winged behaviour increased as the day proceed. Gular flutter was least in the morning hours than in the afternoon hours. The rate was 0.44% between 6.30 and 7.30 and 8.90% between 15.30 and 16.30 hours. Fan drying was observed from 6.30 to 10.30 and from there onwards till 16.30 hours it was not observed. Again from 16.30-18.30 hours, the rates were 1.74% and 1.57% respectively.

Preening activity showed a peak in the morning between 8.30 and 9.30 hours. There was another peak (17.33%) in the noon between 12.30 and 13.30 hours. In the afternoon the rate increased again upto 18.60%. Perching was highest (59.87%) during 6.30 to 7.30 hours (Fig. 4.6). It was lowest (8.57%) between 15.30 and 16.30 hours. The maximum alertness (4.23%) was found between 7.30 and 8.30 hours. The bird was not at all alert after 15.30 hours. Paddling was highest at noon and the maximum value was observed between

13.30 and 14.30. Least paddling activity was found between 15.30 and 16.30 hours. Bathing and ruffling was low at noon and the least activity was found between 6.30 and 7.30 hours (0.57%). The highest percentage of bathing and ruffling was found between 15.30 and 16.30 hours. Fighting was not intense during postmonsoon season. Spread-winged preening was less than that of premonsoon season and maximum value (3.05%) found between 8.30 and 9.30 hours.

4.4.2.2 Darter

Premonsoon

Darter utilized less than half of the daily hours for maintenance activities (46.52%). Frequency of feeding was less (40.99%) when compared to maintenance. There were 3 peaks for the feeding activity, one in the morning (62.75%) between 8.30 and 9.30 hours, another (50.68%) between 12.30 and 1.30 hours, and a third one (37.06%) in the afternoon between 5.30 and 6.30 hours (Fig. 4.13). The feeding activity was least (32.46%) between 10.30 and 11.30 hours after the morning peak.

The frequency of spread-winged behaviour increased as the day proceeds and reached the peak rate (9.18%) between 15.30 and 16.30 hours. The least value (1.62%) was observed between 6.30 and 7.30 hours in the morning (Fig. 4.16). Gular flutter was very low (0.90%) during 6.30 to 7.30 hours and maximum between 15.30 and 16.30 hours. After 16.30 hour gular flutter decreased. The pattern of time allotment was almost similar for spread-winged behaviour and gular flutter. Fan-drying behaviour was observed between 6.30 and 10.30 hours and it ranged between 0.24 to 1.62%. From 10.30 to 16.30 hours fan drying was not observed. In the late evening fan-drying was observed and it ranged between 0.61 to 1.84% (Fig. 4.17).

The bird utilized more time in preening during the noon hours and the peak (8.68%) was between 13.30 and 14.30 hours. Another peak (9.86%) was observed between 15.30 and 16.30 hours.

Perching behaviour predominated in the morning hours and ranged between 14.17% to 51.94%. The bird perched for very short period between 15.30 and 16.30 hours.

Darter was found to be alert especially in the morning hours with a peak (1.85%) between 7.30 and 8.30 hours. Another peak (4.6%) was observed between 17.30 and 18.30 hours. At noon it was less alert during which disturbances were less in the feeding site.

While feeding it took short flights from one feeding location to another. It spent very less time for flight (0.75 to 1.99%). Paddling was observed frequently at noon while feeding activity was less. It paddled slowly over long distances and a peak activity (2.72%) was observed between 13.30 and 14.30 hours.

In the premonsoon the bird spent more time for feeding than for perching and other activities (Fig. 4.10). When maintenance activities were considered feeding was less.

Monsoon

The allocation of time for feeding activity was less (32.18%) during monsoon season and maintenance was highest (61.84%) (Fig. 4.14). The bird exhibited 3 peaks of feeding activity. In the morning there was one peak (46.69%) between 8.30 and 9.30 hours. Another peak (41.57%) was observed in the noon session between 12.30 and 13.30 hours. The bird also showed an evening peak (54.22%) in the feeding activity. Lowest feeding rate was observed between 10.30 and 11.30 hours.

There was a slight decrease in the rate of spread-winged behaviour in the monsoon season when compared to the other seasons. The rate of activity slowly increased from 1.62 to 9.18% till 16.30 hours and then decreased (2.5%). The rate of gular flutter was low during monsoon season (Fig. 4.18). In the morning hours it was at a decreased rate. At noon the rate of gular flutter increased and reached a peak rate between 16.30 and 17.30 hours. Fan-drying was high during monsoon season. The highest rate was observed between 9.30 and 10.30 hours.

The duration of perching was high during monsoon season (Fig. 4.15). A peak value (70.99%) was found between 6.30 and 7.30 hours. The lowest value (21.78%) was observed between 16.30 and 17.30 hours. Flying activity was low during breeding season. Flying rate was 0.82 to 1.72% and the highest rate (1.72%) was observed between 9.30 and 10.30 hours. Paddling rate was low and it ranged between 0.64 and 1.74%.

There was no specific pattern of time allotment for vigilance during monsoon season. The bird spent very small percentage of time for this activity (0.66-1.31%). The bird was less active during monsoon season (Fig. 4.11).

Postmonsoon

During postmonsoon season Darter spent about 37.26% time of the daily hours for feeding. Time spent for maintenance was 55.40%. Allocation of time (37.26%) for feeding activity was greater than that in monsoon season (32.18%) and less than that of pre monsoon season (40.99%).

The pattern of spread-winged activity was similar to that of pre monsoon season. In the morning hours the rate was less whereas in the noon and afternoon hours the rate was greater. The value ranged between 1.12 and 8.39%.

In the morning hours gular flutter was much reduced. The rate of gular flutter increased slowly during noon and evening hours. The value ranged between 0.58 and 5.73%. Fan-drying was recorded from 6.30 to 10.30 hours.

It was absent from 10.30 to 16.30 hours. From 16.30 onwards the behaviour was recorded again.

Preening activity showed a peak of 5.59% in the morning hours. Then it increased gradually till 17.30 hours. The lowest value (2.83%) was observed between 6.30 and 7.30 hours. The maximum value (8.35%) was observed between 16.30 and 17.30 hours. Perching was highest (63.39%) in the morning between 6.30 and 7.30 hours. The lowest rate of (19.97%) perching was found between 16.30 and 17.30 hours.

There was no specific pattern for paddling during postmonsoon season. Highest activity (2.58%) was found between 14.30 and 15.30 hours. Lowest activity (0.63%) was observed between 16.30 and 17.30 hours. Flying activity was low and it ranged between 0.91 and 2.00%. The bird was alert throughout the day. But it constituted only a small percentage. The bird was more active when compared to monsoon season (Fig. 4.12).

4.5 Discussion

4.5.1 Little Cormorant

Awakening and roosting of birds usually coincides with sunset and sunrise respectively. However in Little Cormorants they woke up earlier than sunrise and reached the feeding site later than other species. Similarly they left the feeding habitat before sunset. Stonehouse (1967) reported that White throated shags, *P. melanoleucos brevirostris* and Black Shags, *P. carbo novaehollandiae* started their feeding later than other wetland birds (terns, herons and other waders) and their feeding ended an hour before sunset. As suggested by Stonehouse these timings could be related to good light, presumably essential for visual hunting under water. An underwater forager like Little Cormorant also follow the same pattern of awakening and roosting since good light is essential for hunting of its prey. According to Raveling (1972) and Swingland (1976), temperature and light intensity influence the time of awakening and roosting in birds.

Little Cormorants like other colonial wetland birds usually roost away from their feeding site (Urfi, 2003). So they have to start and end their daily activities accordingly.

Like most of the cormorants, Little Cormorant also showed an uninterrupted wing flapping during flight. This observation agrees with the flight patterns of Double-crested Cormorant (Owre, 1967). Adequate space for a long take off over water is a must for Little Cormorant, and it preferred open water which is available in the study sites.

While swimming at water surface, the back and shoulders were exposed in the case of Little Cormorant compared to Darter. This shows that it is more buoyant than Darter and can adjust buoyancy using air insulation in the body plumage as suggested for other cormorants (Casler, 1973). Powerful musculature and webbed feet of the hind limbs are adapted for swimming at the water surface for a long period (paddling) (Owre, 1967). Such an inclination for paddling after foraging could be noticed in Little Cormorants.

Birds foraging in a group increase the chance of success in finding and exploiting the source of food (Pettingill, 1970). Little Cormorants gathered in great numbers, formed tight bunches on the water surface to locate and concentrate fishes during foraging. This type of foraging was referred as "concert catch fish" (Grzimek, 1990) which enhances feeding efficiency. Flocking behaviour was also observed at nesting and roosting sites of Little Cormorants. This enhances information transfer regarding food resources and increased vigilance against predators (Brown, 1964; Pettingill, 1970).

The spread-winged behaviour is well known in cormorants and darters (Clark, 1969; Lindahl, 1970). The suggested functions include balancing posture (Stabler, 1957); intraspecific signal of successful fishing (Jones, 1978); aid to thermoregulation (Lindahl, 1970; Hennemann, 1982); wing drying (Rijke, 1968); Vitamin D synthesis or the removal of ectoparasites (Kennedy, 1969). The wing drying hypothesis of Rijke (1968) and Casler (1973) proved that these birds possess wettable plumage and allows water to penetrate the air spaces next to the skin. This reduces buoyancy and facilitates underwater foraging. In my study, Little Cormorants also showed this behaviour immediately after returning from water. Quick drying of wings help to regain air worthiness of the plumage which in turn facilitates heat conservation. Wing drying and thermoregulation could be the most probable functions underlying this behaviour in Little Cormorants also. Gular fluttering is also an activity for thermoregulation.

Wing drying could be facilitated by fanning of the wings which was especially useful in the absence of direct sunlight. This agrees with the findings of Dick and Wurdinger (2001).

Physical displays are important means of communication among social species like Little Cormorant. Aggressive display involves pointing the bill at the opponent as observed in other Phalacrocoracidae (Snow, 1960). Observations during the study period showed that Little Cormorant is less aggressive compared to Great Cormorant (Mathews and Fordham, 1986).

Calls were produced in the colony when intruders were present. Normally the adults were very silent and became noisy only in the presence of intruders and juveniles. An alarm call was lacking in Little Cormorant as in other phalacrocoracidae (Mathews and Fordham, 1986).

Time activity budget reflects a combination of factors including individual physical condition, social structure and environmental conditions (Paulus, 1988). The amount of time allocated to various behaviours is therefore critical in understanding the ecological needs of a species. Most organisms allocate their time for different behavioural activities and optimal time budgeting is influenced by circadian and seasonal rhythms.

A piscivorous bird like Little Cormorant foraged for a small percentage of time when compared to herbivorous birds as reported by Paulus (1988).; Carnivorous species may have to spend less time feeding than herbivorous species as the food material has a higher calorific value than plant materials (Driver *et al*., 1974). Further, cormorants are opportunistic foragers decreasing diving costs during foraging (Wanless *et al*., 1993) using various tactics. Again the feeding behaviour differ considerably among the species depending on timing and location.

A bimodally distributed feeding activity was noticed in the present study (Fig. 4.19). There were two peaks of activity, one during the morning session and another in the afternoon with a precipitous drop by noon or mid-day.

Environmental characteristics influence the feeding activity of Little Cormorants. The studies of Kasthurirangan (1957) showed that annual maximum of inshore sea surface temperature reaches by April/May. During this premonsoon period the temperature of the inshore water increases and the warmer water provides a suitable environment for the foraging of Little Cormorant without much energy loss.

In June with the onset of monsoon, temperature in the coastal water decreases; the oxygen content and nutrients increase. Nutrient availability enhances the productivity of coastal waters creating a suitable environment for fishes to breed (Seshappa and Jayaraman, 1956). Availability of food is an important factor for the juveniles to grow and recruit into the population in the monsoon and postmonsoon months. Hence the food availability increases and Little Cormorants foraged for a decreased time as compared to premonsoon. Foraging cost of these birds become high as the temperature of water decreases during monsoon and postmonsoon and they utilize less time for feeding.

Gremillet *et al.* (2001) reported that wintering Great Cormorants in Greenland alter their foraging activity, by minimizing time spent in water. Similarly in our study also Little Cormorants adjusted their feeding time according to the changes in the environmental conditions and prey availability. In cold water, heat losses will be amplified. During winter Great Cormorants at Loch Leven decreased their dive time and increased their diving efficiency inorder to proportion the energy budgeting in the colder climate (Gremillet *et al.*, 2003). In cold water they acquire food faster and target high density prey patches.

Little Cormorants spent more time for maintenance in monsoon and postmonsoon than premonsoon. It was observed that the bird set aside only a small proportion of time for feeding compared to maintenance (Fig. 4.19). These two activities are inversely related. The environmental factors (temperature and rainfall), the nature of the habitat and availability of nutritious food explains the variations in seasonal time allotment for various activities. Whenever there was a time lag to locate the prey the bird paddled at the water surface. Paddling was found after feeding also and it was more frequent at noon. A similar activity was observed by Stonehouse (1967) among White throated Shags and Black Shags. After the final dive of a feeding bout, the bird shook its plumage vigorously, with head dipping, wings extended, and feathers ruffled (bathing and ruffling). This presumably displaces water from the feathers and increases buoyancy to take-off from water.

4.5.2 Darter

The first sighting of Darter in the field was half an hour after sunrise. This could be the time required to fly from roosting site to the feeding habitat. Similarly it left the field about 15 minutes earlier than sunset. Light is a limiting factor for underwater foraging (Stonehouse, 1967) and Darters also may require clear vision for its diving expedition like Little Cormorant.

During flight Darter adjusted its wings at intervals according to height and occasionally flew to great altitudes. Soaring was also observed as mentioned by Ali and Ripley (1987). As Darter took-off from feeding habitat it gained altitude rapidly by adjusting its wings. It circled motionless in summer to great heights as observed in the American Darter (Meanley, 1954).

In the present study, it was observed that Darters swam with only head and neck raised above water whereas Little Cormorant swam with head, neck, back and shoulders raised above water. This shows that Little Cormorant is more buoyant than Darter. This may be due to possession of wettable plumage by Darter and partially wettable plumage by Little Cormorant as noticed by Casler (1973) in other cormorant species. In Darters paddling was similar to Little Cormorant but at a slower speed. Flock feeding was not observed among Darters.

Spread-winged behaviour was exhibited by Darter also, the function of which seems to be absorption of solar radiation, rapid wing drying and conservation of heat energy. It has been described by Hennemann (1982) in American Darter. Wing-spreading has been documented for several orders of birds mainly the Pelecaniformes, Ciconiformes and Falconiformes (Clark, 1969; Lindahl, 1970). In the absence of direct solar radiation wing drying was compensated by the active convection induced by fanning of the wings (fan-drying). This behaviour was observed for Darters in the present study. Fanning of the wings will improve evaporation by actively shaking their feathers.

At the end of feeding, bathing and ruffling was not observed in Darters. In the present study this behaviour was reported for Little Cormorant. Darters were found to crawl back to the river banks after feeding, with their water-laden plumage. The wettable plumage of Darter could not get rid off water easily.

Most of the behaviours observed in Little Cormorant were found in Darter also. The activity pattern may depend upon the species living in different climatic conditions and geographic locations (Heatwole and Taylor, 1987). Both Little Cormorant and Darter are piscivorous and forage under water, but depending upon the habitat and food availability they showed differences in the activity pattern.

The present study showed seasonal variations in the activity pattern of Darter. Feeding rates were higher than that of Little Cormorant (Fig. 4.21). This variation could be due to the difference in the feeding habitat. The feeding site of Little Cormorant was at Kallampara backwaters which is influenced by tidal cycles and the food availability was greater when compared to the feeding site of Darter. Kalpally-Palliyol wetland, the feeding site of Darter carries plenty of submerged vegetation and it is deeper than Kallampara feeding site. The underwater diving pattern of Darter is more complicated in comparison to that of Little Cormorant (Hustler, 1992). Darter moves slowly searching the entire water column in the underwater expedition. It spent more time for maintenance than for feeding (Fig. 4.20).

Spread-winged behaviour increased in frequency depending upon the time of the day and season as noticed in American Darter (Hennemann, 1982). To enhance drying of the wings, in the absence of direct sunlight fan drying was performed by Darters also. Gular fluttering was also performed by Darters as a mechanism to get rid off excess heat but the frequency was less when compared to Little Cormorant (Fig. 4.22).

Fig. 4.1. Activity Pattern of Little Cormorant during Premonsoon (2006)

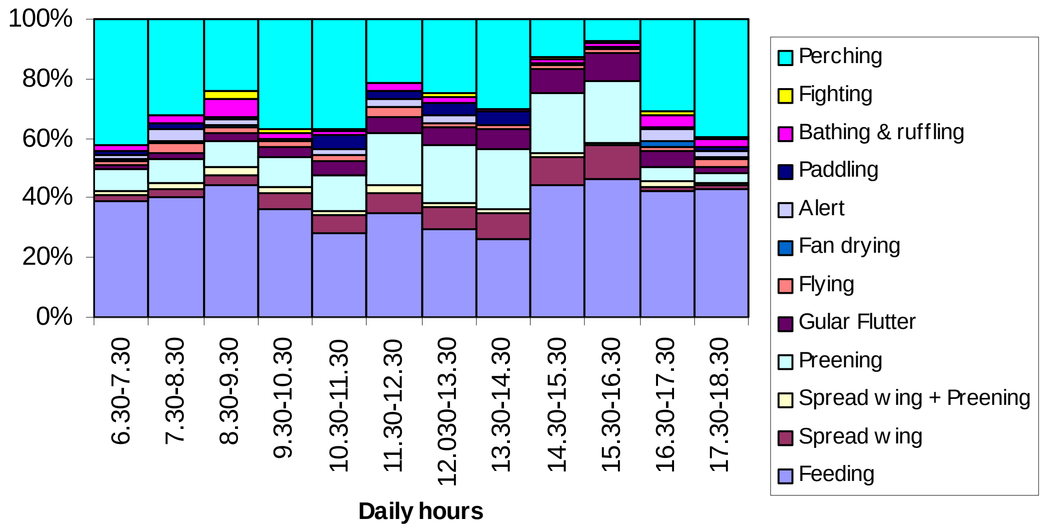


Fig. 4.2. Activity Pattern of Little Cormorant during Monsoon (2006)

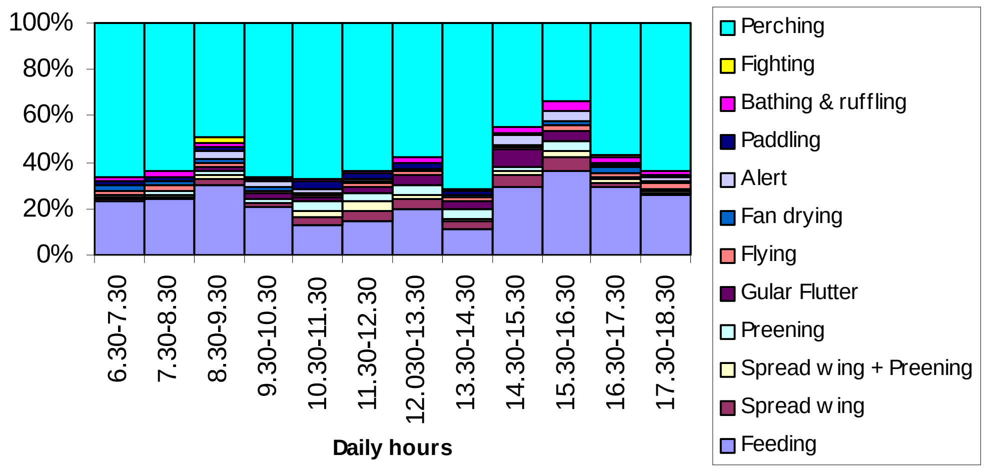


Fig. 4.3. Activity Pattern of Little Cormorant during Postmonsoon (2006)

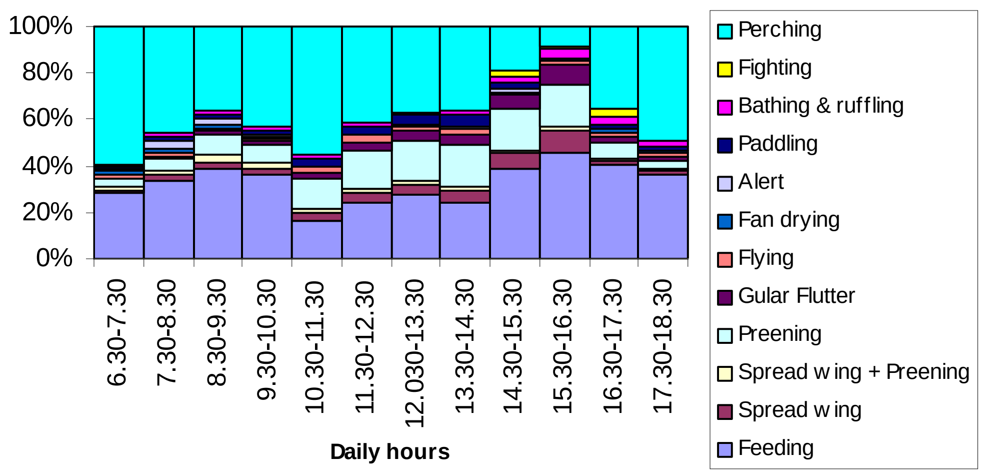
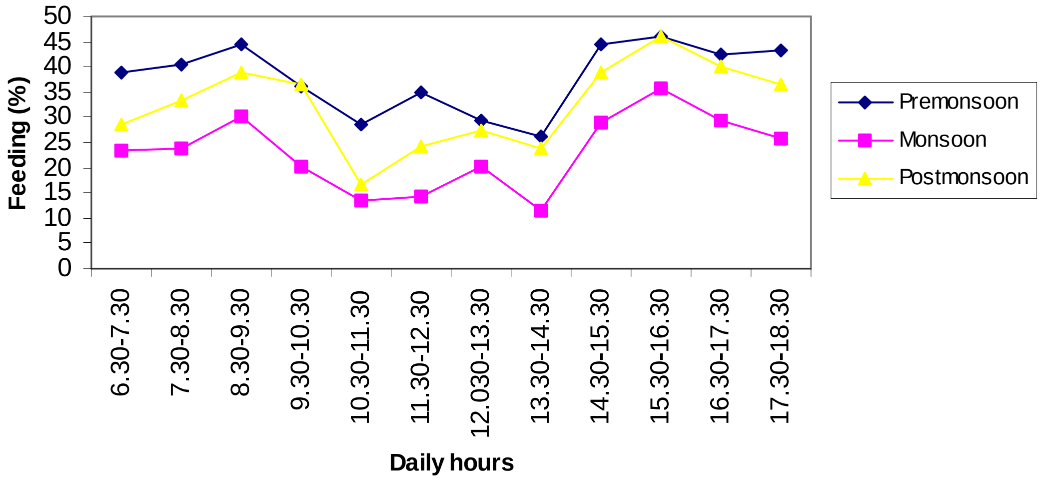


Fig. 4.4. Feeding behaviour of Little Cormorant during different seaons (2006)



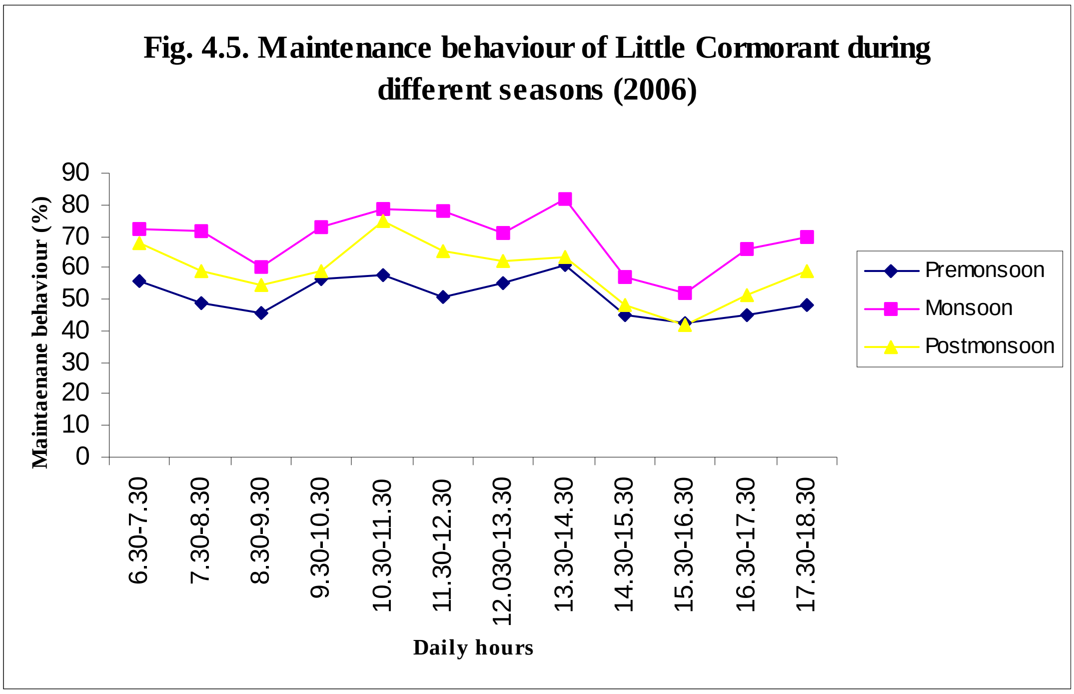


Fig. 4.5. Maintenance behaviour of Little Cormorant during different seasons (2006)
Maintaenane behaviour (%)
90
80
70
60
50
40
30
20
10
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.030-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours
Premonsoon
Monsoon
Postmonsoon

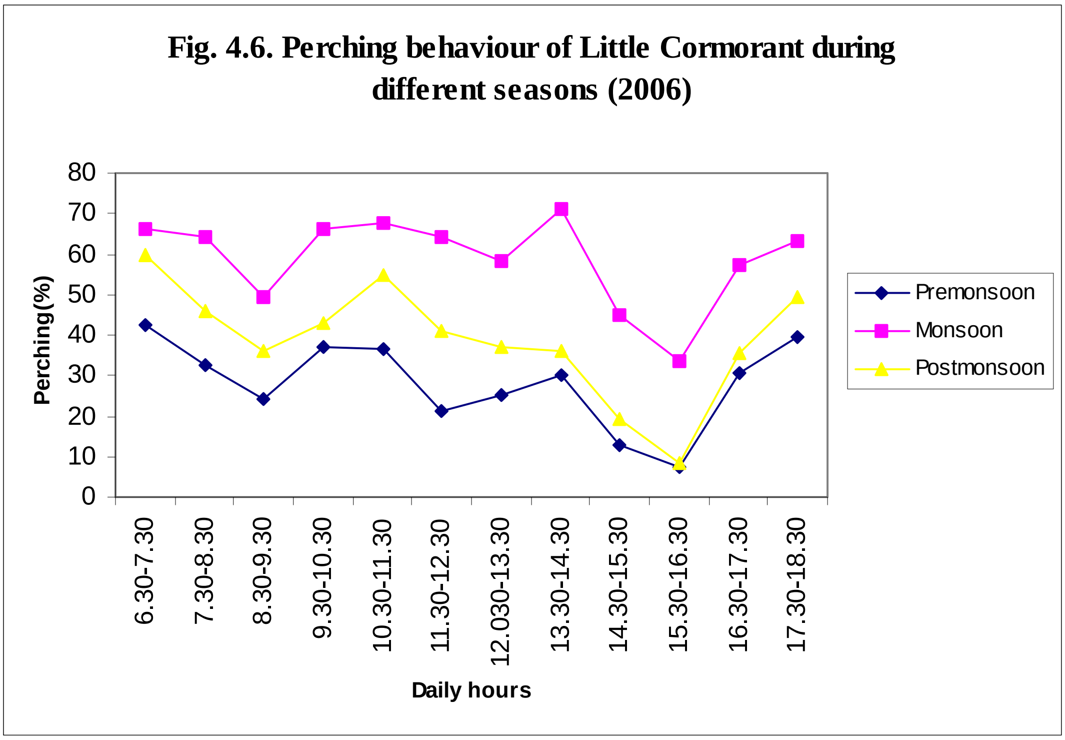


Fig. 4.6. Perching behaviour of Little Cormorant during different seasons (2006)
Perching(%)
80
70
60
50
40
30
20
10
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.030-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours
Premonsoon
Monsoon
Postmonsoon

Fig. 4.7. Little Cormorant: Pattern of Spread wing in different seasons (2006)

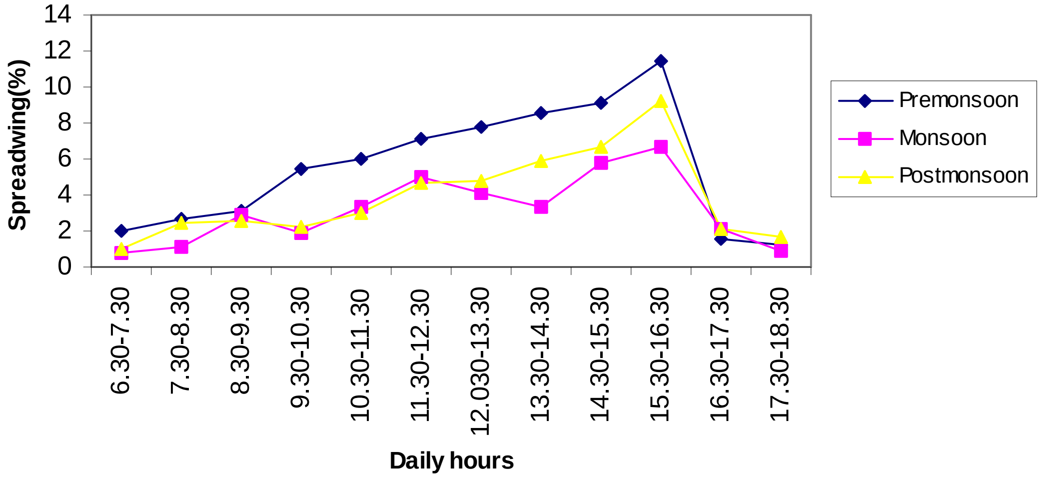
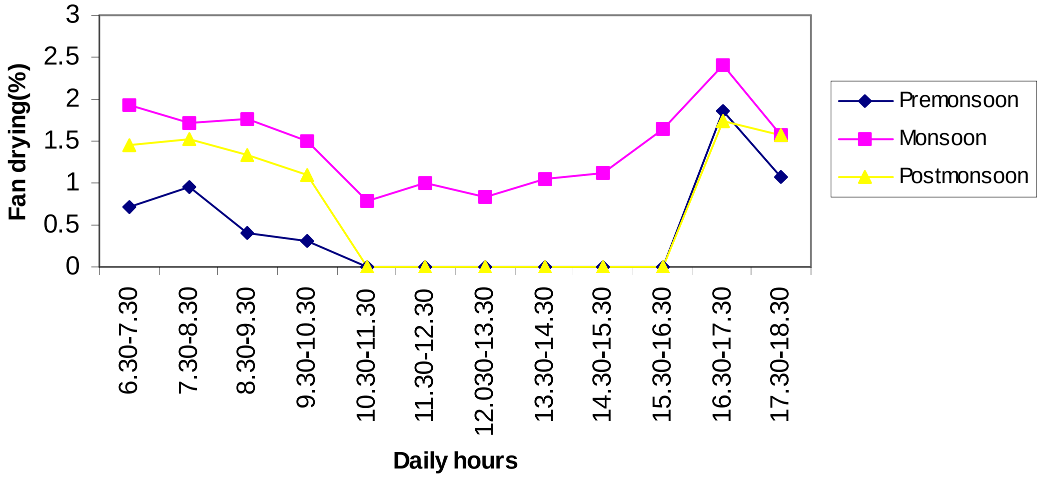


Fig. 4.8. Little Cormorant: Pattern of Fan drying in different seasons (2006)



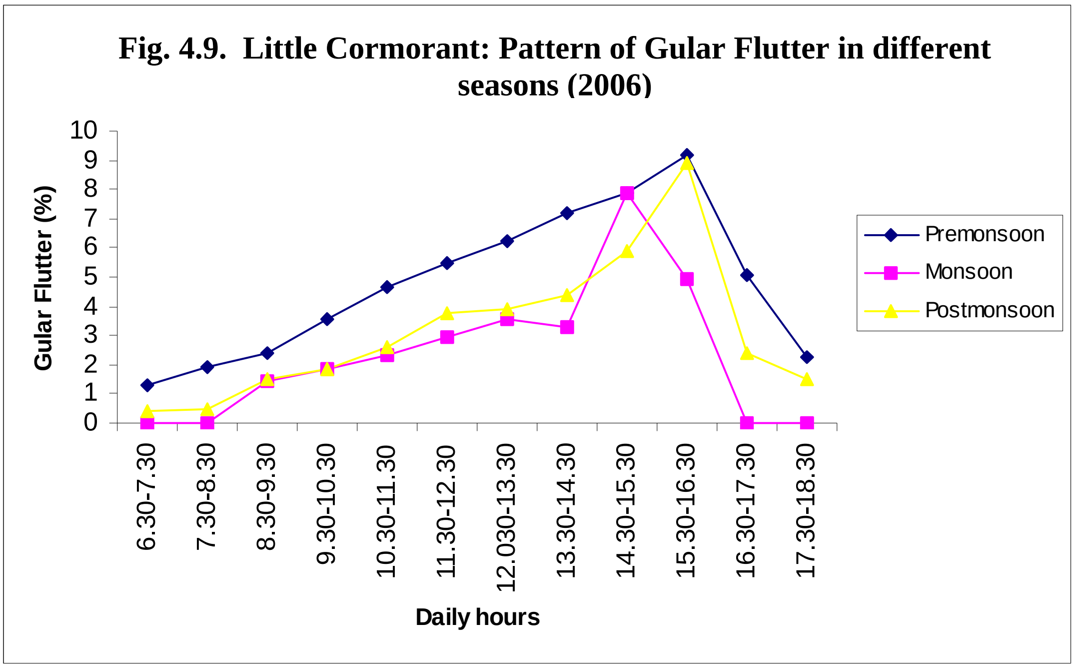


Fig. 4.9. Little Cormorant: Pattern of Gular Flutter in different seasons (2006)
Gular Flutter (%)
10
9
8
7
6
5
4
3
2
1
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.030-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours
Premonsoon
Monsoon
Postmonsoon

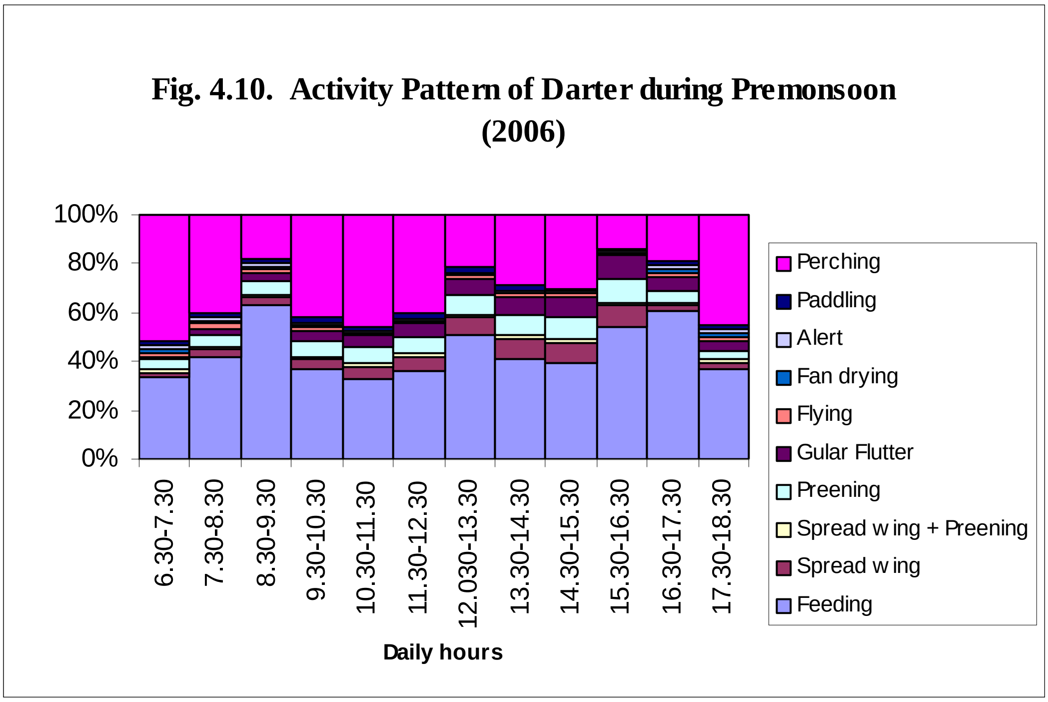


Fig. 4.10. Activity Pattern of Darter during Premonsoon (2006)
100%
80%
60%
40%
20%
0%
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.030-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours
Perching
Paddling
Alert
Fan drying
Flying
Gular Flutter
Preening
Spread w ing + Preening
Spread w ing
Feeding

Fig. 4.11. Activity Pattern of Darter during Monsoon (2006)

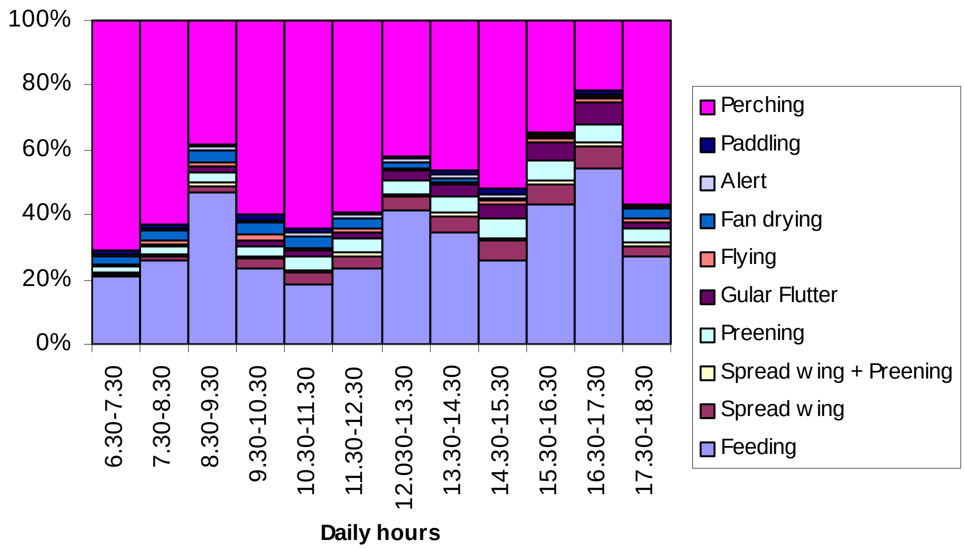


Fig. 4.12. Activity Pattern of Darter during Postmonsoon (2006)

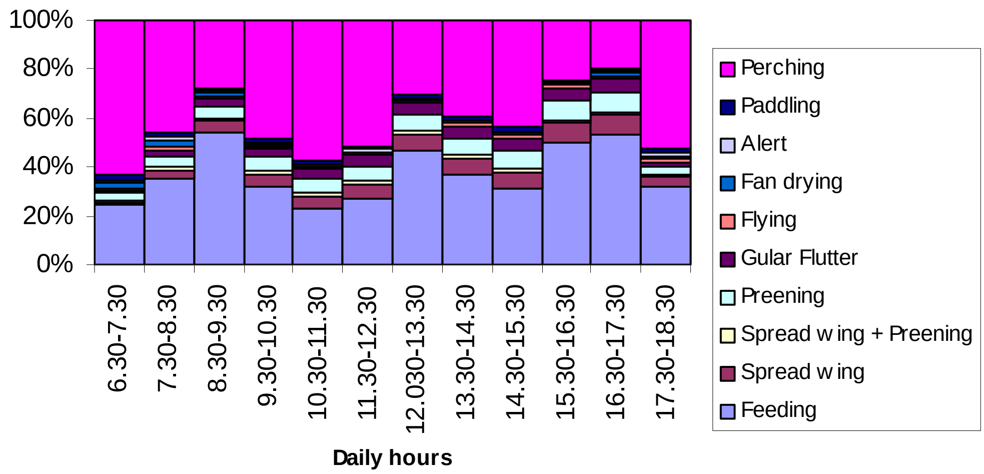


Fig. 4.13. Feeding behaviour of Darter during different seasons (2006)

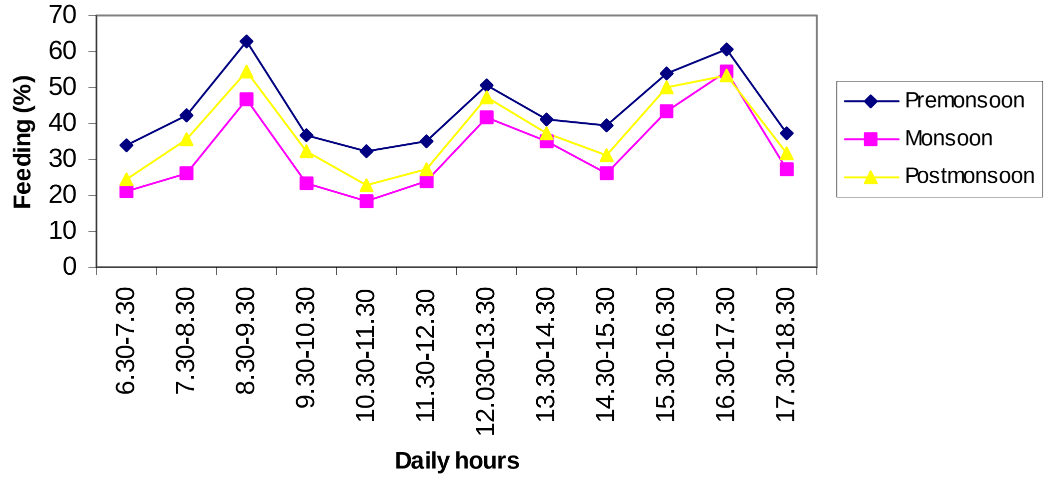


Fig. 4.14. Maintenance behaviour of Darter during different seasons (2006)

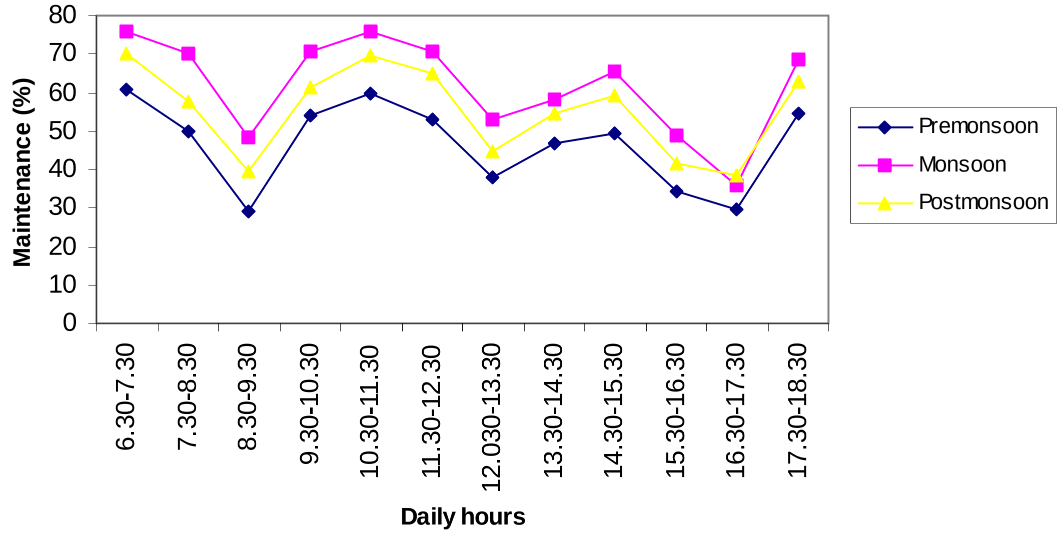


Fig. 4.15. Perching behaviour of Darter during different seasons (2006)

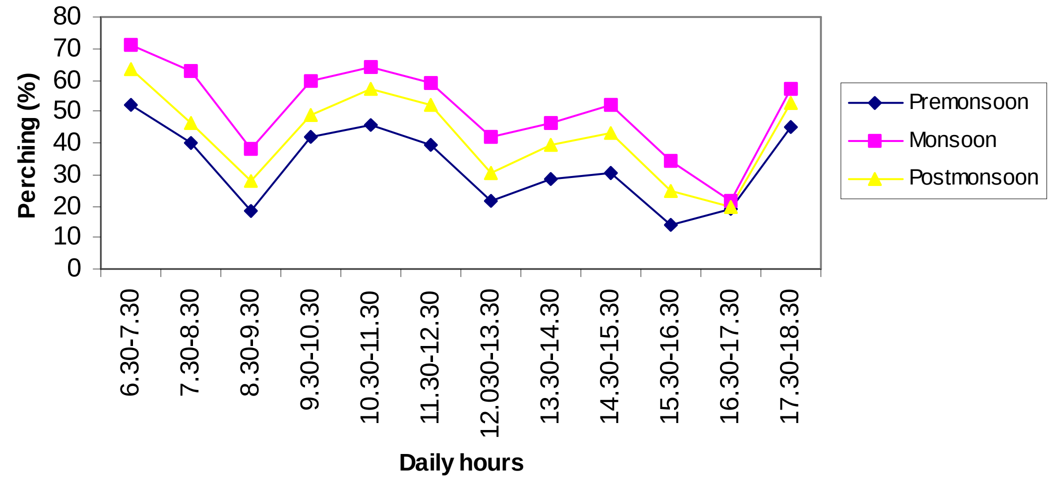


Fig. 4.16. Darter : Pattern of Spread wing in different seasons (2006)

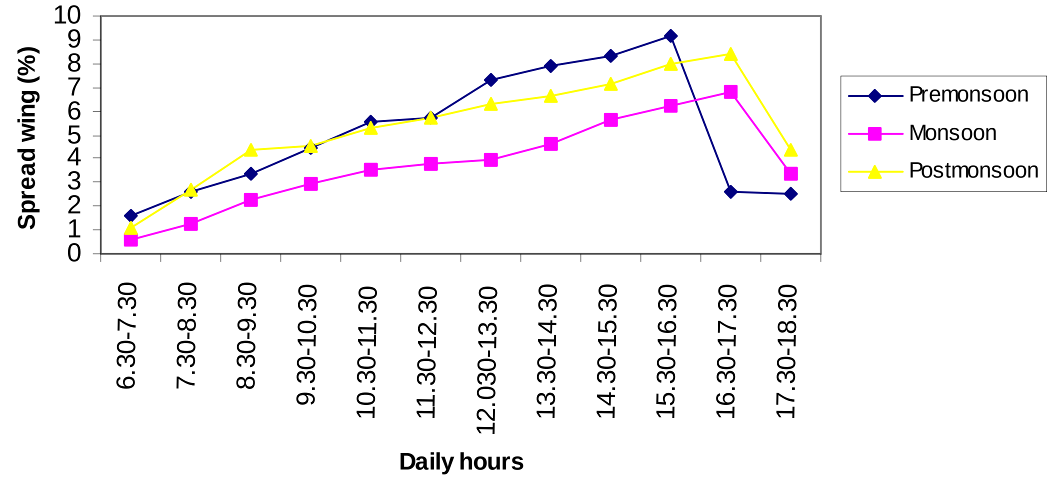


Fig. 4.17. Darter: Pattern of Fan drying in different seasons (2006)

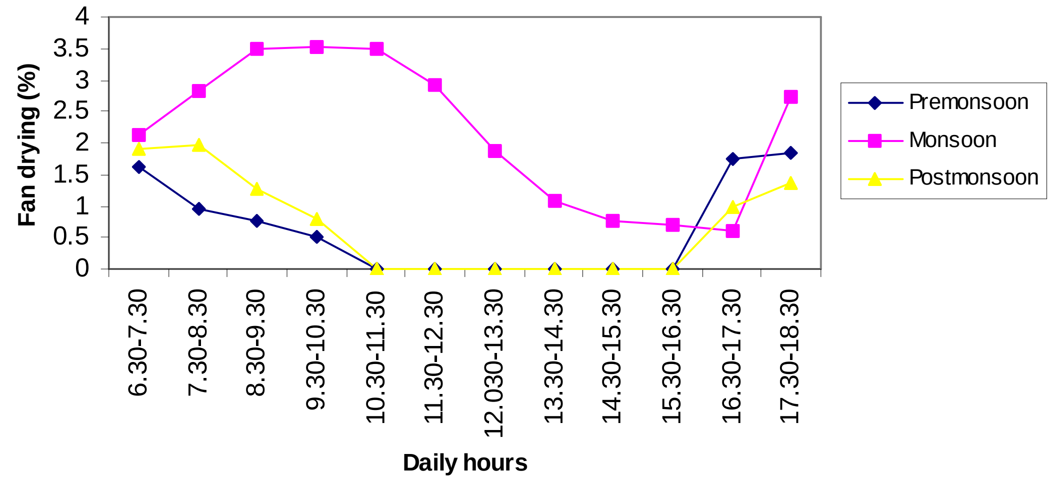


Fig. 4.18. Darter: Pattern of Gular Flutter in different seasons (2006)

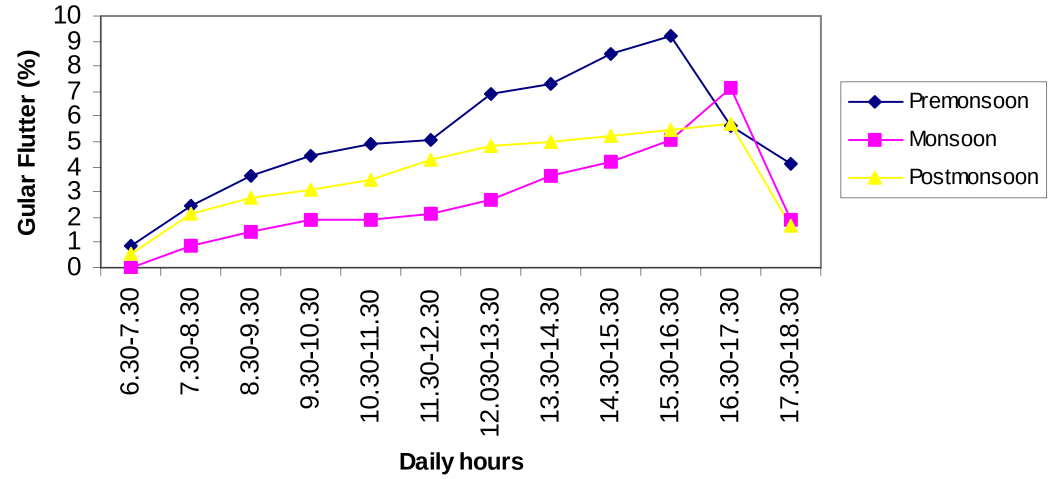


Fig. 4.19. Pattern of feeding versus maintenance behaviour in Little Cormorant

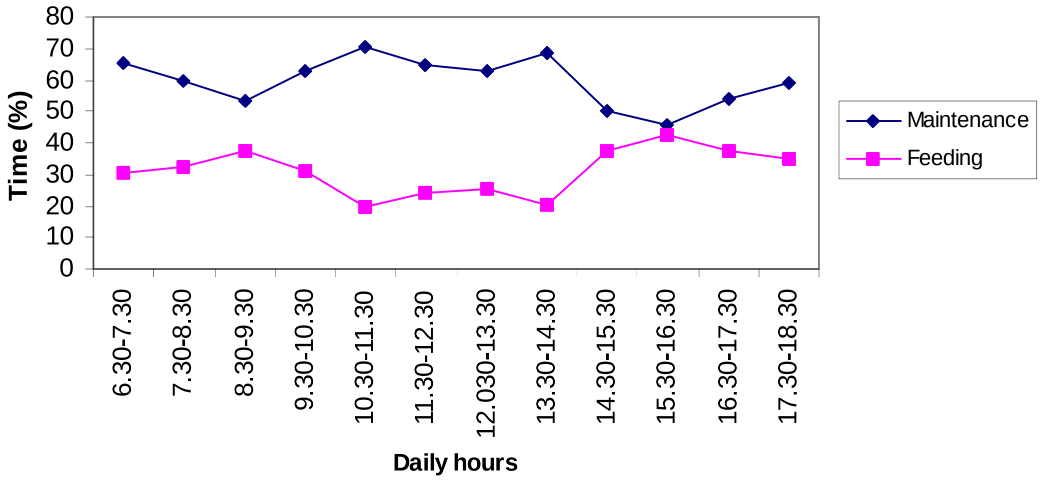


Fig. 4.20. Pattern of feeding versus maintenance behaviour in Darter

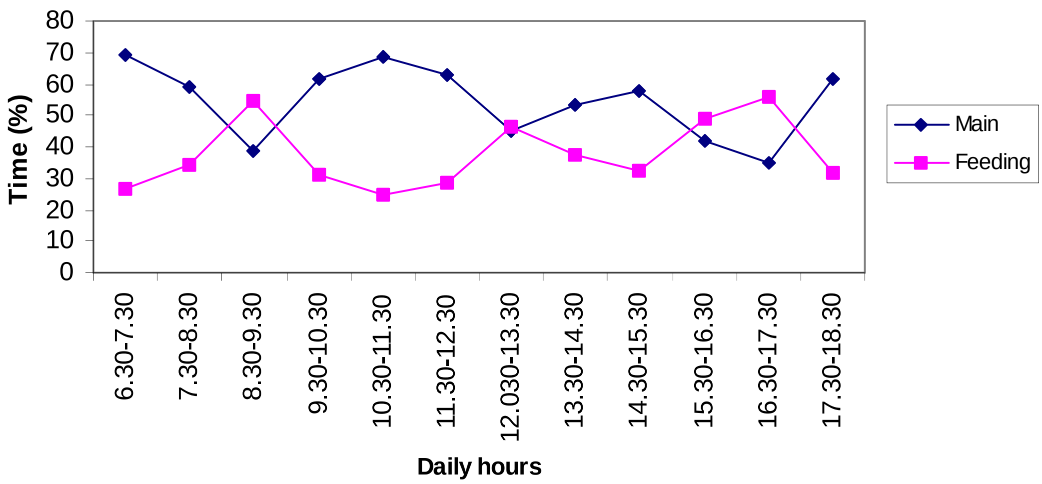


Fig. 4.21. Feeding activity of Little Cormorant and Darter

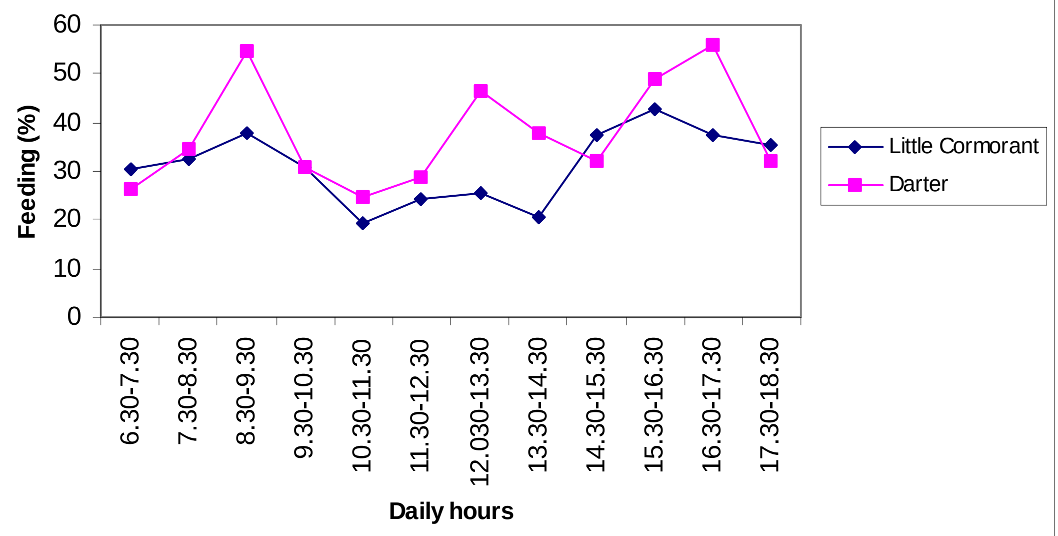
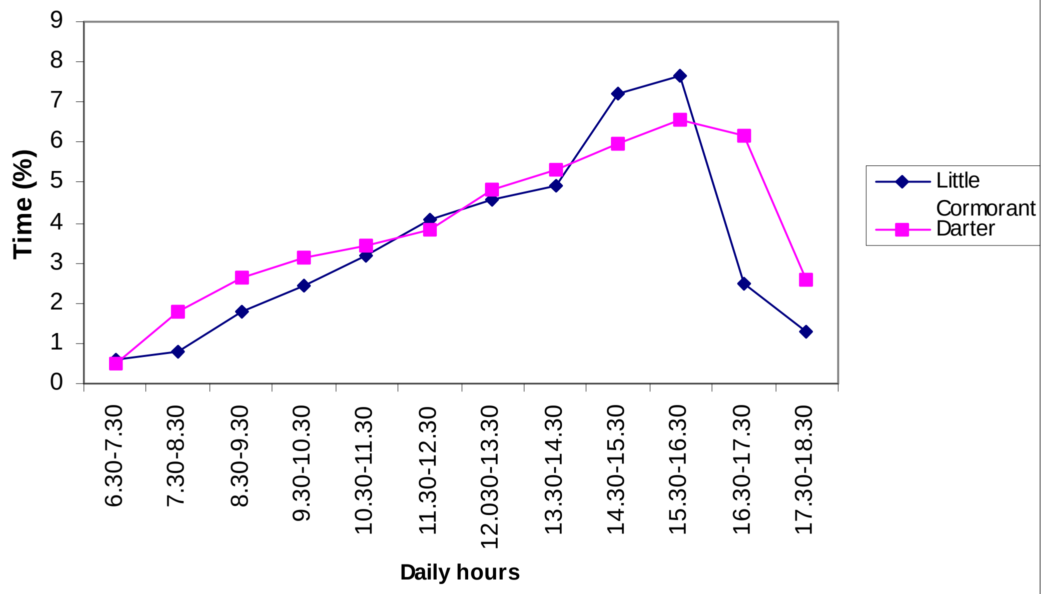


Fig. 4.22. Gular Flutter activity of Little Cormorant and Darter



Chapter 5

FORAGING BEHAVIOUR AND DIVING PATTERN

FORAGING BEHAVIOUR AND DIVING PATTERN

5.1 Introduction

Underwater activity of a diving fowl is quite fascinating to Ornithologists. Although some dives by birds are made during courtship or to escape from predators, most are made to capture food. Diving birds may be considered as central-place foragers (Orians & Pearson, 1979; Lessels and Stephens, 1983) which make repeated foraging excursions from surface to which they must always return to breathe. Under water, they travel to the bottom, search for, pursue, and capture prey and return to the surface. Prey is usually handled and consumed on the surface.

Cormorants are foot-propelled pursuit divers (Ashmole, 1971). They are inshore versatile foragers that may switch from benthic to pelagic foraging and from fish to invertebrate prey (Leopold and Van Damme, 2003). They typically forage by undertaking a series of dives from water surface interspersed with brief recovery periods or surface pauses (Cooper, 1986). Cormorants and shags appear to be well adapted to dive in shallow waters (Wilson and Wilson, 1988; Wilson *et al.*, 1992; Cooper, 1986) and some species may minimize foraging cost by diving near surface (Wanless *et al.*, 1993).

Many studies have been carried out on the feeding behaviour of cormorants. They include comparison of dive and rest times (Stonehouse, 1967; Morrison and Slack, 1977; Williams and Cooper, 1983), comparison of dive times of different species (Cooper, 1986) and study of diving patterns of Antarctic Shag (Casaux, 2004). Foraging behaviour of Rock Shags (Quintana, 2001), diving patterns of Antarctic blue-eyed shag (Croxall *et al*., 1991), feeding performance and foraging area of Red-legged Cormorant (Gandini *et al*., 2005), foraging behaviour of Imperial Cormorants, *P. atriceps* (Sapoznikow and Quintana, 2003), diving behaviour of the Red-legged Cormorant (Frere *et al*., 2002), foraging location and site fidelity of the Double-Crested Cormorant (Coleman *et al*., 2005) and foraging behaviour of Japanese Cormorants (Kato *et al*., 1998; Watanuki *et al*., 2004) are the other studies. However, studies on Little Cormorant is lacking.

Although there have been studies on feeding ecology and diet of Darter *A. melanogaster*, the diving pattern is not documented (Birkhead, 1978; Donnelly and Hustler, 1986). The effect of changing buoyancy on the diving behaviour of Reed Cormorants, *P. africanus* and Darters *A. melanogaster* was investigated by Hustler (1992).

Diving behaviour is controlled mainly by physiological constraints within a group: larger species with a potentially larger capacity for oxygen storage, should be able to stay submerged longer than smaller ones (Butler and Jones, 1982; Cooper, 1986; Butler and Stephen, 1987; Kooyman, 1989).

Like other avian divers, the feeding performance of cormorants is influenced by a variety of environmental factors such as water depth, nature of the bottom and prey density (Dewar, 1924; Ydenberg and Forbes, 1988; Croxall *et al*., 1991; Carbone and Houston, 1994; Monaghan *et al*., 1994). Environmental variables like tidal cycles also influence the diving behaviour of Red-legged Cormorants (Frere *et al*., 2002). They are able to forage by selecting appropriate tidal conditions and optimum time to feed (Gandini *et al*., 2005).

Solitary feeding is the most frequently used foraging strategy among cormorants (Watanuki *et al*., 2004) and Shags (Casaux, 2004). Occasionally, small and large groups were found to exploit the prey population (Watanuki *et al*., 2004; Bernstein and Maxson, 1985). Diving sea birds like Common Loons (Thompson and Price, 2006) and Black-legged Kittiwakes (Irons, 1992; Bayer, 1983) used to forage in large flocks. Flock feeding may enhance foraging efficiency (Harrison *et al*., 1991). Sea birds can locate feeding flocks by observing the flight of other birds towards a feeding flock (Hoffman *et al*., 1981). This type of information transfer is called network foraging (Wittenburger and Hunt, 1985).

Diving sea birds may use different foraging tactics to exploit unpredictable and predictable prey (Watanuki *et al*., 2004). If diving sea birds forage on ephemeral prey, they enhance their ability to locate prey patches by joining other feeding flocks (Hoffman *et al*., 1981). If they feed on predictable prey, they seem to forage on the basis of the knowledge of the locations of persistent schools of prey (Davoren *et al*., 2003a&b).

Cormorants prey on both epipelagic and demersel prey (Schreiber and Clapp, 1987; Johnsgard, 1993; Gremillet *et al*., 1998b) in coastal areas (Gremillet *et al*., 1999; Wanless *et al*., 1999). They forage in large flocks when they do so on ephemeral epipelagic prey (Watanuki *et al*., 2004). Recent studies show high flexibility in their foraging behaviour (Wanless *et al*., 1998; Gremillet *et al*., 1998b).

5.2 Objectives

1. To study the foraging behaviour and diving pattern of Little Cormorant and Darter.

2. To study the flock feeding behaviour of Little Cormorant.

3. To find out the changes in the diving pattern in relation to different diving depths.

5.3 Methodology

The study was conducted from October 2005 to May 2006, mainly based on direct observational method (Altmann, 1974). Data were collected during day time between 6.30 to 18.30 hours. Focal observations were carried out on randomly selected foraging Little Cormorants and Darters. Observations were made from convenient vantage points on the shore using a stopwatch and binoculars (8x40).

Cormorants and darters foraging solitarily were studied. Flock feeding of Little Cormorant was also studied. The duration of a diving bout is taken as the time between submerging on the first dive of a series and surfacing after the last dive. A dive cycle consists of a single dive and a single surface pause. Diving efficiency is defined as the ratio between mean diving time and mean recovery period (Dewar, 1924).

Data were collected from both the study sites – Kallampara and Kalpally-Palliyol. From Kallampara, data for Little Cormorant were collected whereas from Kalpally both the birds were observed and data collected.

Depth profile of the feeding locations were determined at different tidal conditions. The foraging behaviour of Little Cormorant was studied at different diving depths at different tidal conditions. Data were recorded during high tide, the first quarter of receding tide (immediately after high tide), low tide and the first quarter of advancing tide (immediately after low tide).

A mean value of each diving variable was determined for every diving bout. Mean $\pm$ SD values are presented in the table. Scheffe multiple test was used to find significance of various diving parameters among different birds, at different places and during different seasons. P-value < 0.05 is considered significant. Two-way ANOVAs were used to test significance between different diving parameters at different tidal cycles. P-value < 0.05 is considered significant.

5.4 Results

Foraging behaviour and diving pattern of both Little Cormorant and Darter were studied by focal observation methods. Darters fed solitarily but Little Cormorants fed solitarily as well as gregariously. Both of them followed similar patterns of behaviour, but differences were also observed. They were active from dawn to dusk, with reduced feeding activity at noon. Coinciding with tidal cycles flock feeding was observed among Little Cormorants.

The data analysed by Scheffe Test (Appendix V.A) shows significant variations in the time spent for foraging activities by Little Cormorant and Darter. It also shows changes in the foraging durations of Little Cormorant at different feeding habitats. The results of ANOVA for diving parameters were plotted as graphs (Appendix V.B).

5.4.1 Diving pattern

Both Little Cormorant and Darter followed a specific foraging pattern which consisted of flying from their overnight roosts to the river bank and perching near the inshore waters. They perched on the nearby mangrove trees, other trees as well as on stakes and mudflats prior to the beginning of the dive. The perch was used as a base while foraging. After settling on the base the bird dropped into water and started diving. The first dive was followed by a short recovery period (surface pause) and then continued a series of alternative dives and surface pauses for a specific period (bout duration).

Various diving parameters were recorded in both the cases and they preferred shallow water for feeding. The diving behaviour consisted of a series of dives and surface pauses which form a diving bout.

Data were obtained on the following aspects of diving behaviour (a) Dive duration (b) Surface pause time or recovery period (c) Duration of diving bout (d) Diving efficiency (e) Dive frequency percentage per hour (f) Number of dive cycles per bout (g) Time spent under water per dive cycle (h) Duration of a dive cycle.

5.4.1.1 Little Cormorant

Foraging behaviour and diving pattern of Little Cormorant was studied at Kallampara river site and Kalpally-Palliyol wetland. At both the feeding sites 991 dive cycles and 36 diving bouts were recorded covering different times of the day from 6.30 hours to 18.30 hours. Daily trends in diving pattern related to different hours and different time periods were recorded to understand the foraging intensity. Foraging intensity varied at different times of the day. There was a decline in the time spent for foraging parameters at noon.

In a diving sequence, the bird performed a general pattern of immersion longer than the intervals on the surface. Pause duration increased with the increase in dive duration. Number of dive cycles are more in the morning and evening hours, with low frequency at noon. Diving efficiency also showed a similar trend which declined at noon.

At Kallampara, maximum dive duration was 18.15 sec (n=124) and minimum duration was 5.49 sec. (n=61) (Table 5.1). The pause duration varied between 3.00 sec to 6.99 sec. Diving efficiency ranged between 1.83 and 3.21. The bird spent 64-76% of the dive cycle under water. At Kalpally-Palliyol wetland also a similar pattern was observed (Table 5.2). Maximum dive duration was 25.33 sec (n=100) and minimum dive duration was 11.39 sec (n=66). The pause duration varied between 5.20 sec and 10.64 sec. Diving efficiency ranged between 1.69 and 2.82. The bird spent 63 to 79% of the dive cycle under water. There was a decline in the diving performance between 10.30 and 14.30 hours, during which the frequency and timing of different diving parameters showed a decrease in their intensity. The mean dive duration at Kallampara was 11.73 sec and at Kalpally it was 18.96 sec (Fig. 5.1). At Kalpally-Palliyol duration of dive cycle (Fig. 5.2) and bout duration (Fig. 5.3) were greater than at Kallampara.

5.4.1.2 Darter

The diving pattern of Darter was studied at Kalpally-Palliyol wetland only. The diving pattern was very much similar to that of Little Cormorant, but the timings were different (Table 5.3). We have recorded 1063 dive cycles and 36 diving bouts for Darter at Kalpally-Palliyol wetland. Dive duration ranged between 35.62 sec (n=72) to 59.05 sec (n=114) and the mean value was 48.86 seconds (Fig. 5.4). Pause duration varied between 10.15 sec and 16.87 sec. Bout duration varied between 19.67 min and 51.67 min (Fig. 5.5). Maximum diving efficiency was 3.86 and minimum was 3.19. Darter spent a greater proportion of its dive cycle under water (75.71% to 78.81%). Duration of dive cycle (Fig. 5.6) was greater for Darter than for Little Cormorant.

5.4.2 Flock feeding

Solitary feeding was the most frequently used foraging strategy among Little Cormorants. Occasionally they foraged in groups (Plate X). Flock feeding was observed only at Kallampara river. Small groups (upto 5 individuals), medium group (5-10 individuals) and large groups (more than 10 individuals) were identified under different tidal conditions. Flock feeding was most frequent during low tide and advancing tide (Table 5.4). Maximum flock size observed during advancing tide was 84.48 $\pm$ 74.69 (n=25). During low tide it was 33.19 $\pm$ 15.55 (n=26). The flock size decreased during high tide (13.27 $\pm$ 1.68, n=11) and first quarter of receding tide (12.57 $\pm$ 1.50, n=14).

Dive and bout duration varied among the feeding flocks (Table 5.5). Large flocks showed short dive and bout duration compared to small flocks. The latter had both increased dive and bout duration.

Another significant observation was that individual birds were found to join the feeding flocks frequently (Table 5.5). When recorded, maximum number of birds were found to join larger feeding flocks (59.81%) than smaller flocks (14.95%).

During advancing tide and low tide conditions, large flocks of birds encircled the fish groups detected at the surface layers of water and foraged them quickly. But the smaller feeding groups foraged slowly as in the case of solitary feeding without encircling the fishes.

5.4.3 Adaptation to diving depth

Depth profile of the feeding locations were recorded. The depth measurements were 3.83 ± 0.53 m (high tide), 2.78 ± 0.39 m (receding tide), 1.34 ± 0.21 m (low tide) and 1.08 ± 0.12 m (advancing tide) respectively.

Little Cormorants observed, foraged solitarily in shallow water and displayed relatively short diving bouts, composed of few dives. In this study 20 diving bouts and 506 dive cycles were recorded (Table 5.6). Diving parameters showed variations at different tidal conditions. During high tide, mean dive duration was 16.43 ± 1.25 sec (n=98), whereas during receding tide, it was 12.34 ± 1.50 sec (n=116). Mean dive duration was 7.11 ± 1.05 sec (166) for low tide and 5.94 ± 0.69 sec (n=126) for advancing tide. During high tide, surface pause duration was 7.11 ± 1.15 sec (n=98) and it was 6.16 ± 0.82 sec (n=116) for receding tide. It further decreased during low tide (2.37 ± 0.40 sec, n=116) and advancing tide (2.26 ± 0.26, n = 126).

Mean number of dive cycles also showed variations at different tidal conditions. During high tide and receding tide the number of dive cycles were less 19.60 ± 1.34 and 23.20 ± 1.79, while the number increased during low tide (33.20 ± 3.35) and advancing tide (25.20 ± 5.97). Similarly the dive/ pause ratio at low tide and advancing tide were greater (3.01 ± 0.17 and 2.64

± 0.17) when compared to high tide (2.33 ± 0.21) and receding tide (2.01 ± 0.15). Bout duration was high at high tide (8.23 ± 1.52 min) and receding tide (11.12 ± 1.27 min) and decreased during low tide (6.68 ± 1.08 min) and advancing tide(4.56 ± 1.17 min) (Fig. 5.7). Underwater time during each dive cycle varied between 66-75%.

5.5 Discussion

5.5.1 Diving pattern

The diving behaviour and related diving parameters of Little Cormorant and Darter were investigated in this study. It has been observed that surface pause duration increased with increasing dive duration. This possibly suggests that the surface pause between successive dives represent a period of recovery from the physiological effects of diving. The underwater time is utilized for searching, pursuing and capturing the prey. Thus the relationship between dive and subsequent pause gives a good estimate of the time required for complete physiological recovery from a dive of a given duration (Ydenberg and Forbes, 1988; Ydenberg & Guillemette, 1991). A positive relation between dive duration and subsequent recovery time was observed in Little Cormorant as in other Cormorants (Casaux, 2004). Among Darters also a positive correlation between dive duration and recovery time was found.

A common feature of the foraging behaviour of Little Cormorant and Darter is that there are two high intensity feeding periods (forenoon & afternoon) punctuated by a low intensity period between 10.30 hrs and 14.30 hrs. Increased foraging efforts in the morning and afternoon bouts has been recorded for Double-crested Cormorant by Coleman *et al*. (2005). Diel patterns have been observed in the foraging behaviour of shag species also (Wanless *et al*., 1999).

5.5.1.1 Little Cormorant

The mean dive duration of Little Cormorant recorded per day at Kallampara was 11.73 sec and at Kalpally-Palliyol, it was 18.96 sec. In response to foraging condition, birds can adjust feeding time as diving is energetically expensive (Woakes and Butler, 1986). Divers can prolong underwater time if they subsequently increase the surface time between dives (Ydenberg, 1986). It was found that the dive time of Little Cormorant increased at Kalpally-Palliyol suggesting that it might be due to the increased depth of the feeding location and might be due to the presence of submerged plants in this feeding site. Both these factors might be constraints for underwater foraging.

5.5.1.2 Darter

Darters showed increased dive duration than Little Cormorants. Hustler (1992) had found no relationship between the time spent underwater and the depth of water for Darters. According to him they often pause mid way through a dive before continuing to the bottom and do not swim at the same velocity. Hence they are able to exploit the whole water column and increased dive duration may be due to this particular type of behaviour. Also darters swam slower than cormorants. As observed by Casler (1973) Darter is less buoyant than cormorants and it drinks water before swimming, as ballast. It can expel air before it dives and the air sacs of Darter is permanently and greatly reduced in volume and in the extent of bone penetration. All these features make them less buoyant and could be able to submerge more time under water as observed in our study.

5.5.2 Flock feeding

In this study it was revealed that solitary feeding was the most common method of feeding among Little Cormorants. However flock feeding was also observed coinciding with tidal cycles at Kallampara backwaters. A similar behaviour has been reported in the Japanese Cormorants by Watanuki *et al*. (2004). Flock feeding would be helpful in detecting the prey easily. This mode of foraging seems suitable for exploiting the epipelagic fish schools efficiently. According to Hoffman *et al*. (1981) feeding flocks facilitate locating and exploiting readily available epipelagic fish patches. Little Cormorants gain an additional advantage by feeding in flocks to enhance the foraging success. Also, dense schools of epipelagic fish might have attracted larger flocks of birds. Little Cormorants have a potential to exploit both transitory epipelagic fish schools and also sparse fish found under water efficiently by changing the utilization pattern.

Individual Little Cormorants feeding solitarily joined larger feeding flocks more frequently. The probable reason may be that these birds by joining the feeding flocks can easily detect and forage upon the prey population to enhance foraging success.

5.5.3 Adaptations to diving depth

Little Cormorant made foraging trips to inshore water < 5 m deep near the bank within a small feeding range (< 1 km) at various tidal conditions. During different tidal conditions, surface pause duration increased with increasing dive duration and a positive relation was observed in Little Cormorant as in other cormorant species (Casaux, 2004; Cooper, 1986; Croxall *et al*., 1991). Dive duration increased with height of the tide. During high tide and receding tide it almost doubled than at low tide.

When we consider the mean values of diving parameters for all tidal conditions (Table 5.6) it is clear that dives (10.46 $\pm$ 4.86 sec.) and surface pauses (4.48 $\pm$ 2.52 sec) are relatively short for Little Cormorant. It performed relatively shorter diving times and surface pauses than other diving birds like Red-legged Cormorant (Frere *et al*., 2002), Rock Shag, *P. atriceps*

(Quintana, 1999) and Imperial Shag (Croxall *et al*., 1991). The differences in the diving parameters could reflect variation in the diving depth.

Diving birds may use different foraging tactics to exploit prey. In this study, mean dive duration and mean recovery time were linked to the height of the tide (diving depth) as described for Red-legged Cormorant (Frere *et al*., 2002). For longer dives the corresponding rest periods increased and dive/pause ratio (diving efficiency) decreased at high tide and receding tide. During this condition, water depth and volume may increase and prey density falls. Little Cormorants spent more time searching for prey and foraging efficiency decreased at increased diving depth. This might be the probable reason for increased dive duration and subsequent long surface intervals and also decreased diving efficiency.

Little Cormorants foraging in shallow water during low tide and advancing tide might have fed on fishes shoaling close to the surface as in Japanese Cormorant (Watanuki *et al*., 2004). Fishes brought in during high tide may gather during low tide and the density increases. These fish groups could be easily detected and foraged with increased efficiency within short dive duration in shallow water. Hence Little Cormorants foraged successfully in shallow water with increased diving efficiency, reducing diving cost and energy as has been noticed in other studies on cormorants (Wanless *et al*., 1993).

As in Red-legged Cormorants (Frere *et al*., 2002), the foraging behaviour of Little Cormorant was strongly influenced by many environmental characteristics of the habitat. The present study shows that the foraging behaviour is controlled by height of the tide as well as diving depth. Diving seems to be an indicator of the foraging condition, mainly prey availability. Low tide and shallow water might be the optimal condition for Little Cormorant to acquire food faster and reduce diving cost.

Table 5.1. Hourly distribution of diving parameters of Little Cormorant at Kallampara river

No.	Time of Day	No. of dive cycles per bout	Total no. of dive cycles observed	Bout duration (min)	D% Frequency per hour	Dive Duration (Sec.)	Pause Duration (Sec.)	Dive/Pause Ratio	Time under water %
1.	6.30-7.30	45.67 ± 3.06	n = 137	22.5 ± 2.18	3.39 ± 0.11	15.70 ± 0.07	5.43 ± 0.13	2.85 ± 0.09	74.12 ± 0.38
2.	7.30-8.30	40.33 ± 5.51	n = 121	13.5 ± 2.29	5.00 ± 0.18	14.17 ± 0.67	4.71 ± 0.41	2.88 ± 0.09	75.10 ± 0.74
3.	8.30-9.30	41.33 ± 6.11	n = 124	13.33 ± 2.52	5.19 ± 0.23	18.15 ± 0.25	5.55 ± 0.32	3.13 ± 0.18	76.59 ± 1.08
4.	9.30-10.30	35.33 ± 1.53	n = 106	10.67 ± 0.76	5.39 ± 0.40	12.31 ± 0.76	5.05 ± 0.47	2.55 ± 0.18	70.96 ± 1.00
5.	10.30-11.30	18.67 ± 1.53	n = 56	9.9 ± 0.36	3.14 ± 0.15	11.18 ± 1.41	6.02 ± 0.41	1.83 ± 0.12	64.92 ± 1.40
6.	11.30-12.30	12.67 ± 1.15	n = 34	5.5 ± 0.7	3.85 ± 0.15	13.04 ± 2.93	6.99 ± 0.95	2.16 ± 0.17	64.86 ± 3.32
7.	12.30-13.30	20.3 ± 3.21	n = 61	12.2 ± 1.71	2.77 ± 0.13	5.49 ± 0.58	3.00 ± 0.66	1.87 ± 0.35	64.89 ± 4.24
8.	13.30-14.30	16.00 ± 2.65	n = 48	11.00 ± 1.4	2.14 ± 0.10	6.14 ± 0.53	3.21 ± 0.45	1.93 ± 0.10	65.84 ± 1.32
9.	14.30-15.30	27.67 ± 2.08	n = 83	13.77 ± 1.94	3.37 ± 0.21	9.76 ± 1.04	3.14 ± 0.31	3.11 ± 0.04	73.21 ± 4.59
10	15.30-16.30	26.67 ± 3.51	n = 80	16.00 ± 1.80	2.78 ± 0.07	14.60 ± 1.23	6.13 ± 0.94	2.17 ± 0.12	70.5 ± 2.50
11.	16.30-17.30	27.33 ± 2.52	n = 82	13.23 ± 1.96	3.46 ± 0.18	11.44 ± 0.87	3.51 ± 0.32	3.21 ± 0.10	76.52 ± 0.59
12.	17.30-18.30	18.33 ± 1.53	n = 55	12.3 ± 0.70	2.47 ± 0.08	8.74 ± 0.86	3.97 ± 0.20	2.30 ± 0.06	68.71 ± 1.44

Table 5.2. Hourly distribution of diving parameters of Little Cormorant at Kalpally-Palliyol wetland

No.	Time of Day	No. of dive cycles per bout	Total no. of dive cycles observed	Bout duration (min)	D% Frequency per hour	Dive Duration (Sec.)	Pause Duration (Sec.)	Dive/Pause Ratio	Time under water
1.	6.30-7.30	38.33 ± 2.08	n = 115	24.5 ± 1.5	2.63 ± 0.06	24.02 ± 1.82	8.34 ± 0.05	2.73 ± 0.08	74.14 ± 1.41
2.	7.30-8.30	35.66 ± 1.53	n = 107	23.17 ± 1.04	2.57 ± 0.20	24.4 ± 0.40	8.64 ± 0.21	2.82 ± 0.02	73.92 ± 0.32
3.	8.30-9.30	33.33 ± 3.79	n = 100	19.83 ± 1.61	2.80 ± 0.12	25.33 ± 1.05	9.01 ± 0.21	2.76 ± 0.10	73.76 ± 0.37
4.	9.30-10.30	29.00 ± 3.00	n = 87	11.5 ± 1.32	4.23 ± 0.57	16.7 ± 1.77	6.89 ± 0.43	2.52 ± 0.07	70.72 ± 1.67
5.	10.30-11.30	22.00 ± 3.00	n = 66	11.67 ± 2.93	3.20 ± 0.37	11.39 ± 0.22	5.48 ± 0.08	2.12 ± 9.09	67.49 ± 0.50
6.	12.30-13.30	20.67 ± 0.58	n = 62	9.33 ± 0.29	3.69 ± 0.19	13.38 ± 0.89	6.35 ± 0.31	2.14 ± 0.02	67.78 ± 0.44
7.	11.30-12.30	23.33 ± 1.53	n = 70	12.67 ± 2.25	3.11 ± 0.36	14.34 ± 3.00	8.83 ± 1.26	2.14 ± 0.05	67.72 ± 0.91
8.	13.30-14.30	20.00 ± 1.00	n = 60	9.33 ± 0.29	3.57 ± 0.10	8.98 ± 0.36	5.20 ± 0.34	1.69 ± 0.02	63.37 ± 1.13
9.	14.30-15.30	27.67 ± 1.15	n = 83	15.67 ± 1.04	2.95 ± 0.19	20.62 ± 1.69	9.34 ± 0.64	2.19 ± 0.02	68.61 ± 0.64
10.	15.30-16.30	28.00 ± 1.00	n = 84	17.17 ± 0.58	2.72 ± 0.05	24.47 ± 0.86	10.64 ± 0.37	2.35 ± 0.13	69.68 ± 1.15
11.	16.30-17.30	29.67 ± 4.04	n = 89	17.17 ± 4.31	2.95 ± 0.45	23.51 ± 3.29	9.81 ± 1.16	2.47 ± 0.07	79.73 ± 15.49
12.	17.30-18.30	22.67 ± 1.53	n = 68	11.5 ± 0.50	3.28 ± 0.09	20.33 ± 0.93	9.30 ± 0.38	2.31 ± 0.05	68.60 ± 0.34

Table 5.3. Hourly distribution of diving parameters of Darter at Kalpally-Palliyol wetland

No.	Time of Day	No. of dive cycles per bout	Total no. of dive cycles observed	Bout duration (min)	D% Frequency per hour	Dive Duration (Sec.)	Pause Duration (Sec.)	Dive/Pause Ratio	Time under water
1.	6.30-7.30	23.33 ± 3.06	n = 70	27.33 ± 3.06	1.42 ± 0.03	49.00 ± 3.00	14.45 ± 2.15	3.63 ± 0.50	77.26 ± 2.69
2.	7.30-8.30	32.00 ± 2.00	n = 96	34.00 ± 2.65	1.63 ± 0.25	46.61 ± 2.90	14.07 ± 2.18	3.79 ± 0.18	78.16 ± 0.73
3.	8.30-9.30	49.33 ± 2.08	n = 148	51.67 ± 2.52	1.59 ± 0.02	52.58 ± 2.39	14.56 ± 0.14	3.86 ± 0.14	75.71 ± 4.27
4.	9.30-10.30	30.00 ± 2.00	n = 88	30.00 ± 2.65	1.67 ± 0.06	50.89 ± 2.88	13.78 ± 1.59	3.79 ± 0.38	78.69 ± 1.94
5.	10.30-11.30	24.00 ± 2.00	n = 72	27.33 ± 3.06	1.46 ± 0.06	35.62 ± 3.74	10.15 ± 0.47	3.31 ± 0.55	77.74 ± 1.83
6.	11.30-12.30	17.67 ± 5.13	n = 53	19.67 ± 5.13	1.49 ± 0.05	42.99 ± 6.19	15.67 ± 5.13	3.68 ± 0.41	78.31 ± 2.60
7.	12.30-13.30	28.00 ± 2.65	n = 84	32.00 ± 2.65	1.45 ± 0.02	49.63 ± 3.38	13.34 ± 1.21	3.69 ± 2.65	78.83 ± 0.41
8.	13.30-14.30	24.00 ± 2.65	n = 72	27.67 ± 3.06	1.45 ± 0.03	45.08 ± 3.60	12.60 ± 3.08	3.51 ± 0.16	76.68 ± 0.16
9.	14.30-15.30	30.00 ± 1.00	n = 90	33.33 ± 2.08	1.50 ± 0.05	48.84 ± 2.51	14.85 ± 0.65	3.19 ± 0.16	76.68 ± 0.16
10.	15.30-16.30	38.00 ± 1.73	n = 114	47.00 ± 2.65	1.35 ± 0.02	59.05 ± 3.09	15.88 ± 0.94	3.45 ± 0.57	78.81 ± 0.67
11.	16.30-17.30	31.33 ± 2.52	n = 93	36.67 ± 3.51	1.42 ± 0.03	59.16 ± 4.19	16.87 ± 0.95	3.38 ± 0.07	77.79 ± 0.58
12.	17.30-18.30	27.67 ± 3.79	n = 83	29.67 ± 3.06	1.55 ± 0.06	46.89 ± 5.06	13.96 ± 2.04	3.32 ± 0.27	77.09 ± 0.71

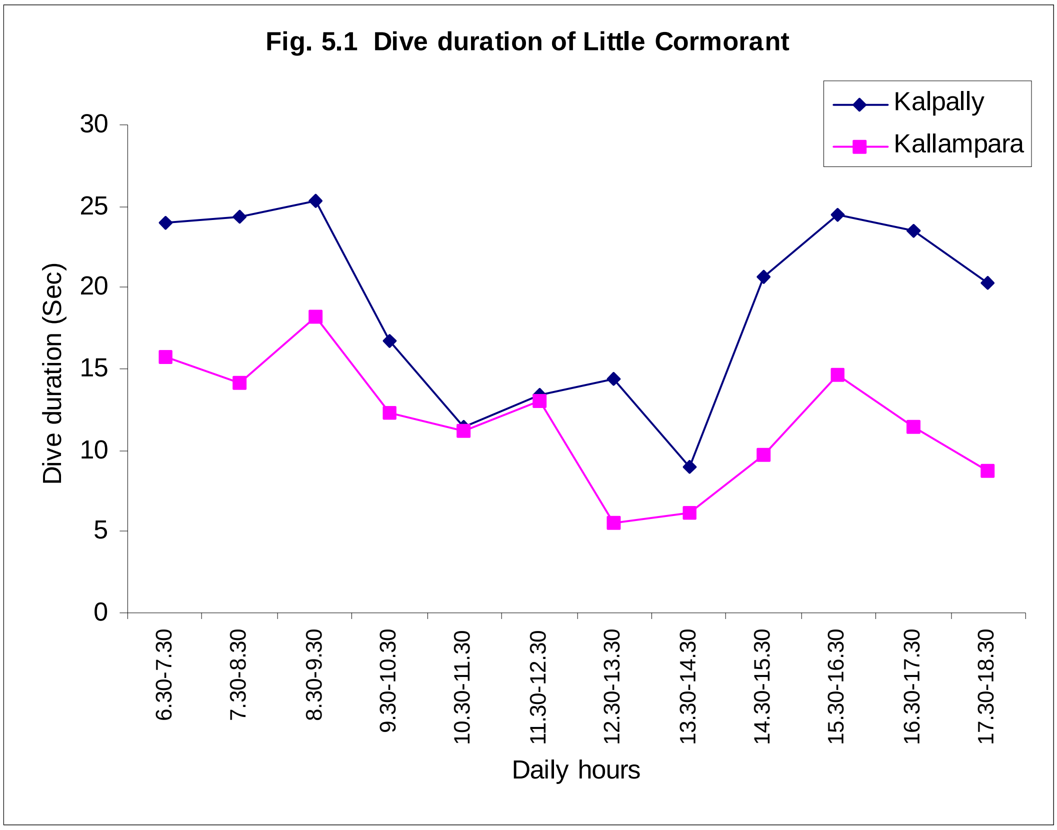


Fig. 5.1 Dive duration of Little Cormorant
Kalpally
Kallampara
Dive duration (Sec)
30
25
20
15
10
5
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.30-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours

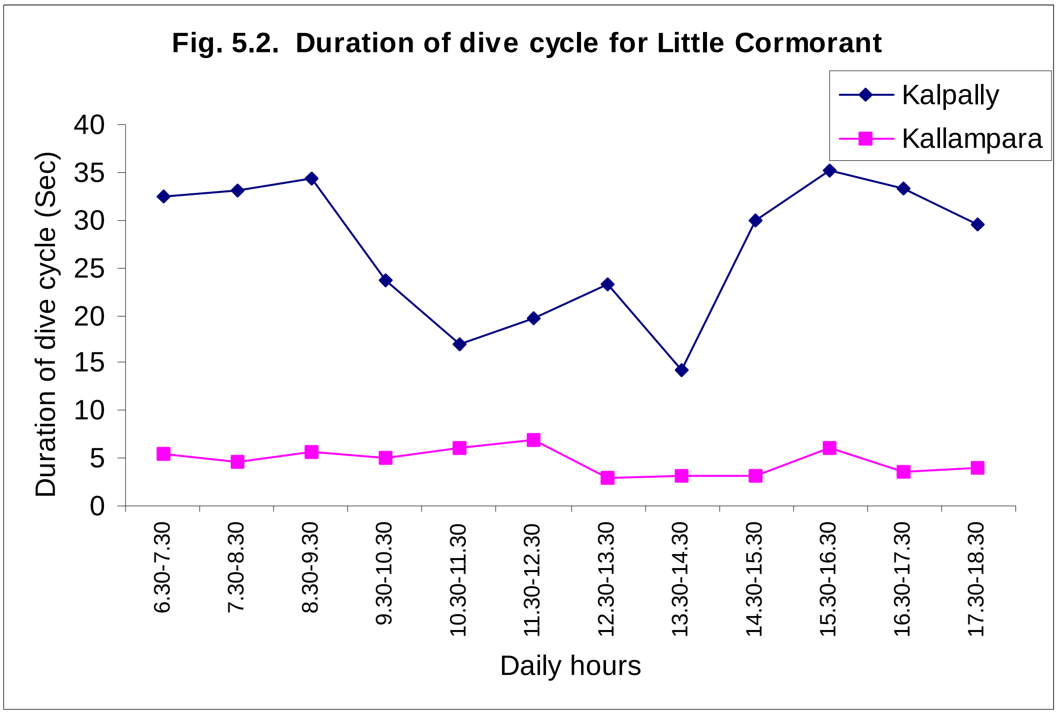


Fig. 5.2. Duration of dive cycle for Little Cormorant
Kalpally
Kallampara
Duration of dive cycle (Sec)
40
35
30
25
20
15
10
5
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.30-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours

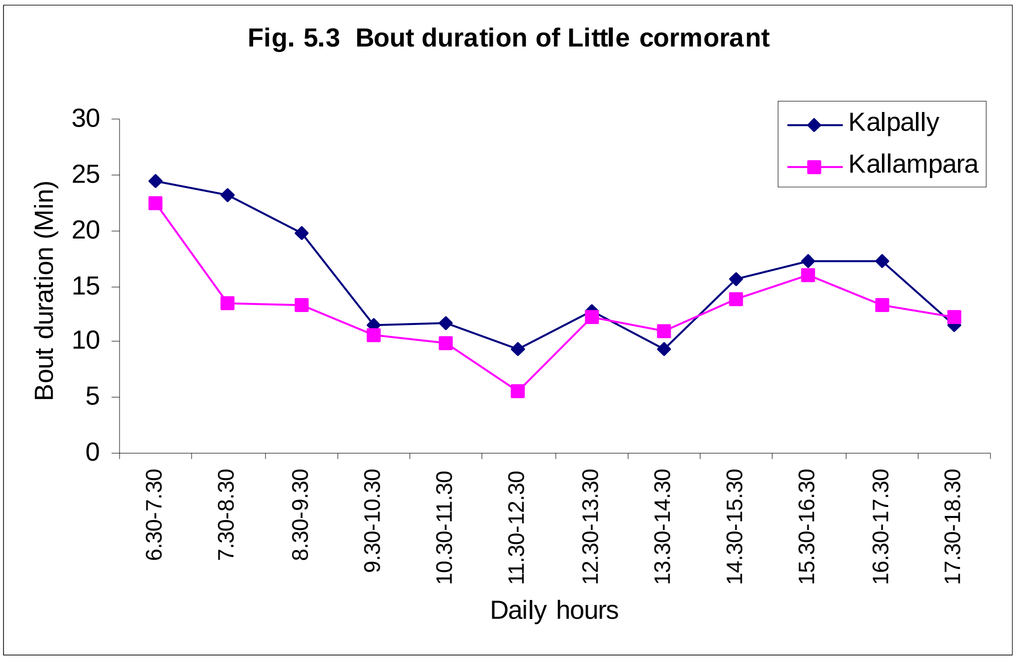


Fig. 5.3 Bout duration of Little cormorant
Kalpally
Kallampara
Bout duration (Min)
30
25
20
15
10
5
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.30-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours

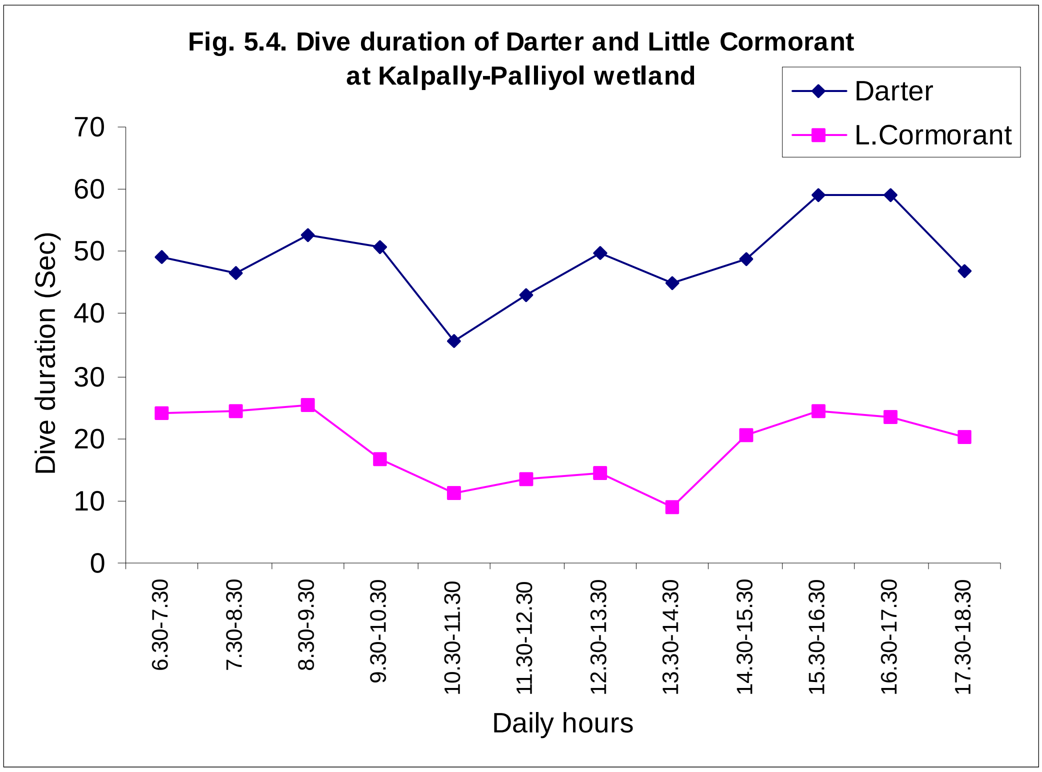


Fig. 5.4. Dive duration of Darter and Little Cormorant
at Kalpally-Palliyol wetland
Darter
L.Cormorant
Dive duration (Sec)
70
60
50
40
30
20
10
0
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.30-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours

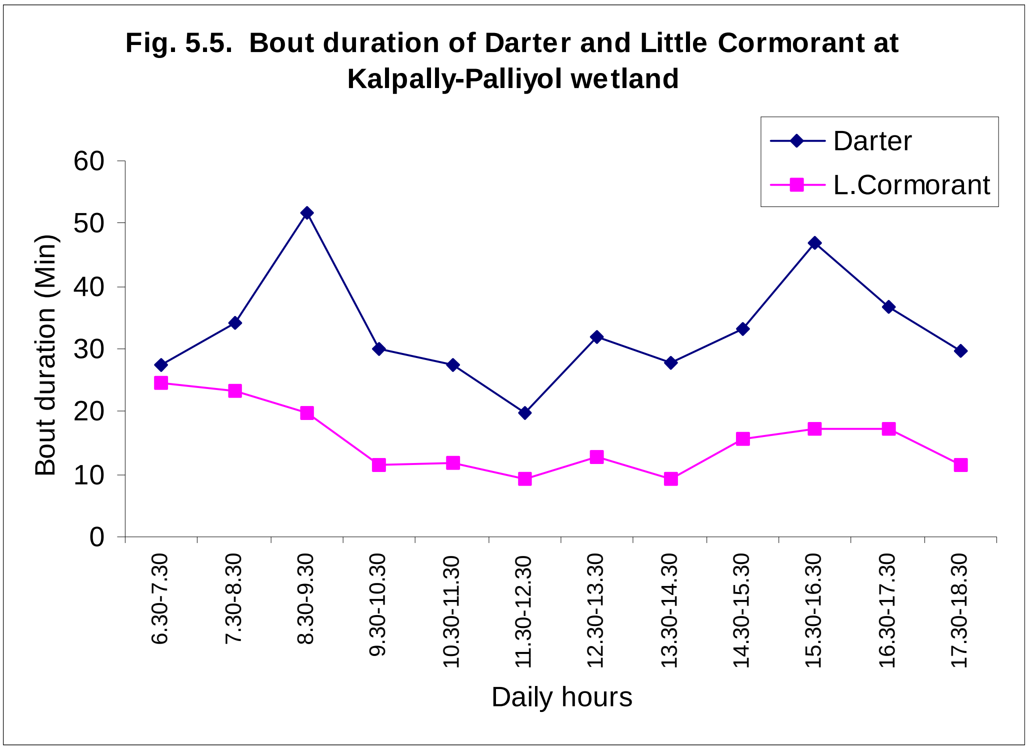


Fig. 5.5. Bout duration of Darter and Little Cormorant at Kalpally-Palliyol wetland
Darter
L.Cormorant
Bout duration (Min)
0
10
20
30
40
50
60
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.30-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours

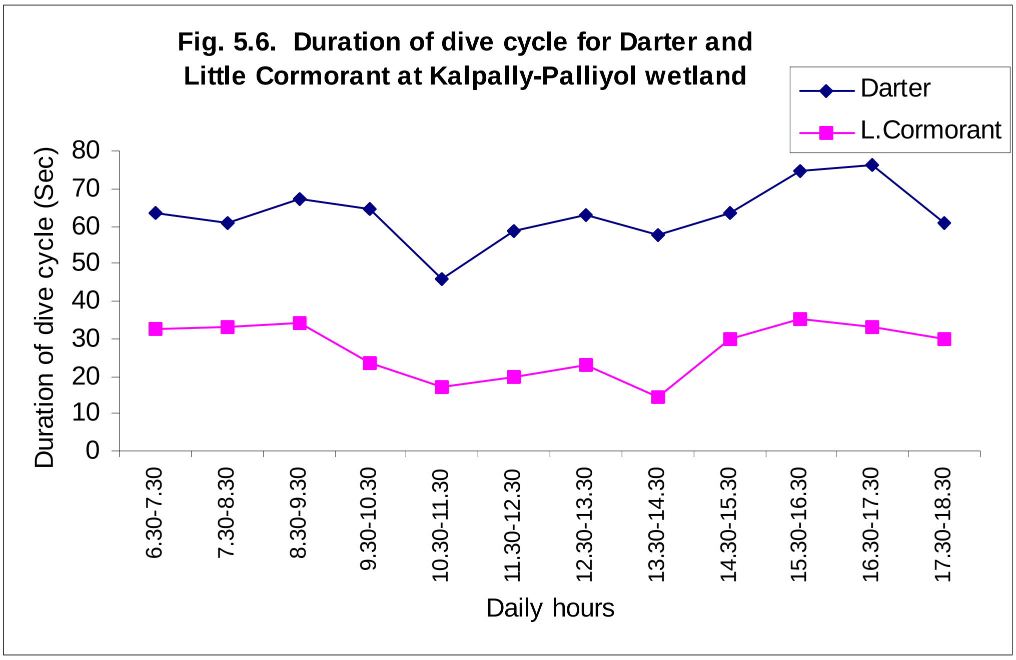


Fig. 5.6. Duration of dive cycle for Darter and Little Cormorant at Kalpally-Palliyol wetland
Darter
L.Cormorant
Duration of dive cycle (Sec)
0
10
20
30
40
50
60
70
80
6.30-7.30
7.30-8.30
8.30-9.30
9.30-10.30
10.30-11.30
11.30-12.30
12.30-13.30
13.30-14.30
14.30-15.30
15.30-16.30
16.30-17.30
17.30-18.30
Daily hours

Table 5.4. Flock size of Little Cormorant at different tidal conditions

Sl. No.	Tidal Condition	Flock Size of Little Cormorant		
		Small	Medium	Large
1.	Receding Tide	3.41± 0.98 (n=32)	6.91 ± 1.06 (n=22)	12.57 ± 1.50 (n=14)
2.	Low Tide	3.21 ± 1.11 (n=33)	8.25 ± 1.84 (n=16)	33.19 ± 15.55 (n=26)
3.	High Tide	3.78 ± 1.20 (n=23)	7.00 ± 0.87 (n=17)	13.27 ± 1.68 (n=11)
4.	Advancing Tide	3.15 ± 0.88 (n=26)	7.88 ± 1.36 (n=17)	84.48 ± 74.69 (n=25)

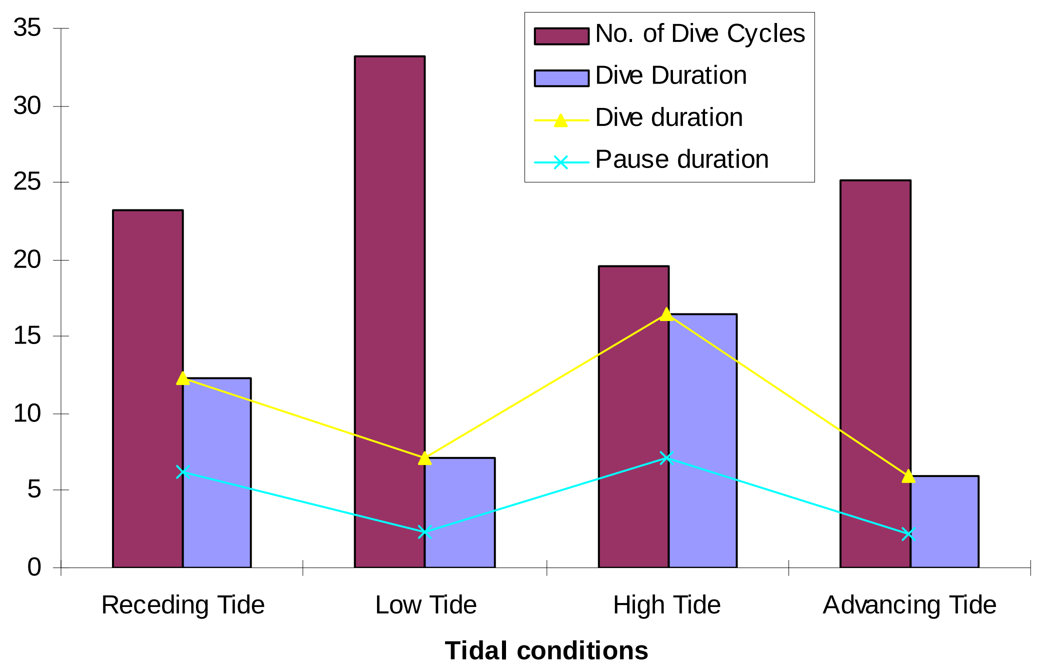
Table 5.5. Diving parameters of Little Cormorant during flock feeding

Flock Size	Dive duration (sec.)	Pause duration (sec.)	Bout duration (min)	Percentage of birds joining the flocks
Small	15.44 ± 2.24 (n=32)	6.83 ± 1.03 (n=32)	8.56 ± 1.25 (n=27)	14.95
Medium	8.81 ± 1.69 (n=27)	4.07 ± 0.99 (n=27)	7.76 ± 2.16 (n=21)	25.25
Large	4.57 ± 1.84 (n=29)	2.12 ± 0.73 (n=29)	3.75 ± 1.18 (n=22)	59.81

Table 5.6. Little Cormorant : Diving parameters during tidal cycles

Sl. No.	Tidal Condition	No. of Dive Cycles	Bout Dura-tion (min)	Dive% Fre-quency Per Hr.	Dive Dura-tion (sec)	Pause Dura-tion (sec)	Dive/ Pause Ratio	Time Under Water (%)
1	Receding Tide (n=116)	23.20 ± 1.79	11.12 ± 1.27	3.49 ± 0.22	12.34 ± 1.50	6.16 ± 0.82	2.01 ± 0.15	66.70
2	Low Tide (n=166)	33.20 ± 3.35	6.68 ± 1.08	8.36 ± 0.72	7.11 ± 1.05	2.37 ± 0.40	3.01 ± 0.17	75.03
3	High Tide (n= 98)	19.60 ± 1.34	8.23 ± 1.52	4.04 ± 0.47	16.43 ± 1.25	7.11 ± 1.15	2.33 ± 0.21	69.91
4	Advancing Tide (n=126)	25.20 ± 5.97	4.56 ± 1.17	9.27 ± 0.70	5.94 ± 0.69	2.26 ± 0.26	2.64 ± 0.17	72.46

Fig. 5.7. Little Cormorant: Interrelations of diving parameters



Chapter 6

BREEDING BIOLOGY AND ASSOCIATED BEHAVIOUR

BREEDING BIOLOGY AND ASSOCIATED BEHAVIOUR

6.1 Introduction

The breeding biology and associated behaviour of many African, European and North American cormorant species have been already studied. These include studies on Reed Cormorant (Olver, 1984), Double-crested and Pelagic Cormorant, *P. pelagicus* (Causey and Hunt, 1986), Double-crested Cormorant (Post and Seals, 1991), Great Cormorant (Childress, 1998), European Shag (Velando and Freire, 1999) and Rock Shag and Imperial Shag (Punta *et al*., 2003),. Courtship display and sexual behaviour of Little Pied Cormorant has been investigated by Mathews and Fordham (1986) and that of Brandt Cormorant by Williams (1942). Patterns of interaction in the courtship behaviour of European Shag has been documented by Graves and Ruano (1994). Kortlandt (1995) has studied the patterns of pair formation and nest building in the European Shag *P. carbo sinensis.* Various aspects of breeding biology of cormorants have been investigated by Childress and Bennun (2000), Potts *et al*. (1980), Aebischer *et al.* (1995) and Van Erden *et al,* (1991). Nest size and location in relation to reproductive success of tree nesting Great Cormorant has been presented by Childress and Bennun (2000). However there is very little information available about the breeding biology and related behaviour of Little Cormorant and other cormorant species in India.

No ecological studies have been done on Darters though it is a widely distributed species. The limited data available is on the North American species *A. anhinga* (Meanly, 1954). Investigations on Indian species have been limited to chick mortality (Palhak et al, 2004).

This chapter presents the data on breeding biology and associated behaviour of Little Cormorant *P. niger* and Darter *A. melanogaster*.

6.2 Objectives

1. To study the breeding behaviour including nest building.

2. To study the courtship display and mating behaviour.

6.3 Methodology

The study was conducted by direct observation of heronries (Altmann, 1974). Breeding population of Little Cormorant at Ramanattukara heronry was observed from April to November during the years 2004, 2005 and 2006. Two visits of two hours each were made per day to study various aspects of breeding biology. Nests were observed from six fixed points including a four-storied building. One large rain tree *Samanea saman* (about 14 m height) was selected for detailed study of nest building behaviour, courtship display and mating, egg laying, incubation, hatching, nestling behaviour, nestling mortality, parental care and hatching success. The rain tree supported the largest number of nests and it was observed regularly. Observations on the nesting associates (Pond Heron and Night Heron) and nest predators (birds like Crow and Kite) were also carried out at the nest site.

The birds were observed with binoculars (8 x 40) and monocular spotting scope (32 x). The breeding activities of the birds were followed continuously for two hours in each bout of observation. Total number of nests at Ramanattukara was counted in each season. Nest construction and nest building behaviour were recorded in the beginning of breeding season. Various phases of courtship display were observed and recorded.

Seven nests on the rain tree close to a four-storied building were selected for detailed study. The nests were examined daily during the laying period and at weekly interval during incubation and hatching periods. The clutch size, egg loss, incubation and parental care were also studied. Nest dimensions, nesting materials and location and distribution of the nests on the nesting tree were also observed and recorded.

Breeding population of Darters were studied from May to August, 2006 at Mangalavanam mangrove, Cochin. They started nesting on 19th May upon a rain tree of about 25 m height. Nest building, courtship behaviour, incubation, hatching of chicks, nestlings and fledglings were also observed.

6.4 Results

6.4.1 Little Cormorant

Breeding season

The nesting period of Little Cormorant have been from April to November. Breeding of the species seemed to coincide with Southwest monsoon. Largest number (36 -39%) of nests were found in July. In the years 2004 and 2005 no nests were found in November, but in 2006, 6 nests (1.22%) were found in this month (Fig. 6.1). Number of nesting pairs increased every year. The last set of fledglings left their nest on 29th November in 2006. Total number of nests of Little Cormorant increased from 82 in 2004, to 122 in 2005 and to 186 in 2006 (Table 6.3). Observation of the bird collecting nest materials was first noted on April 18th, 2006. Six nests were completed within one week. By May 10th more nests were established. The nesting colony was established in a grove of trees on either side of the National Highway at Ramanattukara town and it included Pond Herons and Night Herons also. It was a mixed colony and more appropriately it could be called as heronry. However the number of Pond Herons and Night Herons were less when compared to Little Cormorant.

Territory and defence

Males proclaimed the territory by advertising display and the females are attracted to the males. Pairing up and copulation took place in the territory and the nest was built. The minimum space maintained between the nests (in clusters) on a tree was about 1-3 ft. In colonial species territory is in the immediate vicinity of the nest. The breeding territory was defended by the pairs and the males were the chief guards of the territory. Brooding cormorants maintained an alert posture to prevent the entry of intruders including conspecific, which consisted of raising the head with bills opened and turning the head to all sides. Threat displays were also used for defending the territory. Crows were the major predators from which the parent birds guarded the eggs and nestlings.

Nest site selection

Nest sites were selected in areas where large trees are present (Plate XI) and there is abundant supply of food throughout the nesting season. About 12 trees were found used for nesting at Ramanattukara (Table 6.1). The height of the trees ranged from 10 to 20 m.

A road side survey of breeding site showed that Little Cormorant and the nesting associates like Night Heron and Pond Heron used large trees on either side of the road at Ramanattukara for nesting and breeding (Plate XI.A). Territorial rivalry was not observed between breeding Little Cormorants and their nesting associates.

The nests of Little Cormorants are normally located at the top canopy (Table 6.2). The canopy cover was least (n=61, 57.08%) for nests of Little

Cormorant when compared to that of Pond Heron (75.68%, n=28) and for Night Heron (64.05%, n=21). Nests were located above and below the canopy. The nests of Pond Herons are found towards the periphery of the canopy. Nests of Night Herons were located towards inner side of top canopy (Table 6.3).

Pairs that bred earlier in the season selected top canopy (Table XI.B) as nest sites and built largest nests. Frequency of nestlings were greater (3.20 ± 0.94, n=54) in the canopy top nests (Table 6.4) than below canopy nests (1.77 ± 0.67, n=31). The canopy top nests were arranged in a non-random way and the nests were clustered as specific groups (Plate XI C & D).

Nests

The nests of Little Cormorant were built at a minimum heights ranging from 6 to 20 m above ground level. The platform nests were massive, constructed with dry and green twigs with a few leaves and have a shallow depression in the centre. The mean outer diameter of the nest was 36.44 cm (n=9) and the mean inner diameter was 19.5 cm (n=9) (Appendix VI). The mean depth was 8.72 cm (n=9).

Both the parents participated in nest construction. The nest materials were collected by the male and actual building was done by the female. The nests were usually placed in the vertical forks of three or four branches on the outer side of the upper canopy. A few nests were placed on the inner side of the upper canopy. Number of nests on a tree depended on the availability of branched forks on the tree. On a large rain tree (height -14m) more than a hundred nests were accommodated.

The outer shell of the nest was made up of dry and fresh branched twigs (Table 6.5) which when placed on a suitable site will not only intermesh into a strong foundation and side walls, but also bind on to the fork of the tree or to the twigs of the tree top in which it was built. For attachment, no fibrous material was used.

Once the outer shell was built it was padded on the inner side with smooth twigs which subsequently form the middle layer. The inner most lining was made up of green leaves (Plate XI.E). This is done before the laying of the eggs. Addition of lining material continued throughout incubation period. The number of twigs used for nest construction varied between a minimum of 78 and a maximum of 192 plus a few green leaves (14-47). As the thorny twigs holding the nest get gradually detached or weakened, the outer shell of the nest is reinforced with fresh twigs.

Courtship and mating behaviour

Among Little Cormorants breeding activity was initiated by the males. They perched with nesting material (green leafy twig of Acacia) in the bill and slowly hopped on the branches. The male then settled on one of the branches, put down the twigs between the legs (nesting material ceremony) and started advertising display (Plate XII.A-E). Other males in the vicinity also started the display.

Advertising display is the first phase of the sexual cycle in Little Cormorants. From the normal posture (Plate XII.A), the bird squatted with the breast almost touching the branch. The neck was drawn back, the nape nearly resting on back; the head was thrusted suddenly upwards with the bill pointing up. The tail feathers were spread in a fan-like manner. The crest on the forehead was raised and the feathers of the head and neck together with white silky filamentous plumes of the region were ruffled. The gular pouch was bulged. As the bird assumed this "squat thrust" position (Plate XII.B-D) which is the first part of the advertising display, the wings were lifted slightly off the back.

The second part of the display consisted of a "stroke" (Plate XII.E). In the stroke, the lifted wings were replaced on the back. The head was thrust forward and downward in a hammer-like stroke. The bill was brought down partly opened. The gular pouch was still distended and head and neck feathers ruffled. After a slight pause in this position, the head and neck were recoiled and the stroke was repeated.

In the squatting posture the stroke was repeated several times ($\overline{X}$ = 9.75, n=40) followed by a pause. After the pause the first part of the display was repeated once, continued by downward stroke several times.

While a male was advertising, various females visited him. The females moved among the advertising males with outstretched necks, looking keenly at one advertiser and then another and so on. When the females approached, advertising was intensified by the males. As soon as a female reached a male, the two birds, entered the "pair up" posture and the male stopped his advertising (Plate XIII.A).

During pairing, the strokes of the advertising display of male merge into the lower pre-coitional posture. In this posture, the head and neck were held in a horizontal line. The feathers of head and neck were relaxed. The female at the same time assumed the upper pre-coitional posture, and pushed the head and nape of the male with her bill. Male stretched the head and neck again. The female on a few occasions mounted (reverse mounting) upon the male (30.64 secs, n=12). But more often male took the upper pre-coitional posture and male immediately mounted. Both of them brought the bills together.

Both sexes performed the upper and lower pre-coitional postures and even mountings. Finally the male mounted upon the female and it lasted for 60.41 secs (n=22). The interval between two successive mounting varied from 45 to 65 minutes (n=5). During a single breeding season 121 mountings were recorded, of which 12% were reverse mountings. The remaining mountings were monogamous.

After dismounting, both the birds stretched up, male ruffled its head and neck feathers and its gular pouches distended. The bills of the pair touched each other. Immediately the male went in search of nest material. As he returned to the place where he left the female, he alighted with head high, gular pouch distended and head and neck feathers erected. The female got up from the squatting posture to take hold of the material from his bill. The material was held by both the birds and placed it on the nest. From here onwards the male brought nest materials and female added them to the nest (Plate XIII.B). Both the pairs were busily engaged in nest building with intermittent mountings and copulation, followed by preening.

As the breeding activity advanced, “squat thrust” behaviour was not observed among the males. Instead a 'gape-bow' behaviour was shown by the males in which the male stood erect, stretching the whole body and neck forward and downward, so as to reach the head below the feet (Plate XIII.D).

Threat and appeasement displays

Threat displays were used by both sexes during breeding season. There were two types of threat displays; "threat posture" and "peck threat". In the "threat posture" the neck was thrust towards the intruder who came to steal the nest material. The head and neck feathers were ruffled out, the wings were slightly raised, gular pouch distended and the bill was partly opened (Plate XIV.A). The "peck threat" was a sudden peck or a series of pecks towards an intruder. Occasionally a "peck threat" was given by a male against a female with whom he had been engaged in mutual displays. In appeasement display, bill was directed away from the opponent (Plate XIV.B).

Egg laying and clutch size

Nest building was completed in 2-4 days. The first egg was laid immediately after the completion of the nest. Nest materials were added even after the complete clutch was laid.

In the 15 nests observed, the clutch size varied from 2 to 5 (Table 6.9). Two eggs each were found in 4 nests, 3 in 2 nests, 4 in 6 nests and 5 in 3 nests. The clutch size was 4 in majority (40%) of nests and clutch size of 3 were found in minimum (13.33%) nests.

Eggs and egg loss

The eggs are oval in shape, pale bluish green in colour with chalky surface. Heavy rain during June and July along with strong wind damaged some of the nests (n=4). This resulted in the falling of eggs and young ones. Crows were the major predators of eggs. Brahminy Kites and Pariah Kites also preyed upon the eggs and chicks.

Incubation and hatching

Incubation started before laying is completed. Both the male and female were seen incubating the eggs. Change over of incubation duty was accomplished with a greeting ceremony in which the sitting bird got up and vacated with a head bowing behavior. When intruders of the same species approached the nest, the incubating bird protected the nest by threatening and alert postures (Plate XIII.E). The incubation period was 24-28 days (X = 25.86, n=7). Hatching took place in a period of 24 hrs. time and all eggs were found hatched, in 5 nests (Table 6.6). But in 2 nests one egg each remained unhatched. The empty egg shell was ejected out of the nest by the attending parents.

Nestlings

Newly hatched young ones were nidicolous and altricial. After about 10 days the body of the chicks was found covered with black down feathers. The mouth cavity was red (Plate XI.F). They made peculiar begging calls. For about 6-7 weeks (about 42 days) they remained with their parents in the nest. By that time they developed feathers and are capable of fledging.

They took regurgitated food from the parent's gullet. The nestlings inserted their head into the parent's gullet or pharynx by extending their neck. Shaking and swaying excitedly from side to side tickled the parent's bill. When begging for food they raise their head and called loudly (Plate XIII.F). Older nestlings while begging flapped their wings. Nestlings were found to gular flutter from about 3 weeks onwards. Fall from the nesting trees caused the death of nestlings in addition to predation by crows (Table 6.10).

Parental care

Both the parents took part in the feeding of young ones. One week old nestlings were fed with partly digested regurgitated food and after that they were fed with small fishes which sometimes fall to the ground below nesting trees. Subsequently they were fed with larger fishes. Early nesters were found to make larger massive nests which give more protection to eggs and young ones. The older chicks had a greater chance of getting food than young ones. Atleast one parent actively guarded the nestlings till they attained the age of 4 weeks (n=5 nests). There after they were left unguarded.

Hatching and breeding success

Hatching and breeding success varied in different nests. Out of 28 eggs in 7 nests, 5 (17.86 %) were lost. Of the remaining 23 eggs, 21 (75%) hatched and the remaining 2 (7.14%) did not. In 2 nests (with clutch size 2 and 4) all eggs hatched. In 3 nests (with a clutch size of 4), 4 eggs were lost and remaining eggs hatched. In one nest (with clutch size 5) one egg lost and one did not hatch and 3 eggs hatched. In another nest 4 eggs hatched and one unhatched (Table 6.7).

Total hatching success in the 7 nest was 91.30%. Out of the 21 chicks hatched 3 chicks were missing due to various reasons. The breeding success was 85.71% (Table 6.8).

Predators

The main predators of Cormorant chicks were Pariah Kite, House Crow, Jungle Crow and Brahminy Kite (Table 6.11). The birds made frequent visits to the heronry. They perched on the nearby trees like *Mangifera indica, Cocos nucifera, Peltophorum pterocarpum, Syzguim cumini and Largerstroemia speciosa.*

The predator made frequent visits to the nest site during breeding season (Table 6.13). They were sighted 240 times during the breeding season in the year 2006. House Crow appeared in the highest frequency of 121 (50.42%) and they took 20 eggs (52.63%) and 4 chicks (40%). The frequency of visits by Jungle Crows were 101 (42.08%) and they predated upon 14 eggs (36.84%) and 3 chicks (30%). Brahminy kites came third with 9 numbers and took 3 eggs (7.84%) and 2 chicks (20%). Predation attempts by Pariah Kites were found 9 times. They took 1 egg (2.63%) and 1 chick (10%).

Although House Crows made 72 attempts (Table 6.12; Fig. 6.2) to prey on eggs and chicks of Little Cormorants; they succeeded only 24 times (33.33%). Jungle Crows made 68 attempts and succeeded 17 times (25%). The Brahminy Kites made 22 attempts and succeeded in 5 attempts (22.72%). Pariah Kites made 14 attempts and succeeded in 2 attempts (14.29%) (Table 6.14).

Thermoregulation

Little Cormorant incubated the eggs by sitting on them and covered the eggs with its feathers. At certain times the feathers were kept fully raised and may be for passage of air for dissipating heat. The brooding bird gave shade to the chicks with the wings when there was direct radiation from the sun. It kept its beak open and carried out gular fluttering. The nestlings also performed gular fluttering when they were exposed to direct sunlight.

6.4.2 Darter

Breeding Season

The breeding season of Darter in the study area started in the middle of May and ended in August, 2006. Darters colonized a rain tree of about 25 m height present at the Mangalavanam mangroves (Plate XV.A & B). They constructed nest on the upper canopy of rain tree. On 19th May eight pairs of Darters were observed constructing nest. On the 28th May, 4 more pairs were found building nest. All the nests were found on a rain tree where bats were roosting (Plate XV.C). The nesting colony consisted of only darters and no other birds were found nesting at Mangalavanam during this period.

Territory and Defence

Darters were monogamous and pair bonded during breeding season. They are highly territorial and defended the nest and juveniles from predators and other conspecifics. The breeding territory was defended by the pairs. Aggressive displays were performed by the birds to defend the territory. "Peck threat" was seen between conspecific which was like stabbing with the beaks.

Nest site selection

The nest location of darter was on a large rain tree (about 25 m height) in the Mangalavanam mangrove. The site was in the mangrove area composed of a shallow tidal lake in the centre with its edges covered with thick mangrove vegetation. The lake provided abundant supply of food for the breeding darters and their young ones. The lake has a connection with the backwaters. In the middle of the lake there is a small mangrove island that act as perching site for darters after prolonged feeding expeditions. The larger rain tree provided ample protection for the nesting darters especially the canopy top nest locations. In addition to *Samanea saman, Tectona grandis, Alstonia scholaris* and *Caryota urens* were present in the surrounding areas. Prominent mangrove species are *Avicennia marina*, *Rhizophora mucronata* and *Acanthus ilicifolius*.

Nests

The nests of darters in the study area were constructed at about 25 m height towards the upper canopy. The large platform nests were built on the forks of trees with dry twigs and green leafy twigs. Green leaves were added to the nest throughout incubation period and after hatching. They used large dry twigs with branches to construct the outer shell of the nest. It was padded with small unarmed twigs and the inner most layer lined by green twigs with leaves. Nests were more compact and of greater depth than those of herons.

Dry twigs of *Alstonia scholaris, Samanea saman, Terminalia catappa* and *Tectona grandis* were collected by the birds for making the foundation and outer shell of the nest. The long twigs (n = 19) were about 30-45 cm in length and short twigs (n = 35) were about 5-11 cm in length. Nest materials were collected from the vicinity of the breeding site. Fresh twigs with leaves were collected from Acacia, rain tree and eucalyptus trees. Both the male and female took part in nest building, but male brought most of the nest materials. The nest materials were arranged by the female. The green lining materials were also taken from the nesting tree itself.

Courtship and mating behaviour

The male initiated the pair formation. An unmated male started its courtship display after keeping a green leafy twig at a nest site. The head and neck were moved up and down (Plate XVI) and a low pitched caw…. caw calls were made. The wings were raised and flapped (Plate XVI) followed by stretching of the neck and snapping of the head towards a twig or nest material. Along with these the tail feathers were also raised. These movements slowly increased in frequency followed by pairing up.

After pairing up, the birds held the nearby small branch with leaf and shook it vigorously (twig shaking). Again both of them moved their neck and bill pointing upwards, followed by rubbing of the bill. Then the female bowed its head and neck followed by mounting of the male upon the female.

The male then dismounted and repeated the twig shaking. Thereafter, the female remained perched on the site and the male flew off to collect nest material. The male returned with a twig and both of them performed twig grasping. The female made occasional flight to collect sticks, but most frequently stayed in the nest, positioning the twigs in a shaking shoving motion.

Incubation and hatching

The nest building was completed in 3 days and incubation started on the same day. The incubation period was about 27-30 days. The chicks were naked and fully parent-dependent when hatched.

Nestlings

White down feathers were acquired by the nestlings within a week (Plate XV.E). Fledglings had darker juvenile plumage, but white down feathers persisted on head, neck and under parts. While feeding, the bill and head of chick has been thrust violently into the parent's gullet. The nestlings fed on regurgitated food from the gullet. Nestlings were noisy while begging for food.

Parental care

When foraging parents arrived at the nest, the nestlings begged for food by up-stretching neck, vigorously shaking and tickling the parents throat. Parent bird opened the bill, and allowed the nestlings to thrust the entire head into the gullet (Plate XV.F). Both the parents alternately relieve one another during incubation, feeding and brooding of young. Gular fluttering was observed among adult Darters while brooding.

6.5 Discussion

Nesting colonies of birds have been described as 'central place system' (Urfi, 2003) as an individual belonging to the colony has to assure the unavoidable return to it every day during the breeding season because a breeding bird may have chicks or eggs in the nest. Colonial nesting is an important feature among majority of the members of Pelicaniformes and Ciconiformes (Ali & Ripley, 1987; Burger, 1981; Krebs, 1978). Heronries are a concentrated breeding effort in time and space (Urfi, 2003) and due to this reason they are significant in the study of breeding behaviour of many birds that have conservation importance. Little Cormorants and Darters breed in heronries and exhibited an elaborate sequence of courtship behaviour. The behaviours associated with colonial breeding are most adapted to the environment (Pettingill, 1970) and assure the continued existence of the species.

The breeding season of birds is intimately associated with the distribution and abundance of food resources in their environment. Birds select a nesting site by looking at the tree structure, availability of nest materials, proximity to feeding sites and safety from predators and human disturbances. Dark plumage of Little Cormorant and Darter has been evolved for social inconspicuousness as proposed by Goodfellow (1977).

6.5.1 Little Cormorant

In this study the major nest site of Little Cormorant was located at Ramanattukara which in turn is very close to Azhinjilam Wetland, the main feeding habitat of the breeding birds. The other observed feeding sites of the species situated very close to the breeding site were a Jheel at Feroke Chungam, Thottungal Kadavu, Muttiara stream, Chellipadam and inundated paddy fields at Ayikkarapadi and Pulikkal. Southwest monsoon was the major breeding season and it extended beyond Northeast monsoon. According to Ali (2002), the breeding season of Little Cormorant is from July to September in North India and November to February in South India. In this study Little Cormorants have a prolonged breeding season, from April to November in 2006. Earlier food availability for the chicks due to early onset of monsoon rains could be the probable explanation for the starting of breeding season from April itself. Monsoon represents the breeding season of fishes and provides an uninterrupted food supply needed for the growth of young ones. Continuous supply of food from the nearby wetlands could have helped the breeding birds to protect juveniles from predators as they can stay at the nest for longer periods. Once this advantage is assured, the birds select the sites for nesting (Maheswaran, 1998; Krishnan, 1980; Maheswaran & Rahmani, 2005; Vyas, 2006). In the case of Little Cormorant the nest site selection was influenced by the above factors.

A grove of closely grown trees at Ramanattukara appear to be the most congenial for a breeding colony. This assured the supply of thorny twigs, smooth twigs and leafy material. Nest site characteristics have shown to affect the breeding success of a broad range of colonial sea birds (Potts *et al*., 1980; Aebischer *et al*., 1995; Van Erden *et al*., 1991; Kortlandt, 1995). The present study indicated that there was a positive relationship between canopy-top nests, nest size, and number of nestlings among Little Cormorant. The significance of this relationship was emphasized by Childress and Bennun (2000) in the tree nesting Great Cormorant, *P. carbo* and Double–crested Cormorant, *P. auritus* (Lewis, 1929). Pairs of Little Cormorants that bred earlier preferentially selected top canopy nest sites and built large nests. A larger nest might reduce nestlings from falling out especially during the heavy monsoon rains. Canopy-top locations could provide more sanitation. Being on the top, falling of excreta from other nest was avoided. It also aided the birds in their easy landings and take-off as explained by Krishnan (1980).

It is commonly suggested that the earliest breeders are older, more experienced individuals that are more efficient foragers and thus able to locate better nest sites and better nutritional resources required to breed earlier. They also lay larger clutches and successfully feed larger broods (Bregnballe, 1996). In Little Cormorants the canopy top nests were larger with increased number of nestlings. The early nesters were found to be larger in body size also.

The presence of a large number of nests in the same plane (towards the upper canopy) would help the parent birds to have an easy vision at the predators. Intraspecific competition could also be reduced by occupying a vast expanse of canopy. The nests showed a clustering pattern in which 3 to 10 nests were found as groups. This clustering pattern gives protection from predators. Nest defense against potential predators has been suggested as an important force in the evolution of coloniality in birds (Lack, 1968). It is generally accepted that non-random distribution patterns are the result of natural selection (Cody, 1985).

In the observation of the breeding colony of Little Cormorants, early nesters have selected the best sites and late nesters have constructed their nest close to the early nesters. This would have resulted in the non-random distribution of the nest and resulted in the clustering pattern of the nest distribution. As in the case of European Shag (Snow, 1963) it was observed that newly formed pairs of Little Cormorants breed close to nests that are already established.

In birds, the choice of nest location could be influenced by conspecific attraction based on mating tactics (Ramsay *et al.*, 1999). In this socially monogamous species early breeding males gained extra pair copulation with the late breeding females that nest close to the former. Experienced males were more successful in attracting females to their territories for extra pair copulation. Females seeking extra pair copulation have identified older and experienced males by their gape-bow behaviour. This behaviour has been noticed in Little Pied Cormorant, *P. melanoleucos* (Mathews and Fordham, 1986) whereas in European Shag, *P. aristotelis*, a closely related dart-gape behaviour was observed (Graves *et al*., 1993). In this manner the clustering pattern of the nest has some survival value in the life history of the bird. "Commodity selection" has been proposed to explain colonial breeding in that birds which breed colonially choosing commodities such as breeding habitats or mates that in turn creates breeding aggregations (Wagner *et al.*, 1996; Wiley & Poston, 1996; Danchin & Wagner, 1997).

The present study is based on data collected during 2004 to 2006, but the heronry at Ramanattukara was under observation for about 10 years. This confirmed the existence of nest site fidelity among Little Cormorants. It is advantageous to the birds as they become familiar with the area and enhances foraging success, predator avoidance, defense and other behaviours which contribute to successful reproductive performance (Newton & Wyllie, 1992).

When the colony of the breeding birds first started (10 years ago), there were only a few nests of Pond Herons and Little Cormorants. It is the suitability of the habitat in terms of protection, availability of nest materials and food which might have attracted the birds to the heronry. About 85% of the nest sites of Little Cormorants were found close to human habitations (Subramanya, 2005). This may be the result of shrinkage of wetlands due to developmental activities and destruction of associated mangroves and other vegetation.

Little Cormorant used territories for courtship and nesting, but they disperse to feed. As the same territory was used for both courtship and nesting, breeding could proceed undisturbed. Holding a territory is expensive in terms of time and energy spend for defending it, but it helps to raise increased number of offsprings (Burton, 1941).

An advertising male Little Cormorant with a female close to him showed threat posture and peck threatened other males that approached them. A brooding pair peck threatened the neighbours against stealing nest materials. Williams (1942) explained a similar behaviour in Brandt

Cormorant, *P. penicellatus* during breeding period performed by both the sexes. Even though fight was less frequent in Little Cormorant during breeding season, it was noticed between conspecifics during non-breeding season. Compared to *P. penicillatus*, Little Cormorant is less aggressive like Little Pied Cormorant (Mathews & Fordham, 1986). Among Little Cormorants vocal communication was very limited and the bird did not produce any calls during threat display.

Threat displays were performed by Brandt Cormorant towards murres (Williams 1942). Unlike Little Pied Cormorant, *P. niger* exhibited antipredator behaviour, but alert posture has been more frequent in Little Cormorant which helped them to keep away predators and intruding conspecifics. Very rarely peck threat was performed (n=2) against House Crows.

The Great Cormorant, *P. carbo* made heavy nests with outer shell, middle layer, and inner lining (Krishnan, 1980). At Ramanattukara heronry, Little Cormorant also constructed a similar type of nest with a definite structural pattern. Green leaves were added to the nest until the young ones were about to leave the nest. According to Rodgers hypothesis, a nest with fresh greenery had higher insulation value especially during early morning hours. This may be due to the initial higher water content of the fresh greenery. When the environment gets hotter, water content evaporates and there will be cooling effect (Rodgers *et al*., 1988). Temperature control would be effected by the green leafy materials added as lining material to the nest. Nest insulation depends on the materials used in nest construction which depends on availability of the materials (Whittow and Berger, 1977; Skowron and Kern, 1980). Birds nesting inside leafy trees and below canopy locations used much less green foliage for their nest than those nesting in more open locations (Krishnan, 1980).

Intraspecific stealing of nest material was observed among Little Cormorants as already reported for *P. auritus* (Lewis, 1929) and *P. penicillatus* (Williams, 1942).

At the beginning of courtship display 'nest-material ceremony' was performed by unpaired male Little Cormorant. A similar display was noticed in Brandt Cormorant, *P. penicillatus* (Williams, 1942) and in Double crested Cormorant, *P. auritus* (Lewis, 1929; Reinhold *et al*., 1998). Lack (1940) interpreted this behaviour as a 'symbolic display' and in his opinion it is functionless before the actual nest building, since the material would be stolen by others or fallen from the tree branches. After pair bonding it will be guarded by the female and a nest rapidly takes shape.

Little Cormorant started the courtship display from squat posture of the body followed by the "squat thrust" and ended with the "stroke." During "squat thrust" the tail was cocked and wings were raised, without fluttering movement. A similar "squat thrust" behaviour was noticed in *P. melanoleucos*, as an independent display, not followed by "stroke" (Mathews and Fordham, 1986). In Brandt Cormorant, *P. penicillatus*, Williams (1942) has noticed "squat thrust" behaviour which was characterised by "wing fluttering". In *P. auritus*, wing movement was explained as "wing jerking" (Lewis, 1929). All the species described here cocked their tail during display. *P. aristotelis* started the display from a similar posture and there was no wing movement (Selous, 1927) as in Little Cormorant

In *P. penicillatus*, the display effects have been achieved by striking postures and the brilliance of the pouch alone and not by voice (Williams, 1942) *P. auritus* has some degree of all three qualities; posture and pattern of plumage and voice (Lewis, 1929). In Pied Little Cormorant, posture and voice were described as important features along with raising of the forehead crest and chest expansion (Mathews and Fordham, 1986). Observations on the Little Cormorant showed that display effects were achieved by the posture and purple colouration of the expanded gular pouch and raised forehead crest. The bird was almost silent during the display and white head plumes were conspicuous.

The sexes could be identified in Little Cormorant from the general body size and bill size during breeding season, when male and female come closer. A similar distinction was described for *P. penicillatus* by Williams

(1942) and Rock Shag by Quintana *et al.* (2003). Males were significantly larger than females in Little Cormorant.

Females reacted to the male advertising display by hopping all around the branches and around the male in the case of Little Cormorant. This behaviour has also been reported for *P. penicillatus* (Williams, 1942) and *P. aristotelis* (Selous, 1927).

In Phalacrocoracidae reverse mounting has been described for Brandt Cormorant, *P. penicillatus* (Williams, 1942) and Cape Cormorant, *P. capensis* (Berry, 1976) which is very evident among Little Cormorants also.

The clutch size of Little Cormorant varied between 2 and 5 in the present study. According to Ali and Ripley (1983) the normal clutch size was 3 to 5. Ali (2002) has reported that the number of eggs in a clutch was 4 or 5. In Kerala it has been reported as 4 or 5 (Neelakantan, 1958). In my study, as mentioned earlier, clutch size 4 was in the highest frequency and 2 was in the lowest frequency. Childress and Bennun (2000) mentioned larger brood size in canopy top nests than below canopy nest in the tree nesting Great Cormorants. A similar observation was noticed for Little Cormorant also. Further study will be necessary to prove increased reproductive success in the canopy top nests of Little Cormorant. Clutch size of birds varied with age, weather conditions, season, individual variation, geographical area, presence of predators and types of nests (Pettingill, 1970). Canopy-top nests of Little Cormorants were comparatively larger and possessed larger brood size.

In Little Cormorants, incubation started after the first egg was layed. At a stretch the incubation continued for about 50.77 (n=13) minutes. The breeding system of Phalacrocoracidae is based on social monogamy, and both sexes participate in the incubation and rearing of the brood (Snow, 1963; Cramp and Simmons, 1977). According to Pettingill (1970) there is some correlation between colour of the male and his role in incubation. If his colouration is similar to that of the female, the male also incubates. This correlation is appropriate in the case of Little Cormorant. Both sexes incubated the eggs. Change over of incubation duty may be accomplished with a greeting ceremony. The incubation period of Great Cormorant was 28 days according to Childress and Bennun (2000). In this study Little Cormorant spent about 24 to 28 days for incubating the eggs.

Asynchronous hatching was very evident among Little Cormorant and each nest possessed young ones of different ages. Eggs in a clutch do not hatch simultaneously, because incubation began before the clutch was complete. Asynchronous hatching has been observed in Great Cormorants also (Childress and Bennun, 2000). Larger young ones were found to peck the smaller ones. The parents were found to feed the older chicks more which begged violently. The eggs hatched in the sequence in which they were laid.

Therefore, the age difference between the eldest and youngest chick in a brood was quite often more than 4 or 5 days.

Parental care was very pronounced among cormorants (Lohikoinen, 2005). The young ones were fed for 3 weeks in the nest. After that they were found sitting on the nearby branches still guarded by the parents. The young ones were fed with regurgitated fish from the gullet of the parents. Cormorants diet has been reported to change seasonally (Engstrom, 2001; Wziatek *et al*., 2003) according to the needs of the nestlings. A similar switch has been reported in larger gulls also during breeding season (Bertellotti and Yorie, 1999). When the young ones grow, the food requirements increase (Gremillet *et al*., 1996) and larger fishes are consumed.

The conspecifics and intruders were strongly defended by the alert and aggressive postures of the parents as found in Brandt Cormorant (Williams, 1942).

Nests, eggs, and nestlings of colonial waterbirds face a number of natural as well as anthropogenic threats. Natural calamities like wind (Subramanya, 1996), fires (Epanchin *et al*., 2002) and predation by enemies (Naoroji, 1990, Bogliani and Bellinato, 1998) are of important concern. They are also susceptible to human interferences because of their high density nesting habits (Rodgers and Smith, 1995). In the case of Little Cormorant, predator attack and heavy monsoon rains caused the death of nestlings.

Human interferences also disturb the nest sites by cutting of the tree branches, cutting the whole tree and burning waste materials below the nesting colony. For these Ciconiform and Pelecaniform waterbirds, however, the strategy of nest concealment in order to escape from threat is not possible as the nesting sites are prominent, conspicuous, crowded and also noisy (Bures and Pavel, 2003).

To keep the temperature of the egg steady during incubation, the adult bird must balance the heat transferred from its body against the heat of the environment and that generated by respiration within the developing embryos. The environmental temperature markedly affects the time spent incubating (Burton, 1941) by the parent bird. Little Cormorant performed different strategies like keeping the wings in a particular position, shading the chicks with wings and gular fluttering to provide the needed temperature to the eggs and nestlings. Altricial young ones developed gular fluttering ability by the third week of their development to maintain the body temperature. Shivering of the wings and legs were also observed among older fledglings during heavy rain. Young altricial birds usually acquire control of their body temperature during the middle of the nestling period (Olson, 1994; Choi *et al*., 1993).

6.5.2 Darter

The nesting season of Darter varies from June to August in North India and from November to February in South India (Ali, 2002). In the present study it was from May to August 2006. The breeding season was associated with the Southwest Monsoon, which is the breeding season of fishes and other aquatic organisms. The nesting site of Darter at Mangalavanam was a small mangrove area comprising of a shallow tidal lake in the centre with its edges covered with thick mangrove vegetation. The nest was built among the canopy top branches of a raintree of about 25 m height. Such a nesting site with water in the vicinity is typical for Darters as mentioned by Ali (2002).

Variations in the breeding season of Darter were also noticed by Palhak *et al*. (2004). They mentioned that the breeding season was from June to August as met within the Gir Forest. In the Thiruvananthapuram Zoo, Darter nested from October to March, in 2005 and 2006 (Raju and Rajashree, 2007). This shows that the bird can breed throughout the season if food source and nesting materials are available in plenty. The Mangalavanam mangrove with a large number of mangrove trees and larger trees like *Samanea saman, Alstonia scholaris* and *Caryota urens* with the nearby tidal lake appears to be the most suitable site for the nesting of Darter.

The nests of twelve pairs of Darters were seen distributed randomly on the canopy top layer of the rain tree. As observed in Little Cormorant this may help the birds to take off and land easily as explained by Krishnan (1980).

Nest site fidelity was observed in Darters. They used to nest at Mangalavanam mangroves every year along with Little Cormorants (Jayson, 2001). But in 2005, they were not found to breed at Mangalavanam and might be due to construction works around this area. At Thiruvananthapuram Zoo, Darter nested continuously for two years according to the observations of Raju and Rajashree (2007).

Courtship and nesting were performed at the territories. Darters were more aggressive at the territories than Little Cormorants. The pairs defended their territory individually and together. As mentioned by Palhak *et al*. (2004) aggressive behaviour was exhibited by Darter between conspecifics and also against the intruders. Some of the nests were placed close to each other and stealing of nest materials resulted in aggressive behaviour. During aggressive display the head and neck were quickly extended at the intruder with gaped bill. In the alert posture the neck was stretched forward, turning the head to all sides and this behaviour was found throughout the incubation period for guarding the nest. A similar alert posture was noticed for Little Cormorant also.

The nest was actually a twig platform as informed by Ali and Ripley (1983), but it was massive and lined with green leafy twigs. Raju and

Rajashree (2007) observed that breeding Darters encroached the nests of Black crowned Night Herons, displaced the nests and occupied them at Thiruvananthapuram Zoo. They bred successfully in such nests. It is not known whether the encroachment was through direct fighting or by display. It has been argued that aggressive interactions and arrival times of various species in mixed species heronries are the deciding factors regarding the pattern and species composition of the breeding colony (Burger, 1978). The nest site competition observed here could be the manifestation of the acute shortage of suitable nest sites, being faced by colonial waterbirds in Kerala. Nest appropriation from herons and egrets was reported for American Darter by Meanley (1954).

At the beginning of the courtship display the male held a piece of nesting material in his beak, which was mentioned in *A. anhinga* (Grzimek, 1990), as a symbolic display which represented a future activity of nest building. Male Darters produced caw .... caw .... calls of very low frequency during courtship (Ali & Ripley, 1983). In the present study also males made a similar call during courtship behaviour.

While feeding, chicks pushed their head into the gullet of the parent. The chicks flapped their wings and stretched their head forward oscillating irregularly towards gaped bill of the parents. The process lasted for a few seconds (42.5 sec, n = 12). The extraction of food from the gullet of the parent was stimulated by tickling the parent's throat. When one chick was offered food, the others made begging calls showing impatience. Jostling behaviour of the chick to obtain food was observed by Ali and Ripley (1983). Begging calls were produced by nestling on the arrival of foraging parents at the nest.

Table 6.1. **Nesting trees in the heronry (Ramanattukara)**

Sl. No.	Common name	Scientific name
1.	Rain tree	*Samanea saman*
2.	Ezhilampala	*Alstonia scholaris*
3.	Copper pod	*Peltophorum pterocarpum*
4.	Jack tree	*Artocarpus heterophyllus*
5.	Mango tree	*Mangifera indica*
6.	Banyan tree	*Ficus religiosa*
7.	Manimaruthu	*Lagerstroemia speciosa*
8.	Badam	*Terminalia catappa*
9.	Tamarind	*Tamarindus indica*
10.	Njaval	*Syzgium cumini*
11.	Pezhu	*Careya arborea*
12.	Red silk cotton tree	*Bombax ceiba*

Fig. 6.1. Litte Cormorant: Frequency (%) of nests on the Rain Tree at Ramanattukara heronry

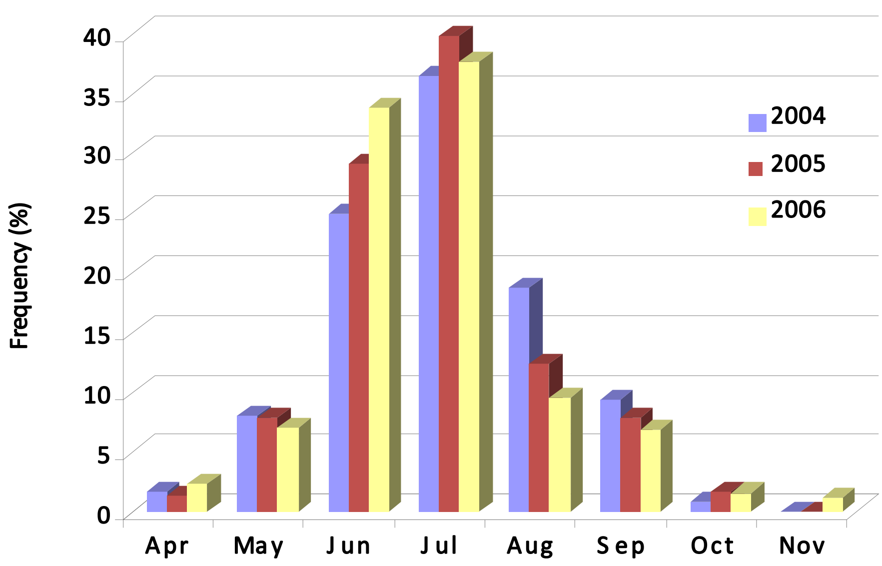


Table 6.2. Nest location and nesting tree preference of Little Cormorant and its nesting associates – 2006 (Ramanattukara)

Sl. No.	Nesting trees	Number and Location of nests in the heronry during the year 2006																	
	Common Name	Nest of Little Cormorant						Nest of Pond Heron						Nest of Night Heron					
		No. of nest	% Fre-quency	Canopy top nest	% Fre-quency	Below canopy nest	% Fre-quency	No. of rest	% Fre-quency	Canopy top nest	% Fre-quency	Below canopy nest	% Fre-quency	No. of nest	% Fre-quency	Canopy top nest	% Fre-quency	Below canopy nest	% Fre-quency
1.	Rain tree	186	51.10	184	98.92	2	1.08	10	5.46	7	70.00	3	30.00	6	12.77	5	83.33	1	16.67
2.	Copper pod	42	11.54	32	76.19	10	23.81	36	19.67	29	80.56	7	19.44	7	14.89	6	85.71	1	14.29
3.	Ezhilampala	29	7.97	24	82.76	5	17.24	13	7.10	9	69.23	4	30.77	3	6.38	2	66.67	1	33.33
4.	Manimaruthu	26	7.14	24	92.31	2	7.69	17	9.29	10	58.82	7	41.18	10	21.28	7	70.00	3	30.00
5.	Jack tree	25	6.87	23	92.00	2	8.00	35	19.13	28	80.00	7	20.00	--	--	--	--	--	-
6.	Tamarind	13	3.57	10	76.92	3	23.08	32	17.49	21	65.63	11	34.38	4	8.51	2	50.00	2	50.00
7.	Banyan tree	12	3.30	8	66.67	4	33.33	2	1.09	1	5.00	1	50.00	9	19.15	7	77.78	2	22.22
8.	Njaval	10	2.74	6	60.00	4	40.00	15	8.20	2	13.33	13	86.67	2	4.26	1	50.00	1	50.00
9.	Mango tree	8	2.20	7	87.50	1	12.5	11	6.01	8	72.72	3	27.27	1	2.13	--	--	1	100
10.	Pezhu	5	1.37	4	80.00	1	20.00	7	3.83	5	71.43	2	28.57	5	10.64	4	80.00	1	20.00
11	Badam	5	1.37	2	40.00	3	60.00	5	2.73	2	40.00	3	60.00	--	--	--	--	--	--
12	Cotton tree	3	0.82	--	--	3	100	--	--	--	--	--	--	--	--	--	--	--	--
	Total	364		324		40		183		122		61		47		34		13	

Table 6.3. Preference of nest location in the rain tree (Ramanattukara heronry)

Year	Total number of nest	Nest of Little Cormorant						Nest of Pond Heron						Nest of Night Heron					
		Total number	% F	Canopy top	% F	Below canopy	% F	Total number	% F	Canopy top	% F	Below canopy	% F	Total number	% F	Canopy top	% F	Below canopy	% F
2004	86	82	95.35	79	96.34	3	3.66	2	2.33	--	--	2	100	2	2.33	1	50.00	1	50.00
2005	133	122	91.73	116	95.08	6	4.92	9	6.77	1	11.11	8	88.89	2	1.50	1	50	1	50
2006	202	186	92.08	184	98.92	2	1.08	10	4.95	7	70.00	3	30.00	6	2.97	5	83.33	1	16.67

Table 6.4. Proportion of nestlings in the canopy top and below canopy nests of Little Cormorant (2006)

Sl. No.	Breeding site	Total number of nest	Canopy top nest				Below canopy nest			
			Frequency	% F	No. of nest observed	Mean number of nestlings in each nest	Frequency	% F	No. of nest observed	Mean number of nestlings in each nest
1.	Ramanattukara	364	324	89.01	54	3.20 ± 0.94	40	10.99	31	1.77 ± 0.67
2.	Meenchanda Byepass	22	17	77.27	13	3.77 ± 0.73	5	22.73	5	1.5 ± 1.05
3.	Areekad	65	60	92.31	43	3.53 ± 0.91	5	7.69	5	1.6 ± 0.55

Table 6.5. Plant materials used for nest building by Little Cormorant

Sl. No.	Plants		Layers of the Nest						
	Common name	Scientific name	Outer shell			Middle layer		Inner lining	
			Dry twigs	Fresh twigs	Fresh flower	Dry twigs	Fresh twigs	Dry leaves	Fresh leaves
1.	Rain tree	*Samanea saman*	--	--	--	--	--	--	✓
2.	Kanhiram	*Strychnos nuxvomica*	--	--	--	--	--	--	✓
3.	Ilanchi	*Mimusops ilanchi*	--	--	--	--	--	--	✓
4.	Red silk cotton tree	*Bombax ceiba*	--	--	--	--	--	--	✓
5.	Cashew	*Anacardium occidentale*	✓	--	--	✓	--	--	✓
6.	Mango tree	*Mangifera indica*	✓	--	--	✓	--	--	--
7.	Tamarind	*Tamarindus indica*	✓	--	--	✓	--	--	--
8.	Njaval	*Syzgium cumini*	✓	--	--	--	--	--	--
9.	Acacia	*Acacia auriculiformis*	--	✓	✓	--	--	--	--
10.	Teak	*Tectona grandis*	--	--	✓	--	--	--	--
11.	Jack tree	*Artocarpus heterophyllus*	--	--	--	✓	--	--	✓
12.	Loranthus	*Loranthus intermedius*	--	--	--	✓	--	--	✓
13.	Gulmohar	*Delonix regia*	--	--	--	✓	--	--	✓
14.	Manimaruthu	*Peltophorum pterocarpum*	✓	--	--	--	--	--	--

Table 6.6. Little Cormorant : Nesting details

Nests studied	Clutch size	Eggs predated	Eggs hatched	Eggs unhatched	Chicks died	Chicks survived
1	4	1	3	--	--	3
2	2	--	2	--	--	2
3	5	1	3	1	1	2
4	4	1	3	-	-	3
5	4	2	2	--	--	2
6	4	-	4	-	1	3
7	5	--	4	1	1	3
Total	28	5	21	2	3	18

Table 6.7. Little Cormorant : Hatching Success

Total number of eggs laid	Eggs lost	Eggs remained	Eggs hatched	Eggs unhatched	Hatching success
28	5 17.86%	23 82.14%	21 75%	2 7.14%	91.30%

Table 6.8. Little Cormorant : Breeding success

Total number of chicks	No. of chicks lost	No. of chicks survived	Breeding success
21 75%	3 14.29%	18 85.7%	85.71%

Table 6.9. Little Cormorant : Clutch size

Clutch Size	Frequency	Clutch size %
2	4	26.67
3	2	13.33
4	6	40.00
5	3	20.00

Table 6.10. Ramanattukara heronry : Nestling mortality

Month	Total Number of nestlings died	Little Cormorant	Pond Heron	Night Heron
June	2	2	--	--
July	16	15	--	--
August	5	4	1	1
September	7	6	--	1
October	36	33	1	2
Percentage	--	91.67	2.78	5.56

Table 6.11. Predators associated with heronry (Ramanattukara)

Sl. No.	Common name	Scientific name
1	House crow	*Corvus splendens*
2	Jungle crow	*Corvus macrorhynchos*
3	Brahminy kite	*Haliaster indus*
4	Pariah kite	*Milvus migrans*

Table 6.12. Predation attempts upon Little Cormorant

Predator Birds	Total attempts	Successful attempts	Failure attempts
House crow	72	24	48
Jungle crow	68	17	51
Brahminy kite	22	5	17
Pariah kite	14	2	12

Fig. 6.2. Predation attempts upon Little Cormorant

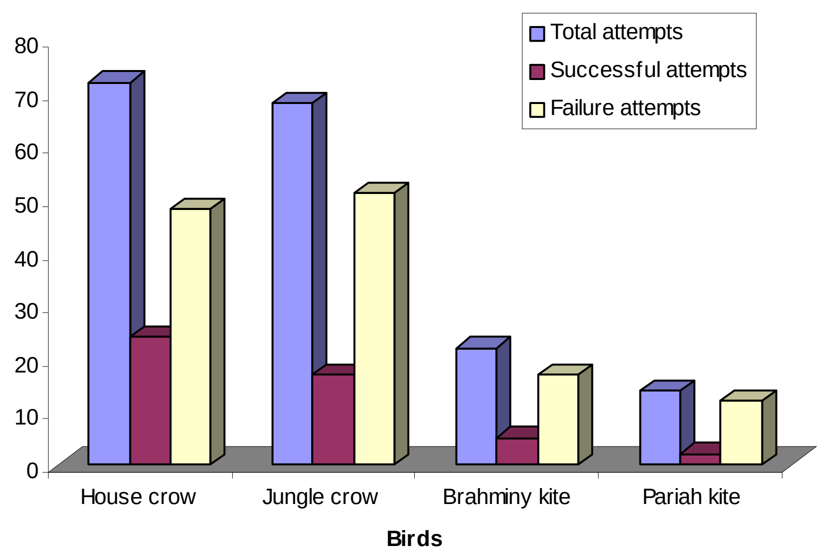


Table 6.13. Predation of eggs and chicks of Little Cormorant by birds during breeding season (2006)

Predator birds	Eggs							Chicks						
	June	July	August	September	October	Total	%age	June	July	August	September	October	Total	%age
House crow	2	7	10	0	1	20	52.63	1	1	2	--	--	4	40
Jungle crow	3	4	6	1	--	14	36.84	--	2	1	--	--	3	30
Brahminy kite	-	1	2	--	--	3	7.89	--	1	1	--	--	2	20
Pariah kite	--	--	1	--	--	1	2.63	--	--	1	--	--	1	10
Total	5	12	19	1	1	38		1	4	5	--	--	10	

Table 6.14. Sightings of Predator birds during breeding season: 2006 at Ramanattukara heronry

Predator birds	Sightings of birds					Total
	June	July	August	September	October	
House crow	22	41	38	8	12	121
Jungle crow	18	26	26	15	16	101
Brahminy kite	3	4	2	--	--	9
Pariah kite	2	3	2	1	1	9

Chapter 7

ADAPTATIONS FOR THERMOREGULATION

ADAPTATIONS FOR THERMOREGULATION

7.1 Introduction

Unlike marine mammals that rely on blubber for thermal insulation, aquatic birds are insulated by the air trapped in their plumage. The use of air for insulation is better for flying birds that need to minimize their wing load, but results in high buoyancy when submerged (Lovvorn and Jones, 1991a, 1994; Wilson *et al*., 1992). Ducks are reported to invest upto 95% of their mechanical work to counter buoyancy during dives (Stephenson *et al*., 1989). Diving birds reduce their buoyancy by diving deep so that ambient pressure compresses the air volumes in the plumage and air sacs making the bird less buoyant (Lovvorn and Jones, 1991b; Taylor, 1994; Gremillet *et al*., 1998a; Lovvorn *et al*., 1999; Watanuki *et al*., 2003). However, the birds still need to work against buoyancy during the descent and the large air volumes of birds render them positively buoyant at moderate depths (Wilson *et al*., 1992).

Reduced volume of air in the plumage of cormorants may help them to counter buoyancy while diving under water (Ribak *et al*., 2005). Cormorants have partially wettable plumage (Rijke, 1968) that holds water and maintain a thin layer of air next to the skin while foraging (Casler, 1973). This affords insulation while immersed in water. The quantity of water retained in the plumage increases as a function of time spent in water (Ribak *et al*., 2005). As dive duration increases there will be gradual increase in water retention which penetrates the plumage and replaces air. This results in the reduction of buoyancy and insulation buffering heat loss. In order to dry the plumage, cormorants perform spread-winged behaviour (Hennemann, 1984), which helps to regain air insulation close to the skin to conserve metabolic heat. Rapid drying of wings and body plumage increases the thickness of the insulation air layer adjacent to the skin and reduce heat loss after wet period. Thus the ultimate goal of spread-winged behaviour is to conserve metabolic energy.

Casler (1973) and Rijke (1968) found that Darters possess wettable plumage, which allows water to penetrate the air space next to the skin. This reduces buoyancy, but facilitates heat loss from the body while foraging. Spread-winged behaviour allows fast drying of the wing and body plumage to regain the layer of air close to the skin after foraging which aids to conserve metabolic energy. According to Hennemann (1982), the high thermal conductance and wettable plumage of Anhingas cause thermoregulatory problems during wet periods. Hence spread-winged posture offers an inexpensive behavioural means of reducing heat loss. In addition, it is an adaptation to balance energy budgets of these birds, supplementing metabolic energy with insolation compensating for heat loss, via evaporation and convection due to wetting of plumage.

In the absence of direct sunlight and wind, wing drying in cormorants and darters is enhanced by fanning or fan drying behaviour (Dick & Wurdinger, 2001). When there is direct sunlight, heat stress of the bird is relieved by gular fluttering behaviour (Hennemann, 1984). It is a non-ventilatory expansion and compression of the buccal cavity (gular area) that contribute to evaporative cooling.

7.2 Objectives

1. To study the effect of various climatic conditions upon the spread-winged behaviour, fan drying and gular fluttering

2. To understand the structural peculiarities of the feather of Little Cormorant.

7.3 Methodology

Observations of spread-winged behaviour, fan-drying and gular fluttering of Little Cormorant and Darters were made throughout the study period (Chapter IV). Binoculars (8x40) and a compass were used to determine the orientation of the birds to incident sunlight. Ambient temperature was measured with field thermometer.

The time taken by each bird for spread-winged behaviour, gular fluttering and fan-drying were recorded at an interval of 5 minutes. If the individual under observation exhibited more than one type of behaviour within the 5 minutes interval, the fraction of the interval devoted to each specific behaviour was recorded. The frequency of each behavioural category was then calculated as

$$\frac{\text{No. of observation of the behaviour}}{\text{Total No. of observations}} \times 100$$

under each specific set of environmental conditions (Hennemann, 1982).

The results were statistically analysed. Two-way ANOVAs were used to test significance between different behaviours in various climatic conditions. P-value < 0.05 is considered significant.

Samples of the dorsal and ventral body feathers were used for surface area measurements to find out the structural peculiarities of the partially wettable feathers of Little Cormorant. Ten feathers each from the dorsal and ventral sides of the body were taken carefully from a preserved specimen. Flattened surface of central and peripheral parts of feathers was measured on digital pictures. Actual values were calculated by eliminating the magnification factor. The boundary between the central and the peripheral parts of the feather is defined as the line where the gap between barbs become visible to the naked eye. To find out the boundary more accurately, the feathers were examined under light microscope (Gremillet *et al.*, 2005).

7.4 Results

7.4.1 Thermoregulatory behaviour

Behaviour in general and spread-winged behaviour in particular was highly dependent on weather (Appendix VII). The influence of various environmental conditions upon spread-winged behaviour, fan drying and gular fluttering of Little Cormorant and Darter were recorded.

During premonsoon season both Little Cormorant and Darter spent more time for feeding when compared to postmonsoon and monsoon seasons. Likewise spread-winged behaviour was higher for both the birds during pre monsoon than for post monsoon and monsoon as described in Chapter IV.

7.4.1.1 Little Cormorant

Spread-winged behaviour was performed by Little Cormorant, mainly under direct solar radiation. On cloudy days, during rain and under shade, the frequency was less (Table 7.1). Fan-drying was more common on rainy days, cloudy days and under shade. Under direct sunlight the frequency was less. The frequency of wing-flapping was 5.44 $\pm$ 2/sec (n = 53) (Table 7.3). Under direct sunlight, gular fluttering rate was very high for Little Cormorants. During rain and under shade, gular fluttering was very low (Appendix VII a, b & c).

In spread-winged posture about 67% Little Cormorants oriented back to the sun (Table 7.4). While gular fluttering, greater number (85%) of Little

Cormorants faced the sun. The rate of gular fluttering increased slowly between 20-30ºC and the increase was very high between 30-40ºC (Table 7.5 and Appendix VII.d). Gular fluttering rate was higher for Little Cormorant (88.15 to 303.27/minute) than Darter.

7.4.1.2 Darter

The frequency of spread-winged behaviour was highest in direct sunlight than other activities. Fan drying was more frequent when the bird was sitting under shade than spread-winged behaviour and gular fluttering. Darter showed low wing flapping frequency during fan drying (3.06 $\pm$ 0.80/sec, n = 44). Gular fluttering rate was very low in Darters under direct sunlight in comparison to Little Cormorant. During rain and under shade it was very low as shown in Table 7.2.

During spread-winged posture, greater number of Darters oriented with back to the sun than Little Cormorants (Table 7.4). The percentage of gular fluttering Darters facing the sun was 55% whereas the percentage of Little Cormorant was 85%. The rate of gular fluttering increased with increase in temperature and it was from 63.53 to 200.39/min (Table 7.5)

7.4.2 Feather structure

Visual examination of the structure of body feathers of Little Cormorant revealed that they have two distinct zones (Plate XVII.A-D). The central part, which runs parallel to the rachis, has a typical regular feather structure, the barbules of each barb run parallel to each other on each side of the barb and are interconnected by hooklets. In contrast, the peripheral part of the feather has a very loose irregular structure (Plate XVIII). There was a significant difference between dorsal and ventral feather types, in the relative surface areas (Table 7.6 & 7.7) with the ventral feathers having a higher proportion of the outer loosely structured part than dorsal feathers.

7.5 Discussion

Both Little Cormorant and Darter spent only a small proportion of time for feeding. Their wettable plumage results in increased rates of heat loss, therefore it would appear suitable for them to spend less time in water and more time on land. During premonsoon season (summer) they spent proportionately more time for feeding when compared to postmonsoon and monsoon (cold weather). As proposed by Ribak *et al*. (2005) there might be an increased water retention in the plumage due to increased feeding time in summer and hence birds have utilized more time for spread-winged behaviour for drying the wings. This will regain the air insulation close to the skin and prevent heat loss in the birds.

There are similarities in the use of spread-winged behaviour for both Little Cormorant and Darter. Both of them face away from the sun during sun-drying. However the tendency is much stronger in Anhingas, as reported by Hennemann (1984). Most of the birds oriented back to the sun during spread-winged behaviour in order to increase the surface area exposed to the sun. This will aid to take full advantage of the heat absorbing qualities of the black plumage to conserve energy after wetting. Orientation, facing the sun would reduce the amount of surface exposed to it, as demonstrated for Herring Gulls (*Larus argentatus*) (Lustick *et al*., 1978).

The frequency of Darters orienting back to the sun during spread-winged posture was greater than Little Cormorants. Darters with fully wettable plumage may get greater advantage of this behaviour than Little Cormorants.

It has been observed during the present study, that wings of Darters appear water-laden when they leave water and must dry their plumage before they fly. This observation is supported by the findings of McAtee and Stoddard (1945). Darters usually crawled (n = 119) out of water after finishing their feeding bouts and perched very close to the water body confirms that they cannot fly far off without drying their wings. Quick drying of plumage by spreading the wings is a means of regaining air worthiness. But Little Cormorants fly and perch away from the water body just after the feeding bout. This observation indicates that the feathers of Darters are more wettable than that of Little Cormorant.

The higher wing flapping frequency of Little Cormorant can be correlated to its smaller body size compared to the Darter (Campbell & Lack, 1985). In our study also there was higher wing flapping frequency for Little Cormorant than Darter. Fan drying behaviour aids to dry the plumage rapidly when sunlight is not available.

Orientation during gular fluttering was almost similar in both the species. But the frequency of birds facing the sun was greater among Little Cormorants than Darters. Darters have low basal metabolism (Hennemann, 1982) and they can gain energy by maximizing the surface area facing the sun and can conserve energy by minimizing the rate of gular fluttering.

Among Little Cormorants the gular fluttering individuals are more in number showing that they have high metabolic rate and spread-winged behaviour was followed by gular fluttering. Here gular fluttering was found to be a mechanism to relieve heat stress. Among Darters spread-winged behaviour was not usually followed by gular flutter which shows that spread-winged behaviour is a mechanism to dry plumage and to conserve energy through regaining airworthiness and to absorb solar energy.

Water absorbing plumage is an adaptation to reduce buoyancy for underwater foraging which is best developed in Darters (Casler, 1973). The plumage is partially wettable and less water repellant in Cormorants (Rijke, 1968) and maintain a layer of air insulation close to the skin while foraging.

It has also been observed that Little Cormorants swim at the water surface with their head, back and shoulders exposed, whereas Darters swim with their head and neck exposed. This shows that Darter is less buoyant than Little Cormorant and may be due to the presence of air insulation close to the skin in Little Cormorant.

Gular fluttering rate increased with heat stress among Little Cormorants as observed by Bartholomew *et al.* (1968) in Double-crested Cormorants. Darters also gular flutter, the rate of which progressed with heat stress but at a slower rate as compared to Little Cormorants. As the environmental temperature becomes too hot, these birds mobilize water to lose heat through evaporative cooling.

The feather structure of Little Cormorant is yet to be studied. In this study, I have attempted to find out the structural adaptation of the body feathers. Microscopic examination of body feathers revealed the presence of two distinct parts. Body feather has a loose instantaneously wettable outer part and a highly water proof central part. In the outer part there is wide gap between the barbs and are devoid of hooklets. This observation agrees with the findings in Double-Crested Cormorant (Casler, 1973). Due to the presence of a highly water proof central area the bird can retain an insulating layer of air in its plumage. The air insulation close to the skin can maintain buoyancy and can conserve heat while swimming (Wilson *et al*., 1992). The loose peripheral portion is easily wettable and can reduce buoyancy and aid in underwater foraging. This view is supported by the findings of Gremillet *et al*. (1998a). The partial wettability is linked to the structure of body feathers rather than to the lack of plumage oil, as the uropygial gland is fully functioning in Little Cormorant. The ventral body feathers have greater proportion of wettable area than dorsal feathers as in the case of Great Cormorant (Gremillet *et al*., 2005) and reduces buoyancy constraints. This type of partially wettable plumage may be the most suitable adaptation for an underwater forager like Little Cormorant. It can be expressed as an unusual morphological-functional adaptation to diving which balances the antagonistic constraints of thermoregulation and buoyancy.

Table 7.1. Little Cormorant : Thermoregulatory behaviour during different environmental conditions

Environmental Condition	Frequency of behaviour (%)			Total observation
	Spread wing	Fan-drying	Gular flutter	
Direct sunlight	41.88	5.18	52.94	425
Cloudy day	19.47	48.23	32.30	226
Under shade	16.58	61.81	26.63	199
Rain	15.53	73.29	11.18	161

Table 7.2. Darter : Thermoregulatory behaviour during different environmental conditions

Environmental Condition	Frequency of behaviour (%)			Total observation
	Spread-wing	Fan-drying	Gular flutter	
Direct sunlight	51.90	26.58	21.52	158
Cloudy day	26.14	53.41	20.45	88
Under shade	26.67	62.22	11.11	45
Rain	28	56.00	16.00	75

Table 7.3. Rate of wing flapping during fan-drying

Bird species	Wing Flapping (beats/sec)				
	Under shade	Under wind	Cloudy day	Direct sunlight	Rain
Little Cormorant	5.13	3.91	7.2	3.18	7.76
Darter	3.11	2.43	3.67	2.11	4.00

Table 7.4. Orientation of birds during different behaviour patterns

Bird species	Behaviour pattern	Orientation of the bird (%)			Total observation
		Back to the sun	Side to the sun	Front to the sun	
Little Cormorant	Spread wing	66.54	16.54	16.93	254
	Gular flutter	5.04	9.66	85.29	238
Darter	Spread wing	79.59	12.24	8.16	98
	Gular flutter	31.91	12.77	55.32	47

Table 7.5. Rate of gular fluttering at different temperatures

Temperature Range	Rate of gular fluttering / minute	
	Little Cormorant	Darter
20 – 25°C	88.15 ± 7.05	63.53 ± 11.08
25 – 30°C	108.23 + 5.31	69.00 ± 3.61
30 – 35°C	178.6 ± 12.49	118.73 ± 12.69
35 – 40°C	303.27 ± 11.98	200.39 ± 15.78

Table 7.6. Little Cormorant : Surface Area of Dorsal Body Feathers

Sl. No. of feathers	Feather Surface Area (cm^2)				
	Central Part		Peripheral part		Total Area
	Area	Percentage	Area	Percentage	
1.	0.93	33.34	1.86	66.66	2.80
2	0.76	29.71	1.80	70.29	2.56
3	0.79	30.65	1.78	69.36	2.57
4	0.73	32.72	1.50	67.29	2.23
5	0.95	33.79	1.85	66.21	2.80
6	0.88	30.35	2.03	69.65	2.91
7	0.86	34.08	1.67	65.92	2.53
8	0.91	30.23	2.09	69.77	3.00
9	0.90	31.02	2.01	68.98	2.91
10	0.91	34.11	1.76	65.89	2.66
Mean ± S.D	0.86 ± 0.08	32.00 ± 1.77	1.84 ± 0.18	68.00 ± 1.77	2.70 ± 0.23

Table 7.7. Little Cormorant : Surface Area of Ventral Body Feathers

Sl. No. of feathers	Feather Surface Area (cm^2)				
	Central Part		Peripheral part		Total Area
	Area	Percentage	Area	Percentage	
1.	1.59	23.43	5.18	76.57	6.76
2.	1.61	20.26	6.33	79.74	7.93
3.	1.61	23.38	5.27	76.62	6.88
4.	1.36	23.85	4.36	76.15	5.72
5	1.42	28.03	3.63	71.97	5.05
6	1.69	21.16	6.28	78.84	7.97
7	1.24	18.84	5.32	81.16	6.55
8	1.67	25.58	4.87	74.42	6.54
9	1.40	20.89	5.31	79.11	6.71
10	1.33	21.92	4.74	78.08	6.07
Mean ± S.D	1.49 ± 0.16	22.73 ± 2.71	5.13 ± 0.81	77.27 ± 2.71	6.62 ± 0.90

Chapter 8

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

The behaviour and adaptation of Little Cormorant, *P. niger* and Darter, *A. melanogaster* from 2004 to 2006 was studied at Kallampara river site, Kalpally-Palliyol wetland and Ramanattukara and Mangalavanam heronries .

To study the population trend of the above two bird species, census was held using the total count method (Gaston, 1973) from 2004 to 2006 at Kallampara river and during 2005 and 2006 at Kalpally-Palliyol wetland. The population of Little Cormorant showed maximum abundance during premonsoon season throughout the study period. During monsoon season the population declined and gradually increased in the postmonsoon season. Birds congregated at heronries away from Kallampara river and Kalpally-Palliyol wetlands during monsoon season and they shifted their feeding to habitats close to heronries.

Darter population exhibited an abundance during premonsoon and postmonsoon season at Kalpally-Palliyol wetland. During Southwest monsoon the birds congregated for breeding at heronries away from major wetlands and resulted in the decline of bird population in this area.

The activity pattern and behaviour of the birds were investigated by focal animal sampling (Altmann, 1974). The awakening and roosting pattern of Little Cormorant is closely related to sunlight conditions. Preening, spread-winged behaviour, fan-drying, spread-winged preening, perching and bathing and ruffling were the prominent maintenance activities of the bird. The important agonistic behaviours displayed by the bird included aggressive displays and fighting. Flocks of Little Cormorants gathered in tight bunches on water surface to feed on shoals of fish. The vocal repertoire of the bird was very limited. It became noisy, only during breeding season. Out of the 12 activities recorded, the bird allocated the maximum time of daily hours for maintenance with less time for feeding. Seasonal variation was observed in the timing of daily activities. The bird spent more time for feeding during premonsoon season than other seasons. Two feeding peaks were observed in the daily activity during all the seasons. The activities like spread-winged behaviour and fan-drying were found to be adaptations closely related to underwater diving.

Darters also reached the feeding site after sunrise and left the habitat before sunset. Flock feeding was not observed in Darters – they were individualistic in their feeding activity. They congregated only during breeding season. The major behaviours recorded during the study were preening, spread- winged behaviour, fan-drying, spread-winged preening and perching. Bathing and ruffling was not performed by Darter. Agonistic behaviour was performed only during breeding season and adult Darters were noisy.

Time budgeting for 10 major activities were recorded for Darter. Maximum time out of daily hours were spent for maintenance than for feeding. Seasonal variation was observed in the pattern of daily activity. Darter spent more time for feeding in premonsoon than monsoon and postmonsoon. There were three peaks for feeding activity during all the seasons. When the data of the three sessions were pooled separately, it has been found that forenoon and afternoon were high intensity periods for feeding with a low intensity period at noon, both for Little Cormorant and Darter.

Foraging behaviour and diving pattern of Little Cormorant and Darter were studied by direct observational method (Altmann, 1974). Cormorants and Darters foraging solitarily were observed. The duration of a diving bout is taken as the time between submerging on the first dive of a series and surfacing after the last dive. A dive cycle consisted of a single dive and a single surface pause. Diving efficiency is defined as the ratio between mean diving time and mean recovery period (Dewar, 1924). Flock feeding and adaptation of Little Cormorant to changes in diving depths during various tidal cycles were also investigated.

Solitary feeding was the common method found among Little Cormorant and Darter. They made foraging trips to inshore water less than 5 m deep and perched near the shore. After settling, the bird dropped into water and then started diving. The first dive was followed by a recovery period and then continued a series of alternating dives and surface pauses for a specific period (bout duration). The study revealed a specific diving pattern which consisted of the following parameters: (a) Dive duration (b) Surface pause duration or recovery period (c) Duration of diving bout (d) Diving efficiency (e) Dive frequency percentage per hour (f) Number of dive cycles per bout (g) Time spent under water per dive cycle (h) Duration of a dive cycle. Pause duration increased with the increase in the dive duration.

Foraging behaviour of Little Cormorant was studied at Kallampara river site and Kalpally-Palliyol wetland. The mean dive duration of Little Cormorant recorded for one day at Kallampara was 11.73 sec. and at Kalpally-Palliyol wetland it was 18.96 sec. Corresponding pause durations were 4.73 sec and 8.16 sec respectively. The increased dive duration of Little Cormorant at Kalpally-Palliyol wetland may probably be due to increased depth of feeding locations and abundant growth of submerged vegetation.

The mean dive duration of Darter was 48.86 sec. and pause duration was 14.18 sec. at Kalpally-Palliyol wetland. When compared to Little Cormorant, Darter showed increased dive duration and a corresponding increase in pause duration. The possible reasons may be that Darters often pause midway through a dive before continuing to the bottom and exploit the entire water column. Further, its reduced buoyancy may be an advantage.

In the present study, flock feeding was observed among Little Cormorants, at Kallampara back waters. Group feeding would be helpful in detecting the fishes easily and exploiting it to the maximum extent when it is available. Another important finding was that Little Cormorants were able to forage depending on the tidal cycles. The birds foraged successfully in shallow water and diving efficiency was inversely proportional to diving depth.

The study of breeding biology was aimed at understanding the breeding behaviour of Little Cormorant and Darter. The study was conducted by direct observation of the heronries (Altmann, 1974). Nest location, nesting patterns, nest building, courtship behaviour, brooding behaviour and parental care were studied. Little Cormorant showed nest site fidelity at the Ramanattukara heronry which is about 10 years old. The study revealed that the breeding season of Little Cormorant was from April to November at Ramanattukara, coincided with Southwest Monsoon. The heronry was located on either side of the National Highway and the nesting colony included Pond Herons and Night Herons.

Little Cormorant constructed large massive nests which were placed towards the top canopy of the trees. A clustering nest pattern (non-random distribution) was observed. The breeding pairs defended the territory through aggressive behaviour, alert posture and appeasement display. At the beginning of breeding season the males exhibited an elaborate courtship behaviour starting from "squat posture" of the body followed by "squat thrust" which ended with the "stroke". Little Cormorant is monogamous, but extra pair copulation was observed towards the end of the breeding season. As the breeding actively advanced "gape bow" behaviour was shown by males which seek extra pair copulation. Brooding pair was alert and protected the young ones from direct sunlight and heat. Canopy-top nests possessed larger brood size.

Darters were also monogamous and pair bonded during breeding season. Large platform nests were constructed and the breeding territory was actively defended. The male initiated pair bond formation through courtship display and nest material ceremony. Wing flapping and movement of the neck were the main courtship displays. Incubation and parental care was shared by both parents.

Thermoregulatory adaptations of Little Cormorant and Darter were studied by observing spread-winged behaviour, fan-drying and gular fluttering after leaving water at various climatic conditions. The frequency of different behaviours were recorded at specific intervals (Hennemann, 1982). Dorsal and ventral body feathers of Little Cormorant were studied to find out the structural adaptations of partially wettable plumage (Gremillet, *et al*., 2005).

During premonsoon, Little Cormorant and Darter spent proportionately more time for feeding than monsoon and postmonsoon. This increases water absorption by the wettable plumage and results in increased heat loss from the body. Hence the birds utilized more time for spread-winged behaviour. Both spread-winged behaviour and fan-drying were performed to dry the wings. Fan-drying was more frequent in the absence of sunlight to quicken the drying process. The drying of wings after leaving water, improves air worthiness and prevents heat loss from the body. Further, spread-winged behaviour in direct sunlight helps in the absorption of solar radiation. Under heat stress, gular fluttering rate was greater for Little Cormorant than Darter. In Little Cormorant, spread-winged behaviour was accompanied by gular flutter but in Darter it was never followed by gular flutter.

Microscopic examination of the body feathers revealed the presence of two distinct parts. Body feather has a loose instantaneously wettable outer part and a highly water proof central part. Ventral body feathers have a high proportion of outer loosely structured part than dorsal feathers. This might be explained as an unusual morphological-functional adaptation to diving which balances the antagonistic constraints of buoyancy and thermoregulation.

Little Cormorant and Darter were found in similar habitats. The behaviour of both the species were sensitive to environmental changes. They preferred shallow water for feeding. Darters fed solitarily but Little

Cormorants fed solitarily as well as gregariously. Both of them exhibited a specific feeding method and diving pattern.

Little Cormorants swam at water surface with back and shoulder exposed and Darters with only head and neck raised above water. This shows that Darter is less buoyant than Little Cormorant. Little Cormorant performed "bathing and ruffling" at the end of each feeding bout, however this activity was not found in Darter. Only wet individuals performed spread-winged behaviour in both species which was followed by gular fluttering in Little Cormorant, but never accompanied by gular fluttering in Darter. Darter was more aggressive during breeding season when compared to Little Cormorant. An elaborate courtship display was performed by Little Cormorant, but it was less pronounced in Darter. Competition for nest site and nest material might be the probable reason why Darters are rarely seen in the heronries of Northern Kerala.

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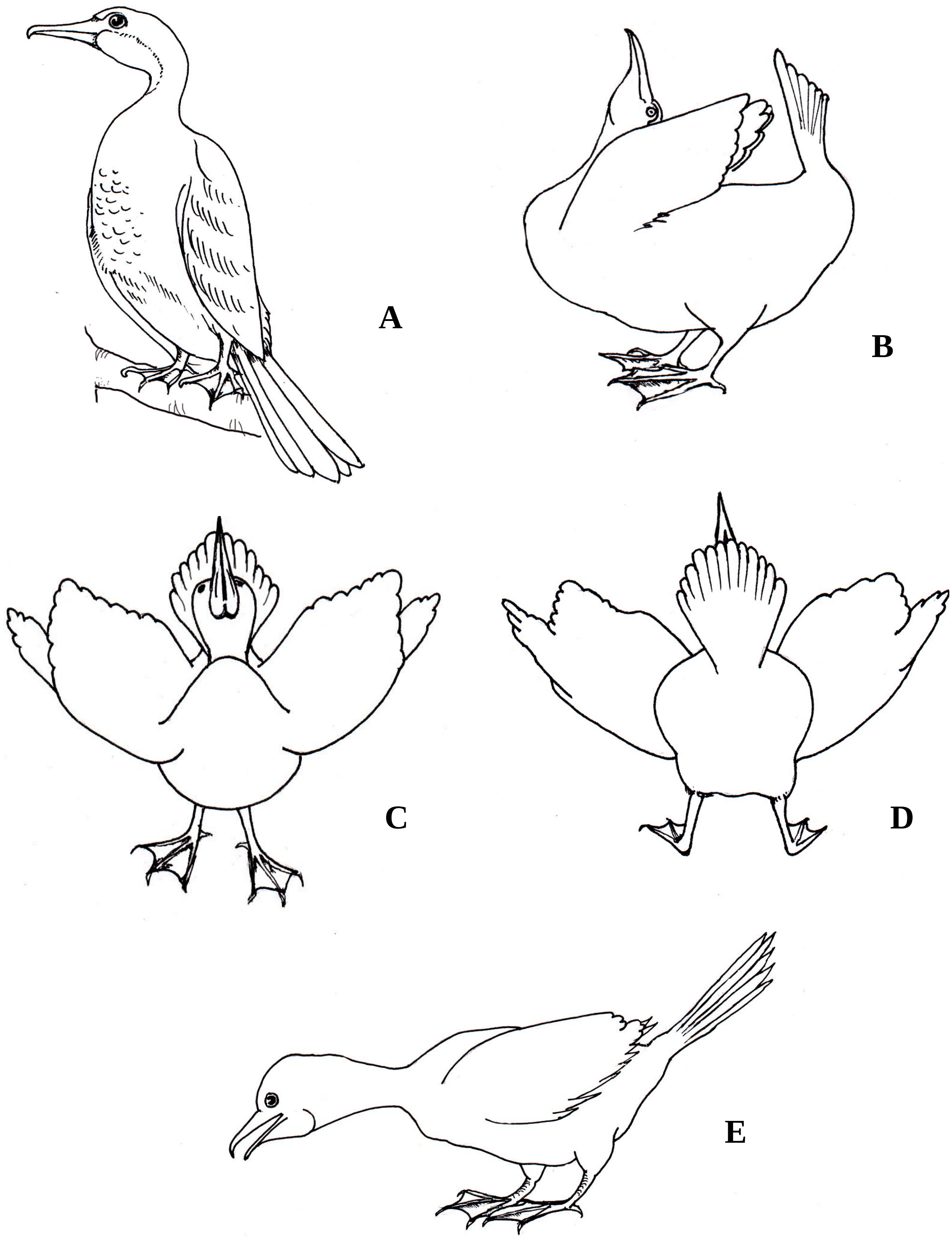
PLATE XII

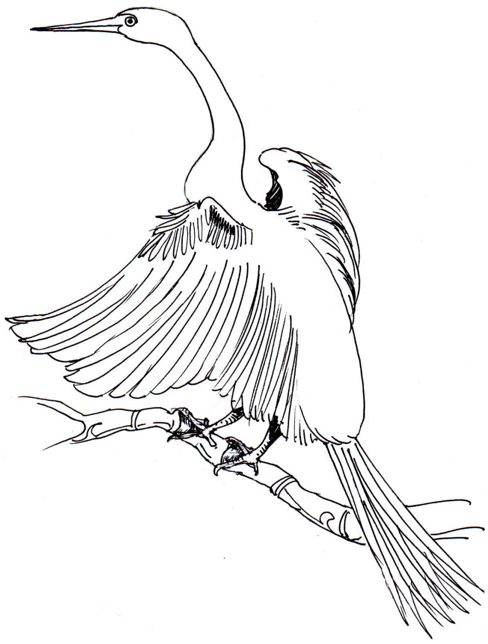
LITTLE CORMORANT: MALE COURTSHIP BEHAVIOUR



(A) Normal Posture; (B) Squat thrust: head pointing upwards – Side view; (C) Same - Front view; (D) Back view – Tail up and fanned, wings raised; (E) Stroke: head downwards, bill open and tail up

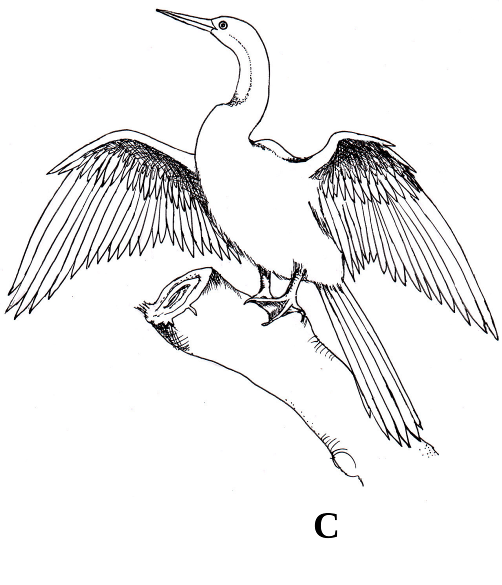
PLATE XVI

DARTER: MALE COURTSHIP BEHAVIOUR

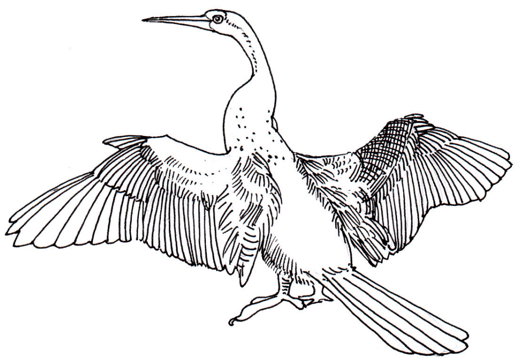


A

B



C

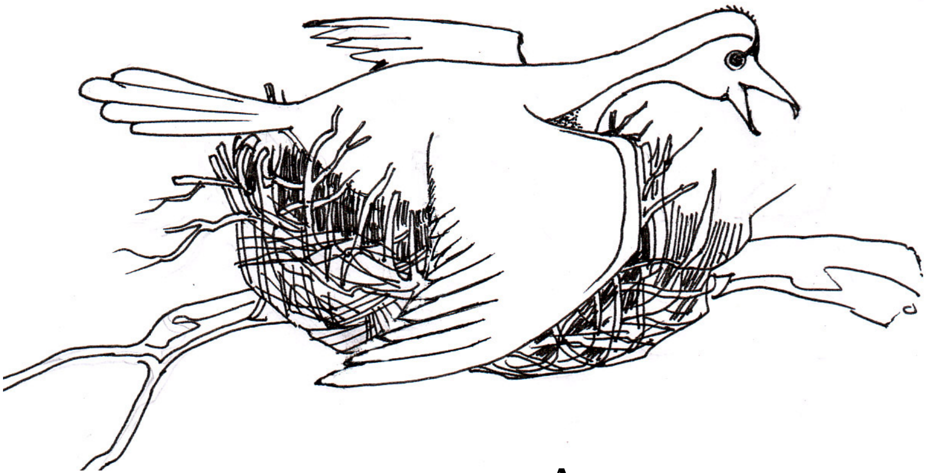


D

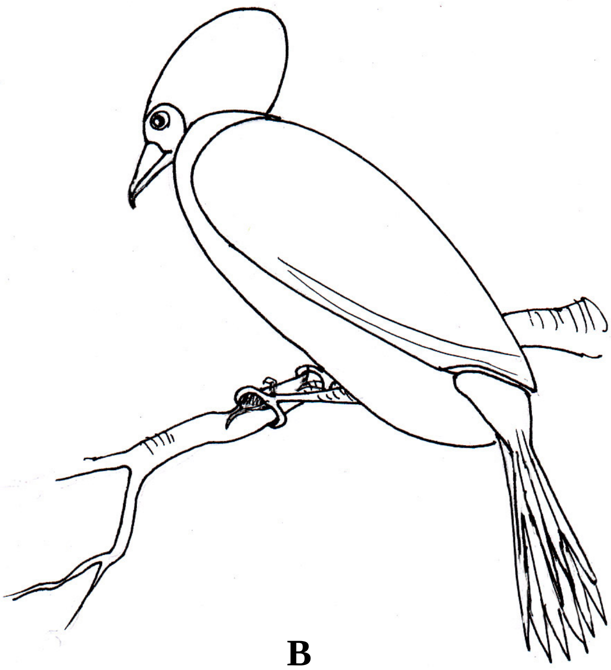
(A) Neck up posture; (B) Neck down posture; (C) Wings up movement – front view; (D) Wings down movement – rear view

PLATE XIV

LITTLE CORMORANT: AGONISTIC BEHAVIOUR



A



B

(A) Aggressive posture; (B) Appeasement posture

APPENDIX I

Heronries visited during the study period

Sl. No.	Place of Heronry	District	Location	Nesting species				
				Little cormorant	Pond fern	Night fern	Darter	Little Egret
1	Ramanattu-kara	Kozhikode	Road side	✓	✓	✓	--	
2	Areekadu	Kozhikode	Roadside	✓	✓	✓	--	
3	Meenchanda	Kozhikode	Roadside	✓	✓	✓	--	
4	Kondotty	Malappuram	Roadside	✓	✓	✓	--	
5	Pulikkal	Malappuram	Roadside	✓	✓	--	--	
6	Randathani	Malappuram	Roadside	✓	✓	✓	--	
7	Kandanakam	Malappuram	Roadside	✓	✓	✓	--	
8	Kozhichena	Malappuram	Roadside	✓	✓	✓	--	
9	Parammal	Kozhikode	Roadside	✓	✓	✓	--	
10	Mavoor	Kozhikode	Roadside	✓	✓	✓	--	
11	Kalletinkara	Thrissur	Railway station	✓	✓	--	✓	
12	Chungam	Kozhikode	Roadside	✓	✓	--	--	
13	Kuttippuram	Malappuram	Near Railway station	✓	✓	--	--	✓
14	Kottapuram	Malappuram	Road side	--	✓	--	--	--
15.	Mangala-	Ernakulam	River bank	--	--	--	✓	--

	vanam							

APPENDIX II

A. Birds of Kallampara river site

Sl. No.	Common name	Scientific name	Status
	Order : Pelecaniformes **Family : Phalacrocoracidae**		
1.	Little Cormorant	*Phalacrocorax niger*	LM
	Order : Ciconiiformes **Family : Ardeidae**		
2.	Indian Pond Heron	*Ardeola grayii*	R
3.	Cattle Egret	*Bubulcus ibis*	R
4.	Large Egret	*Ardea alba*	R
5.	Little Egret	*Egretta garzetta*	R
6.	Night Heron	*Nyticorax nyticorax*	R
7.	Grey Heron	*Ardea cinerea*	R
	Order : Gruiformes **Family : Rallidae**		
8.	White breasted Waterhen	*Amaurornis phoenicurus*	R
	Order : Charadriiformes **Family : Charadriidae**		
9.	Little Ringed plover	*Charadrius dubius*	M
10.	Common Sandpiper	*Actitis hypoleucos*	M
11.	Little stint	*Calidris minutus*	M
12.	Common snipe	*Capella gallinago*	M
13.	Common Redshank	*Tringa totanus*	M
14.	Common Greenshank	*Tringa nebularia*	M
	Order : Falconiformes **Family : Accipitridae**		
15.	Black kite	*Milvus migrans*	R
16.	Brahminy kite	*Haliastur indus*	R
17.	Shikra	*Accipiter badius*	
	Order : Coraciiformes **Family : Alcedinidae**		
18.	White breasted Kingfisher	*Halcyon smyrnensis*	R
19.	Lesser Pied Kingfisher	*Ceryle rudis*	R

R = Resident, M = Migrant, LM = Local Migrant

Sl. No.	Common name	Scientific name	Status
20.	Small Blue Kingfisher	*Alcedo atthis*	R
	Order : Cuculiformes		
	Family : Cuculidae		
21.	Koel	*Endynamys scolopaceae*	R
22.	Southern Crowpheasant	*Centropus sinensis*	R
	Family : Dicruridae		
23.	Black drongo	*Dicrurus macrocercus*	R
	Family : Passeriformes		
	Family : Corvidae		
24.	Indian Treepie	*Dendrocitta Vagabunda*	R
25.	House Crow	*Corvus splendens*	R
26.	Jungle Crow	*Corvus macrorhynchos*	R
	Order : Apodiformes		
	Family : Apodidae		
27.	Palm swift	*Cypsiurus parvus*	R
	Family: Muscicapidae		
28.	Whiteheaded Babbler	*Turdoides affinis*	R
	Order : Passeriformes		
	Family: Sturnidae		
29.	Common Myna	*Acridotheres tristis*	R
	Order : Coraciiformes		
	Family : Meropidae		
30.	Small Green Bea eater	*Merops orientalis*	R
	Order : Passeriformes		
	Family: Nectarinidae		
31.	Indian Purple Sunbird	*Nectarima asiatica*	R
32.	Indian Purple rumped sun bird	*Nectarinia zeylonica*	R

B. Birds of Kalpally – Palliyol wetland

Sl. No.	Common Name	Scientific Name	Status
	Order : Podicipidiformes **Family: Podicipididae**		
1.	Little Grebe	*Tachybaptus ruficollis*	R
	Order : Pelecaniformes **Family :** Phalacrocoracidae		
2.	Little Cormorant	*Phalacrocorax niger*	LM
	Family : Anhingidae		
3.	Oriental Darter	*Anhinga melanogster*	LM
	Order : Ciconii formes **Family :** Ardeidae		
4.	Purple Heron	*Ardea purpurea*	R
5.	Little Green Heron	*Ardea striata*	R
6.	Pond Heron	*Ardeola grayii*	R
7.	Cattle Egret	*Bubulcus ibis*	R
8.	Large Egret	*Casmerodius albus*	R
9.	Median Egret	*Mesophoyx intermedia*	R
10.	Little Egret	*Egretta garzetta*	R
11.	Black crowned Night Heron	*Nycticorax nycticorax*	R
12.	Chestnut Bittern	*Ixobrychus cinnamomeus*	R
	Family : Ciconiidae		
13.	Asian Openbill Stork	*Anastomus oscitans*	LM
14.	Oriental White Stork	*Ciconia boyciana*	M
	Order : Anseriformes **Family :** Anatidae		
15.	Lesser Whistling Duck	*Dendrocygna javanica*	R
16.	Common Teal	*Anas crecca*	M
17.	Northern Pintail	*Anas acuta*	M
18.	Gargany	*Anas querqudula*	M
19.	Cotton Teal	*Nettapus coromandelianus*	LM

Sl. No.	Common Name	Scientific Name	Status
	Order : Falconiformes **Family :** Accipitridae		
20.	Black Kite	*Milvus migrans*	R
21.	Brahminy Kite	*Haliaster indus*	R
22.	Shikra	*Accipiter badius*	R
23.	Western Marsh Harrier	*Circus aeruginosus*	M
	Order : Gruiformes Family : Rallidae		
24.	Ruddy Crake	*Porzana fusca*	R
25.	White breasted Water	*Amaurornis phoenicurus*	R
26.	Common Moorhen	*Gallinula chloropus*	R
27.	Purple Moorhen	*Porphyrio porphyrio*	R
28.	Common coot	*Fulica atra*	LM
	Order : Charadriiformes **Family :** Jacanidae		
29.	Pheasant-tailed Jacana	*Hydrophasianus chirurgus*	LM
30.	Bronze-winged Jacana	*Metopidius indicus*	R
	Family : Charadriidae		
31.	Red-wattled Lapwing	*Vanellus indicus*	R
32.	Lesser sand plover	*Charadrius mongolus*	M
33.	Wood Sandpiper	*Tringa glareola*	M
34.	Common Sandpiper	*Actitis hypoleucos*	M
35	Common Snipe	*Gallenago gallinago*	M
	Family : Laridae		
36.	Whiskered Tern	*Chlidonias hybridus*	LM
	Order : Columbiformes **Family :** Columbidae		
37.	Blue Rock Piegeon	*Columba livia*	R
38.	Spotted Dove	*Streptopelia chinensis*	R
	Order : Psittaciformes **Family** : Psittacidae		
39.	Rose-ringed parakeet	*Psittacula krameri*	R

Sl. No.	Common Name	Scientific Name	Status
40.	Plum-headed parakeet	*Psittacula cyanocephala*	LM
	Order : Cuculiformes **Family :** Cuculidae		
41.	Brainfever Bird	*Hierococcyx varius*	LM
42.	Asian Koel	*Eudynamys scolopacea*	R
	Order : Strigiformes **Family :** Strigidae		
43.	Spotted owlet	*Athene brama*	R
	Order : Apodiformes		
44.	House swift	*Apus affinis*	R
45.	Asian palm swift	*Cypsiurus balasiensis*	R
	Order : Coraciiformes **Family : Alcedinidae**		
46.	Lesser Pied Kingfisher	*Ceryle rudis*	R
47.	Small Blue Kingfisher	*Alcedo atthis*	R
48.	Stork-billed Kingfisher	*Halcyon capensis*	R
49.	White breasted kingfisher	*Halcyon smyrnensis*	R
	Family – Meropidae		
50.	Blue tailed Bee-eater	*Merops philippinus*	LM
51.	Small Bee-eater	*Merops orientalis*	
	Family : Capitonidae		
52.	White cheeked Barbet	*Megalaima viridis*	R
	Family : Picidae		
53.	Goldenbacked Woodpecker	*Dinopium benghalense*	R
	Order : Passeriformes **Family :** Motacillidae		
54.	Paddy field pipit	*Anthus rufulus*	LM
55.	Large pied Wagtail	*Motacilla maderaspatensis*	R
56.	Eurasian Golden Oriole	*Oriolus oriolus*	LM
57.	Black headed Oriole	*Oriolus xanthornus*	R

Sl. No.	Common Name	Scientific Name	Status
	Family : Dicruridae		
58.	Black Drongo	*Dicrurus macrocercus*	LM
	Family : Sturnidae		
59.	Common Myna	*Acridotheres tristis*	R
	Family : Corvidae		
60.	Indian Treepie	*Dendrocitta vagabunda*	R
61.	House Crow	*Corvus splendens*	R
62.	Jungle Crow	*Corvus macrorhynchos*	R
	Family : Irenidae		
63.	Common Iora	*Aegithina tiphia*	R
	Family : Picnonotidae		
64.	Red-whiskered Bulbul	*Pycnonotus jocosus*	R
65.	Red-vented Bulbul	*Pycnonotus cafer*	R
	Family : Tamaliinae		
66.	White-headed Babbler	*Turdoides affinis*	R
67.	Common Babbler	*Turdoides caudatus*	R
	Family : Turdinae		
68.	Oriental Magpie Robin	*Copsychus saularis*	R
	Family : Dicaeidae		
69.	Tickell's Flower pecker	*Dicaeum erythrorhyncos*	R
70.	Thick-billed Flower pecker	*Dicaeum agile*	R
	Family : Nectariniidae		
71.	Purple-rumped sunbird	*Nectarinia zeylonica*	R
72.	Purple sunbird	*Nectarinia asiatica*	R
	Family : Estrildidae		
73.	Black-headed Munia	*Lonchura malacca*	R

APPENDIX III

Analysis of abundance and seasonality

a) Population of Little Cormorant at Kallampara during 2004, 2005 and 2006

1-YEAR

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Year	2	876.361084	33	6374.127	0.137487	0.872042	

SEASON

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	98289.2188	33	470.3175	208.9848	**1.83E-19**	**Highly Significant**

Scheffe test

	Premonsoon	monsoon	Postmonsoon	
	194.5833	23.00000	58.87500	Mean
Premonsoon		**9.3173E-19**	**9.83E-16**	Bold value represent the significant difference
monsoon	**9.31729E-19**		**0.001277**	
Postmonsoon	**9.83168E-16**	**0.00127716**		

1-MONTH

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	11	18716.2637	24	259.1667	72.21709	**1.22E-15**	**Highly Significant**

Significant variation with reference to season and month.

b) Population of Little Cormorant at Kalpally-Palliyol Wetland during 2005 and 2006

1-YEAR

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Year	1	12.760417	22	106.7907	0.11949	0.732872	

SEASON

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	995.65625	21	17.65923	56.38165	**3.6E-09**	**Highly Significant**

Scheffe test

	Premonsoon	monsoon	Postmonsoon	
	31.50000	10.18750	15.12500	Mean
Premonsoon		**8.0642E-09**	**6.35E-07**	
monsoon	**8.06421E-09**		0.086183	
Postmonsoon	**6.35221E-07**	0.08618334		

1-MONTH

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	11	204.707382	12	9.197917	22.25584	**2.73E-06**	**Significant**

Significant variation with reference to season and month.

c) Population of Darter at Kalpally-Palliyol wetland during 2005 and 2006.

Summary of all Effects; design: (popul~1.sta)

1-YEAR

	df Effect	MS Effect	df Error	MS Error	F	p-level
Year	1	0.04166667	22	24.14962	0.001725	0.967242

SEASON

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	156.385422	21	10.40774	15.02588	**8.9E-05**	**Significant**

Scheffe test

Probabilities for Post Hoc Tests

	Premonsoon	monsoon	Postmonsoon
	10.31250	2.562500	10.12500
Premonsoon		**0.00041531**	0.993269
monsoon	**0.000415312**		**0.000542**
Postmonsoon	0.993269145	**0.00054196**	

Summary of all Effects; design: (popul~1.sta)

1-MONTH

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	11	44.348484	12	3.625	12.23407	**6.86E-05**	**Significant**

Significant variation with reference to season and month.

APPENDIX IV

Analysis of time budgets and activity pattern

(a) Feeding

Summary of all Effects; design: (data.sta)
1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	1047.586	66	90.94661	11.51869	**5.12E-05**	**Significant**
Bird	1	777.2866	66	90.94661	8.546625	**0.004738**	**Significant**

Feeding activity is significant with reference to season and birds.

Probabilities for Post Hoc Tests

	Premonsoon	monsoon	post mosnsoon
Premonsoon		**5.28E-05**	0.107807
monsoon	**5.28E-05**		**0.036037**
post mosnsoon	0.107807	**0.036037**	

Scheffe test; variable FEEDING (data.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: BIRD

	L.cormorant 31.16726	Darter 37.73861
L.cormorant		**0.004738**
Darter	**0.004738**	

(b) Spread-winged behaviour

Summary of all Effects; design: (data.sta)
1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	21.0923	66	5.994701	3.51849	**0.035321**	**Significant**
Bird	1	5.975396	66	5.994701	0.99678	0.321737	

Spread-winged behaviour is significant with reference to season only.

Probabilities for Post Hoc Tests
MAIN EFFECT: SEASON

	Pre 5.297913	mon 3.444403	post 4.615930
pre		**0.037971**	0.629859
mon	**0.037971**		0.260314
post	0.629859	0.260314	

(c) Spread-winged Preening

Summary of all Effects; design: (data.sta)
1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	0.196925	66	0.316201	0.622785	0.539571	
Bird	1	4.455709	66	0.316201	14.09136	**0.00037**	**Significant**

Spread-winged preening is significant with reference to birds only.

(d) Preening

Summary of all Effects; design: (data.sta)
1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Season	2	277.0836	66	15.00024	18.47194	**4.26E-07**	**Signicant**
Bird	1	194.9939	66	15.00024	12.99938	**0.000599**	**Significant**

Preening is significant with reference to season and birds.

Probabilities for Post Hoc Tests

	pre	mon	post
pre		**2.41E-06**	0.711805
mon	**2.41E-06**		**5.08E-05**
post	0.711805	**5.08E-05**	

Probabilities for Post Hoc Tests
MAIN EFFECT: BIRD

			{1}	{2}
			8.940751	5.649399
....	1	{1}		**0.000599**
....	2	{2}	**0.000599**	

(e) Gular Flutter

Summary of all Effects; design: (data.sta)
1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level
Season	2	37.3075	66	5.09526	7.322	**0.001343Significant**
Birs	1	4.155556	66	5.09526	0.815573	0.369762

Gular flutter is significant with reference to season only.

Scheffe test; variable GULAR_FL (data.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: SEASON

	pre	mon	post
	5.006688	2.548532	3.414925
Pre		**0.001591**	0.057479
mon	**0.001591**		0.417992
post	0.057479	0.417992	

(f) Fan-drying

1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level
Season	2	11.54457	66	0.616546	18.72459	**3.62E-07Significant**
Bird	1	1.530961	66	0.616546	2.483124	0.119855
12	2	0.956735	66	0.616546	1.551765	0.219504

Fan-drying is significant with reference to season only.

Probabilities for Post Hoc Tests

	pre	mon	post
Pre		**2.24E-06**	0.737002
mon	**2.24E-06**		**4.06E-05**
post	0.737002	**4.06E-05**	

(g) Perching

Summary of all Effects; design: (data.sta)
1-SEASON, 2-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level
Season	2	3525.09	66	165.3671	21.31676	**7.21E-08Significant**
Bird	1	0.029033	66	165.3671	0.000176	0.989468

Perching is significant with reference to season only.

Scheffe test; variable PERCHING (data.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: SEASON

	{1}	{2}	{3}
	30.64492	54.75227	40.51617
1 .... {1}		**8.3E-08**	**0.034784**
2 .... {2}	**8.3E-08**		**0.001309**
3 .... {3}	**0.034784**	**0.001309**	

APPENDIX V

A. Analysis of diving pattern

(a) Different birds

Dive duration

Summary of all Effects; design: (dat.sta)

1-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	1	1788.718	34	195.7378	9.138336	**0.004735Significant**

Scheffe test; variable DIVE_DUR (dat.sta)

Probabilities for Post Hoc Tests

MAIN EFFECT: BIRD **1->Darter** **2->L.cormorant**

	{1}	{2}
1 {1}		**0.004735**
2 {2}	**0.004735**	

Bout Duration

Summary of all Effects; design: (dat.sta)

1-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level
1	1	629.1196	34	114.2084	5.508523	**0.024887Significant**

Probabilities for Post Hoc Tests

	{1} 33.02833	{2} 24.16042
1 {1}		**0.024887**
2 {2}	**0.024887**	

Duration of dive cycle

Summary of all Effects; design: (dat.sta)

1-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level
Bird	1	2582.648	34	285.524	9.045292	**0.004928Significant**

Scheffe test; variable DIVE_CYC (dat.sta)

Probabilities for Post Hoc Tests

MAIN EFFECT: BIRD

	{1} 63.04333	{2} 45.07583
1 {1}		**0.004928**
2 {2}	**0.004928**	

Significant variation have been observed in dive duration, bout duration and duration of dive cycle between Little Cormorant and Darter.

(b) Little Cormorant : Different places

Dive duration

The variable Place for Little cormorant

Summary of all Effects; design: (dat.sta)

1-PLACE

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Place	1	1788.718	34	195.7378	9.138336	**0.004735**	**Significant**

Bout duration

Summary of all Effects; design: (dat.sta)

1-PLACE

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Place	1	629.1196	34	114.2084	5.508523	**0.024887**	**Significant**

Duration of dive cycle

Summary of all Effects; design: (dat.sta)

1-PLACE

	df Effect	MS Effect	df Error	MS Error	F	p-level	
place	1	2582.648	34	285.524	9.045292	**0.004928**	**Significant**

Significant variation have been observed in dive duration, bout duration and duration of dive cycle for Little Cormorant at Kallampara and Kalpally-Palliyol wetlands.

(c) Kalpally-Palliyol wetland (Different birds)

Dive duration

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Bird	1	5366.153	22	37.61124	142.6742	**4.34E-11**	**Significant**

Bout Duration

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Bird	1	1887.359	22	52.05023	36.26033	**4.63E-06**	**Significant**

Duration of dive cycle

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Bird	1	7747.945	22	57.87115	133.8827	**7.98E-11**	**Significant**

Significant variation have been observed in dive duration, bout duration and duration of dive cycle between Little Cormorant and Darter at Kalpally-Palliyol wetland.

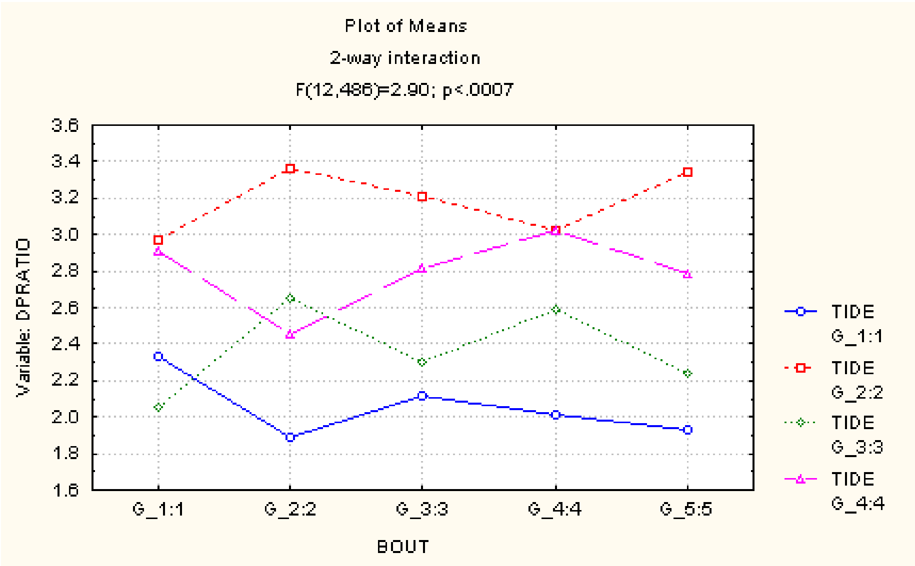
B. Analysis of diving parameters at different depths

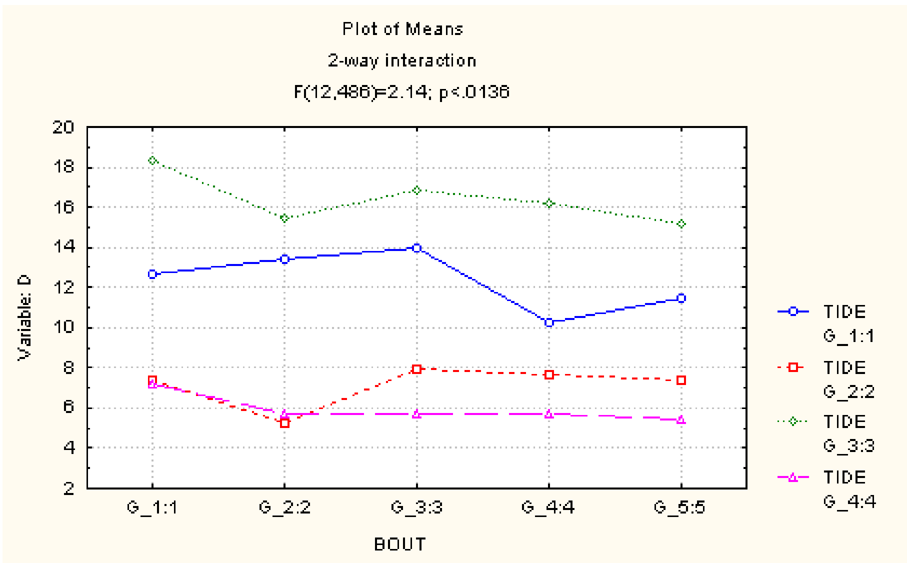
Two way ANOVA

	df Effect	MS Effect	df Error	MS Error	F	p-level	
Tide	3	32.57422638	486	0.481823623	67.60612488		**0Significant**
Bout	4	0.142899692	486	0.481823623	0.296580911	0.88018298	
Interaction	12	1.398782015	486	0.481823623	2.903099537	**0.00067735**	**Significant**

Significant differences in diving parameters at different tidal cycles.

Two way Interaction





Tide: 1. Receding; 2. Low; 3. High; 4. Advancing
D = Dive duration; D/P ratio – Dive/Pause ratio.

APPENDIX VI

A. Little Cormorant : Number and Dimensions of nest materials

Number of nests examined	Total number of nest materials	Long twigs (cm) mean	Small twigs (cm) mean	Number of leaves
1	178	38.65	16.90	47
2	78	35.05	13.37	14
3	156	35.66	17.76	42
4	163	36.21	10.19	38
5	121	31.65	11.63	14
6	120	28.78	11.31	18
7	100	38.34	16.72	22
8	107	30.76	9.98	24
9	142	31.94	17.75	36
10	192	25.43	9.25	28
Mean	135.7 $\pm$ 36.58	33.25 $\pm$ 4.28	13.49 $\pm$ 3.46	28.3 $\pm$ 11.85

B. Little Cormorant : Nest dimensions

Nest Examined	Outer diameter (cm)	Inner diameter (cm)	Depth (cm)
1	38	19.50	9.5
2	42	20.00	8.5
3	30.5	14.50	7.5
4	33.5	15.5	8.00
5	32.0	15.00	6.50
6	44	22.0	10.5
7	36	18.00	8.00
8	34	14.00	8.5
9	38	19.00	10.5
Mean	36.44 $\pm$ 4.51	17.5 $\pm$ 2.84	8.61 $\pm$ 1.34

APPENDIX VII

Analysis of Thermoregulatory behaviour
(Spread-winged behaviour, Fan-drying, Gular flutter)

a) Association with weather

Little Cormorant

Summary of all Effects; design: (data.sta)

Summary of all Effects; design: (data.sta)
1-WEATHER, 2-BEHAVIOUR

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	69.69709	141	9.845	7.07944	**0.000182**	**Significant**
2	2	6.966055	141	9.845	0.707573	0.49458	
12	6	116.6098	141	9.845	11.84457	**9.81E-11**	**Significant**

Significant difference between behaviours with respect to weather.

Darter

Summary of all Effects; design: (data.sta)
1-WEATHER, 2-BEHAVIOUR

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	20.04185	89	2.005832	9.991791	**9.65E-06**	**Significant**
2	2	23.39351	89	2.005832	11.66275	**3.17E-05**	**Significant**
12	6	36.28928	89	2.005832	18.09188	**1.29E-13**	**Significant**

Significant difference between behaviours with respect to weather.

Little Cormorant Vs Darter

Summary of all Effects; design: (data.sta)
1-BIRD, 2-WEATHER, 3-BEHAVIOUR

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	1	304.4116	230	6.811583	44.69029	**1.73E-10**	**Significant**
2	3	63.81255	230	6.811583	9.36824	**7.24E-06**	**Significant**
3	2	16.84	230	6.811583	2.472259	0.086634	
12	3	19.84295	230	6.811583	2.913119	**0.035174**	**Significant**
13	2	18.391	230	6.811583	2.69996	0.069339	
23	6	127.8192	230	6.811583	18.76498	**9.55E-18**	**Significant**
123	6	13.52397	230	6.811583	1.985437	0.068646	

At different weather conditions behaviours vary with respect to birds.

b) Behaviour at different weathers

Little Cormorant
Spread wing
Summary of all Effects; design: (ld.sta)
1-WEATHER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	83.72979	40	7.674811	10.90969	**2.27E-05**	**Significant**

Scheffe test; variable VALUE (ld.sta)
Probabilities for Post Hoc Tests Bold values represent significant difference.
MAIN EFFECT: WEATHER

		{1} 8.900000	{2} 4.888889	{3} 4.714286	{4} 3.125000
D	{1}		**0.009742**	**0.014799**	**0.000211**
C	{2}	**0.009742**		0.999473	0.636523
U	{3}	**0.014799**	0.999473		0.74699
R	{4}	**0.000211**	0.636523	0.74699	

D – Direct sunlight; C – Cloudy weather; U – Under shade; R – Rainy weather.

Fan drying
Summary of all Effects; design: (ld.sta)
1-WEATHER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	91.7531	53	7.980874	11.49662	**6.47E-06**	**Significant**

Scheffe test; variable VALUE (ld.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: WEATHER

		{1} 2.444444	{2} 7.133333	{3} 9.461538	{4} 5.900000
D	{1}		**0.003315**	**1.07E-05**	**0.034541**
C	{2}	**0.003315**		0.20588	0.653956
U	{3}	**1.07E-05**	0.20588		**0.010001**
R	{4}	**0.034541**	0.653956	**0.010001**	

Gular flutter
Summary of all Effects; design: (ld.sta)
1-WEATHER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	168.5715	47	13.47792	12.50723	**3.89E-06**	**Significant**

Scheffe test; variable VALUE (ld.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: WEATHER

		{1}	{2}	{3}	{4}
		10.71429	6.636364	4.416667	2.571429
D	{1}		**0.041285**	**0.000338**	**0.000116**
C	{2}	**0.041285**		0.557168	0.170053
U	{3}	**0.000338**	0.557168		0.773349
R	{4}	**0.000116**	0.170053	0.773349	

Darter
Spreadwing
Summary of all Effects; design: (ld.sta)
1-WEATHER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	47.81295	29	1.774836	26.93937	**1.58E-08**	**Significant**

Scheffe test; variable VALUE (ld.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: WEATHER

		{1}	{2}	{3}	{4}
		6.833333	2.875000	1.714286	3.500000
D	{1}		**7.39E-06**	**1.4E-07**	**0.000374**
C	{2}	**7.39E-06**		0.431886	0.859584
U	{3}	**1.4E-07**	0.431886		0.146013
R	{4}	**0.000374**	0.859584	0.146013	

Fan drying
Summary of all Effects; design: (ld.sta)
1-WEATHER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	19.75535	37	2.624978	7.525912	**0.000472**	**Significant**

Scheffe test; variable VALUE (ld.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: WEATHER

		{1}	{2}	{3}	{4}
		2.470588	5.222222	4.666667	4.666667
D	{1}		**0.002707**	0.058578	**0.0222**
C	{2}	**0.002707**		0.934715	0.911725
U	{3}	0.058578	0.934715		1
R	{4}	**0.0222**	0.911725	1	

Gular flutter

Summary of all Effects; design: (ld.sta)
1-WEATHER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	16.86464	23	1.30107	12.96213	**3.65E-05**	**Significant**

Scheffe test; variable VALUE (ld.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: WEATHER

		{1}	{2}	{3}	{4}
		4.857143	2.111111	1.250000	1.714286
D	{1}		**0.001046**	**0.000562**	**0.000437**
C	{2}	**0.001046**		0.668751	0.922883
U	{3}	**0.000562**	0.668751		0.934648
R	{4}	**0.000437**	0.922883	0.934648	

Spread-winged behaviour is significant under direct sunlight.
Fan-drying is highly significant under shade.
Gular fluttering is highly significant under direct sunlight.

c) Wing Flapping – Association with weather

Little Cormorant VS Darter

Summary of all Effects; design: (flap.sta)
1-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	1	137.992996	95	3.491338	39.52439	**9.81E-09**	**Highly Significant**

Scheffe test; variable VALUE (flap.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: FLAPPING

			{1}	{2}	{3}	{4}	{5}
			4.118055	3.168831	5.433333	2.646465	5.884615
....	1	{1}		0.25003251	**0.035483**	**0.011203**	**0.000706**
....	2	{2}	0.250032514		**1.08E-05**	0.771799	**2.5E-08**
....	3	{3}	**0.035482597**	**1.0761E-05**		**1.94E-08**	0.829956
....	4	{4}	**0.011203003**	0.77179945	**1.94E-08**		**1.67E-11**
....	5	{5}	**0.000706386**	**2.4961E-08**	0.829956	**1.67E-11**	

1 – Under shade; 2 – Under wind; 3 – Cloudy weather; 4 – Sunlight; 5 – Rain.

d) Gular flutter at different atmospheric temperature

L.Cormorant Vs Darter

Summary of all Effects; design: (gflutter.sta)
1-BIRD

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	1	104802.766	117	5455.719	19.20971	**2.57E-05**	**Significant**

Summary of all Effects; design: (gflutter.sta)
1-GFLUTTER

	df Effect	MS Effect	df Error	MS Error	F	p-level	
1	3	198970.125	115	1271.404	156.4964	**0**	**Significant**

Scheffe test; variable VALUE (gflutter.sta)
Probabilities for Post Hoc Tests
MAIN EFFECT: GFLUTTER

		{1}	{2}	{3}	{4}
		74.20000	89.76000	148.6667	249.3235
1	{1}		0.46118417	**2.98E-11**	**0**
2	{2}	0.461184174		**4.35E-07**	**0**
3	{3}	**2.98216E-11**	**4.3527E-07**		**1.65E-18**
4	{4}	**0**	**0**	**1.65E-18**	

1 = 20-25ºC; 2 = 25-30ºC; 3 = 30-35ºC; 4 = 35-40ºC.

Gular flutter is highly significant with increase in temperature.