ECOLOGY AND CONSERVATION OF THE SPOT-BILLED PELICAN *PELECANUS PHILIPPENSIS* IN ANDHRA PRADESH, INDIA

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N. SHEEBA
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DIVISION OF CONSERVATION ECOLOGY
SÁLIM ALI CENTRE FOR ORNITHOLOGY AND NATURAL HISTORY (SACON)
ANAIKATTY, COIMBATORE 641 108

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CERTIFICATE

This is to certify that the thesis, entitled "**Ecology and Conservation of the Spot-Billed Pelican *Pelecanus philippensis* in Andhra Pradesh, India**", submitted to the Bharathiar University in partial fulfillment of the requirement for the award of the degree of Doctor of Philosophy in Zoology is a record of original research work done by **Ms. N. Sheeba** during September 2006 - December 2011 of her research in the Division of Conservation Ecology, Sálim Ali Centre for Ornithology and Natural History (SACON) under my supervision and guidance and the thesis has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title of any candidate of any University.

Signature of the Research Guide
DR. LALITHA VIJAYAN

Counter signed

30/12/11

Head of the Department

Dr S Bhupathy
Principal Scientist & Head
Department of Zoology
Salim Ali Centre for Ornithology and Natural History
Anaikatty (Post), Coimbatore 641 108

Director

DECLARATION

I, Ms. N. Sheeba, hereby declare that the thesis, entitled "**Ecology and Conservation of the Spot-billed Pelican *Pelecanus philippensis* in Andhra Pradesh, India**", submitted to the Bharathiar University, in partial fulfillment of the requirement for the award of the degree of Doctor of Philosophy in Zoology is a record of original and independent research work done by me during September 2006 - December 2011 under the Supervision and Guidance of Dr. Lalitha Vijayan, Senior Principal Scientist (Retd.), Division of Conservation Ecology, Sálim Ali Centre for Ornithology and Natural History (SACON) and it has not formed the basis for the award of any Degree / Diploma / Associateship / Fellowship or other similar title of any candidate of any University.

Signature of the candidate

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Assistance given by those who ne'er received our aid,
Is debt by gift of heaven and earth but poorly paid.

(The gift of) heaven and earth is not an equivalent for a benefit which is conferred where none had been received

-Thirukkural

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N. Sheeba

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INTRODUCTION

Wetland habitats are among the most productive ecosystems and harbour a unique variety of plants and animals (Owen & Black 1990). The term 'wetland' groups together a wide range of habitats that share a number of common features, the most important of which is continuous, seasonal or periodic standing water or saturated soils (Finlayson & Van der Valk 1995). Wetlands are the "area of marsh, swamp, pebbles or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salty, including areas of marine water, the depth of which does not exceed six meters" as defined in the text of the Convention on Wetlands of International Importance especially as Waterbird habitats known as the Ramsar Convention. Wetlands are important conservation sites due to the extensive food chain and rich biodiversity they support (Getzner 2002). In most ecosystems, wetlands receive an important conservation priority because of the large number of species associated with them and their loss to a great extent due to human activities (Dahl 1990; Catallo 1993). Wetlands are the important bird habitats and birds use them as migratory resorts, for breeding, feeding and roosting (Weller 1999).

Birds are one of the best indicators of the status of a wetland. Many waterbirds are obligately tied to wetlands for most or all of their life cycle (Susan *et al.* 1998). Changes in wading bird number, location and nesting efforts were studied to assess the health of wetland ecosystems (Crozier & Gawlik 2003). Ecology, survival rate, contamination and spatial aspects of colonial waterbirds biology continue to serve as sensitive bioindicators of environmental changes, as they respond rapidly to changing conditions (Kushlan 1993; Weller 1999; Bryan *et al.* 2003).

Colonial wading bird studies can continue to contribute to understand biology and conservation if they seek to address answerable questions of basic importance through appropriate methods and statistically valid analyses (Kushlan 1992). Effects of conspecific and heterospecific attraction on landscape-level population structure, abundance, phenology of use at different sites, population trends and impact of management activities will indicate the productivity of wetlands (Haig *et al.* 1998). Fluctuating population of the Great White Pelican was studied in response to changing water-level because of their reliance primarily on aquatic food (Bowker & Downs 2008 a) and effect of drawdown on waterbird communities and changes in grasslands (Taft *et al.* 2002). Effect of offal and discarded waste from commercial fishery brought changes in the diet switching and predation of sea-bird community (Stephen *et al.* 2004). Conservation objectives in areas of national significance include the preservation of rare species and unique environments, the maintenance of diversity and the protection of representative ecosystems (Pyrovetsi & Crivelli 1988). There are about 242 wetland bird species among the 1300 species of birds recorded in the Indian subcontinent (Grimmett *et al.* 1999; Manakadan & Pittie 2002). Of these 125 are migrants, among which 102 species are winter migrants, 10 are summer migrants and 3 are passage migrants. Approximately 12% of Asian birds are globally threatened (Arun Kumar *et al.* 2003). Wetland birds comprise about 10% of the globally threatened species and 20% of Asian threatened species. About 34 of the wetland birds are globally threatened species, 34 are critically endangered and one conservation dependent (Manakadan & Pittie 2001). Unfortunately, many ornithologically important wetlands all over the world are threatened and waterbirds are under pressure from increasing human population, socioeconomic activities and man-induced adverse natural phenomena (Jagtap 1985; Parnell *et al.* 1988; Hussain 1991;

Balachandran 1990; Arun Kumar *et al.* 2003). Such being the case, it is important to see that the wetland habitats of various waterbirds are properly conserved through scientific management. Sound management of such habitats is only possible by using available information on existing habitat components.

1.1 WATERBIRDS STUDIES UNDERTAKEN IN INDIA

By examining the environmental correlates of the distribution of species assemblages, this protocol can assess the indicator properties of target species groups. Pattern of habitat use by the Sarus Crane *Grus antigone* on canal linked reservoir along with presence of crop pattern, temperature and water availability which are the governing factors, were studied with reference to conserve the habitat (Mukherjee *et al.* 1999); their status and ecological requirement were studied in Rajasthan (Ramachandran & Vijayan 1994; Vyas 2001).

In Mandapam, coastal wetlands in Gulf of Mannar where distribution, population dynamics, site fidelity, flock fidelity, different habitat use of waterbirds and the comparative density and diversity in different habitats were studied by Balachandran (1990). A comparative study at Great Vedarayam Swamp between natural and salt works sites showed marked negative influence on ducks which feed on macrophytes; status, abundance, species composition and seasonality and spatio-temporal variations in the abundance and species richness of plovers and sandpipers (Manakadan 1992). A few species, especially fish-eating birds, namely the Spot-billed Pelican *Pelecanus philippensis*, Brahminy Kite *Haliastur indus*, gulls and terns are benefited from salt works. While the Lesser Flamingo *Phoenicopterus minor* experienced loss of their habitat by the establishment of salt works, the Greater Flamingo *Phoenicopterus roseus* found reservoirs and condensers of salt works an

important source of food during the monsoon and post-monsoon periods (Manakadan 1995).

Several species specific studies reveal ecosystem functions of wetlands and species indicators aided prioritizing wetlands for conservation. Behavioural and ecological studies were conducted on Black-necked Stork *Ephippiorhynchus asiaticus*, prey availability on foraging success, prey profitability and change in foraging pattern due to rain, and breeding success (Maheswaran 1998) and similarly on the Greater Adjutant Stork *Leptoptilos dubius* (Singha 1998). Comparative ecological and behavioural studies of storks (Ishtiaq 1998), resident ducks population and resource utilization of waterfowl (Bhupathy 1991) and ecological study on fish-eating birds (Sivasubramanian 1992) were done in Keoladeo National Park, Bharatpur, Rajasthan. Ecological requirement of waterfowl in urban ecosystem was studied by Mukherjee *et al.* (2002). Habitat preference study on Pheasant-tailed *Hydropahasianus chirurgus* and Bronze-winged Jacanas *Metopidius indicus* revealed that habitat alteration causes fluctuation in population and breeding density and hence considered as indicators of the habitat quality (Ramachandran 1993). Adaptive significance of the Sarus Crane in agricultural marsh land and nest-site selection revealed that change in agricultural practice and water regime may cause threat to species (Mukherjee *et al.* 2000). The study conducted on Andaman Crake *Rallina canningi* revealed clear preference to water vicinity and huge trees with buttresses for nesting (Ezhilarasi 2009; Ezhilarasi & Vijayan 2010). Similarly, site specific studies on habitat evaluation at Chilika Lake, Orissa (Balachandran *et al.* 2005), Pichavaram wetlands (Nagarajan & Thiyagesan 1996), negative effect of salinity hike in coastal mangrove and depended birds were addressed by Sandilyan *et al.* (2010) and study of waterbirds in Pong Dam Sanctuary (MuthamizhSelvan 2010). Decline of breeding bird population was observed in Kumarakom heronry due to changing

Phragmites regime (Narayanan 2004; Narayanan & Vijayan 2007) and ecological studies in Keoladeo National Park, Rajasthan (Vijayan *et al.* 1991) were conducted showing avian population dynamics. Precise ecological study with habitat use and impact of disturbance was carried out for Flamingos in Sewri Bay, Mumbai (Vijayan *et al.* 2008).

1.2 PELICAN STUDIES

Brown Pelican *P. occidentalis* is the well studied species among pelicans. Nesting bird explorations were carried out in early 1900' s in the Pacific coast specifically in southern California sea coast and in Coronado Islands (Finley 1907) and later, habitat use and seasonal changes in population size and centers of concentration, and influence of environmental factors were well studied by Briggs *et al.* (1981). Brown Pelican reproductive output is more precisely related to local aspects of prey availability and abundance (Anderson *et al.* 1982). Method employed and use of the bill and pouch by the Brown Pelican to capture prey by under water diving were described by Schreiber *et al.* (1975). Age-related differences in patch use and foraging skill of adults and sub-adults were studied (Brandt 1984). Similarly, foraging effect of adult and sub-adult with environmental factors such as influence of sun position and glare on dive success were studied at Port Canaveral, Florida (Carl 1987). Infestation of Argasid ticks which is coupled with Brown Pelican nest abandonment in coast of South Carolina was documented (King *et al.* 1977; Reeves *et al.* 2006). Eggert and Jodice (2008) found that behavioral or physiological adaptations developed by the adults or nestlings may inhibit the expected negative effect of ectoparasites on nestling growth at sub-lethal levels of infestation. Detailed study of growth and development of culmen, wing, and tarsus lengths and weight are described along with plumage characteristics at various stages of nestling; the implications to survival of different growth rates of various

parts of the body of the captive chicks are also discussed (Schreiber 1979). Effect of accidental oil spillage in North Carolina supported the earlier experimental studies that indicate oil applied to eggs of waterbirds during incubation result in decreased hatching success (Parnell *et al.* 1984). Negative effect of rehabilitated oiled Brown Pelican was elaborated by Anderson *et al.* (1996). The urban adaptation, scavenging behavior of Peruvian Pelican *Pelecanus thagus* in famine year was documented at Lima, a port city in Peru (Leck 1973).

Banding study conducted at California states that there is no evidence of any migratory movement on the part of young Brown Pelican and return is recorded from Anacapa Island which is about 165 miles up the coast (Bond 1942). From the Atlantic Coast and Florida Gulf Coast marking studies revealed the movement of first year youngs primarily towards south in the fall but remain along the East Coast and away from the natal colony during the first months out of the nest (Strait & Sloan 1975). Patterns of dispersal movement of young Brown Pelican were studied in two colonies namely Carolina and Florida for around 60 years which revealed that Florida birds move shorter distance (Schreiber & Mock 1988). By using advance radio-tagging method continuous data on movement and activities showed clear diurnal pattern and efficiency in foraging were assessed by low value of percent time in activity (Croll *et al.* 1986). Least occasional nocturnal activity was also recorded by Robert and McNeil (1989). Efforts were made to understand the limiting factors in localized condition such as food supplies with nesting chronology and effect of pesticides on population decline in Brown Pelican (Jehl 1973; Kushlan & Frohring 1985). Intra-clutch variation in egg volume and hatching asynchrony in the establishment of mass hierarchies in broods of the Brown Pelican were studied by Shields (2000).

Status assessment and population dynamics of the White Pelican *P. onocrotalus* with specific emphasis on 20 of 22 years from 1966 through

1987 in the Molly Island and determining factors such as temperature and flooding were studied (Diem & Pugesek 1994). Population of the White Pelican over 80 years and reproductive success were assessed with environmental factors in south Texas and northern Tamaulipas (Chapman 1988). Nesting strategy of White Pelican at Weld country, Colorado compared changes that had occurred in the size of the nesting island and the extent of its vegetation (Miller 1982). Spatial and temporal distribution of White Pelicans nesting efforts at Gunnison Island and variations in reproductive success were assessed in spatially and temporally separated colonies (Knopf 1979). Breeding behavior was illustrated by Schaller (1964). In American White Pelican *P. erythrorhynchos*, asynchrony in hatching and brood reduction by siblicide were enhanced by adult who helped in raising the potential survivor offspring (Cash & Evans 1986; Evans 1996; Ploger 1997).

Year-to-year and within-breeding season variation existed with use of different foraging habitats in American White Pelican (Findholt & Anderson 1995 a). Similarly, patterns of the foraging trips of White Pelicans, their seasonal variation in daily foraging time, group size and flight direction were studied. Foraging areas were assessed as they changed with different breeding period. Early breeding makes minimum round trip to obtain food, as the season progressed pelican flew maximum daily roundtrips about 354 km from Lake Mikri Prespa to Lake Kerkini and Axios delta. After chicks fledged, pelicans remained overnight on the feeding ground (Pyrovetsi 1989). Prey use patterns of American White Pelican and diet composition were studied at Pathfinder reservoir and variation within breeding season and year to year difference were studied (Findholt & Anderson 1995 b). Group foraging and patterns of movements by individuals within groups was clearly consistent with the notion that the American White Pelican were dividing or beating for prey scattering (Anderson 1991). Kaeding (2002) examined the biotic and

abiotic factors in which spawning of Yellowstone Cutthroat Trout influenced spatial and temporal exploitation in the foraging sites.

Twenty-one American White Pelicans were equipped with radio transmitters to study the winter distribution and habitat use in south Louisiana and the delta region of Mississippi. Numbers peaked in February and March corresponding with spring migration and percentage time spent in foraging for the following habitats were observed, namely borrow ditch, catfish ponds, crawfish ponds, lake and river, and found that less time was spent in rich foraging sites (King & Werner 2001). American White Pelican interactions with south-eastern aquaculture were summed up and management strategies were given (King 2005). Spatial and seasonal pattern in different foraging sites is strongly determined by the prey availability and spawning activity of fishes, marked cooperative fishing, association with cormorants in shallow and deep water. Feeding requirement was assessed by the prey length and food availability in the Great White Pelican (Hatzilacou 1996). Peruvian Pelican preferred shallow water to forage and adapted mostly surface seizing method followed by plunging and piracy (Duffy 1983).

Kleptoparasitism, socially parasitic foraging behavior was illustrated in American White Pelican with co-existing specific species in Grand Rapids, Manitoba. This inter and intra-specific interactions include grasping food from Osprey, Double-crested Cormorants and utilized plunge diving of Herring Gulls and Terns (Brian *et al.* 1983). Kleptoparasitic attempts by gulls towards immature was more as the adults used a variety of passive and aggressive behaviors to thwart gulls (Tersh, Breese & Meyer 1990).

Before breeding White Pelican undergoes the pre-supplemental molt which is restricted to the head and neck regions and bill horn. It involves replacement of the white nuptial crest by short, dark gray black plumes. The timing and functional aspect of molt were discussed by Knopf (1975). Aerial activities of American White Pelican during breeding season attract

other pelicans to a currently active colony site and may thereby facilitate the synchronous breeding aggregation (Evans & Cash 1985). In American White Pelican, Evans (1989; 1990) suggested that pelican eggs become exposed to increased temperature variation from pipping onwards, and that calling in response to cooling provides a mechanism whereby pipped eggs can potentially influence their own incubation temperature by communicating with the parent and hence do not neglect the terminal eggs. Breeding periodicity of Great White Pelican at Rondevlei Bird Sanctuary, their temporal variation in sanctuary visitation, breeding and foraging activities were correlated with environmental factors (Guillet & Crowe 1983). Occurrence and breeding performance of the Great White Pelican and Pink-backed Pelican *P. rufescens* over 1933-2005 were assessed in south-eastern Africa (Bowker & Downs 2008 b; Bowker *et al.* 2010). Reduction of suitable nesting site over pelican range is a major concern and to treat this, in Greece, alternative nesting habitat were provided; installation of rafts and island were created with herbaceous plants for Dalmatian Pelican *P. crispus* (Pyrovetsi 1997). The status of Great White and Pink-backed Pelicans in north-eastern KwaZulu with reference to foraging sites was assessed (Bowker & Downs 2008 c). Breeding performance and nest site characters were assessed in Mediterranean Lagoons where openness of nesting area, wind action and sudden rises in water level determined the colony size which is notably very small compared to the inland wetlands (Peja *et al.* 1996). Breeding biology of the Dalmatian Pelican in relation to trophic condition was studied in Divjaka-Karavasta National Park (Kallfa & Bino 2010). Accounts on breeding behaviour and ecology of Australian Pelican *P. conspicillatus* were illustrated by Vestjens (1977).

The upset of avian calcium metabolism which results in eggshell thinning has been attributed to certain organochlorine compounds, particularly DDE, which is a metabolite of DDT. The significance of

eggshell thinning as an indicator of pollution trends has been worked out in a few pelican species. In Brown Pelican, level of organochlorine in Carolina and Florida colonies and eggshell thinning were documented as reason for declining population (Blus 1970; King *et al.* 1985). Levels of organochlorine compounds and trace elements were evaluated which is thought to be a major threat to the population decline of American White Pelican (Knopf & Street 1974; Donaldson & Braune 1999). Similarly, in Greece the decreasing trend of chlorinated hydrocarbon in egg of Dalmatian and Great White Pelicans over ten years were documented by Crivelli *et al.* (1999). Blood clotting abnormalities were studied in Pink-backed Pelicans which was associated with the consumption of excessive amounts of vitamin E (Nichols *et al.* 1989). In addition, impact of Lead by ingestion and entangled fishing tackle were investigated in Brown Pelican (Franson *et al.* 2003).

A natural dynamism-oriented nature restoration plans such as the effect of the dam construction, vegetation with the progress of the development of irrigation agriculture, degradation of *Phragmites* communities could be the cause of the loss of breeding sites, and the loss of fish production could have lead to the degradation of feeding habitat oriented nature restoration strategy proposed as a counter measure for the Aral Sea crisis (Morimoto *et al.* 2005). Degradation of wetlands was identified as the major threat to population of the Spot-billed Pelican and, conservation through community participation was carried out in Uva province, Sri Lanka (Weerakoon & Athukorala 2008). With the help of band recoveries of the Dalmatian Pelican *Pelecanus crispus,* mortality caused by electric power lines was studied at Porto - Lago. The incident was high during the dispersal and in wintering periods. Mortality rate was high when poor weather and highest proportion of immature were recorded (Crivelli *et al.* 1988). Impact of "alien predation" in Brown Pelican nesting colony was assessed (Anderson *et al.* 1989).

1.3 PELICAN STUDIES IN INDIA

In early 90's exploration of nesting colonies was carried out at Kundakulam in Kanyakumari, extreme southern district in Tamil Nadu by Rhenius (1907). Contemporaneously another breeding site was reported with nesting Spot-billed Pelican *P. philippensis* and Painted Stork *Mycteria leucocephala* from Cuddapah District of Madras Presidency (Campbell 1902). Similarly, nesting pelicans were documented with Painted Stork at Vedanthangal waterbird sanctuary (Paulraj & Gunasekaran 1988) where an occurrence was noticed three decades before by Raj (1956). Later breeding of this pelican was documented in Kolleru (Gee1960; Guttikar 1978). Neelakantan (1949) identified important wetlands as a habitat for the Spot-billed Pelican. Feeding and breeding ecology of the Spot-billed Pelican was studied in Nelapattu Bird Sanctuary (Nagulu 1983) with status (Nagulu & Ramana Rao 1983). Brief note on breeding Spot-billed Pelican in Assam was given by Das (1991). In India only few studies conducted on this species are mainly on their status (Subramanya 1996; Talukdar 1999; Parasharya 2002; Manakadan & Kannan 2003). Effect of rainfall on breeding performance was studied in Nelapattu (Sharma & Raghavaiah 2002). Experiments were done on artificial breeding at Zoological Parks at Chennai and rearing stray chicks till fledging in breeding sites at Kokkere Bellur (Paulraj *et al.* 1990; Subramanya & Manu 1996). However, no detailed studies were done on the ecology of the Spot-billed Pelican after Nagulu (1983).

Therefore the present study has been carried out with the following objectives:

- Assess the current status and population of the Spot-billed Pelican in Andhra Pradesh
- Evaluate habitat requirements and factors determining habitat selection.

- Understand its foraging and breeding ecology
- Examine potential threats to the population of this species and suggest conservation measures

The thesis is organized in seven chapters as follow:

1) General introduction to the study and literature review are given.
2) Account of intensive study area and study species is presented.
3) The current status of the Spot-billed Pelican is assessed with the colony site dynamics in Andhra Pradesh.
4) Nesting habitat characteristics and breeding performance of the Spot-billed Pelican in Uppalapadu bird habitat are analysed.
5) The foraging ecology is documented.
6) Activity budget of the Spot-billed pelican in the Uppalapadu bird habitat during the breeding season is recorded.
7) Summary and conclusions with conservation needs are presented and site specific actions are suggested.

Appendices and references are listed at the end.

STUDY AREA AND SPECIES

2.1 INTRODUCTION

In the Deccan Plateau, a large number of man-made inland irrigation tanks play an important role in providing feeding and nesting habitats for colonial nesting birds (Subramanya 1996). In south India, particularly Andhra Pradesh, Karnataka and Tamil Nadu the substantial area under tank irrigation is accounting nearly 60% of the total area (Vaidyanathan & Sivasubramaniyan 2001). In Andhra Pradesh, village tanks constitute 3,666,06 km^2 (about 61%) of the total inland wetland cover. The spatial distribution of wetlands for the entire state shows that the low rainfall districts have a large number of wetlands, while the relatively wet districts have fewer numbers of them. Such a clustered distribution of wetlands in the drier localities will have a substantial bearing in the status, distribution and abundance pattern of birds and other fauna and flora. Uppalapadu is one of the Important Bird Areas (IBAs) in India (Islam & Rahmani 2004) and this area falls under waterlogged area of less than (<) 56.25 ha eligible to be declared as a Ramsar site (Vijayan *et al.* 2004).

2.2 INTENSIVE STUDY AREA: UPPALAPADU WATER TANK

LOCATION: The study was conducted at Uppalapadu bird habitat (16^0 16' 26" N, 80 ^{0} 21' 58" E), located about 7 km East of Guntur, Andhra Pradesh, India. Uppalapadu is known for the Spot-billed Pelican since 1999. The field study was carried out between February 2007 and April 2010. Concurrently, surveys were carried out in five more sites in Andhra Pradesh. A detailed account of the main study area is descried in this chapter, while details of other Pelicanries are given in chapter III.

HISTORY: Uppalapadu stands for 'the place with salt water'. The village has 30 acres of big water reserve of which 53% were converted into agricultural land (Fig.2.1).

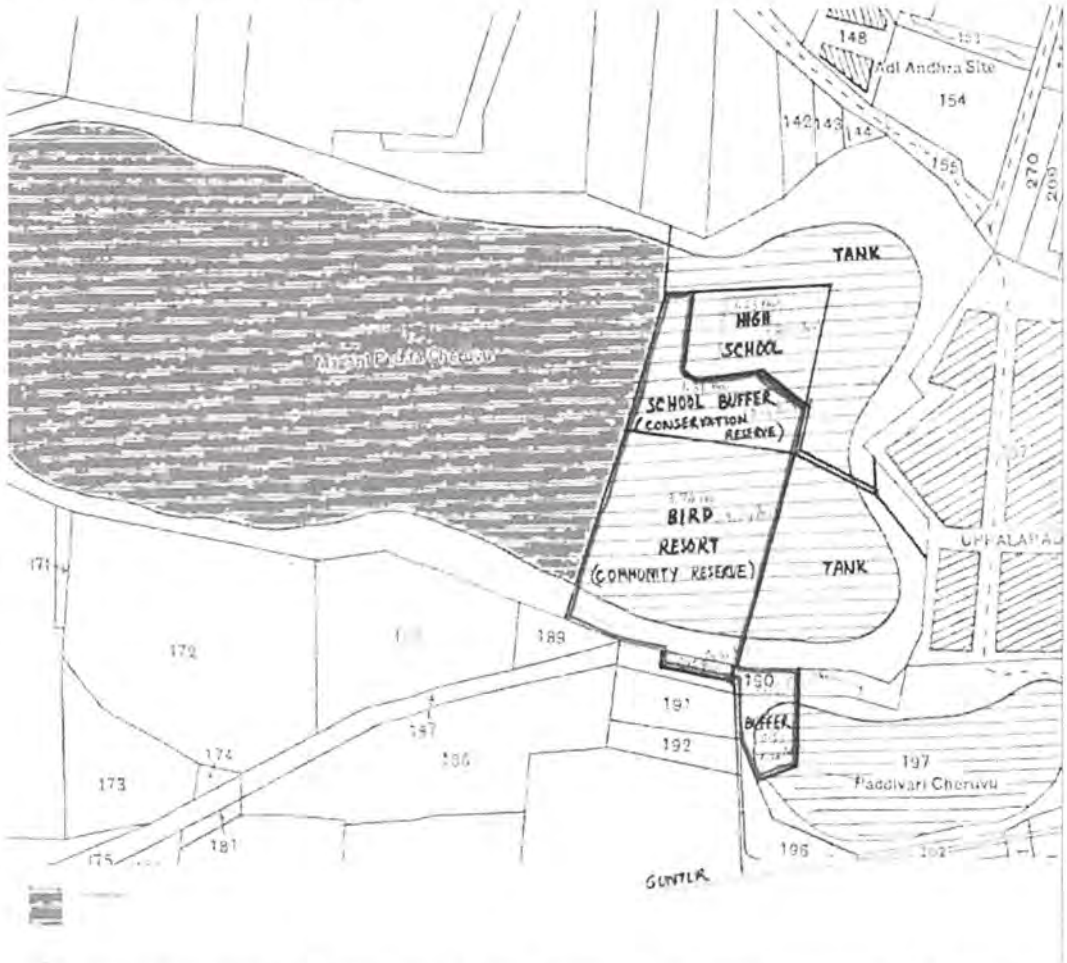


Fig.2.1. Traditional Pond area with grey colour is currently converted gricultural land.

Currently, the 14 ha reserve is used to fulfill the villagers' water demand. In this 2.54 ha was reclaimed for high school buildings which comprise the Jilla Parishad school (Local Government School) building, play ground and stagnant puddle which is bordered by a few *Prosopis juliflora, Acacia*

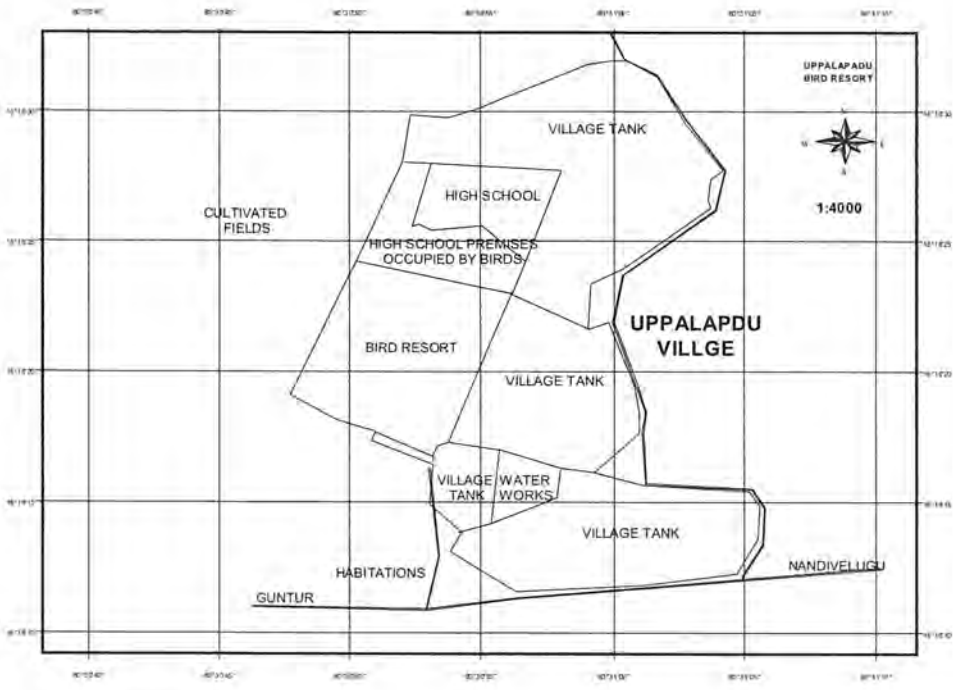


Fig. 2.2. Current boundary of warter tank at Uppalapadu Village.

Remaining 11.46 ha of tank is used to store water for domestic purposes. Changes of land use pattern and poor maintenance lead to rapid growth of *Prosopis* in the pond. It provided roosting and nesting sites for many migratory and resident birds, namely Cattle Egret, Little Cormorant, Asian Openbill, Black-crowned Night Heron, Jacanas, Purple Moorhen and Spot-billed Duck. From 1992, Painted Storks, Black-headed Ibis and Glossy Ibis have also been visiting this tank. Nomadic Glossy Ibis use this pond only during rainy season for roosting (Rao 2002). Due to high avian density and water pollution by their excreta, foul smell became a problematic issue and polluted water became considered as causes of skin diseases. To overcome this conflict, the span of 3.74 ha was parted by bund and allotted for birds from 11.46 ha village tank. The tank is characterized by mounds with *Prosopis juliflora* and *Pithecellobium dulce.*

WATER SOURCE: Uppalapadu receives water from the Krishna Western Delta Canal System (KWDS). It has a main canal length of 355.44 km in total and 1,135 km of branch canals and covers 24 mandals (Paul

Prabhakar 2007). Through this western Krishna delta, Guntur is getting water through Prakasam barrage. It reaches Uppalapadu through near by Thekkallpadu channel.

WATER DEPTH: The water depth is more or less constant and only in summer water recedes down (Fig 2.3). During this study, water level was very low from March 2008 to June 2008 due to management activities.

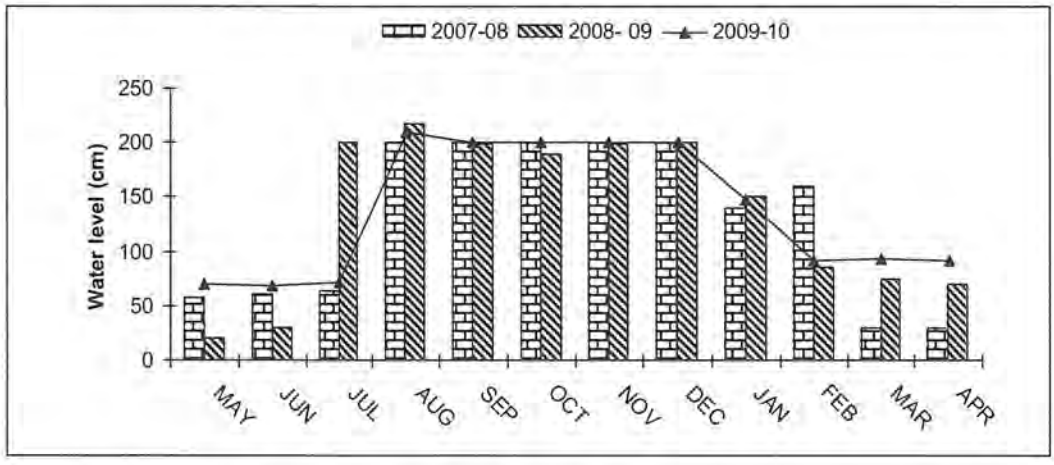


Fig 2.3. Water depth during the study period

CLIMATE: The area experiences greater variations in temperature, maximum of 45°C during May and minimum of 18°C in December, and the annual rainfall is about 872.2 mm. In this 59% contribution is from South-West monsoon and 26% from North-East monsoon (Fig 2.4, 2.5) and peak rainfall varied between June and August. Relative humidity ranged from 30 to 80%; wind speed was calculated as 4.5 to16.3 km/hr (Prabhakar 2007).

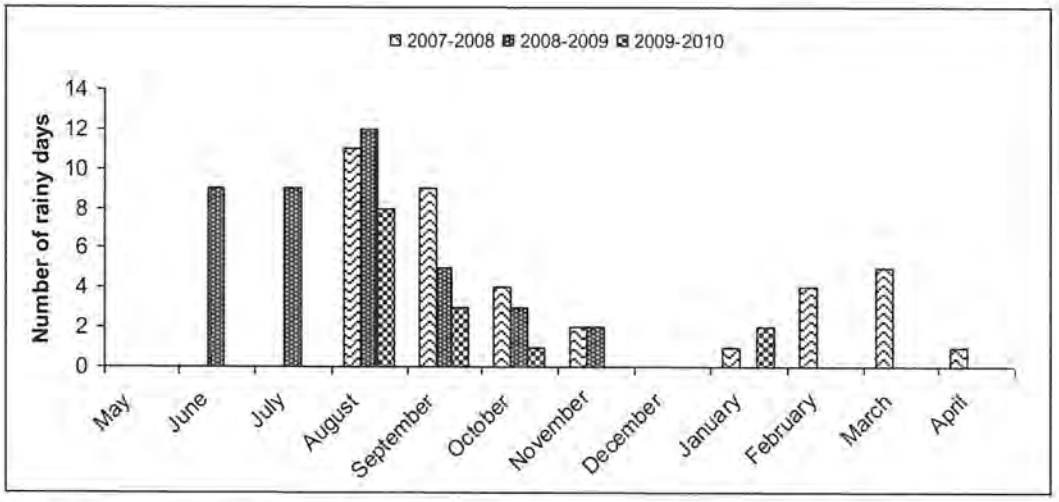


Fig.2.4 Number of rainy days recorded during the study period

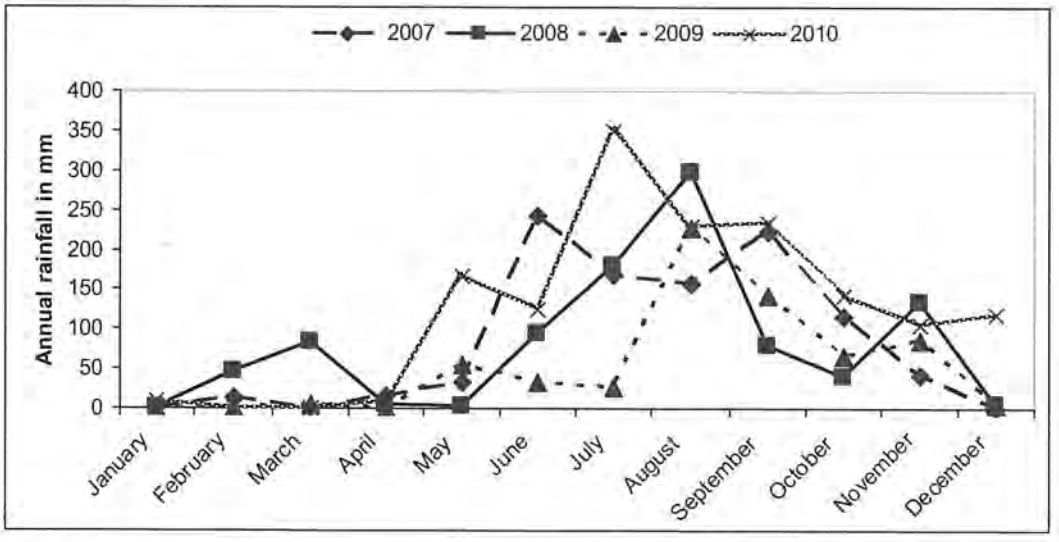


Fig.2.5 Amount of monthly rainfall (mm) recorded in Guntur district

Source- India Meteorological Department (http://imd.gov.in/section/hydro/distrainfall/districtrain.html)

PHYSICAL AND CHEMICAL FEATURES: This bird area is characterized by mounds in the middle of the tank with dense *Prosopis*. Totally 14 mounds were recorded. Out of 14 mounds 3 were devoid of vegetation. During later part of this study *Prosopis* saplings were planted by forest department in the vacant mounds.

VEGETATION: *Prosopis juliflora* and *Pithecellobium dulce* were the chief tree species found in the study area. *Pongamia pinnata*, *Delonix regia*, *Leucaena leucocephala*, *Syzygium cumini* and *Bambusa* sp. were found

along the bund. Apart from this *Ipomoea aquatica, Ipomoea carnea, Cyperus alopecuroides, Cynodon dactylon, Paspalum distichum, Polypogon monspellensis, Eichhornia crassipes* were also identified in the tank.

FISHES: Common fish species found in this area were *Labeo rohita, Notopterus notopterus, Cirrhinus mrigala, Catla catla*, and *Chanda nama.*

WATERBIRDS: Since it meets the international criteria set by the BirdLife International in terms of supporting globally threatened birds and ranked for conservation priorities, this wetland was recommended for declaring it as a Ramsar site among the inland wetlands of India (Vijayan *et al.* 2004). The Uppalapadu bird habitat was supported by 75 species of birds belonging to 12 orders and 31 families: among these 48 species were waterbirds. Of the total of 48 species recorded, 16 species were (33%) residents, 18 species (38%) local migrants, 12 species (25%) winter visitors and 2 species (4%) were partial and occasional migrants (Appendix I & II). Twenty colonial breeders belonging to Ciconiiformes (55 %), Pelecaniformes (15%), Gruiformes (20%), and Charadriiformes (10%) used this heronry as nesting site. Occasional sightings of 2 species belonging to Order Pelecaniformes, Ciconiiformes and Anseriformes each, and rare sightings of 1 species belonging to order Ciconiiformes are notable.

LAND BIRDS: Twenty nine species belonging to 6 orders, namely Passeriformes (62%), Cuculiformes (14%), Falconiformes (10%), Coraciiformes (7%), Piciformes (3%) and Psittaciformes (3%) were recorded in and around the study area. Among these 16% was constituted as winter visitors (Appendix 2).

MAMMALS: Grey Mongoose *Herpestes edwardrsii* was identified from the study area.

EARLIER STUDIES IN THIS PLACE: Since 1999, the tracks of nesting Spot-billed Pelicans were studied by Rao & Kumar (2000), Rao &

Ramana (2000) and Rao (2001, 2002, 2005). A detailed description of the area and breeding birds' status were reported by Taher (2007). A brief comparison of nesting birds with that of Nelapattu was made by Sailaja *et al.* (2007).

2.3 THREATS AND LIMITING FACTORS

REDUCTION OF THE TANK AREA

The major concern over wetland is area reduction. Drastic change in land use pattern has major influence on habitat destruction. After establishment of assured irrigation system the wetlands adjacent to agricultural lands were converted in to paddy fields. The school zone with puddle is having threat of being converted to bare land and trees around this buffer zone is facing has severe threat from villagers for using as fuel wood.

POLLUTION

One of the major threats identified by Rao (2002) was death of nesting trees by bird dropping with highly concentrated uric acid.

DISTURBANCES

Incidental occurrence of disturbance by firewood collectors was recorded in school zone. Fishing activity around bird protected area was also recorded. Disturbance by photographers and visitors was observed who went closer for better experience with birds.

2.4 MANAGEMENT ACTION

To improve habitat, installations of artificial iron nesting poles were carried out in breeding season. For this purpose water was drained out which attracted dogs to scavenge dead fishes and subsequently nesting birds were disturbed.

COMMUNITY SUPPORT

Opposition from local populace was observed due to pollution of water by bird excrement which is believed to be a cause for skin disease (Rao 2002).

A landscape perspective is essential for building sound conservation programmes for water bird assemblages (Guadagnin *et al.* 2005). Based on the pressure and status of birds a detailed study of the species ecology and habitat requirement is proposed.

2.5 STUDY SPECIES

PELECANIDAE

The four big ones, namely Great White Pelican *Pelecanus onocrotalus*, American White Pelican *P. erythrorhynchos*, Australian Pelican *P. conspicillatus* and Dalmatian Pelican *P. crispus* are ground nesters and considered to be replacement species in four widely separated regions, though Great White and Dalmatian overlap in their distribution. Great White Pelican occurs in Eastern Europe, Asia and Africa, whereas Dalmatian Pelican distribution extends from Eastern Europe to China (Crivelli & Vizi 1981; Crivelli & Schreiber 1984; Sibley & Monroe 1990; Brouwer et al. 1994; Nelson 2005). Their ecology and behavior show many similarities. Usually, Brown Pelican *P. occidentalis* is ground nesting species and its status along distribution in North Carolina through the Gulf of Mexico and Caribbean Sea region to eastern Venezuela was studied and recommended to be place in endangered species (Schreiber 1980). Spot-billed Pelican *Pelecanus philippensis* and Pink-backed Pelican *P. rufescens* are wholly or partly arboreal and differ far more from each other than do the big four (Nelson 2005). Geographically the former is present in South-east Asia and the later occurs in Africa, south-west Arabia and Madagascar (Sibley & Monroe 1990). Recently, aerial surveys were conducted in Saudi Arabia in Red Sea water to estimate mid wintering population size and distribution of

Pink-backed and Great White Pelicans as it is speculated as important and poorly known wintering range of the Palaearctic breeding population (Newton & Symens 1996). In India three species occur, namely the Spot-billed, Great White and Dalmatian Pelican (Ali & Ripley 1978). Out of the three, the Spot-billed Pelican is considered as resident and breeding, confined to Andhra Pradesh, Assam, Karnataka and Tamil Nadu. The occurrence of Great White is restricted to Northern India and winter visitor to Uttar Pradesh, Rajasthan, Kutch, Saurashtra, northern Gujarat and a few scattered occurrences are also recorded in south India (Jacob *et al.* 1995; Gopalakrishna & Pushpalatha 2003; Taher & Mani 2008; Sheeba & Vijayan 2009). The Vulnerable Dalmatian is reported as winter visitor and occurs in Rajasthan, Kutch, Saurashtra and northern Gujarat (Ali & Ripley 1978).

PHYLOGENY

The term Pelican is formed from 'pelekon' which is derived from the Greek word 'pelekys' means 'axe'. 'Pelecanus' implies, also a shovel (Nelson 2005). The Spot-billed Pelican belongs to family Pelecanidae comprising six other species namely Pink-backed Pelican *P. rufescens,* Australian Pelican *P. conspicillatus,* American White Pelican *P. erythrorhynchos,* Great White Pelican *P. onocrotalus,* Dalmatian Pelican *P. crispus* and Brown Pelican *P. occidentalis* (Crivelli & Vizi 1981; Brouwer *et al.*1994: Nelson 2005). Additionally, Peruvian Pelican *P. thagus* is considered as a distinct species by T. S. Schulenberg highlighting the size and bill colour (Sibley & Monroe 1990). *P. thagus* previously lumped into *P. occidentalis* (Sibley and Monroe 1990, 1993) following SACC (2005), are now considered as distinct species by SACC (2007).

This family belongs to the order Pelecaniformes which also comprise the cormorants, anhingas, frigatebirds, boobies, and tropicbirds with unique totipalmate character, all four toes connected by a web feet (Lanham 1947; Van Tets 1965; Schreiber 1980; Blair & Charles 1994).

Pelecaniformes is traditionally recognized as monophyletic order (Sibley & Ahlquist 1990) which included the Shoebill (*Balaeniceps rex*) as sister-taxon to Ciconiiformes and Pelecaniformes through cladistic analysis (Cracraft 1985; Livezey & Zusi 2007), predicted through social displays (Kennedy et al. 1996) and weakly confirmed by Kennedy and Spencer (2004). Recently, micro satellite markers developed from *Pelecanus onocrotalus* primers used to determine the degree of gene flow among colonies from Namibia and South Africa; cross-species amplification studies revealed diverse heterozygosity levels and unique alleles for three other pelicans, namely Pink-backed Pelican, American White Pelican and Brown Pelican (De Ponte *et al.* 2009).

TAXONOMY AND NOMENCLATURE OF THE SPOT-BILLED PELICAN

Nomenclature of the Spot-billed Pelican is complex and subject to considerable discussion and revision; the Spot-billed *Pelecanus philippensis* is considered as the same as *P. onocrotalus roseus* which partly occurs in south eastern distribution range of the Spot-billed (Ali & Ripley 1978; Nelson 2005). *P. onocrotalus* was considered a synonym of *P. roseus* (Sibley & Monroe 1990).

P. philippensis was often considered conspecific with *P. crispus* (Crivelli & Vizi 1981; Sibley & Monroe 1990; Nelson 2005; Manakadan and Pittie 2001). *Pelecanus roseus* was allocated to both, which were then separated as *P. r. roseus* (Spot-billed) and *P. r. crispus* (Dalmatian). But *roseus* has been applied to the so called Great White (rosy) Pelican *P. onocrotalus* (Nelson 2005). In India, confusion existed in usage of common name Grey Pelican for both *P. philippensis* and *P. crispus* by Dharmakumarsinhji (1954) and Parasharya (2002). The Spot-billed is considered as a subspecies of *P. philippensis* (*P. p. philippensis*) and distinguished from Dalmatian *P.p.crispus* with the morphological characters, colour of legs and feet pink instead of dark grey; and

forehead feathers ending in a pointed wedge instead of a concave crescentic line (Ali & Ripley 1978).

MORPHOLOGY

Spot-billed Pelican strikes a viewer by its long, dagger-like bill and large loose bag of thin skin which hangs from it like the double-chin of some glutton (Neelakantan 1993). Body is silver-grey on back, darkish centre to wing-coverts and whiter under parts. The crest on the back of the head is composed of elongated brown feathers tipped with white. Bill is pinkish in non-breeding season and brighter yellow margin in and bluish spots on the upper mandible and yellowish towards tip with orange nail and pouch is dull purple colour. Feet are dark brown (Ali & Ripley 1978; Nelson 2005). Spot-billed Pelican is an isomorphic bird but distinguished colour variation is observed during breeding season. Male develops the reddish eye with bright yellow eye ring; in the case of female the eye ring is yellow (Nagulu 1983).

2.6 BIOGEOGRAPHY

Once widespread in Asia, presently is confined to south-eastern India and Sri Lanka (Crivelli & Schreiber 1984). Distributed in lowlands of South Asia from Pakistan, India, south through south-east Asia to Sumatra, Java and Philippines but breeding is uncertain and restricted to four or five colonies in southern India and in Assam. In south-east China ranges from south-east Yunnan east to Kwangtung, and North to Kiangsi including Hainan (Sibley & Monroe 1990).

2.7 LIFE HISTORY

BREEDING

Spot-billed Pelican is tree nester (Ali & Ripley 1978; Nagulu 1983; Brouwer *et al.* 1994). Prefer to nest in large trees such as *Tamarindus indica*, *Pithecelobium* and *Ficus spp.* Palmyra and Coconut trees were also used as nesting site (Gee 1960). Breeds in winter season from

October to March. Usually nests in mixed colonies of Storks. Nest type is closely arranged cluster of nest, stick platform cemented with birds excreta and later on add green lining materials (Nagulu 1983). The nests touch one another in a continuous untidy ring platform (Ali & Ripley1978). The clutch size is three (Ali & Ripley 1978; Nagulu 1983). The mean incubation period is 30 to 33 days (Ali & Ripley 1978; Paulraj *et al.* 1990). Chick is altricial. Fledging period is 90 to 120 days (Ali & Ripley 1978; Nagulu 1983).

FEEDING

Chief food of the Spot-billed Pelican is fishes and adopts cooperative feeding (Ali & Ripley 1978). Frogs and prawns were also reported as food by Nagulu (1983). In earlier stage of development chicks are fed on regurgitated liquid matter or soup by parents and later stages insert bill into the gullet of the Parents.

HABITAT REQUIREMENT

The Spot-billed Pelican generally prefers fresh water tracks and found in marshes, jheels, rivers, estuaries, reservoirs, tanks, flooded fields, large lakes, brackish lagoons, tidal creeks and along the coast; often feeds in quiet backwaters (Ali & Ripley 1978). Locates colony in huge trees in and around the village or isolated area where the disturbance is less and near water tracks.

MOVEMENT

Ali and Ripley (1978) stated that this species move locally according to food and breeding condition. Manakadan and Kannan (2003) consider them as sedentary in some areas.

2.8 CONSERVATION STATUS

In 1920s, more than a million Spot-billed Pelicans were believed to exist in South and South-east Asia (Nelson 2005). But 1990s the number had dropped to fewer than 12,000 birds, and the species was listed as

Vulnerable. Spot-billed Pelican underwent a rapid decline in the recent past. Its small population continues to decline, though at a slow rate, as a result of widespread degradation and exploitation of wetlands and colonies. The decline was largely caused by conversion of wetlands and loss of nesting sites (BirdLife International 2006). Hence, it was considered as vulnerable {A1c, d, e; C1} which has high risk of extinction in the wild. Due to thriving awareness and constant conservation efforts at species specific sites it showed steady state of increases in number. The taxon is Near Threatened (IUCN 2007) when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future (IUCN Redlist categories 2010).

BREEDING COLONY SIZE AND COLONY SITE DYNAMICS

3. 1 INTRODUCTION

The Spot-billed Pelican *Pelecanus philippensis* currently breeds in 7 to 9 colonies extending from south-east India (Andhra Pradesh, Karnataka, Tamil Nadu and Kaziranga Wildlife Sanctuary in Assam), Sri Lanka, Burma, Thailand, Cambodia (Tonle Sap Lake as well as Koh Andeth and Borey Chulsar Districts of Tekeo Province), Laos, Vietnam, south-east Malay Peninsula and south-east China (Kiangsu on the lower Yangtze River, Xinjian lake, Chekang, Fukien, Kwangtung, Kwangsi, south-east Yunnan, Hainan) and suspected Sumatra. Seasonal movements are poorly known, but occasionally visits south-east Asia and the Philippines. Earlier, this species occurred in Persian Gulf, Pakistan, Nepal, Java and the Philippines (Luzon and Mindanao) (Hoyo *et al.* 1992). The Spot-billed Pelican breeds colonially in large congregation. Coloniality in birds is defined as dense nesting within limited territories (Sachs *et al.* 2007). Colonial breeding can be defined as breeding in extremely high densities at sites used for no other purpose (Danchin & Wagner 1997). In herons decrease in colony size was demonstrated by the reduced nesting places (Jakubas 2005) and by disturbances in colony site in colonial sea birds (Erwin *et al.* 1981). Distribution of colonies, suitable habitat selection and proximate foraging site were explained for exhibition of variation in colony size in birds (Brown *et al.* 1990). Similarly, in Brown Pelican variation in density distribution was reported with distance to the mainland, water depth and temperature (Briggs *et al.* 1981) and its function as information centers about resources (Bayer 1982; Evans & Cash 1985; Elgar & Harvey 1987; Doligez *et al.* 2003). Breeding bird numbers and habitat use were

important parameters to assessing the condition of population which varies greatly in time and space (Erwin 1978).

In south India, Andhra Pradesh has been supporting a large population of breeding Spot-billed Pelican from early 1900's century to present (Campbell 1902; Neelakantan1949; Gee 1960; Nagulu & Ramana Rao 1983; Manakadan & Kannan 2003; Subramanya 2006). Generally this species construct nests in the vicinity of freshwater and prefers huge nesting trees or irrigation tanks with nesting trees. Breeding is restricted to inland wetlands and specific site preference for breeding, the same nesting sites tend to be used year after year, although shifts in colony sites are generally not unusual. Nest site tenacity has been associated with habitat stability (McNicholl 1975). Therefore, we expect that colony shifts may be more common in Andhra Pradesh where new aquaculture practices, changing land use pattern and habitat reduction has been observed. In addition, recreational activity, destruction, contamination and human disturbance in the breeding colony sites in Andhra Pradesh might have affected the significant portion of the Spot-billed Pelican population.

About 15 breeding sites of the Spot-billed Pelican were documented in India from Andhra Pradesh, Assam, Karnataka and Tamil Nadu (Subramanya 1996). A total of 30 Spot-billed Pelican breeding sites were documented in southern India by Kannan and Manakadan (2005) and 21 existing colonies were reported by Subramanya (2006). Stable population of about 800 - 1200 birds was documented from Andhra Pradesh (Manakadan & Kannan 2003). However, the estimates were based on a few visits to the sites and conducted at different parts of the year.

I tried to quantify the population size from the breeding colonies and studied its distribution in the State based on data gathered during the period 2007- 2009. In this chapter I discuss the recent status and distribution changes of the Spot-billed Pelican in Andhra Pradesh and potential threats in breeding and non-breeding sites (foraging sites) are

summarized and recommendations made for management and conservation of this species in Andhra Pradesh. Specific objectives of the study are to:

- Assess the current status and population of the Spot-billed Pelican in Andhra Pradesh.
- Analyze the colony sizes and locations variability between years and to understand the characteristics of the major colony sites.
- Study the distribution and habitat use of the Spot-billed Pelican.

3. 2 STUDY AREA

Surveys were carried out in four breeding colonies, namely Nelapattu, Telineelapuram, Ramachandrapalayam and Uppalapadu and 2 to 4 days' surveys were conducted in foraging sites, namely Kolleru Lake, Naupada Swamp & Kakarapally Creek and Pulicat Lake during October 2007 to March 2010 (Fig. 3. 1. & Table 3. 1).

Fig. 3. 1. Breeding and foraging sites of the Spot-billed Pelican in Andhra Pradesh

Table 3. 1. Description of breeding and foraging sites of the Spot-billed Pelican in Andhra Pradesh

Pelicanry	Coordinates	Area	Status
Naupada Swamp & Kakarapally Creek	18° 31' 41.5" N 84° 17' 40.9" E to 18° 33' 46.8" N 84° 21' 25.6" E	15-20 km2	Proposed Protected Area (Srinivas 2010)
Kolleru	16° 33' 54.52"N 81° 05' 07.52"E to 16° 45' 33.86" N 81° 21' 02.84" E	901.00 km2	Ramsar site (Protected)
Nelapattu Bird Sanctuary	13° 42' 42.4" N 80° 05' 31.8" E to 13° 43'13.00" N 80° 06'54.03" E	458 ha/ 82.56 ha	Bird Sanctuary (Protected)
Ramachandrapalayam	16° 17' 11.2"N 80° 29' 44.2"E	5 ha	Private fish tank (Not Protected)
Pulicat lake	13° 42' 42.4" N 80° 05' 31.8" E	60,000 ha	Ramsar site (Protected)
Telineelapuram	18° 34' 04.9" N 84° 15' 56.4" E	460 ha	Village Pelicanry Protected (2009)
Uppalapadu	16° 16' 26" N 80° 21' 58" E	14 ha (3.35Ha)	Community reserve (Protected)

Details of the sites surveyed are given below:

Nelapattu Bird Sanctuary is located adjacent to Nelapattu village bounded by dry evergreen scrub forest with fluctuating water level. This rain-fed tank is characteristically covered with *Barringtonia acutangula* which act as nesting site for Pelicans (Sharma & Raghavaiah 2002). Preliminary notification of this sanctuary was issued on 20.09.1976 and final notification on 15.09.1997 under section 26 A of the Wildlife Protection Act of 1972 (ELDF and WWF India 2009). This site was considered the largest Pelicanry in south-east India (Sharma & Raghavaiah 2002; Nandakumar *et al.* 2009).

Ramachandrapalayam is a recently emerged breeding site of the Spot-billed Pelican and Painted Stork in January 2008. It is a fish farming tank covering an area of about 6 hectares with a single mound in it. *Acacia nilotica* and *Prosopis juliflora* were present which acted as nesting

substrate for the Spot-billed Pelican, Painted Stork *Mycteria leucocephala* and Black-headed Ibis *Threskiornis melanocephalus*. Spot-billed Pelicans were noticed here during 2007 and 2008. Totally 16 bird species were recorded including Darter *Anhinga melanogaster*, Painted Stork and Little Cormorant *Phalacrocorax niger*. Compared to Uppalapadu, intrusion by fish feeder and boat movement was regular in the pond. Despite these aquaculture activities birds established the colony.

Telineelapuram: Since 1980 this village Pelicanry was known for nesting Spot-billed Pelican and Painted Stork. Nesting tree species identified are *Tamarindus indicus*, *Azadirachta indica*, *Ficus religiosa*, *Enterolobium saman* and *Prosopis juliflora* (Kannan & Manakadan 2005). The nesting birds were mainly depending on the Kakarapally creek which is located 10 km from the site (BirdLife International 2010). This protection was extended by forest department in 1978 (Nagulu & Ramana Rao 1983) and is now under threat because of the development projects reported at Nawapada swamp which is around 5 km from this nesting site.

Uppalapadu: This site is known for the Spot-billed Pelican from 1999 (Rao and Kumar 2000). Detailed description of this site is given in Chapter 2.

Kolleru is one of the largest natural freshwater lakes formed in a depression between two great rivers Godavari and Krishna in the southeast coast of India. It covers an area of 178.92 sq. km (Rao *et al.* 2000). Kolleru lake in Andhra Pradesh, once a major Spot-billed Pelican breeding and feeding area (Neelakantan 1949; Gee 1960; Guttikar 1978) is now almost completely converted to aquaculture (Rao *et al.* 2004; Jayanthi *et al.* 2006; Wetlands International 2008; Rao *et al.* 2010). Preliminary notification of bird sanctuary was issued on 25.09.1995. Proclamation was issued on 17.03.1997 (ELDF and WWF India 2009). The lake was declared a wildlife sanctuary in 1999 under India's Wildlife Protection Act of 1972, and later in November 2002 designated as a

Ramsar Site (No.1209), which gives it the status of a Wetland of International Importance (GoAP 2007b) under the International Ramsar Convention held on 19 August 2002. The Kolleru Wildlife Sanctuary forms an integral part of the wetland system covering the area below +5 feet amsl contour line. The protected area covers 308 km^2 (Venot *et al.* 2008). Kolleru had been historically managed for capture fisheries and traditional agriculture by the communities living in and around (Wetlands International 2008). The increase in area of agricultural land, aquaculture and impact of aquaculture, drastic changes in land use pattern have been documented (Islam & Rahmani 2004; Rao *et al.* 2004; Jayanthi *et al.* 2006; Ramakrishna 2007; Irrinki & Irrinki 2008; Rao *et al.* 2010).

Pulicat Lake is the largest brackish water lagoon extending from Andhra Pradesh to Tamil Nadu. This lake acts as the major feeding area for lot many migratory birds including the Spot-billed Pelican. The lake has 16 island villages. Preliminary notification of this site as wildlife sanctuary was issued on 20.09.1976 and final notification on 28.08.1997 (ELDF and WWF India 2009). Status and future conservation strategies for water birds in this lake were addressed by Sanjeevaraj *et al.* (2009); it is functioning as foraging ground and largely supports many nesting colonies in and around Nellore district.

Naupada or Tekkali swamp also called Kakarapally creek covers an area of about 1000 ha, not protected legally, and extending between Bhavanupadu and Meghavaram; forms the major feeding ground for the Spot-billed Pelican and many major migratory waterfowl. It can be proposed as a protected area. During the survey we found the Spot-billed Pelican in core swamp area where intense traditional fishing activity occurred. Hydrological regime is seasonal.

3.3 METHODS

Surveys were conducted at the breeding sites identified based on known information. The terminologies described by Kushlan (1986) were used, for survey involves the "colony site"; a census involves the inhabitant, which is the "colony" itself. These are exceptionally useful distinctions. The "colony site" is the place where colonial nesting occurs. The "colony" is the collection of birds using such a site. Furthermore, a colony was defined as a location containing two or more nests. Birds nesting in different clumps of shrubs or trees within the same habitat were considered to be one colony if the groups of nests could be enclosed within a 1,200 m diameter circle (Bryan 2003). The demographic samples with in each breeding units were defined as Population (Anderson 2005).

3.3.1 Counting methods

Pelican nests were counted individually from ground in breeding sites. Total bird counts were also made in loafing and foraging areas (Bibby *et al.* 1998). In addition, surveys were conducted in a few inland wetlands in and around breeding colonies and foraging sites. In each breeding sites total number of nests, number of active nests, and number of adult birds associated with nest, chronology of nesting activity and stages of fledged young were recorded. For each nest, nest substrate, height at which the nest was placed, nearest water spread area, colony sub-units and disturbance during breeding season were recorded. Crivelli *et al.* (1998) suggested three time survey of breeding colony as the birds breed asynchronously and tend to move locally for suitable environmental condition. In human altered habitat and drastically changing heterogeneous system, bird distribution and abundance estimation with high temporal frequency may enable a pre and post-construction comparison of the bird population (Fox & Petersen 2006).

During this study, two surveys were conducted through the breeding season during 2007-08 to 2009-10 in order to assess the population. Pelican nests were individually counted by total ground count in Telineelapuram, Uppalapadu and Nelapattu. Total counts were also made in and around loafing areas. For the final estimate, nest number was taken into account for the population at each breeding colony (Dunbar 1982; Wilkinson *et al.* 1994; Holm *et al.* 2003; King & Anderson 2005). The nest estimates were doubled to obtain a breeding bird estimate (King & Anderson 2005). Nest number records from forest department were also taken into account to study the trend.

Census of Pelicans was carried out in other known foraging sites, namely Kakarapally creek, Kolleru lake and Pulicat lake. Vehicular surveys were conducted where lake is served with road and by feet where water body was inaccessible from road. Vantage points were selected randomly to cover whole lake area. The northern part of Pulicat lake was not surveyed due to *ad hoc* reason. In each point numbers of pelicans were counted and habitat types were noted. In Kakarapally creek which lies parallel to Bay of Bengal, about 1.5 Km were regularly surveyed at nine sites, namely Sonapali, Sitanagaram, Muthakota, Marripadu, Naupada salt pan, Akasalakavaram, Dandagopalapuram, Thampara and Bhavanapadu. In Kolleru lake Gudivakalanka, Prattikotalanka, Paidichintapadu, Chettunapadu, Kammagum, Agadalanka, Komatilanka, Atapaka, Pandiripallegudam, Kolletikota, Agadallanka and Mallavaram regions were surveyed. In each wetland sites number of pelican, foraging flock size, water level, fishing activities and fish species were recorded. At each visit threats were recorded in both breeding and foraging sites by inquiring local fishermen and forest officials.

Human intrusion may lead to colony abandonment in water birds (Carney & Sydeman 1999). Therefore observations were made from various vantage points near the pelican colonies in Nelapattu and Uppalapadu taking maximum care not to disturb the birds. In

Telineelapuram, a village Pelicanry, tall nesting trees, namely *Tamarindus indicus*, *Azadirachta indica*, *Ficus religiosa* were observed from the 45 feet high watch tower and huge building situated at the centre of the village. Vicinity of water body from village was recorded and nesting of other species of birds was also noted.

3.3.2 Data analysis

Status and colony size was estimated by the nest number. The nest estimates were doubled to obtain a breeding bird estimate (Dunbar 1982; King & Anderson 2005). Chi-square test was performed to study the inter year variation in each breeding site.

To describe stability of a colony, we considered for each site its occupancy rate (*p*) that is the proportion of year, during study period. For each site turnover rate (t_i) was calculated by adapting Deerenberg & Hafner (1999), for each sites number of switches (S) between subsequent years from presence to absence of a colony at the site or vice versa, as a proportion of the total number of monitoring years (M). The index (t_i=S/M) value ranges between 0 and 1.

As an indicator of the stability in size of colonies, we calculated the coefficient of variation (CV) around the mean size (including years with size zero). The CV is equal to the Standard Deviation divided by the mean and multiplied by 100 to be expressed as percentage (Deerenberg & Hafner 1999; Anderson *et al.* 2007).

3. 4 RESULTS

3.4.1 Colony distribution and nest abundance

The location and number of nests in the four breeding sites and three foraging sites in Andhra Pradesh were obtained between 2007 and 2010 (Table 3. 2).

Uppalapadu breeding colony stands first in proportional mean colony size 56%, 47% and 71% in three consecutive years and was the largest single breeding colony in Andhra Pradesh. Nelapattu was the second

largest breeding colony with proportional mean colony size ranged from 24% to 32%.

Table 3. 2. Colony size of the Spot-billed Pelican in Andhra Pradesh

	2007-08				2008-09				2009-10			
Colony site	Estimated size	Proportion of size(%)	CV (%)	Range	Estimated size	Proportion of size (%)	CV (%)	Range	Estimated size	Proportion of size (%)	CV (%)	Range
Telineelapuram	55.50±50.20	4	90	20-91	36±22.63	4	63	20-52	50±45.25	4	91	18-82
Nelapattu	470±127.27	32	27	380-560	243.50±269.41	24	111	53-434	284±362.04	25	127	28-540
Ramachandrapalayam	119.50±30.41	8	25	98-141	262±115.97	26	44	180-344	0	0	0	0
Uppalapadu	831±126	56	15	742-920	474±210	47	44	325-623	805±120.20	71	15	720-890
Total	1476±333.75	100			1015.5±618.72	100			1139±527.50	100		

Highest number of nest was recoreded at Uppalapadu (831±126) followed by Nelapattu 470±127 in 2007 and the lowest nest number (55.50 ± 50.20) was recorded at Telineelapuram. A new breeding colony of the Spot-billed Pelican was found in Ramachandrapalayam near Uppalapadu colony which accommodated 120±30 nests. The estimated size in 2007 was 1476 ± 333.88. Comparatively less colony size was estimated in 2008 and 2009 as 1015.5± 618.01 and 1139±527.49 respectively in 4-5 breeding sites. Recent population trends indicate increasing breeding population of the Spot-billed Pelican.

3.4.2 Nest site habitat characteristics

Of the four breeding colonies studied three (75%) were at man-made irrigation tanks namely Ramachandhrapalayam, Nelapattu and Uppalapadu. One site (25%) was at village Pelicanry, Telineelapuram. Two (50%) colonies, namely Uppalapadu and Ramachandrapalayam had chief nesting vegetation *Prosopis juliflora*, one colony (25%) had *Barringtonia acutangula* as nesting substrate and another (25%) colony (Telineelapuram) was large woody trees, namely *Tamarindus indicus* and *Ficus religiosa*.

3.4.3 Colony size dynamics

Breeding birds survey and nest counts in four existing breeding colonies showed variation within each year. The Telineelapuram (x^2 =4.45, df=2, p<0.00), Uppalapadu (x^2 =112.64, df=2, p<0.00); Ramachandrapalayam (x^2 =52.78, df=1, p<0.0001) and Nelapattu (x^2 =87.44, df=2, p<0.00) had significant breeding colonies variation among years.

In agreement with the predictions of colony size and duration of presence, occupancy rate of a colony was positively related to colony size (logistic regression, $F = 0.380$, $df = 3$, $P < 0.001$; R^2=160). Colony turnover rate had no obvious relation with colony size.

3.4.4 Colony stability

Turnover rates for Nelapattu, Telineelapuram and Uppalapadu are 0.3 each and Ramachandrapalayam secured 0.5. For each site colony stability was calculated and the highest CV was found in Ramachandrapalayam (103%) followed by Nelapattu (36%) and Telineelapuram and Uppalapadu showed less CV, 21 % and 28% respectively. Kolleru has not received any turnover rate during the study period as there was no breeding colony.

3.4.5 Distribution and habitat use in foraging sites

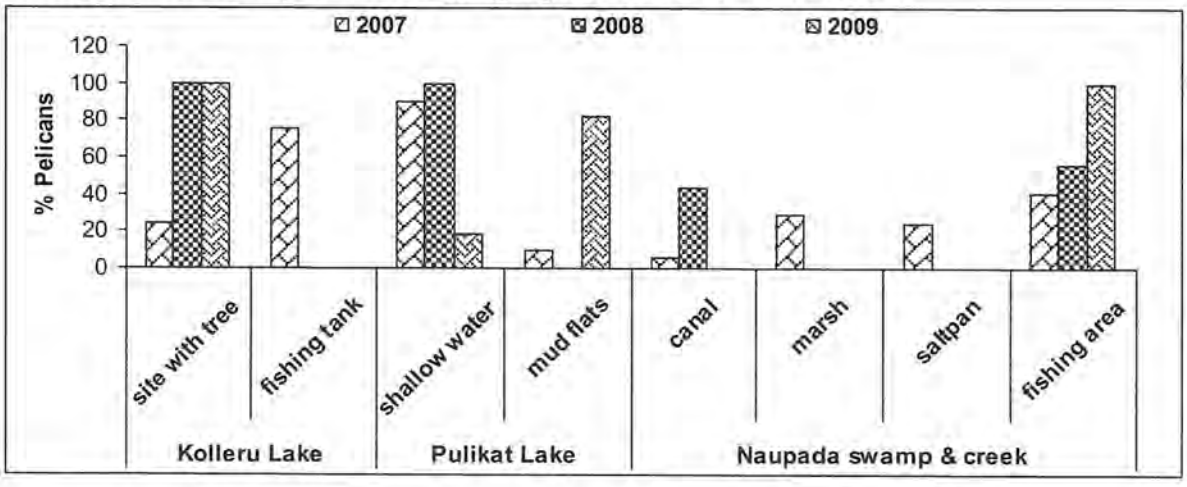
Table 3. 3. Counts of the Spot-billed Pelican in three foraging sites 2007-2010.

Foraging sites	2007-08 (Mean ±SD)	2008-09 (Mean ±SD)	2009-10 (Mean ±SD)
Kolleru	95±69	53±75	35±49
Pulicat	625±707	29±41	55±49
Naupada swamp / Kakarapally creek	21±13	20±23	4±7

Occurrence of pelican was noted along with habitat variables in non-breeding sites. Pulicat lake had the maximum number of birds (625±707) followed by Kolleru lake (95± 69) and Kakarpally creek (21±13) in 2007 (Table 3. 3). Feeding birds were found singly or in loose congregation. In one incident at Pulicat lake large congregation of more than 1000 birds were recorded in circular aggregation in Atakanithipa a shallow lake area

about 3 or 4 meter from the Sriharikota Road. In all other cases birds were seen in small flocks or scattered feeding groups ranged from two to four birds.

Fig. 3. 2. Percentage of Spot-billed Pelicans observed in different habitats during ground surveys at three foraging sites from 2007 to 2009.



Pelicans were found in a wide range of habitats, namely shallow waters, canals, marshes, fish tanks, site with trees, and mud flats. In 2007-08 maximum use was of shallow water, in 2008-09 site with nesting tree and in 2009-10 it was mudflats (Fig. 3. 2). The habitats varied in different locations; At Kolleru site with trees and fishing tanks were used, at Pulicat lake shallow water and mud flats, and at Naupada swamp canal, marsh and fishing area. In Kolleru, Spot-billed Pelican mostly used site with trees in all years while fish tanks were not preferred in 2008 and 2009. In Pulicat lake the Pelican was highly used shallow water and than mud flat. In Naupada swamp and creek Pelican was found associated with fishing area and more frequently in marsh during 2007 and to some extent in canal in 2008 (Fig. 3. 2).

3. 5 DISCUSSION

3.5.1 Historic and current status

Understanding the population status may ensure to develop effective management strategies (King & Anderson 2005). To initiate conservation measures for any species, the current status of its population size and the habitats frequented need to be determined (Jadhav & Parasharya 2004). In Andhra Pradesh the Spot-billed Pelican occurred as resident and local migrant and tended to move locally for suitable nest site and food abundance (Ali & Ripley 1987).

In earlier eighties, only two nesting colonies of the Spot-billed Pelican, namely Telineelapuram and Nelapattu supported 200-250 and 800 - 1000 birds respectively (Nagulu & Ramana Rao 1983) and large congregation of nesting were also reported in Kolleru (Gee1960; Guttikar 1978; Neelakantan (1949).

A recent status report showed that state population of the near-threatened Spot-billed Pelican was relatively stable (Manakadan & Kannan 2003). Steady increasing trend was demonstrated and estimated as 6000 birds from south India by Subramanya (2006). Over all Spot-billed Pelican population in southern India was reported as 2850-3700 individuals (Kannan & Manakadan 2005) and in India around 4000 (BirdLife international 2009). Kannan & Manakadan (2005) estimated around 850 - 1200 individuals in Andhra Pradesh. Recent population trends indicate increasing breeding population of the Spot-billed Pelican. During the study period colony size ranged from 1015.5± 618.01 to 1476 ± 333.88. In 2007-08 the largest colony size was 1476±333.75 with estimated adults of around 600 - 3000 individuals which is higher than earlier report of Kannan & Manakadan (2005). However, there was no increased pattern in nesting sites.

The estimated total colony size within four breeding sites of the Spot-billed Pelican was about 1476±333.75 in 2007-08; 1015.5±618.72 in 2008-09 and 1139±527.50 in 2009-10. The largest colony size among

entire range was observed in Uppalapadu ranged from 831±126, 474±210 and 805±120.20 in 2007-08, 2008-09 and 2009-10 respectively. Proportion of size was 56%, 44% and 71% in three subsequent years. Some change was observed at Uppalapadu colony in 2008-09. The sub-colonies might be formed when the disturbance or overcrowding was more. At Ramachandrapalayam, about 3 km from existing colony of Uppalapadu, a sub-colony was established in 2007-08; the colony size ranged from 119.50±30.41 in 2007-08 to 262±115.97 in 2008-09, whereas in the third year there was no nesting as it was not enhanced /supported by the private tank owners. The second largest breeding aggregation was recorded at Nelapattu as estimated colony size was 470±127.27 in 2007-08, 243.50±269.41 in 2008-09 and 284±362.04 in 2009-2010. Like Uppalapadu the colony size was also dropped down in the 2nd year at Nelapattu because of insufficient water level. Similarly during 2008-09 the Telineelapuram colony size was decreased to 36±22.63. For the first and third year the estimation was 55.50±50.20 and 50±45.25 respectively. At Kolleru the colony disappeared probably because of disturbances, mainly recreational activities.

Holt (1997) suggested that the character of population dynamics (viz., stable vs unstable) may have important implications for whether one observes niche conservatism, or instead niche evolution, in species occupying spatially heterogeneous environments, via the indirect effect of such dynamics on the evolution of dispersal and optimal habitat utilization strategies. Thus qualitative prediction is that species with locally unstable population dynamics should tend to evolve generalized adaptation across many habitats, rather than specialization to any particular one.

3.5.2 Population increases

The increase in population may have resulted from a number of factors like increasing aquaculture practices in Kolleru (Jayanthi *et al.* 2006) and Krishna river basin (Venot *et al.* 2008) which act as food reservoir

(Kannan & Manakadan 2005). The possible relationship between aquaculture and pelican population in Andhra Pradesh is untested although aquaculture is the fastest expanding industry in this region (Nidhi *et al.* 2009).

Recent increase in numbers of the Spot-billed Pelican at particular colonies may be due to reduction in suitable nesting sites. Establishment of new nesting area was observed at Ramachandrapalayam. Over crowding at Uppalapadu, readily available food source, local protection from villagers might have made these birds to establish new nesting colony at Ramachandrapalayam. Compared to Uppalapadu, intrusion by fish feeder and boat movement is regular in this pond. Despite these aquaculture activities birds established the colony, In 2009 the fish pond was drawn out for fish harvest and kept empty during the birds' arrival time to avoid nesting. Hence, the colony establishment by the Spot-billed Pelican was not initiated in the dried pond. Kolleru Lake in Andhra Pradesh, once a major Spot-billed Pelican breeding and feeding area (Neelakantan 1949; Gee 1960; Guttikar 1978) is now almost completely converted to aquaculture (Rao *et al.* 2004; Jayanthi *et al.* 2006; Wetlands International 2008; Rao *et al.* 2010). Also climate changes such as rainfall have positive influence on breeding population (Sharma & Raghavaiah 2002; Nandakumar *et al.* 2009). Nest abundance of the Spot-billed Pelican may be further determined by the distribution and composition of irrigation tanks with safer nesting tree preferably *Prosopis* as it is widely distributed in Andhra Pradesh (Reddy 2010).

3.5.3 Fluctuation in breeding colonies and populations

In earlier eighties, only two nesting colonies of the Spot-billed Pelican, namely Telineelapuram and Nelapattu were reported from Andhra Pradesh (Nagulu & Ramana Rao 1983). However, the number of active pelican colonies had declined from at least seven (two in East and West Godavari districts namely Kolleru and Gunaparam, five in Cuddapah

districts comprising Labaku, Reddipalle, Buchupalle, Pullagurapalle and Short Pelicanry] to three colonies. Currently only three Pelicanries are reported (Kannan & Manakadan 2003). However, wide fluctuation in population is indicative of increasing population instability (Diem & Pugesek 1994). The variability in colony size in the study population was a result of a combination of various local scale ecological factors, probably related to the human induced activity at colony sites. Colony size variation and colony dynamics in the Spot-billed Pelican might be because of reduced habitat availability at some colony sites. Ecological factors operating at a local scale, such as recreation, fishing and management practices, act independently on sites and, changes in individual colony size owing to local factors are expected to be unrelated (Deerenberg & Hafner 1999). Population dynamics can affect both the rate and direction of adaptive evolution. Species with unstable local dynamics in high quality habitats should be selected to utilize a broader range of habitats than species with stable local dynamics, and in particular in some circumstances should utilize sink habitats. This observation has implications for the direction of niche evolution, and the likelihood of niche conservatism (Holt 1997). These habitats of large patches where the species occur is called a continuous landscape. Changes in the carrying capacity of the source patches produce distribution patterns that have profound effects on overall population growth. The interplay of landscape structure and habitat selection choices made by individuals across continuous landscape makes it necessary, to understand the mechanisms that shape distribution patterns in agile species (Donovan & Lamberson 2001).

3.5.4 Distribution in foraging sites

Surveys carried out in three vast foraging sites showed marked changes in habitat use during the three years of study (Fig.3.1). In Kolleru, marked reduction in Pelicans (%) was observed in fishing tanks which was probably due to increased water level and intense aquacultural

practices as this alteration was not preferred by this species. Similarly, In Naupada swamp and Kakarapally Creek 53% were observed in marsh area during 2007-08 and was not recorded in the subsequent years (2008-09 to 2009-10) of study, mainly because of habitat reduction as recorded by Rahmani and Rajvanshi (2009). Apparently this species will nest in a variety of habitats as long as a dependable food source is within a small foraging radius of the colony. However, the established relationship between food abundance and breeding chronology information is needed. In Naupada swamps the Pelican was found associated with fishing area and also canals.

Habitat-specific predictions of demographic parameters such as annual productivity and population growth rate can be used to compare habitat quality among species and habitats for purposes of evaluating management plans (Knutson *et al.* 2006). Understanding the population status will help develop effective management strategies (King & Anderson 2005).

3.5.5 Threats

At present foraging habitat appears to be abundant in terms of aquaculture (Pillai & Katiha 2004; Bhatta 2007). In contrast, only a few suitable nesting sites are available in the state. Several nesting colonies are threatened by deterioration of nesting habitat due to drying of trees with bird droppings and felling (Rao 2002). One of the colony sites was abandoned at Ramachandrapalayam, because of nest tree deterioration. Newly established colony site, Ramachandrapalayam was abandoned in 2009-10 when water level at the nesting tank remained nil during arrival period. Insufficient nesting trees at Uppalapadu are the main reason for regular occupation of trees in the adjacent School zone. During survey it was noticed that recreational activities at Kolleru Lake was a threat as the boating activity near to the nesting trees disturb the nesting activity of the birds. At Uppalapadu, management activities during breeding season was the major concern. As observed, disturbed population move

to alternate nesting habitat i.e. *Ecdore cheruv* and Ramachandra palayam. Lack of local people's support is another threat as it was found in Ramachandrapalayam where nesting activity was not supported in the third year as reduction in yield was observed in the fishing pond. They discouraged the nesting birds by emptying the pond during arrival time. Breeding Pelicans depend on rainfall and water spread as main factors to induce the breeding activity. Insufficient water levels in Nelapattu tanks and dependence of villagers on the tank water are of major concern. The deleterious effects of human activity will lead to shifting of colony sites or desertion (Anderson & Keith 1980; Kushlan & Frohring 1985; Mueller & Glass 1988).

Although the recent increase in the Spot-billed Pelican breeding populations in Andhra Pradesh is encouraging, it is necessary for District or State management to implement public education programmes and other appropriate management strategies to ensure the long-term maintenance of Pelican nesting populations in the State. Active participation of local people through village committees in restoration and monitoring should be encouraged (Ramachandra & Sreekantha 2006).

NESTING HABITAT CHARACTERISTICS AND BREEDING PERFORMANCE

4.1. INTRODUCTION

Reproduction is defined as the number of young that fledge and also both by the number that survive after fledging to breed successfully, and by the negative effects of the breeding effort on the future potential of the parents (Martin 1987). There is a tradeoff on an animal's investment in its young against their own chances to survive and reproduce in the future (Stearns 1992). The environmental factors that control efficiency of breeding have led to the evolution of species-specific breeding periodicities through natural selection (Göcek 2006). Individuals reproduce when conditions are predicted to be conducive for successful reproduction. The optimal pattern of reproductive activity of a population is dependent on the grain of the environment in which the population finds itself, on the interaction of physical and biotic aspects of the environment as they affect probabilities of reproductive success, and on the age specificity of effect of environmental parameters (Giesel 1976). Survival and longevity of parents are often thought to be inversely related to reproductive effort, where reproductive effort is the proportion of total energy and nutrients that an organism devotes to reproduction (Martin 1987).

Spot-billed Pelican *Pelecanus philippensis* breeds in freshwater inland wetlands or in the vicinity of waters. Among four known breeding colonies, three of them are irrigation tanks and one village Pelicanry (Manakadan & Kannan 2003). To understand the habitat requirements and factors determining habitat selection, evaluation of breeding performance, distribution of the colony and adaptations were studied.

Quality of nesting sites were measured by dispersion among sites and the individual responses to the various habitat and occupancy patterns (Morimoto & Wassermani 1991). Spatial distributions of colonial water birds distinguish habitat quality as it is discrete and easily recognizable (Brown *et al.*1990). Individuals will benefit by recognizing spatial variations in habitat quality and from settling accordingly (Orians 1991). Quality, availability size of breeding units and its spatial distribution as limiting factor and positive influence on breeding synchronization in Dalmatian Pelican were addressed (Catsadorakis & Crivelli *et al.* 2001).

Spatial and temporal distribution in nesting efforts, distribution and variation in reproductive success were studied in White Pelicans (Knopf 1979). Very limited documentation of nesting tree preference and habitat use of the Spot-billed Pelican were done by Nagulu (1983) and Manakadan and Kannan (2003). Nest site selection and requirements of the Spot-billed Pelican were poorly known. It is strongly believed that quality, availability and spatial distribution of nesting islands influenced their overall breeding performance. Spatial variation in mean occupancy of nest within the breeding colony is positively correlated with mean productivity, suggesting that mean occupancy could be used as a measure of habitat quality and population performance. To understand the probable causes and population consequence of spatio-temporal variation in territory quality measured by occupancy was investigated in the Spot-billed Pelican from 2008 to 2010.

Breeding success of the birds is influenced by many factors including position and quality of nest-sites (Mitrus & Soćko 2008). Among birds, natural selection should favour the ability to recognize and select habitat suitable for nesting and rearing chicks (Stenhouse *et al.* 2005). Basic aspects of colonial nesting and patterns of reproductive success in White Pelican were studied by Knopf (1979) and also spatial and temporal distribution of nests, colony establishment and variation in reproductive success. Nest site selection was well studied in Dalmatian Pelican by Peja

et al. (1996) and Catsadorakis and Crivelli (2001) and White Pelican by Knopf (1979). However, this aspect was not well established in Spot-billed Pelican by the earlier studies. Identifying habitat conditions needed for successful nesting is an essential part of protecting habitat to maintain populations of birds (Kelly *et al.* 2008). Uppalapadu protected area is known for the Spot-billed Pelican since 1999 and they continue to nest in this habitat even though there have been habitat disturbances and changes in climatic (environmental) factors.

4.2. METHODS

Nesting ecology of the Spot-billed Pelican was studied between February 2007 and March 2010 in 3.34 acre of Uppalapadu bird habitat, located east of Guntur, Andhra Pradesh, India. The nesting area is characterized by tree mounds covered by *Prosopis juliflora* and *Pithecellobium dulce* located at the middle of the pond. In addition to these trees, two artificial iron trees were installed in the pond by the forest department in 2004 and two more in 2008 to provide nesting site. (For details see Chapter 2). Nesting birds and nests of the Spot-billed Pelican were counted from February 2007 to October 2010 in 2.27 acre and also adjacent school zone. Arrival and settlement of birds were monitored at 2 to 3 days interval from the last week of September to 1st week of October after southwest monsoon which usually occurs during June to September (Victor *et al.* 1995).

According to accessibility, nests were studied randomly. A sample of 619 nests (180 in 2007, 246 in 2008 and 193 in 2009) was used for the analysis of nest-site characteristics, nest-site selection (Venkatraman 2007) and breeding success. Individual colonies were recognized and each location was marked in the map with establishment dates for temporal analysis. Nest tree parameters were collected during April 2008 when entire pond was drained and kept dry for three months to install two more artificial trees. Nest counts and bird counts were recorded from

two sides of dikes at fixed vantage points with the help of binoculars (Pentax 8x42) and spotting scope (Nikon 20x60) (Catsadorakis & Crivelli 2001). The asynchronous arrival and reproductive readiness state at the colony of long distance migrant groups of pelicans can affect the accuracy of yearly nesting censuses (Diem & Pugesek 1994). So the breeding birds were observed daily in order to study the precise date of assemblage for lek and locations were recorded with site codes for all the three years. Nest initiation starts after defending site and pairing. Date of establishment of breeding subunits and spatial location relative to distance from path and colony center, nesting substrate, nest density, size of the colony and mound size were recorded. For every nest, nest tree species, distance from path, height of the colonized tree, DBH, height of the nest, vertical position and nest success were recorded. The horizontal position of nests was recorded according to Hafner (1997) and followed by SiBachir *et al.* (2008): (1) against the trunk, (2) on solid branches with vertical structure, (3) on secondary branches in the periphery of the tree or (4) in the extreme periphery. The breeding biology data, namely clutch size, hatched chicks per nest, fledged chicks per nest and losses of eggs and young chicks (up to 20 days) were recorded and compared them with other studies. Usually the chicks after 20–25 days leave the nest and move to other nest in the cluster, the term fledged chicks designate chicks of age up to 20–25 days. The nesting success was expressed as percentage and calculated by number of nest with young fledged from the total number of nests.

Opportunistic visits were made to the breeding colony using boat (4 visits in 2007, 3 visits in 2008 and 1 visit in 2009) to check the clutch size. A total of 27 nests were observed during the study period and these were mapped for easy identification and future monitoring.

In some nests, the exact date of laying of the first egg was recorded with the firm continuous sitting. For the rest, the date of laying first egg was calculated by back-dating, assuming 29-30 days for incubation (see

Nagulu 1983). Active nest was defined as a nest containing one or more eggs or nestlings. With marked raised sitting gesture, frequency of peeping by the adult inside nest and visible inactive pinkish head in the nest were considered as hatched and hatching success was calculated (Naik *et al.* 1981; Parasharya & Naik 1988).

Colonies were checked on a weekly basis for establishment and location throughout the breeding season. Observations on nesting birds were made from dikes in selected vantage points. Pairing, nesting and incubating adults and nests with nestling were observed. Total numbers of nests on the tree, nest height from the water level and ground level, DBH, and bole height, and distance to the nearest water spread area were collected after successful fledging of the young from the nest. The method of Catsadorakis and Crivelli (2001) and Stickney *et al.* (2002) were employed for measuring nest-site selection.

4.2.2. Data analysis

Index of selectivity test (Ivlev 1961) was used to evaluate preference or avoidance of various tree species as nesting sites by following formula.

$$PI = U-A / U+A$$

Where, 'U' denotes percent utilization of substrate and

'A' denotes percent availability of corresponding substrate.

Selectivity values of levels ranged between -1 and +1, where "-" indicates avoidance while "+" indicates preference. The nest tree types /nest substrates used by Spot-billed Pelican were recorded in six randomly plotted mounds in the heronry. For this purpose, in each mound total number of trees, total number of tree species and among them nesting and non-nesting trees were counted as described by Bertolino and Gola (2008) and Santhoshkumar and Balasubramanian (2010).

As indices of quality of breeding pairs, we used residuals from a linear regression between either reproductive success or laying date on the index of physical quality of the nest site in each season.

Differences in nesting success between early and late nesters, center and edge nesters, and neighbors and non-neighbors were examined to determine if these differences only support the Information Center hypothesis, as has been suggested (Elgar & Harvey 1987; Doligez *et al.* 2003).

Student's t-test was used to analyze significance between nesting and non- nesting trees. Pearson correlation co-efficient was used to find out the relationship between the total number of nests in a tree and other parameters. The first three highly correlated parameters were again entered into multiple stepwise regressions with the total number of nests as the dependent factor and the selected parameters as independent factors responsible for the nest site selection.

4.3. RESULTS

4.3.1 Breeding season and start date of arrival at the breeding grounds

Breeding season of the Spot-billed Pelican ranged between October and March at Uppalapadu heronry. The arrival of the Spot-billed Pelican at study site was end of September (Table 4.1).

Table 4. 1. Arrival date of the Spot-billed Pelican at Uppalapadu

Year	First week of September/ Date of first appearance	No of individuals	Last week of September	No of individuals
2007-08	9.09.2007	9	27.09.07	20
2008-09	8.09.2008	3	26.09.08	76
2009-10	5.09.2009	6	26.09.09	95

Before starting nesting, arrived birds regularly roosted at the same site; so also on artificial trees. Breeding season of the Spot-billed Pelican

started when the Asian Openbill Stork (*Anastomus oscitans*) finished breeding and their fledglings seen in the colony sites.

4.3.2 Establishment of colony

Progressive increase in number of the Spot-billed Pelican was observed from 1999 onwards. Since 1999 Uppalapadu was known for the Spot-billed Pelican with increase till 2007 and fluctuating in the later years (Fig 1).

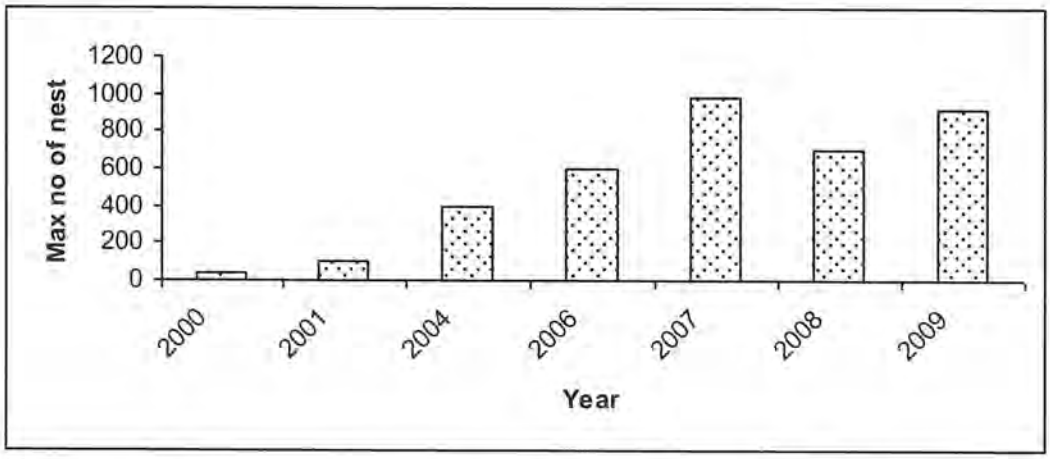


Fig. 4.1. Number of nests of the Spot-billed Pelican at Uppalapadu.

The nesting population expanded to near by school area having nesting trees. At Uppalapadu size of the colony was stable with slight fluctuation during the study period.

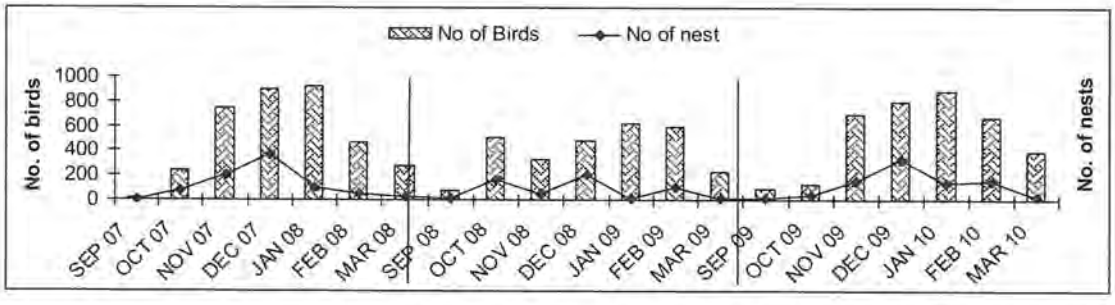


Fig. 4. 2 Breeding population of the Spot-billed Pelican at Uppalapadu during 2007-2010.

In 2008 formation of a new colony was also observed at Ramachandhrapalayam about 2 Km from Uppalapadu. During 2008 two

out of the four artificial trees, newly planted, were immediately used by pelicans.

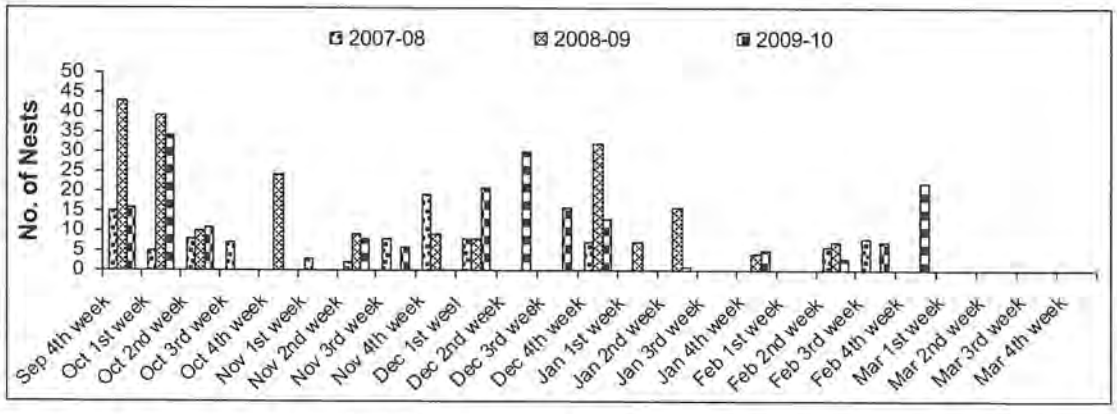


Fig. 4. 3 Number of nests of the Spot-billed Pelican in different weeks of the breeding season

The Pelicans breed asynchronously, showing a marked tri model pattern in each year i.e. In 2007-08 the peak number of nests was observed in the 4th week of September, second peak in the 4th week of November and 3rd peak in mid February with a nest number of eight. In 2008-09 the 43 to 39 nests were observed in the 4th week of September and in the 1st week of October. 2nd peak was observed in the 4th week of December with a nest number of 32. In 2009-2010 the highest peak was observed in the 1st week of October with 34 nest and 2nd and 3rd peaks with 21 and 22 nests respectively in the 4th weeks of December and February (Fig. 4. 3). Fig. 4. 4. shows the number of active nests during the breeding season, along with the total precipitation in each month during the nesting season. It clearly showed three peaks of laying in 2007-08, 2008-09 and 2009-10 with the maximum number of nests observed closely being 32, 73 and 80 respectively. The peak nesting periods of the Spot-billed Pelican was November, October and December in the three years respectively. The peaks were mostly after the onset of northeast monsoon and when monsoon was receding.

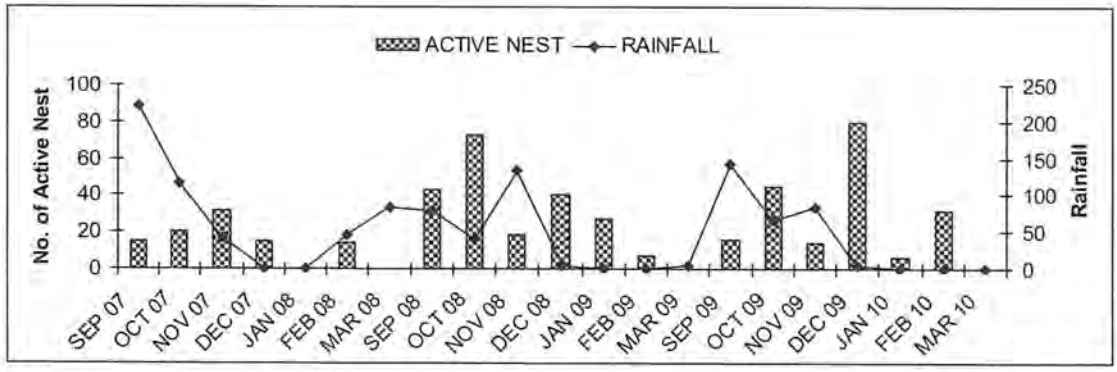


Fig. 4. 4. Rainfall and active nests of intensive observation during the breeding season at Uppalapadu.

4.3.3 Breeding sub-unit

The nests are contiguous and formed clusters or sub-units ranging from 2 to 25 nests. Single nest was found when the other nest in the cluster was deserted. Totally 22, 17 and 42 clusters were studied for size frequency during 2007-08, 2008-09 and 2009-10 respectively. In a breeding colony there were several units of different sizes within which birds laid more or less synchronously. Units were defined according to their laying dates and spatial distribution. Mean colony size of present study was 3.14 ± SD of 2.41 nests in 2007-08, 2.43 ± 1.51 in 2008-09 and 3.50 ± 2.35 in 2009-2010. The most frequent size of a breeding unit was 2-5 nests in 2007-08 and 2008-09. In 2009-10 the breeding unit size was 6-10 nests. The largest breeding unit of over 21 nests was recorded in 2009-10 at artificial nest platform. Widely observed nesting unit of 6-10 accounted for 44%, 39% and 57% of all the units counted from 2007-08, 2008-09 and 2009-10 respectively (Fig. 4. 5).

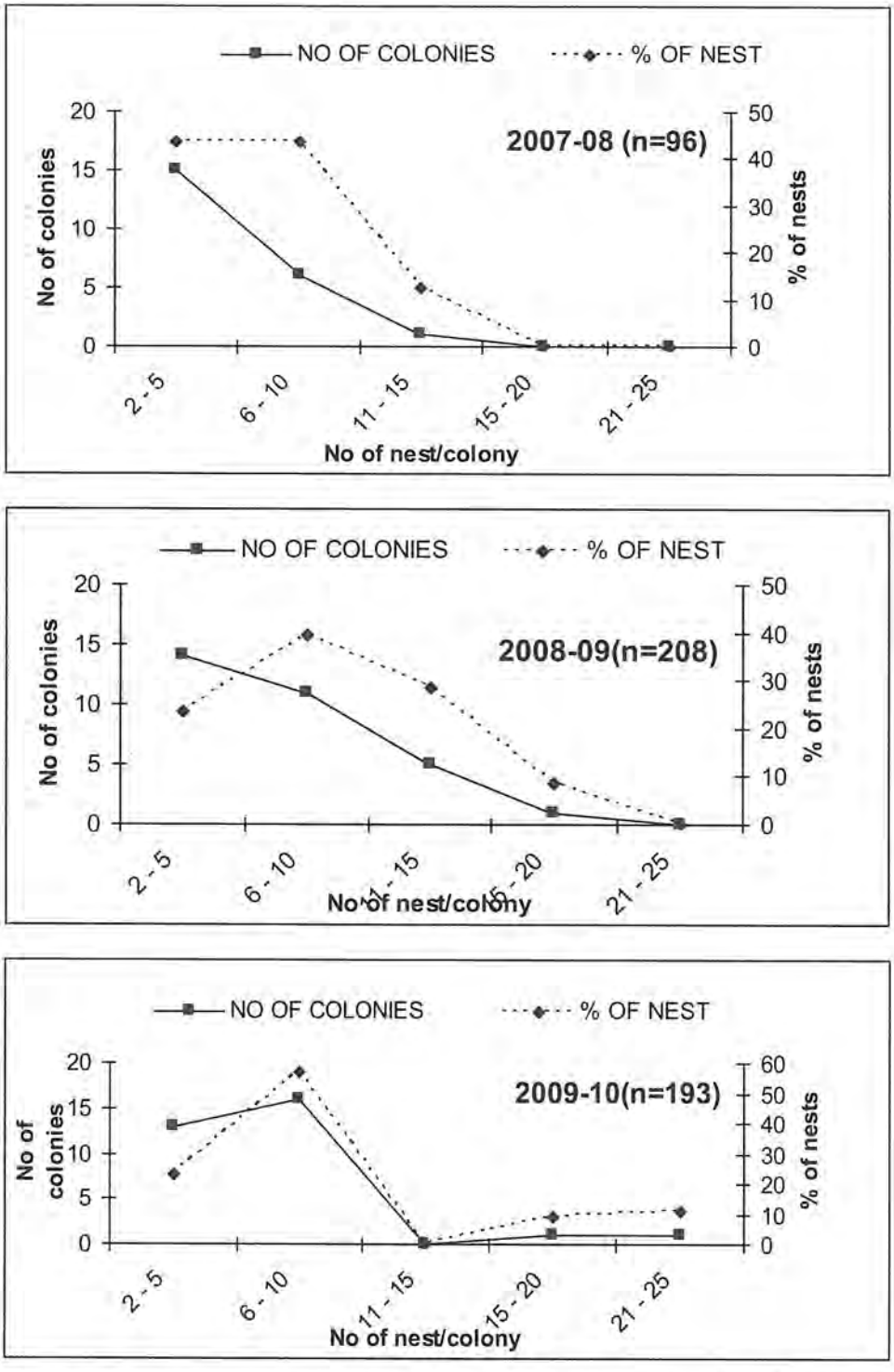


Fig. 4. 5. Size frequency of nest units/cluster and % of observed unit size frequency for 2007-08, 2008-09 and 2009-10.

4.3.4 Nesting substrate and nest tree preference

In Uppalapadu the Spot-billed Pelican nest was mostly recorded on *Prosopis juliflora and Pithecellobium dulce.* Nesting attempts were observed on *Delonix regia.* Other than that nests were observed in artificial iron platforms. Though the supporting structure was placed since 2004, Spot-billed Pelican started nesting on it from 2007 following Darter's (*Anhinga melanogaster*) nesting attempt on it.

Pelican largely preferred to nest mostly in top canopy though a few sub-canopy nests were also observed (Table 4. 7). Incidentally ground nesting of Pelican was also observed *(Pers. obs*). In 2007, a total of 96 nests were located of which 75% nests were found in *Prosopis juliflora,* 21% in artificial tree and 4% in *Pithecellobium dulce.* In the subsequent year 133 out of 213 (62 %) were found in artificial poles, 29% in *Prosopis juliflora;* 6% nest were found in *Pithecellobium dulce* and 2% nests were found on ground. In the 3rd year the maximum number was found in artificial poles with 69 % followed by *Prosopis juliflora* 24% and 7 % in *Pithecellobium dulce* (Table 4. 2).

Table 4. 2. Percentage of nest observed in different substrate

	% of nests		
Nesting substrates/ Years	2007-08	2008-09	2009-10
Artificial trees	21	62	69
Pithecellobium dulce	4	6	7
Prosopis juliflora	75	29	24
Ground	-	2	-
Total number of nests	96	213	176

Density of nesting trees showed variation on different mounds (Table 4. 3); *P. juliflora* was the dominant tree and *Pithecellobium dulce* was rare and occurred on only a few mounds.

Table 4. 3. Nest tree density at Uppalapadu

Sites	Area (m^2)	Total tree density	*Prosopis juliflora* Density	*Pithecellobium dulce* Density
M1	110.24	0.0363	0.02721	0.00907
M2	108.15	0.0462	0.04623	0
M3	219.57	0.0592	0.05921	0
M4	238.03	0.0126	0.0084	0.0042
M5	54.67	0.0549	0.05487	0
M6	197.81	0.0253	0.02022	0.00506

Out of the 14 mounds 3 were free from vegetation. A total of 148 nests were observed till the young fledged. Preference test for nesting tree showed preference for the two nesting tree species, namely *P. juliflora and P. dulce* (Ivlev's index; Table 4. 4). More nests were located in the patches with abundant *P. juliflora.*

Table 4. 4. Ivlev's index value of nest tree preference

Trees	2007-08	2008-09	2009-10
P. juliflora	0.395	0.395	0.463
P. dulce	0.5	0.5	0.5
Artificial trees	0	0	0

4.3.5 Nest-site characteristics of the Spot-billed Pelican

Spot-billed Pelican is a large waterbird, preferably nest in larger trees. Totally 180 nests in 2007-08, 246 in 2008-09 and 231 nests in 2009-10 were studied for nest-site characteristics. Stratification in the location of nests was observed; In 2007-08 23% nests were placed in the lower strata below 1 m height; 66% at the height of 1 – 3 m and 11% above 3 m height. Similarly nest placement in 2008 and 2009 also showed maximum use of the height of 1 – 3 m (Table 4. 5).

Table 4. 5. Percent of nests located in different height classes

Nest height (m)	2007-08	2008-09	2009-10
Below 1	23	13	12
1 to 3	66	46	48
Above 3	11	41	40
Total No. of nests	180	246	231

Early arrivers preferred nesting in higher trees while late nesters used comparatively lower tree heights. Tree variables such as tree height and tree DBH were recorded for 36 nest trees and 17 non-nesting trees (Table 4. 6) and analysis showed that significant variations in the tree height ($t_{0.74}$= 3.466, df=72, p<0.001) and DBH ($t_{2.03}$=4.968, df=72, p<0.001).

Table 4. 6. Tree variables of nesting and non-nesting trees

	Tree variables	Tree height(m)	Tree DBH(m)
2007	Nest site variable	1.86 ±1.51(36)	.341±.466(28)
	Non-nest site variable	1.51±1.18	0.17±0.093
2008	Nest site variable	3.93±3.30 (40)	1.325±1.078(31)
	Non-nest site variable	1.66±0.91	0.17±0.798
2009	Nest site variable	4.35±3.27(42)	1.361±1.071(36)
	Non-nest site variable	1.79±1.50	0.25±0.41

Among nest-site variables tree height, DBH, distance form path, nest height, nest position in the tree such as canopy, sub-canopy and placement in the tress such as lateral or vertical branches were tested with the number of nests found in the tree. Among the nest site variables tree height, DBH and distance from path showed positive correlation (p<0.01) with the number of the nests found in a tree (Table 4. 7). The stepwise multiple regression procedures delineated tree height, distance from path and DBH as important factors that influenced most the nest-site selection of the Spot-billed Pelican in Uppalapadu (Table 4. 7).

Table 4. 7. Number of nest vs tree variables

Dependent Variable	Regression equation	R^2	*P*<
Total number of nest per tree	0.468 tree height	0.219	0.004
	0.577 distance from path	0.114	0.023
	0.518 DBH	0.184	0.001

Nesting ecology was studied from 9 mounds, one bund and 4 artificial trees based on accessibility and unobstructed view. Each mound was irregular in shape and area of the mound varied from 21.81m^2 to 1289.6m^2 (Mean276.74 ±SD 371.91) and mainly covered with *P. juliflora* in contact with open water (Table 4. 8).

Table 4. 8. Size of mounds and Number of nests in different years

Breeding site	Area (m^2)	2007-08	2008-09	2009-10
Artificial tree 1	-	10	5	6
Artificial tree 2	-	9	9	7
Artificial tree 3	-	0	59	47
Artificial tree 4	-	0	60	61
Mound 1	181.74	9	12	0
Mound 2	232.17	14	16	13
Mound 3	28.62	12	7	0
Mound 4	1289.60	6	16	17
Mound 5	232.17	8	3	10
Mound 6	21.812	14	16	13
Bund	136.037	14	10	2
Mound 7	304.81	59	32	48
Mound 7	-do-	7	0	0
Mound 8	35.726	10	4	7
Mound 9	304.81	8	0	0

Spot-billed Pelican normally built their nest centrally and on artificial trees first. Nests were deserted or changed when the human intrusion was more inside pond or in boundary.

4.3.6 Spatial and temporal distribution of nests

The spatial distribution from 2007 to 2010 of breeding units and number of nests within a unit is presented in Fig. 4. 4. Nest initiation, laying dates, re-nesting attempts were studied through out the season. The temporal distribution of the breeding units is linked closely with the attempt of the birds that lost their first clutch or brood and may have renested in some years. The bright white plumages of adult breeding birds disappear when breeding season advances and the birds turn gray in colour. Initially the dark gray or the black dots appear in the mantle region. This was considered as to note the re-nester or late nester. But this needs to be confirmed with marking study. Rainfall is considered as one of the stimulating factors for the arrival of the birds at their breeding grounds.

Spatial patterns of 180, 249 and 231 nests were studied in 2007-08, 2008-09 and 2009-10 respectively (Fig. 4. 4). They preferably nested in top canopy in this study area, but sub-canopy nests were also found in 2007-08 (n=28), 2008-09 (n=111) and 2009-10 (n=97). In general, nests were placed in artificial tree (pole) and subsequently occupied nesting trees which were far from path. Disturbances by human activity cause birds to desert a site or use very less frequently for nesting. At many breeding sites, namely boundary, mound 3 and mound 1 breeding activity declined regularly until the site was abandoned completely. This was because these sites were more near to intrusion route. The mound size and accessibility by path also played important roles. For example, mound 3 harboured 12 nests in the first year while the number went down in the subsequent year. Increase in number of nests was observed in artificial trees.

4.3.7 Courtship

Adult birds reached the breeding ground with bright yellow bill and white breeding plumage. Crest of the pair is grey. Small variation in male and female is seen during courtship period when male will have bright yellow ring around eyes. Female has slightly slender body compared to male. At the end of breeding season the plumage turn into gray. Courting males often use multiple signals to advertise their quality to females. A group of birds gather at suitable nesting sites and defend a small territory; simultaneously visual and vocal display will be carried out by the individuals when the female selects its pair. A Competitive 'lek' performance was observed in the Spot-billed Pelican. Lek assemblage was observed during breeding season. Lek size went up to 32 birds. Group size varied according to the occupied nest site, bigger and larger platform supported more birds.

At nest site unpaired male arrives and it will be almost selected site for nesting. It is observed that before commencing nesting activity they roost continuously at same location. During initiation one of the pair performs neck down sway in which it holds the twig or nest substrate and shakes the head vigorously in between the legs. It usually looks like arranging nest material or egg. After getting the first signal the unpaired individual rushes to the spot. It will be initiated by one or more individuals at a place. The male looks more attentive to receive the pair as it continuously claps its bill and shows open mouth to entering partners. Clapping bill may be to attract the partner. The male will defend the mate from others in the lek group by pecking them and holding the neck of the partner by bill or by neck arch. Bowing display indicates the acceptance and this greeting will be followed whenever the partner returns from outside. When the pair manages to land on nesting site male makes circular flight over nest sites both clock-wise and anticlock-wise. During this whole set of activity nesting partner at nest site shakes its raised wing and some times bill gape is used as threat display

to the near by nesters. Number of head sway and bill clap gradually decrease when both are engaged in nest-making. After partner defense each pair will defend its own nesting place in nest site where the lek occurred. Spot-billed Pelicans nest in clusters with other species in group and use pecking and extending bill as their mode of guarding their nesting territory.

4.3.8 Mating

After pair formation mating was observed. Mating occurred throughout the day with the maximum number of mating activities between 8.00 and 10.00 h and 13.00 and 14.00 h. Of the total 47 mating observations, the average time spent was 18 seconds ranging from 0:00:05 to 0:00:33 seconds. Usually courtship starts while pairing; the male grabs neck of the female by bill and climbs on it.

In this study extra pair copulation was recorded four times. This occurred in the absence of nest partners of nests in the same breeding unit. Usually nest sitters defend this by standing up and or by peck. Forced copulation with nestling by adult was also observed in two incidences.

4.3.9 Nest-building

Generally male partner make more effort in nestbuilding activities. Female gets the nesting material by bill and holds firmly by the feet in the initial stage. It first aggregates all the sticks, make platform and make the circular depressed nest by sitting and arranging nest material in the periphery. Then it is lined with the tender leaves of *P. juliflora*, *Eucalyptus sp* and *Eichhornia sp.* Attempt to get (snatch) nest material from others landing in the nearby nests was also observed in cluster unit. Such stealing of nest material was observed during building stage and in a well built nest it drags the twig into its own nest. The frequency of addition of material to the nest decreases after initiation of incubation. Spot-billed Pelican collects the nest material mainly sticks from the shallow surface of tank or from water surface and ground. They also

collect nest material from used or old nest of the Asian Openbill, Painted Stork and deserted nest of the Spot-billed Pelican. One nest was observed with polythene paper and rubber pieces; in one incident cloth piece was also used. Spot-billed Pelican used feather for lining the nest.

Spot-billed Pelican collected the stick from water by using bill submerged and head submerged search. In the mound surface it walked and collected the nest material. It collected Nest material individually. But many followed the successor. In one incident larger forked branch was dragged by 4 to 8 individuals.

In general, nests were constructed in the top canopy and a few sub-canopy nests were also observed. Ground nests were supported by stone which was placed to stop erosion and layers of sticks were added up. Nesting activity was observed in the end of the breeding season also. After hatching nest intactness increased because of excreta and waste food material and the nest appeared white. At the age of 25 to 30 days, the chicks moved in and around the nest. It was observed that chicks arranged nest material along with parent. After developing the perching ability 45 to 50 day old chicks played with nest material, dragged it with other sibling in the unit. And slowly it droped the nest material one by one. In four incidents nest was defended by the chicks from the stealing adults in the breeding unit.

4.3.10 Egg, laying and incubation

The eggs of the Spot-billed Pelican are chalky white and broad elongate oval in shape. Colony visit made by Management people was opportunistically used to study the clutch size. The entire visit did not exceed more than 15 minutes as the entry was to rescue trapped bird from the tree guard, dead bird collection and removal of *Eichhornia*. In 2007-08, six nests placed in the dry Prosopis tree base above water surface were studied. In 2008-09, 12 nests were checked and in 2009-10, 6 nests were studied and found 3 eggs. Egg laying was not observed directly as the location was higher than the view points. Egg laying

started after 4 to 7 days of nest building. It was assumed from firm sitting on egg and egg arrangement by the nest sitter. It took 4 to 6 days to complete the clutches of three eggs.

Incubation started after laying first egg and both the parents were observed to incubate the egg. The mean incubation period of the Spot-billed Pelican in the present study was 29.7±0.8 days (n=24). Incubating bird sat in the nest with puffed wing. Slight wing shakes were observed during the disturbance caused by neighbors. It may be also to regulate the temperature inside the nest. The incubating bird sat firmly and arranged nest material in front of and sides of the nest and used the bill to arrange the nest under feet. The nest sitter spent most of the time in sleeping during which it placed the bill at the back by turning the head 180° C. Some times it kept it in front and above the crop or breast. The most observed activity was preening. At the end of incubation it threw the waste and raised wing shake was observed. Aggression during incubation was less with other species; an incident of ceasing of Black-headed Ibis *Threskiornis melanocephalus* (3 times), Asian Openbill *Anastomus oscitans* (3), Painted Stork *Mycteria leucocephala* (1) and Crow *Corvus splendens* (1) was observed. With other Pelicans in the unit out of 218 aggressive acts 144 times fight with others was with bill bite and pecking; 74 times threat displays such as open wing-flap, raising, extending neck and extending bill were observed.

4.3.11 Hatching

Hatching occurred asynchronously. From the developed chicks variation between first and third chicks was studied. Most of the eggs hatched within an interval of 24 h, but also at an interval of 2 to 3 days. Egg losses were mainly by *Corvus splendens* in a disturbed colony. In 2008, 2 nests with 3 eggs each were left unattended. Rolling of eggs from the nest was not observed.

4.3.12 Nesting success

Nesting success was calculated from nests with 25 to 30 day old nestlings, as the young one was able to move and aggregate with other chicks in the colony. During 2007-08, 2008-09 and 2009-10, the nesting success ranged from 42 to 93% productivity.

4.3.13 Brood reduction

More chicks were lost due to starvation or some unknown reasons (Table 4. 9). Chick predation by Crow and Black-crowned Night Heron *Nycticorax nycticorax* were observed. Crow enters the nest colony followed by the human intrusion. As the nesting bird gets agitated by human disturbance it flies away from the nest and crows use this chance to prey on the chicks. Generally the Spot-billed Pelican is not aggressive to the crows which feed on waste food material near to nest sites. On the contrary, crows chased the predators namely Black Eagle *Ictinaetus malayensis and* Eurasian Marsh Harrier *Circus aeruginosus* when they were seen hovering in and around heronry for chicks or eggs.

Table 4. 9. Brood reduction caused by predation and unknown reason

Years	Predated by other bird species	Starving or unknown reason
2007-08	4	6
2008-09	2	14
2009-10	2	12

4.3.14 Parental care

Chick is altricial and adult bird gives utmost care. Both parents participate in feeding and rearing the chicks. Peeping frequency of adult birds inside nest increases when an egg hatches.

The adult adopts four methods to feed pre-digested liquid diet to the young ones. The immobile chicks were fed by the parent at the bill tip. For 1 to 3 day old chick a raised sitting adult placed the bill tip near

chick and fed. Chicks ingested food by bill touch. For 1 to 2 week old chick 'Crushing' parent regurgitated food to bill tip and placed it on the nest floor and crushed the food and fed in small pieces. As the growth advanced the adult bird vomited or regurgitated the food and the chick pecked and ate the food. Later the chick slightly extended its bill into mother's gullet and took food.

Gut feeding commenced when chicks grew up to 12 days. The parent stood firmly and extended its neck and facilitated the chick to get the food from its gut. The fallen nestling was also reared by the parents. They returned to the place where the chick rested and fed. Out of five fallen chicks all were guarded by their parents and feeding at fallen site also was observed; but none of them reached fledgling stage. It was noticed that parent fed the fledged chick in the non-nesting site and also in the open water. In some cases both the chicks inserted the bill inside the mother's gut. Competition between siblings was noticed as they pecked or bit each other's bill and competed to insert the bill. To get attention of the parent, the chicks bit its bill, eyes, legs and pouch.

4.3.15 Breeding success

Spot-billed Pelican chicks took 10 to 11 weeks to fledge. During 2007-08, 2008-09 and 2009-10, the annual productivity (fledged chick per nest) was 1.85± 1.18 (0.86-2.33), 1.76 ±0.49 (1.00-3.00), 1.62 ± 0.77 (0.00-3.43) respectively. In the 2nd year and 3rd year productivity decreased slightly due to more intrusion during breeding season. Nests located at the center of island and devoid of intrusion area succeeded to produce 3 fledglings. Multiple stepwise regression analysis showed that tree height, tree density, nest height, tree DBH and rainfall had significant influence on breeding performance of the Spot-billed Pelican (Table 4. 10).

Table 4. 10. Results of a stepwise multiple regression analysis with breeding success as the dependent variable and date of initiation (days), size of nest unit, area, tree density, tree height, DBH, nest height, distance from dikes and amount of rainfall (mm) and temperature(°C) during the study period as independent variables.

Breeding Success	Independent Variables	Regr. Coeff. ± SE	Std. Coeff.	T	P<
2007-08	Constant	-6.56±3.527		-1.861	0.105
	Date of initiation	-0.001±0.004	-0.101	-0.285	0.784
	Nest unit	-0.024±0.046	-0.144	-0.530	0.612
	Area	5.19±0.000	0.034	0.134	0.897
	Tree density	-8.41±0.000	-1.079	-0.465	0.656
	Tree height	0.021±1.463	0.098	0.014	0.989
	Nest height	0.795±1.366	2.781	0.582	0.579
	DBH	-1.765±0.644	-2.189	-2.741	0.029
	Distance from dikes	0.018±0.009	0.754	1.976	0.089
	Rainfall	-0.007±0.006	-0.998	-1.325	0.227
	Temperature	0.271±0.140	1.376	1.930	0.095
2008-09	Constant	6.884±4.418		1.558	0.158
	Date of initiation	-0.036±0.011	-0.832	-3.197	0.013
	Nest unit	-0.017±0.011	-1.227	-1.535	0.163
	Area	0.001±0.001	0.326	1.129	0.292
	Tree density	0.000±0.000	-1.863	-1.486	0.175
	Tree height	0.069±0.237	0.423	0.289	0.780
	Nest height	0.159±0.156	0.619	1.018	0.338
	DBH	0.972±0.363	1.870	2.673	0.028
	Distance from dikes	-0.008±0.005	-0.335	-1.434	0.189
	Rainfall	-0.005±0.004	-0.486	-1.100	0.303
	Temperature	-0.156±0.141	-0.794	-1.108	0.300
2009-10	Constant	3.246±2.083		1.558	0.163
	Date of initiation	-0.008±0.007	-0.503	-1.288	0.239
	Nest unit	-0.015±0.015	-0.214	-1.008	0.347
	Area	-0.001±0.001	-0.507	-1.242	0.254
	Tree density	0.000±0.000	-1.072	-0.310	0.766
	Tree height	-0.322±0.902	-1.801	-0.356	0.732
	Nest height	0.530±0.194	2.039	2.731	0.029
	DBH	0.208±0.909	0.361	0.229	0.825
	Distance from dikes	-0.010±0.016	-0.223	-0.603	0.565
	Rainfall	-0.009±0.006	-0.824	-1.580	0.158
	Temperature	0.018±0.072	0.087	0.256	0.805

Model:2007-08;R^2=0.62;$F_{1,17}$=1.57;df=;P<0.281

2008-09;R^2=0.78;$F_{1,18}$=2.85;df=;P<0.075

2009-10;R^2=0.83;$F_{1,17}$=1.57;df=;P<0.051

In the resulting model three independent variables, Tree height, nest height and DBH had a significant effect on breeding success ($F_{1,17}$ =1.57, P<0 .281) during 2007-08, but it explained only 69% of the variation. Nest height and DBH correlated highly with breeding success (Table 4. 10). In 2008-09, ($F_{1, 18}$=2.85, P<0.075), nest height, DBH and tree height explained 78% of the variation showing significant effect on breeding success. During 2009-10, ($F_{1,17}$=1.57, P<0.051) above mentioned variables explained 84% of the variation showing their significance in determining breeding success.

4.4 DISCUSSION

4.4.1 Arrival and breeding season

Breeding Pelicans arrived at Uppalapadu during end of September and October after the north east monsoon. Birds arrived at the breeding ground when nesting activity of the Asian Openbill was at peak in the Heronry. However, the initiation was October/November and lasted up to May/June in Nelapattu Sanctuary (Ali & Ripley 1978; Nagulu 1983; Nandakumar *et al.* 2009). But arrival is reported in December at Vedanthangal (Paulraj & Gunasekaran 1988) and late September in Assam (Das 1991). Usually Spot-billed Pelicans begin courtship in the first week of October; Birds started arriving in smaller numbers in the first week of September and increased gradually in all the three years. But the number increased in November and December when birds arrived in large groups as observed in Dalmatian Pelican (Crivelli *et al.* 1998).

4.4.2 Nest number and colony establishment

Colony establishment varied in different individuals and groups. These variations in readiness may reflect levels of net energy within different groups of arriving pelicans resulting from (1) different age groupings (Knopf 1979); (2) variable energy supply and demand conditions on the wintering grounds; (3) differences in migration distances traveled; (4)

variable energy supply and demand conditions during migration; and (5) variable energy supply and physiological demand conditions of the courtship activities as explained by Diem and Pugesek (1994).

Breeding of the Spot-billed Pelican was first recorded at Uppalapadu in 2000 (Rao 2002). Estimation of nest number was regularly studied (Rao & Ramana 2000; Rao 2001; Rao 2005; Taher 2007). It is believed that this colony may have been formed by birds which abandoned Kolleru in 1970 (Guttikar 1978; Kannan & Manakadan 2005). The fewer nests in 2008 might be because of the formation of a new colony at Ramachandhrapalayam about 2 Km from Uppalapadu. Although a shortage of suitable nest-sites cannot be demonstrated with the available data, immediate use of two out of the four artificial trees by pelicans in 2008 might indicate a potential shortage of nest-sites.

The nest establishment /phenology show asynchrony of breeding in the Spot-billed Pelican. Rainfall has positive impact in nesting activity of birds (Sharma & Raghavaiah 2002). The occurrence of three peaks in the breeding season of the Spot-billed Pelican cannot be explained by the abandonment of nests due to work in the colony in first year, as the gradual increase in breeding population was observed. There are two possibilities to explain the two periods of nesting: (1) that a new group of pelican took over the nest site and (2) the occurrence of second and repeat clutches. Although the pelicans were not marked, the concordance between the number of nests in each period and the maximum number of adults were counted, as well as the fact that most second peak clutches did not start until nestlings from first clutches had fledged, suggest the double peak was caused by the successful breeders, each laying a second clutch. The other clutches from the second peak were probably repeated attempts by the failed pairs in the first period. Synchronized arrival is reported in the American White Pelican (Evans & Cash 1985; Evans 1996) and Dalmatian Pelican (Crivelli *et al.* 1998; Peja

et al. 1996). But it is difficult to establish the occurrence of new nesting or re-nesting with out a marking study.

4.4.3 Breeding sub-unit

Breeding space is generally considered as a proximate factor in colony size limitation (Grieco 1999). As observed in Sandwich Tern there is no correlation found between sub-colony size and duration of laying. The average duration of laying within a sub-colony varies relatively irrespective of size, suggesting there is a limit to the growth of a sub-colony determined by the difference in breeding cycle (Langham 1974). Birds can choose to nest very close to others because the quality of breeding habitat depends on the presence of nesting conspecifics; extra pair fertilization and density which offers protection against predators (Velando & Freire 2001). In American White Pelican group variations may be a function of the extent of solid lake-ice connections with the mainland or wind blown lake-ice jams connecting the islands to the mainland (Diem & Pugesek 1994). Increased productivity may result simply because large colonies form only where foraging and nesting conditions are most conducive to raising young. The failure of small colonies may result not from insufficient information exchange but from inadequate pairing processes (Hall 1970), a higher proportion of inexperienced breeders (Finney & Cooke 1978; Vermeer *et al.* 1988; Gilchrist *et al.* 1994; Kildaw *et al.* 2005; Lehikoinen 2006) or a lack of social stimulation (Hailman 1964; Bayer 1982). Decreased social stimulation at the end of the breeding season reduced breeding success (Crivelli *et al.* 1998). Nesting pelicans arrange themselves into discrete aggregations. These groupings of nests may partially reflect variations in physiological readiness between birds in various nesting groups (Diem & Pugesek 1994).

4.4.4 Nesting substrate and nest tree preference

At Uppalapadu the Spot-billed Pelican constructed their nests in *P. juliflora* in higher proportion than *Pithecellobium dulce* (Table 4. 3). The Spot-billed Pelicans are arboreal nesters (Nagulu 1983; Ali & Ripley 1987). Generally they nest on large trees such as *Tamarindus indicus, Azadirachta indica, Acacia nilotica, Ficus bengalensis* and *Borassus flabellifer.* Nesting on *Barringtonia acutangula* a mangrove sp, was observed in Nelapattu (Nagulu 1983; Manakadan & Kannan 2003). Manakadan and Kannan (2003) reported 21 nesting tree species used by the Spot-billed Pelican in its' southern distribution. Unusual ground nesting of the Spot-billed Pelican was also recorded during the study. Australian, Dalmatian, Great White and American White Pelicans usually nested in ground (Brouwer *et al.* 1994; Nelson 2005). In the absence of vegetation Brown Pelicans nested in ground (Visser *et al.* 2005). Unusual ground nesting is also reported in Ardeidae in safer nesting sites. Ground nests are observed in inaccessible salt marshes or islands removed from mammalian predators (Burger 1981); in wading birds successful ground nesting occurs only if the nests are protected against predators by extensive areas of barriers surrounding the nesting site such as water cover and dense undergrowth (Hafner 1997).

4.4.5 Nest-site selection of the Spot-billed Pelican

The selection of nest site is an important task in colonial breeders (Venkatraman 2007). This Pelican used larger trees available, taller and thicker, for supporting these heavy birds with chicks. Distance from path was also related for protection of the nest from disturbance to have successful breeding. Colonial breeders selected age-old and thick canopied trees regardless of plant species in Vedanthangal Lake (Venkatraman 2007). Similarly it was observed that nesting sites were repeatedly used in subsequent years. But in the case of artificial platform earlier success played a key role in selection along with supporting many

nests. Site selection by colonial seabirds is often influenced by social cues (Ward *et al.* 2010) and site tenacity; birds reusing previously successful breeding sites, and group adherence — birds nesting with the same sets of neighbors (Visser *et al.* 2005).

4.4.6 Spatial and temporal distribution of nest

Quantifying the spatial distributions of organisms in simple and meaningful ways is important for understanding the ecology and habitat needs of species subject to anthropogenic disturbances (Payne *et al.* 2005). Birds breeding on the outer boundary are especially susceptible to predation, as usually important mammalian predators such as dogs and monkeys are unable to reach an inner mound which is surrounded by water. Patch quality may not be directly related to patch substratum, but to the presence of different potential factors that may vary in time and space (Boulinier 1996). First, compared to older, experienced breeding adults, young pelicans eligible for recruitment as members of the breeding population typically achieve initial breeding readiness later than experienced breeding adults (Diem & Pugesek 1994). Secondly, optimal nesting space is also limited. Thus, delayed reproductive readiness limits nest-site selection to marginal nesting areas. Marginal sites are most often subjected to flooding during nesting, egg laying, or even after hatching as observed by Diem and Pugesek (1994).

4.4.7 Breeding biology

Meteorological trigger for migration at the breeding grounds may be related to deteriorating living conditions, including food availability and habitat suitability, the migratory flight conditions or a combination of these (Owen & Black 1990). In Spot-billed Pelican it was observed by Nandakumar *et al.* (2009).

4.4.8 Courtship

Spot-billed Pelican is a monogamous bird. Pair formation occurs at the nest site as reported by Nagulu (1983) and Nelson (2005). Incidents of forced copulation by adult to young one and then to other pair was

observed as in American White Pelican (Somers *et al.* 2007). First breeding is reported to be at the age of three years (Schreiber 1977). Both the sexes look alike (Ali & Ripley 1987; Nagulu 1983), but slight variation could be observed.

4.4.9 Nest making

Building nest is by available or old nest material from tank or ground. Collecting nest material from in and around the school clearly shows that it uses the source which is available nearby for nesting.

4.4.10 Incubation

Development of brood patch was not observed and it is confirmed that incubation took place by the feet (Nagulu 1983). Brown Pelican and Dalmatian incubate their egg with vascularized legs (Evans 1989; Crivelli *et al.* 1998; Nelson 2005). Incubating adult did not have much activity as it spent most of the time in sleeping. At the end of incubation the adult peeping frequency inside nest increased. Billing the eggs or young included instances where the parent merely touched or nibbled nest contents and instances where the parent physically pushed back the eggs and, on occasion, even a new young. All of the above activity, with the probable exception of preening while sitting, appeared to have potentially important implications for the amount or effectiveness of temperature regulation applied to the eggs or young by the parent (Evans 1989).

4.4.11 Breeding success

Spot-billed Pelicans preferred the artificial platform and taller trees available as nest sites for the early arriving individuals or groups. Their choice of prime, high-elevation nest sites may limit species arriving later in the season from using these sites. Breeding in three consecutive years showed tree height, nest height and DBH as significant factors influencing breeding performance of the Spot-billed Pelican. The distance from path, although important in selecting nest site, was not correlated

with breeding success like other studies (Pearce-higgins *et al.* 2007) because the habitat inside also had equal level of intrusion.

Breeding score is considered an indicator of territory quality. In the studied colonies, the number of feeding visits was the most important factor affecting breeding success. Chick mortality significantly decreased with increasing number of feeding visits per nest in Grey heron (Jakubas 2005) which relate to less sibling aggression (Jakubas 2004). However, there are some other external environmental factors (natural enemies, such as predators and parasites, atmospheric conditions, illness and human disturbance) and intrinsic factors (clutch size, age structure of local population) independent of food abundance which affect the breeding success. Less human interference may affect pelican colony disruption (Kushlan & Frohring 1985). Need of natural vegetation (Visser *et al.* 2005) and threats to the nesting tree (Subramanya 1996; Rao 2002) have to be considered for the conservation of this species.

Plate 1

NEST SITES OF THE SPOT BILLED PELICAN

Nesting in *Barringtonia* sp (Nelapattu)

Nesting in *Prosopis juliflora* (Uppalapadu)

Nesting in *Tamarindus indica* (Telineelapuram)

Birds at *Borassus flabellifer* (Kolleru)

Ground nesting by the Spot-billed Pelican

Sub-canopy nest by the Spot-billed Pelican

FORAGING BEHAVIOUR AND FOOD OF THE CHICK

5.1 INTRODUCTION

Any living organism requires considerable amount of energy for the survival and reproduction. Birds living in mosaic of natural habitat patches may face space and time constraints while securing their energy requirements. Therefore, foraging strategies adapted by birds are one of the major interesting fields to explore (Soni *et al.* 2010). Specific fine scale habitat variables such as ridge and slough habitat, submerged vegetation, peat pop-ups, or solution holes were important to wading bird foraging site selection and also identified landscape characteristics which may act as visual cues guiding birds to higher quality foraging sites. Although strong habitat selection was apparent in this study, it is still unclear how these habitat variables may influence foraging success (Pierce & Gawlik 2010).

Generally, pelicans feed in flocks and in synchronized manner (Cottom *et al.* 1942; Ali & Ripley 1978; Ntiamoa-baidu *et al.* 1998; Battley *et al.* 2003; Nelson 2005). In American White Pelicans *Pelecanus erythrorhynchos*, nocturnal foraging adaptation was addressed with larger foraging flocks and bill dipping rates was high at night (McMahon & Evans 1992b). Kleptoparasitism was also recorded in American White Pelican (Brian *et al.* 1983; Anderson 1991) and in Brown Pelican. In American White Pelican, co-operative herding phenomenon for foraging behaviour is well established by Anderson (1991). In Great White Pelican (*Pelecanus onocrotalus*) foraging range was documented as 60 to 100 Km from their breeding colony (Hatzilacou 1996).

The Spot-billed Pelican (*Pelecanus philippensis*) is mainly a piscivorous bird (Ali & Ripley1978; Nagulu 1983). It usually feeds in lakes, marshes, rivers, inland wetlands, aquaculture ponds and shallow water habitat (Ali & Ripley 1978; Nagulu 1983; Manakadan & Kannan 2003). This chapter

describes mainly the diet composition and foraging behaviour of adults of the Spot-billed Pelican. Recent observations on movements, diet and feeding are combined with a literature review to provide a comprehensive framework for future research.

5.2 METHODS

Birds were studied for their habitat use in open water. Regular scans were made during the daylight hours made using spotting scope (Nikon 20x60). All feeding birds at observation sites were studied for flock size. Two and more than two birds foraging at synchronized directional movements also treated as a socially foraging flock as followed by Battley *et al.* (2003). Birds at social flocks were marked separated by their feeding and non-feeding activities and their patterns were studied. Characteristic feeding behaviour such as dipping bill, neck straightening, scooping with pouch, filtering water from bill and engulfing fish were recorded. Sometimes crushing the fish between the bills were also observed. Bill merged dip, head merged dip and neck merged dip were also adopted. Up-ending and circling were also observed very rarely in foraging group were also observed as foraging techniques.

In the analyses, feeding guilds of waterbirds are defined on the basis of information on the feeding style and sensory mechanism.

Fish found in the bird habitat were studied by using fishing net. Fish catch per attempts were applied to study the abundance and it was not presumed for *ad hoc* reasons.

Diet of young Spot-billed Pelican was studied from regurgitated food samples which were collected from below the nesting trees at the school zone adjacent to the bird habitat. Recently-fed Pelican chicks regurgitate their food if disturbed (Duffy & Jackson 1986; Findholt & Anderson 1995; Hatzilacou 1996). The fire-wood collectors and sheep-herders when entered the accessible nesting sites caused disturbance to the nesting birds; this opportunity was used to collect the fallen regurgitate food

material which was placed in a transparent plastic bag. Five such visits (4 occurred during 23rd to 25th February and one on 11th March 2010) yielded 72 food samples. The species were identified directly. Gut analysis was not carried out as no bird was sacrificed for this purpose. The prey species from regurgitate samples were identified and individually enumerated. The weight and length of each item were noted with the help of a Pesola balance and metric scale. The collected food samples were from 65 to 90 days old chicks. The samples were grouped into two rearing periods according to the stage of the chicks, earlier period (samples collected from 65 to 80 days old chicks) and later (samples collected form above 80 days old chicks).

Diet was studied for relative frequency by numbers (RFN), relative frequency of occurrence (RFO), and relative frequency by weight (RFW) of each prey species as follows:

$$\text{Relative frequency of numbers (RFN)} = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals of all the species}} \times 100$$

$$\text{Relative frequency of weight (RFW)} = \frac{\text{Weight of a species}}{\text{Total weight of all the species}} \times 100$$

$$\text{Relative frequency of occurrence (RFO)} = \frac{\text{No of samples in which the species occurs}}{\text{Total no. of samples}} \times 100$$

By calculating Index of Relative Importance (IRI) adopted by Findholt and Anderson (1995) each prey species were ranked. (IRI = (RFN + RFW) x RFO/200). The value of the IRI ranges from 0, when all three values are 0%, to 100 when all three values are 100%.

Prey size variation along the chick development period was tested by using Mann-Whitney U test.

5.3 RESULTS

5.3.1 Feeding techniques and flock size

The Spot-billed Pelican forage in flock or singly. (Ali & Ripley 1987; Hoyo *et al.* 1992; Nagulu 1983). The Spot-billed Pelican adopts four major feeding methods such as wings closed and strikes, wing opened and strikes and drives fish into shallows and sits on the ground, flies and catches in open water (Manakadan and Kannnan 2003). Totally 89 events of feeding with 1321 individuals were observed. Distinctive feeding behaviour observed in social flocks was listed (Table 5. 1). Pelican adopted bill merged feeding and mean flock size was 6.30±4.52. Scatter feeding is the second most used method and more individuals were observed 18.55±27.02 using it.

Table 5. 1. Occurrence of foraging flocks and number of individuals

	No of individuals	
Feeding methods	Flock size (Mean± SD)	No of individuals (Mean± SD)
Bill merged feeding	6.30±4.52	35.70±20.79
Bill merged and raised wing	1.50±0.58	4.00±2.16
Feeding group	12.45±10.29	17.95±23.31
Head merged	2.00±1.00	1.00±0.00
Moving	2.50±1.29	1.50±0.58
Neck Merged	5.29±5.02	3.71±3.20
Neck merged raised wing	1.00±0.00	5.33±1.53
Neck straightened	8.73±6.56	11.27±16.17
Scatter	11.50±8.09	18.55±27.02
Stable swim	1.57±1.05	3.76

Maximum types of feeding techniques used by the Spot-billed Pelican were bill merged (27%, 357 individuals) and in groups (28% 359 individuals) with a flock size of 1 to 16 individuals, sactter feeding (28%, 371 individuals with a flock size of 1 - 91 individuals and Neck straightening method is adopted by 124 individuals with a flock size of 1-22 individuals (Fig 5.1). 16 individuals used bill merged feeding and moved in row to detect the food. 4 individuals found feeding by head merged method; 6 individuals found moving. 26 individuals used neck merged feeding. 16 birds were found moving in a row and adopting neck

merged and wing raised methods. 124 individuals were observed neck straightening methods to capture the fish. In one incident three birds were observed moving in a row with neck straightening. 371 birds used observed scatter techniques to feed. 41 individuals were found adopting stable swim. (Fig. 5. 1)

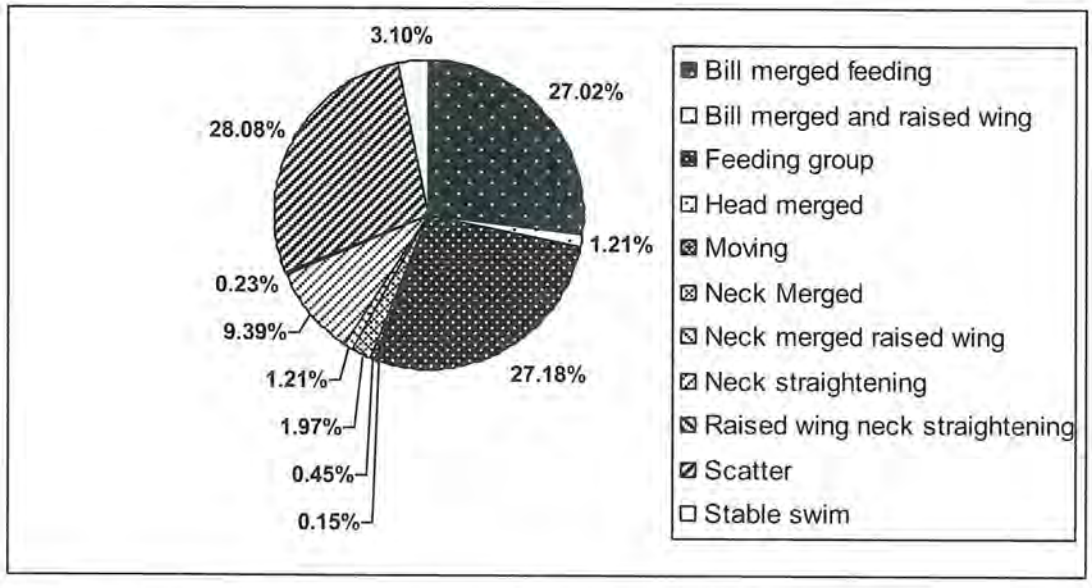


Fig. 5. 1. Feeding methods observed in the Spot-billed Pelican

5.3.2 Prey availability

No systematic measures to calculate fish abundance were made at Uppalapadu, due to small area and higher breeding bird density. By using fishing net, a single attempt was made to study the fish in the pond. Totally 18 fishes, 16 Asian Knifefish and 2 Long- snouted Barb were obtained from the tank. These fishes may be a probable prey item for feeding Pelicans at Uppalapadu. Chief fish fauna found in water reservoir was Long-snouted Barb *Puntius dorsalis,* and Asian Knifefish *Notopterus notopterus*. Magur *Clarias batrachus* was observed during low waterlevel period.

5.3.3 Food items

Species composition of the diet of the chick of the Spot-billed Pelican from regurgitate food samples was studied. Totally 72 fishes were identified coming under four species, namely *Oreochromis mossambicus, Cirrhinus mrigala, Puntius dorsalis* and *Labeo rohita.* Identification of prey items was done from samples collected in February (n=63) and March (n=9). Relative frequency of occurrence (in %), relative frequency of weight in two different rearing periods and relative frequency of number of species in each samples are given in Table 5. 2. & 5. 3. The *Oreochromis mossambicus* occurred in higher frequency 83% to 56 % in the two rearing periods respectively and lower frequency of 5 % was of *Puntius dorsalis* in earlier rearing period. Considering all the above frequency values IRI was calculated for all prey species and found that *Oreochromis mossambicus* (70.52), *Cirrhinus mrigala* (8.76) and *Puntius dorsalis* (1.07) were the most important prey in the earlier period, whereas *Labeo rohita* (70) had the highest IRI value followed by *Oreochromis mossambicus* (15) in the later period.

Table 5. 2. Relative frequency of number of species in early rearing period

Early rearing period (n=63 fishes)				
Species (N)	RFN(%)	RFW(%)	RFO(%)	IRI
Oreochromis mossambicus(52)	83	58.49	100	70.52
Cirrhinus mrigala(8)	13	39.85	33.33	8.76
Puntius dorsalis(3)	5	1.66	33.33	1.07

Table 5. 3. Relative frequency of number of species in later rearing period

Later rearing period (n=9 fishes)				
Species (N)	RFN(%)	RFW(%)	RFO(%)	IRI
Oreochromis mossambicus (5)	55.56	5.32	50	15
Cirrhinus mrigala (0)	0.00	0.00	0	0
Puntius dorsalis (0)	0.00	0.00	0	0
Labeo rohita (4)	44.44	94.68	100	70

Length distribution of prey size was studied. The fish length ranged from 1.5 - 23.5 cm (7.29±17.33) in the earlier rearing period while it ranged from 7 - 35 (5.65±10.72) in the later rearing period (Table 5. 4).

Table 5. 4. Length, width and weight distribution of fishes in chick regurgitate samples.

		Length(cm)	Width(cm)	Weight(cm)
Name of the fish species	Month	Mean ± SE	Mean ± SE	Mean ± SE
Cirrhinus mrigala (8)	FEB	16 ±1.33	3.64±0.337	45.00±10.52
Puntius dorsalis (3)	FEB	6.4±1.2	2.00±0.651	5.00±0.00
Oreochromis mossambicus (52)	FEB	6.008±0.67	1.91±0.282	10.16±3.31
Labeo rohita (4)	MARCH	27.75±3.3	8.75±1.44	325.00±105.00
Oreochromis mossambicus (5)	MARCH	9±0.63	3.36±0.211	14.60±1.63

The p-value = 0.000, the length distribution of food of the Spot-billed Pelican among between early and later periods are significantly different from each other ($p<0.05$); Length size varied between the two different rearing period (U=95, df=71, $p<0.01$), so also width (U=79, df=71, $p<0.01$) and weight (U=82, df=71, $p<0.01$).

5. 4 DISCUSSION

5. 4. 1 Feeding techniques and group size

The thickness of the flock layer could act as a visual cue indicating favourable foraging habitat (Pierce & Gawlik 2010). The Spot-billed Pelican uses the wing closed and bill strikes to captutre fish fry (Manakadan & Kannan 2003). Raised wing gesture is observed in the both bill merged and neck merged feeding as this may be used as social cue or communication to co-ordinate the fishing flock. The raised wing methods were not observed in scatter feeding groups and neck straightening. But solitary feeding birds used raised wing gesture. Scatter feeding method was observed in shallow water area and it was adapted to feeding on small fishes (Manakadan & Kannan 2003).

5. 4. 2 Prey sources

Increased prey availability in managed wetlands produced a positive response in shorebirds (Velasquez 1992). Though Pelicans use this habitat mainly for nesting, feeding also was observed in the pond. Outlets with meshes may naturally retain the fish inside. Providing fingerlings enhances the abundance of temporary food sources. This species can move according to the favourable breeding and feeding condition (Ali & Ripley 1978). Providing alternative reservoirs, with regular food supplies is recommended as suggested by Shmueli *et al.* (2000) for Great White Pelicans.

5. 4. 3 Diet composition

This study revealed four species of the prey in their diet. This study with this meager data shows *Oreochromis mossambicus* and *Labeo rohita* were the important prey species based on the biomass. However, *Cirrhinus mrigala and Puntius dorsalis* were also major components in their diet. These are all the economically important species and shallow dwellers. Though significant difference of prey size selection is recorded the temporal variation in diet was not able to relate dietary changes during the course of each breeding season to concomitant changes in relative

densities of the same species in their foraging ranges. As suggested by Werner (2004) estimating the daily consumption on commercial ponds is needed to further elucidate the economic impacts and it is still untested in the current foraging range.

Chapter 6

ACTIVITY BUDGET

6.1. INTRODUCTION

Activity budget studies quantify the time animals allocate to different activities (Rave & Baldassarre 1989; Upadhyaya & Saikia 2010; Asokan & Ali 2010). The daily balance of energy intake and energy expenditure of individual birds may serve as a link between behavioral decisions and fitness. Behavioural decisions may influence the energy balance, such that a surplus or deficit might have repercussions for the prospects of survival and fitness (Masman *et al.* 1988). Once individuals make the decision to commute, compensation for the commute cost should be revealed in behavioral differences (Preston 2005). The activity budget is an important tool for understanding habitat use and niche separation (Rave & Baldassarre 1989). In water hyacinth American Coot spent more time than open water to exploit food. This Modified physiological constraints of birds in water hyacinth showed modified foraging behaviour (Villamagna *et al.* 2010). Behavioural adjustments may also result from local conditions such as disturbance from human activity, intraspecific and interspecific competition, and climatic variation (Preston 2005). An activity budget study provides insight into the importance of habitats (Petrie & Petrie 1998). Allocation of time and energy to various activities depends on both intrinsic and extrinsic factors (Palmer *et al.* 2001). Time activity budgets reveal the combination of factors including individual physical condition, food availability, social structure and environmental conditions (Clark 1980; Robinet *et al.* 2003 and Symes & Perrin 2003). Patterns of daily activity and behaviour can vary widely between species and this activity budget helps us studying the life history and ecological adaptation of birds (Asokan & Ali 2010). Here, diurnal time activity budget of the Spot-billed Pelican (*Pelecanus*

philippensis) in different time blocks, seasons, years and habitats are illustrated.

6.2. METHODS

6.2.1. Observation

Time activity pattern: Data was collected twice a month from October 2007 to March 2010 covering all the breeding activities (i.e. Display to fledgling stage) in nesting habitat and open water. Two alternate days were utilized to cover 12 hours in four time blocks viz., morning (0600-0900 h), late morning (0900-1200 h), midday (1200-1500 h) and late evening (1500-1800 h). Scan sampling method (Altmann 1974) was adopted to study the cluster of 2 to 27 nest birds and spent 144 hours in 2008 and 120 hours in 2009. In each observation period, time of day, weather condition, and the reproductive stage of each nest based on nest contents were recorded. If chicks were present, the number and stage of chicks were recorded. Totally 2493 records over 144 hours of observation times spread across a total of 12 days in 2008-09 and 2388 records over 120 hours of observation spread across 10 days in 2009-10 were obtained.

Focal animal sampling method was used for intensive observations (Altmann 1974; Altmann & Altmann 2003). In 2007, eight focal nests were selected and observed from nest initiation to fledgling. If focal nests were deserted, nests at the same stages were concentrated. Observations were conducted on days without rain and strong winds. The focal nest was observed with spotting scope (Nikon 20x60) continuously for 15 minutes followed by a 5-minutes break. In one hour three such samples were taken. The duration of each behaviour/activiy was recorded using an electronic stopwatch.

Totally 74 hours were spent to study the activity by using focal animal sampling method. Observation was plotted according to the nesting chronology.

In order to determine the frequency of occurrence of short-duration behavioural events, I carried out continuous 5-minutes focal animal sampling on the chosen individual alternately with the instantaneous sampling (Altmann 1974). During each of these observation periods, I collected data on all occurrences such as arrival with nest material, feeding chick, pecking, and nest maintenance, exhibited by the Spot-billed Pelican. These behaviours could also be considered as behavioural events as they often occurred in very short bouts throughout the day. The scan intervals reported in these studies ranged between 1-15 min. The 5-min interval between records was judged to be sufficient to ensure the independence of samples as followed by Maccarone *et al.* (2010). Adult activities were divided into sitting, standing, preening, feeding chicks, nest maintenance and time away from the nest.

Time spent in different activities in different stages was calculated and from these values the percentage time spent for each activity during different times on the day was estimated. The activities were divided into six major categories:

(i) Domestic chore: Nest making; incubating; nest maintenance; collection of nest material from open water, old nest and from ground; arrival with nesting material.

(ii) Social activity: Lek, bill clap, courtship display, flight-circuit, head swing, mating, defending nest material and pair, pecking, threatening, nest relief, interaction with other species.

(iii) Feeding : Feeding in water

(iv) Feeding chick

(v) Movement: Locomotion in water and soaring.

(vi) Maintenance: Preening, comfort movements, shaking, yawning, wing flapping and bathing.

(vii) Resting: Perched sleeping by placing head on back, head retracted back and eyes closed.

Here, resting was merged with the domestic chore for nesting birds as it was observed that incubating and (brood) guarding bird perched on the nest or near to nest and was considered as domestic chore. To compare the proportion of time spent in each activity as determined from scan samples, each activity is aggregated throughout each observation of the day. The proportion of scores in a given activity represented by the time individuals actually engaged in that activity. Statistical analyses were conducted on proportions (Squires & Anderson 1997) and reported in percentage by adopting Mendiratta (2009).

The percentage time spent on each activity was estimated for each day as

$$T_a = 1/S \sum_{i=1}^{s} n_{ai}/N_i \times 100$$

Where, T_a = Percentage time spent on activity "a" per day,

S = Total number of scans in a day,

'n_{ai}' = Number of records of activity "a" in the i^{th} scan, and

'Ni' = Total number of records in the i^{th} scan.

I estimated the percentage time spent on activity "a" in all the months as

$$1/DTa,$$

Where, D is number of days (Mendiratta 2009).

6.2.2 Data analysis

To analyze the data on the diurnal and seasonal patterns the breeding cycle of the Spot-billed Pelican was divided as follows: incubation period (weeks 1-4), pre-flight nestling stage (weeks 5-12), fledged stage (weeks 13-16) and post-flight stage (weeks 18-21) in the time-activity budget and frequencies of behavioural events in the Spot-billed Pelican.

As mentioned earlier, I calculated the mean frequencies per five minutes, of arrival with nest material, feeding chick, pecking, and nest maintenance using focal animal sampling.

To examine the diurnal variation of these behaviours across seasons, month-wise comparisons were carried out from September to March in two years, 2008-2009 and 2009-2010 of the study. I combined the six

sampling months into four seasons, post south-west monsoon (September), north-east monsoon (October to December), winter (January to February) and summer (March to May).

Further, I classified the day into four time intervals (I = 0600-0900 hours, II = 0900-1200 hours, III = 1200-1500 hours, IV = 1500-1800 hours). For significance testing, comparison of each activity between years was made (years, seasons and time blocks pooled), Kruskal-Wallis test and one-way ANOVA were performed to compare activities between time blocks (year, seasons pooled) and stages overall, and using t-test difference in behaviours were stutied separately. All the analyses are performed using SPSS 11 and SPSS 16 statistical software.

6.3 RESULTS

Diurnal activity of the Spot-billed Pelican in Uppalapadu showed an average of 43.37 % in domestic chore (Table 6. 1) such as incubation, nest building and brooding followed by maintenance (18.13), display (6.45) and feeding (4.29) which varied in different months of the study from September to March (Table 6. 2) and between the years for domestic chore and maintenance (Table 6. 3).

Table 6. 1. Mean percentage of diurnal time spent in various activities by the SBP in Uppalapadu, Andhra during 2008 to 2010.

Activity	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Mean
Display	23.85	9.04	0.39	5.56	3.66	1.69	0.97	6.45
Domestic chore	38.48	50.37	59.85	46.22	31.24	41.03	36.38	43.37
Feeding chick	0.00	0.00	5.14	2.64	0.84	0.59	0.78	1.43
Maintenance	27.34	27.17	17.47	20.81	10.58	12.70	10.89	18.13
Social	2.32	2.90	2.00	2.91	1.36	0.68	1.27	1.92
Movement	2.84	3.34	0.90	2.40	0.62	0.10	2.11	1.76
Feeding	3.09	3.76	5.48	2.39	3.05	9.02	3.27	4.29

Table 6. 2. Mean percentage of diurnal time spent in various activities by the SBP in Uppalapadu in different years
Values are expressed in percentage of time spent engaged in each activity.

		2008-09								2009-10						
Activity	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Overall	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Overall
Display	19.13	11.66	0.56	6.40	0.81	2.08	1.90	6.08	28.56	6.41	0.21	4.71	6.50	1.29	0.03	6.82
Domestic chore	44.85	40.57	58.89	37.37	38.76	38.43	31.55	41.49	32.11	60.17	60.81	55.07	23.71	43.63	41.20	45.24
Feeding chick	0.00	0.00	5.91	1.64	0.46	0.63	0.84	1.35	0.00	0.00	4.36	3.64	1.21	0.55	0.71	1.50
Maintenance	16.98	27.57	19.39	22.59	8.66	12.07	9.04	16.62	37.69	26.77	15.55	19.02	12.49	13.32	12.73	19.65
Social	3.55	1.21	1.60	3.14	1.61	0.84	1.22	1.88	1.09	4.58	2.39	2.67	1.11	0.51	1.31	1.95
Movement	5.13	5.59	0.74	2.55	0.51	0.19	1.77	2.35	0.54	1.09	1.06	2.24	0.73	0.00	2.44	1.16
Feeding	6.18	6.60	0.03	0.12	0.00	7.09	2.98	3.29	0.00	0.91	10.92	4.66	6.10	10.95	3.56	5.30

The time spent for domestic chore was significantly different between the years (t=-3.51, p<0.01) (Table 6. 3). The time spent on maintenance also varied between the years (t=-2.26, P<0.05). However, for display no marked difference was found (t=0.85, p>0.05). 6.45%, 1.42%, 1.92% and 1.76% of times were spent for the following activities respectively, feeding chick, social, movement and display which were different markedly between the years (Tables 6. 2 & 6. 3). Time spent in movement in water was relatively high in 2008-09 while feeding in open water was low compared to 2009-10.

Table 6. 3. Comparison of diurnal time spent during 2008-09 and 2009-10 by the Spot-billed Pelican

Activities	2008-2009 Mean±SE	2009-2010 Mean±SE	*t*	*P*
Adult				
Display	4.03±0.55	3.42±0.47	0.85	0.39
Domestic chore	40.12±1.38	46.94±1.33	-3.51	0.00**
Feeding chick	1.45±0.21	1.61±0.23	-0.48	0.63
Maintenance	14.37±0.90	16.89±0.68	-2.26	0.02*
Social	1.86±0.17	2.10±0.25	-0.74	0.46
Movement	1.88±0.34	1.36±0.25	1.26	0.21
Feeding	1.71±0.29	5.55±0.45	-6.71	0.00**
Young				
Resting	21.11±1.19	13.15±1.06	4.99	0.00**
Maintenance	7.44±0.55	1.93±0.25	9.84	0.00**
Social	0.49±0.08	0.30±0.09	1.47	0.14
Movement	3.21±0.41	2.65±0.40	0.96	0.34
Feeding	3.58±0.42	2.05±0.29	3.09	0.00**
**<0.01	*<0.05			

Seasonal variation

In Post South-west monsoon month the Pelican arrived at the breeding ground. Breeding commenced with the Lek performance. The domestic chore was high (41.10%) (Table 6. 4.) followed by maintenance (23.07%). Among the grouped seasons post south-west monsoon showed high display activity (21.90%) and in North-east monsoon, winter and summer it was 3.97%, 2.92% and 0.83% respectively. As the birds continued

nesting through out the seasons but relatively less mean percentage was observed in north-east monsoon and winter seasons Mean time spent for domestic chore was high through out the seasons (Fig. 6. 1). Movement of the adult Spot-billed Pelican was high in post south-west monsoon period as most of the birds were observed collecting nest material in the pond. Maintenance activity showed marked reduction. Social interaction was high 2.82% in post south-west monsoon and 2.80% in north-east monsoon. Most of the social interaction is for nesting material and space. Less percentage of social activity was observed in winter and summer 1.26% and 1.28% respectively. The young ones spent time mainly for resting and maintenance (Fig. 6. 2). Comparison of time spent across seasons in various activities by the Spot-billed Pelican showed significant variation (Table 6. 4).

Table 6. 4. Comparison of diurnal time spent across seasons in various activities by the Spot-billed Pelican

		South-west monsoon	North-east monsoon	Winter	Summer	X^2	*P*
		Mean ± SD	Mean± SD	Mean± SD	Mean± SD		
Adult	Display	21.90 ±9.73	3.97±6.75	2.92±4.61	0.83±1.82	72.62	0.000
	Domestic chore	41.10±12.15	54.59±19.89	34.13±13.53	37.06±13.29	101.43	0.000
	Feeding chick	0.00±0.00	2.68±4.08	0.74±1.31	0.76±1.86	37.10	0.000
	Maintenance	23.07±13.26	20.98±11.72	10.74±6.49	11.15±6.52	98.09	0.000
	Social	2.82±2.27	2.80±3.79	1.26±1.73	1.28±2.75	45.39	0.000
	Movement	3.78±5.99	1.66±4.51	0.51±1.63	2.15±4.01	14.67	0.002
	Feeding	4.36±5.22	4.22±6.02	3.85±5.95	3.31±5.31	0.94	0.817
Young	Resting	1.54±3.62	5.30±10.85	32.12±12.43	22.08±8.91	220.81	0.000
	Maintenance	0.42±1.07	1.97±4.42	8.80±7.06	4.31±4.90	101.22	0.000
	Social	0.00±0.00	0.08±0.34	0.88±1.72	0.43±1.48	56.78	0.000
	Movement	0.19±0.54	0.55±2.40	2.08±2.97	8.00±7.84	131.64	0.000
	Feeding	0.46±1.63	0.79±1.68	1.93±2.12	7.00±7.24	80.47	0.000

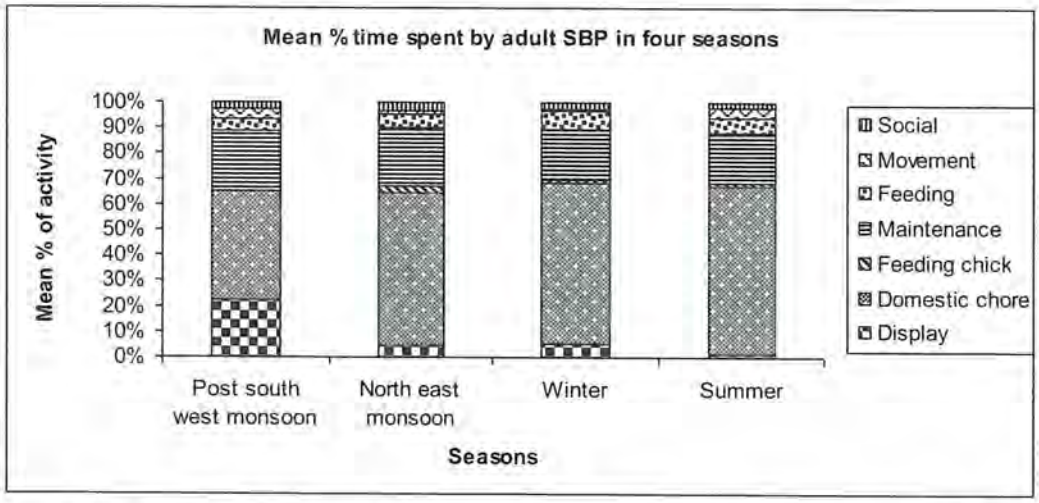


Fig. 6. 1 Mean % of diurnal time spent on various activities by the adult SBP in four seasons.

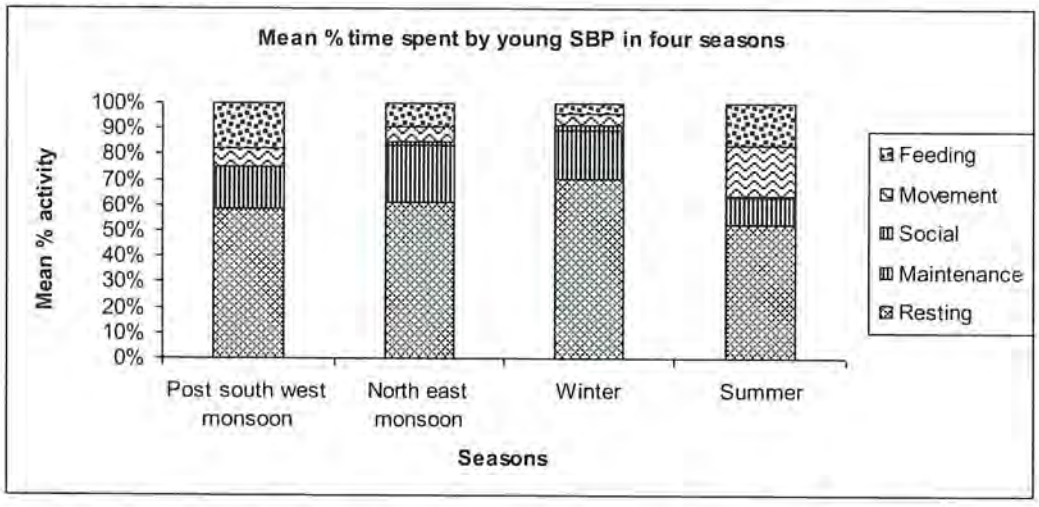


Fig. 6. 2 Mean % of diurnal time spent on various activities by the young SBP in four seasons.

Feeding chick activity across the seasons varied (x^2 =37.10, df= 3, p=0.000) (Table 6.4) as also for movement (x^2 =14.67, df= 3, p=0.002) and other activities except feeding (x^2 =0.94, df= 3, p=0.817). Though reduced percentage of all activity were found across the season no marked difference for domestic chore (x^2 =101.43, df= 3, p=0.000), feeding chick (x^2 =37.10, df= 3, p=0.000), maintenance (x^2 =98.09, df= 3, p=0.000) and social (x^2 =45.39, df= 3, p=0.000) was found.

Maintenance was the major activity through out the day for the adult. It was higher in the morning (20.27%) than during midday (13.27%) and the activity across the time blocks varied significantly (x^2=20.215, df=3, p=0.000) (Table 6. 5 and Fig. 6. 3 & 6. 4). Feeding chick significantly varied among time blocks (x^2=25.413, df=3, p=0.000); it was lower in the morning (0.69%) and higher during midday (2.28%). Feeding chick varied significantly across the 4 time blocks.

Table 6. 5. Mean percentage of diurnal time spent in various activities by the Spot-billed Pelican in different time blocks (years, months and habitats pooled) at Uppalapadu, Andhra Pradesh, India.

	Time Blocks in hours				
Activities/Time blocks	0600-0900	0900-1200	1200-1500	1500-1800	Overall
Display	5.85	3.17	2.89	2.94	3.71
Domestic chore	12.29	12.66	13.04	11.64	12.41
Feeding chick	0.69	2.28	1.66	1.33	1.49
Maintenance	20.27	13.27	13.66	15.83	15.76
Social	2.28	1.62	1.95	2.12	1.99
Movement	1.21	1.59	1.66	1.99	1.61
Feeding	3.01	3.52	4.03	3.75	3.58

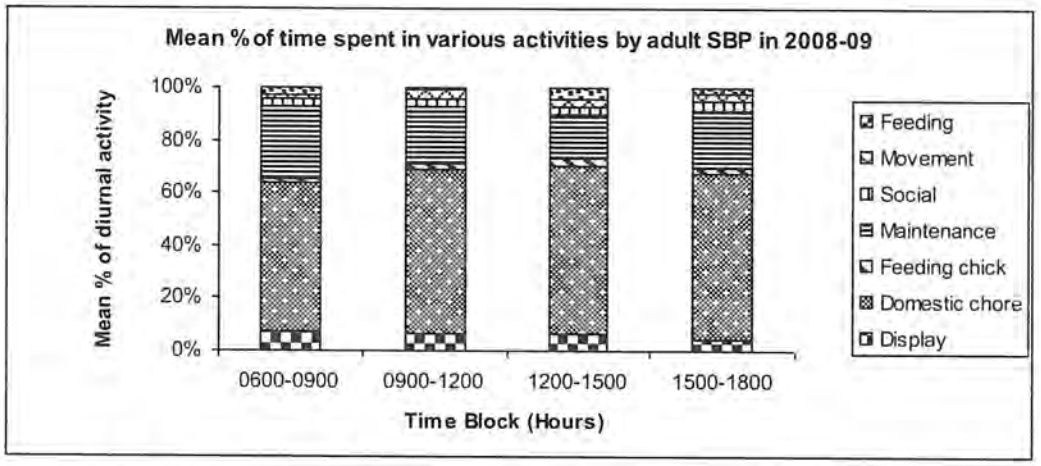


Fig. 6. 3. Mean percentage of diurnal time spent in various activities by the adult Spot-billed Pelican in different time blocks in 2008-09

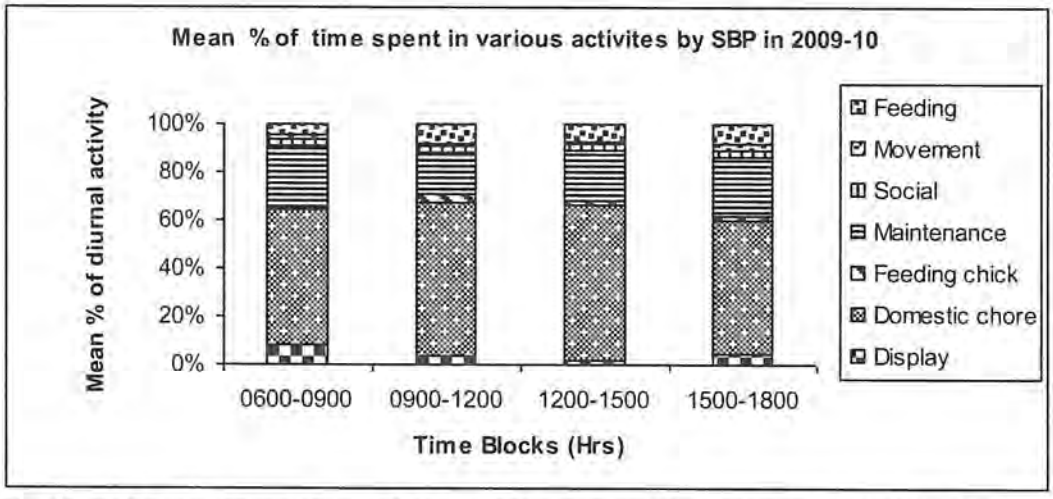


Fig. 6. 4. Mean percentage of diurnal time spent in various activities by the adult Spot-billed Pelican in different time blocks in 2009-10

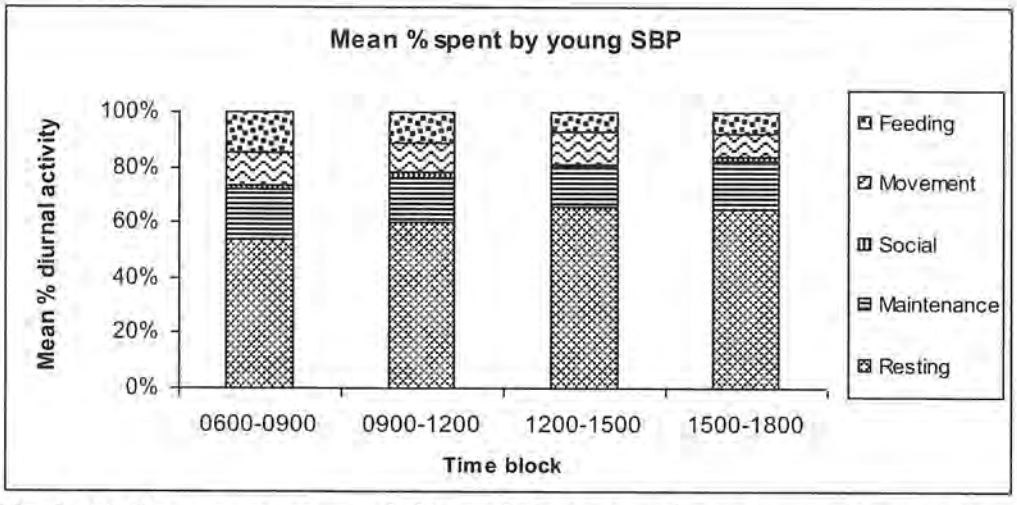


Fig. 6. 5. Mean percentage of diurnal time spent in various activities by the young Spot-billed Pelican in different time blocks (years pooled).

The young Spot-billed Pelican spent most of the time for resting (16.62%) followed by maintenance (4.32%). Feeding was very less in after noon (2.71%) (Fig. 6. 5). Time spent on various activities such as resting, maintenance, social, movement and feeding did not vary significantly across the 4 time blocks (resting x^2=6.090, df=3, p=0.107; maintenance x^2 =4.567, df=3,p=0.206; social x^2 =0.189, df=3, p=0.979; movement x^2 =4.137, df=3, p=0,247; feeding x^2 =0.331, df=3, p=0.954).

Examination of diurnal activities of the Spot-billed Pelican was carried out in terms of its changing contribution to the time activity budget of the individuals. Activity Pattern of the Spot-billed Pelican varied among years and period of diurnal activity (Fig. 6. 6 and Fig. 6.7).

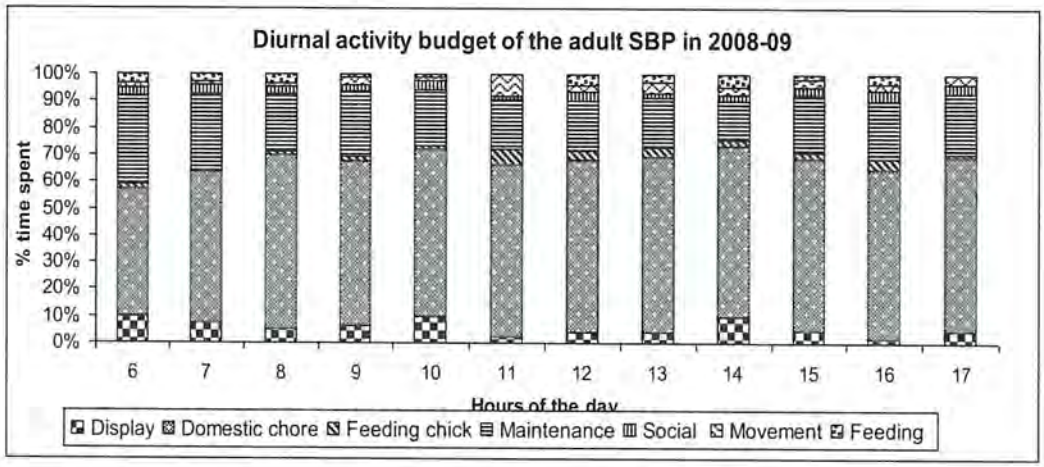


Fig. 6. 6. Diurnal activity budget of the adult Spot-billed Pelican in 2008-09.

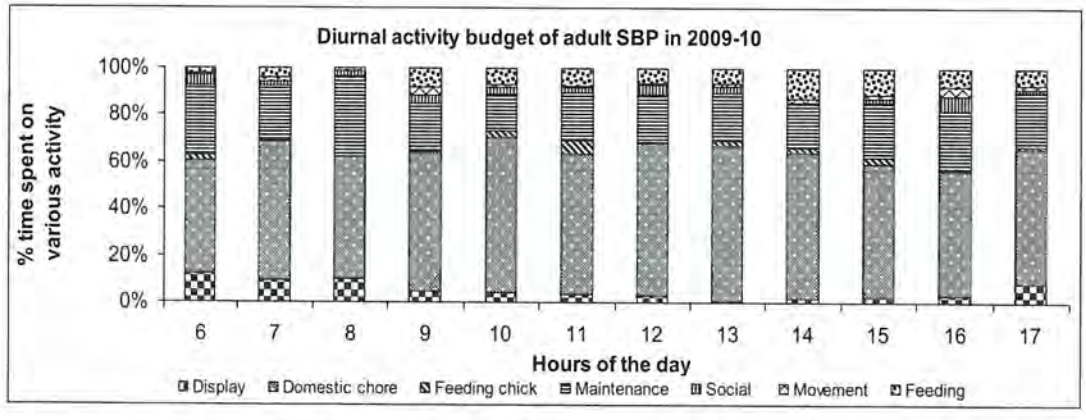


Fig. 6. 7. Diurnal activity budget of the adult Spot-billed Pelican in 2009-10.

Table 6. 6. Comparison of diurnal time spent between years in various activities by Spot-billed Pelican in different time blocks

	Activities	Mean±SD	X^2	*P*
Adult	*Display*	1910.85±6.89	5.671	0.017
	Domestic chore	22652.31±18.75	18.199	0.000*
	Feeding chick	809.57±3.07	1.010	0.315
	Maintenance	8137.51±10.76	11.787	0.001
	Social	1036.56±3.19	5.119	0.024
	Movement	845.97±3.97	24.215	0.000*
	Feeding	1704.32±5.78	39.097	0.000*
Young	*Resting*	9577.52±15.76	36.978	0.000*
	Maintenance	2803.83±6.00	98.779	0.000*
	Social	220.27±1.23	39.822	0.000*
	Movement	1592.20±5.53	19.178	0.000*
	Feeding	1579.11±4.79	19.726	0.000*
*Differ (P<0.01) between years				

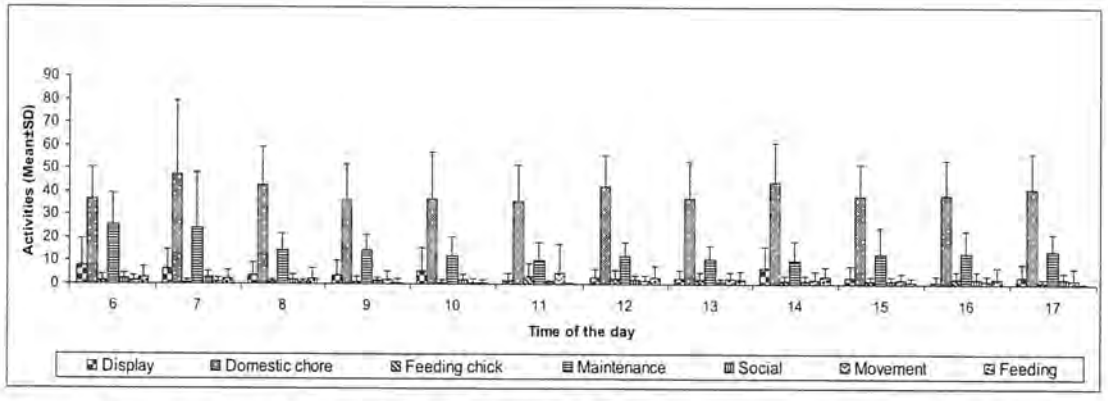


Fig. 6. 8. Activity of the adult Spot-billed Pelican recorded in various hours of the day

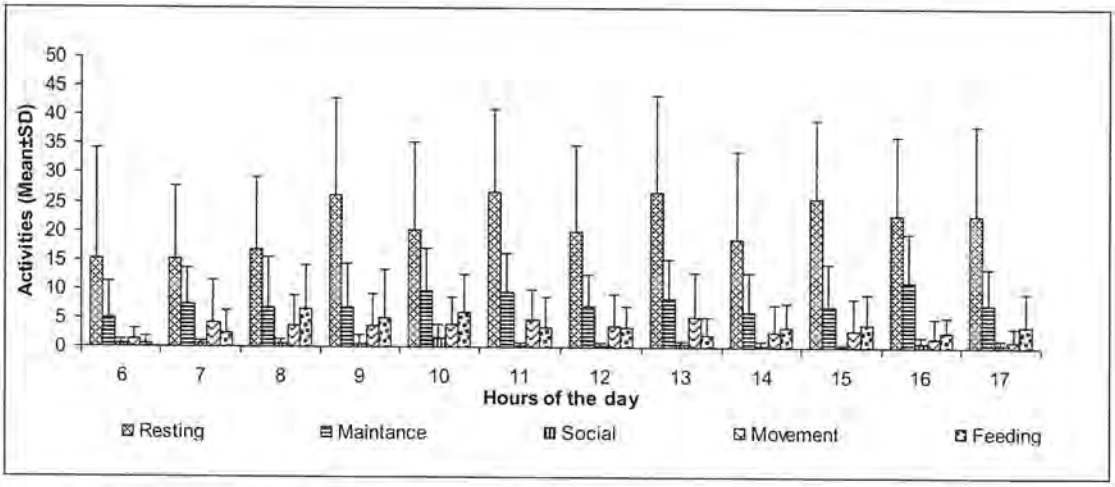


Fig. 6. 9. Activity of the young Spot-billed Pelican recorded in various hours of the day.

The data were pooled for both the years to examine the diurnal activities across the hours of the day. In adult significant variation was found in following activities, namely domestic chore x^2=18.199, df=11, p=0.000, movement x^2=24.215, df=11, p=0.000 and feeding x^2=39.097, df=11, p=0.000 (Fig. 6. 8) and in young one resting, maintenance, social, movement and feeding showed marked difference among the hours of the day (Fig. 6. 9 and Table 6. 6).

6.4 DISCUSSION

The time-activity budget of the Spot-billed Pelican shows that more (43.37 %) of time was spent in domestic chores or nest attendance which included nest making, brooding and guarding followed by maintenance (18.13%). In nidicolous bird species, parents divide their time mainly between attending the nest site and maintenance (Palmer *et al.* 2001; Afton 1979). The wing, head and breast were most often preened by the Spot-billed Pelican. It rubs its head and crest to the back of the body by stretching the neck up right back. The most frequently observed maintenance activities are head scratching, feather shaking and wing

flapping. As observed in Brown Pelican by Schreiber (1977) bathing act as social attraction as other pelicans were joined in open water.

In American White Pelican, preening while incubating, preening in raised sitting gesture and manipulation of nest material at later incubation period were described as effective mean to regulate the temperature of the eggs or young by the parents (Evans 1989). Till the end of developmental stage immobile parent is present or sit near the nest site with very little feeding (Fig.1). Palmer *et al.* (2001) attributes the reason to the energy requirement of large chicks combined with the declining physiological stage of parents. Social interaction such as defending by pecking and open wing display and pecking were high during the early nesting (2.90 % in October) and nestling period. These interactions were intense during September and December when establishment of nesting was observed. Similarly, competition ability increased the successful breeding efficiency (Dwyer 1975). In Brown Pelican decreased aggressive nature among young one was addressed as they spent more time away from the nest site made them less socially interactive (Sachs & Jodice 2009).

Marked difference in time spent on domestic chores was observed between years. Relatively less time was spent in 2008-09 which may be due to more human activities near the nesting site. In colonial nesting American Oystercatchers, disturbance in breeding season reduced the maintenance, feeding and vigilance activity (Sabine *et al.* 2008). Time spent in movement in water was relatively high in 2008-09 when the human activity or management activity was high inside the pond. Similarly high flight movement and feeding activity was recorded in Brent Geese *Branta b. bernicla* (Riddington *et al.* 1996). In 2009-10 the time spent in feeding in open water was high as there was less disturbances due to the management activity compared to previous year. Hence, habitat management activities in the pond should be taken up in non-breeding seasons.

Movement of the adult Spot-billed Pelican was high in post south-west monsoon period as most of the birds were observed collecting nest material in the pond. Maintenance activity showed marked reduction as the birds were engaged in other vital activities. Social interaction was not high in post south-west monsoon and north-east monsoon. Most of the social interaction was for competition for nesting material and space. Less percentage of social activity was observed in winter and summer, as these activities were not used. The young ones spent time mainly for resting and maintenance.

The Spot-billed Pelican spent an average 6.45% time on feeding chick which did not vary among time blocks. While in diurnal feeding act the peak of feeding was observed in the end of forenoon hours and afternoon because the Spot-billed Pelican returned to the breeding ground around 11^{O}' Clock and 12^{O}' Clock, fed the chicks and relieved the nest partner. Relieving act was observed in noon Great White Pelican (Schaller 1964). This may the Pelicans use the thermal up current of air for easy flight for their movement. Wintering Great White Pelican spent less percentage of time in foraging than loafing. Peak foraging activity was observed in forenoon and late evening. A few feeding activity at midday was observed at midday (King & Werner 2001). Afternoon most of the birds returned from the feeding ground. Social activities such as interaction, pecking, threat display and biting were observed in the early hours of the day and during peak feeding hours defending against food stealing.

Movement in open water showed bimodal pattern with peaks in the morning hours and in the mid of the afternoon hours. Late morning before leaving the feeding ground activity in open water was high and in midday to evening also birds used open water for bathing, maintenance and drinking water. Similarly the young ones also were seen using open water during the hot day light hours. Unlike Schreiber (1977) apparent peak for bathing and maintenance peaks were observed in 11th and 16th day light hours. Feeding activity was observed when less human activity

or visitors were found in the pond. At open water feeding attempt by the adult birds was also observed which was higher in the midday and late evening. In waterfowl foraging effort can be adjusted according to the amount of food and daylight availability (Owen & Black 1990). Similar observation was also found in Cotton Pygmy-goose (Upadhyaya & Saikia 2010) and they suggested that understanding the behaviour of a species will help the managers to device effective management strategies in order to increase the response of the water birds. The preservation of buffer zone or less developed zone near waterbird habitat will help in the protection of waterbirds from the disturbance (Traut & Hostetler 2003).

SUMMARY AND CONCLUSION INCLUDING THREATS AND CONSERVATION IMPLICATIONS

7. 1 SUMMARY

Wetlands are the important bird habitats and birds use them as migratory resorts or for breeding, feeding and roosting. Birds are one of the best indicators of the status of a wetland. Examining the environmental correlates of species distribution and life history traits is one of the best protocols to assess the indicator properties of target species groups. The Spot-billed Pelican is one of the near threatened species found in India. The status and colony size of the Spot-billed Pelican were studied in Andhra Pradesh. Nest surveys were carried out in Uppalapadu, Ramachandrapalayam, Nelapattu and Telineelapuram. Bird count and habitat use studies were done at Kolleru, Naupada Swamp and Kakarapally Creek, and Nelapattu, the three foraging sites.

Recent population trends indicate increasing breeding population of the Spot-billed Pelican. Highest number of nests was recorded at Uppalapadu (831±126) followed by Nelapattu (470±127) in 2007and the lowest number of nests (55.50 ± 50.20) was recorded at Telineelapuram. A new breeding colony of the Spot-billed Pelican was found in Ramachandrapalayam near Uppalapadu colony which accommodated 120±30 nests. The maximum estimated size in 4-5 breeding sites was 1476 ± 333.88 in 2007. Comparatively less colony size was estimated in 2008 and 2009 as 1015.5± 618.01 and 1139±527.49 respectively.

Colony size dynamics was studied with the help of colony size and duration of presence. Occupancy rate of a colony was positively related to colony size (logistic regression, F = 0.380, df= 3, P < 0.001; R^2=160) among the breeding sites studied. Pelican population changed with

changes in high quality habitat and broader ranges of habitat with stable local dynamics were used based on availability.

Colony size and location variability were assessed by the colony turnover rate (t_i), the highest CV was for Ramachandrapalayam (103%) followed by Nelapattu (36%). Telineelapuram and Uppalapadu showed less stability 21 % and 28% respectively.

Occurrence of this Pelican in non-breeding sites along with habitat type was studied. Probably, increased water level and intense aquaculture practices were not preferred by this species. In Naupada swamp and Kakarapally Creek 53% was observed in marsh area during 2007-08 and was not recorded in the subsequent years (2008-09 to 2009-10) of study. In Kolleru, Spot-billed Pelican mostly used site with trees in all years while fish tanks were not preferred in 2008 and 2009. In Pulicat lake the Spot-billed Pelican used shallow water than mud flat. In Naupada swamp and creek Pelican was found associated with fishing area and more frequently in marsh during 2007 and to some extent in canal in 2008. Demographic parameters such as annual productivity and population growth rate can be used to compare habitat quality among species and habitats for purposes of evaluating management plans.

To understand the habitat requirements and factors determining habitat selection, evaluation of breeding performance, distribution of the colony and adaptations were studied. Nest placement in 2008 and 2009 showed maximum use of the height of 1 – 3 m. Early arrivers preferred nesting in higher trees while late nesters used comparatively lower tree heights. Tree variables such as tree height and tree DBH were recorded for 36 nest trees and 17 non-nesting trees and analysis showed significant variations in the tree height ($t_{0.74}$= 3.466, df=72, $p<0.001$) and DBH ($t_{2.03}$=4.968, df=72, $p<0.001$). Stepwise multiple regression procedures delineated tree height, distance from path and DBH as important factors that influenced most the nest-site selection of the Spot-billed Pelican in Uppalapadu

According to accessibility, nests were studied randomly. A sample of 619 nests (180 in 2007, 246 in 2008 and 193 in 2009) was used for the analysis of nest-site characteristics, nest-site selection (Venkatraman 2007) and breeding success. Index of selectivity test (Ivlev 1961) was used to evaluate preference or avoidance of various tree species as nesting sites by following the formula: PI= U-A/ U+A. Preference test for nesting tree showed preference for the two nesting tree species, namely *P. juliflora* and *P. dulce* (Ivlev's index). More nests were located in the patches with abundant *P. juliflora.*

The Pelicans bred asynchronously, showing a marked tri model pattern in each year i.e. In 2007-08 the peak number of nests was observed in the 4th week of September, second peak in the 4th week of November and 3rd peak in mid February. Delayed reproductive readiness limits nest-site selection to marginal nesting areas. The nests are contiguous and formed clusters or sub-units ranging from 2 to 25 nests. Widely observed nesting unit of 6-10 accounted for 44%, 39% and 57% of all the units counted during 2007-08, 2008-09 and 2009-10 respectively.

Spot-billed Pelican chicks took 10 to 11 weeks to fledge. During 2007-08, 2008-09 and 2009-10, the annual productivity (fledged chick per nest) was 1.85± 1.18(0.86-2.33), 1.76 ±0.49 (1.00-3.00), 1.62 ± 0.77 (0.00-3.43) respectively. Multiple stepwise regression analysis showed that tree height, tree density, nest height, tree DBH and rainfall had significant influence on breeding performance of the Spot-billed Pelican. In the resulting model three independent variables, Tree height, nest height and DBH had significant effect on breeding success ($F_{1,17}$ =1.57, P<0 .281) during 2007-08, but it explained only 69% of the variation. Nest height and DBH correlated highly with breeding success. In 2008-09, ($F_{1,18}$=2.85, P<0.075), nest height, DBH and tree height explained 78% of the variation while during 2009-10, ($F_{1,17}$=1.57, P<0.051) above mentioned variables explained 84% of the variation showing their significance in determining breeding success.

Birds were studied for the habitat use. Regular scans were made during the daylight hours using spotting scope (Nikon 20x60). All feeding birds at observation sites were studied for the flock size. Two and more than two birds foraging at synchronized directional movements was treated as a socially foraging flock as followed by Battley *et al.* (2003). Totally in 89 events 1321 individuals were observed feeding. Distinctive feeding behaviour observed in social flocks was listed. The Spot-billed Pelican adopted bill merged feeding and mean flock size was 6.30±4.52. Scatter feeding is the second most used method and more individuals were observed 18.55±27.02 using this. Most adapted method by large number of birds as follows with number of individuals in each foraging groups. 357 individuals found using bill merged feeding (35.70±20.79); 124 individuals with neck straightening (11.27±16.17); 371 individuals with scatter feeding groups (18.55±27.02) and 359 in feeding groups of 17.95±23.31.

Diet of the Spot-billed Pelican was studied from regurgitated food samples which were collected from below the nests. The prey species from regurgitate samples were identified and individually enumerated. The weight and length of each item were noted with the help of a Pesola balance and metric scale. The collected food samples were from 65 to 90 days old chicks. The samples were grouped into two rearing periods according to the stage of the chicks, earlier period (samples collected from 65 to 80 days old chicks) and later (samples collected form above 80 days old chicks).

Diet was studied for relative frequency by numbers (RFN), relative frequency of occurrence (RFO), and relative frequency by weight (RFW) of each prey species. Identification of prey items was done from samples collected in February (n=63) and March (n=9). Totally 72 fishes were identified coming under four species, namely *Oreochromis mossambicus, Cirrhinus mrigala, Puntius dorsalis* and *Labeo rohita.* *Oreochromis*

mossambicus occurred in higher frequency 83% to 56 % in the two rearing periods respectively and lower frequency of 5 % was of *Puntius dorsalis* in earlier rearing period. Considering all the above frequency values IRI was calculated for all prey species and found that *Oreochromis mossambicus* (70.52), *Cirrhinus mrigala* (8.76) *and Puntius dorsalis* (1.07) were the most important prey in the earlier period, whereas *Labeo rohita* (70) had the highest IRI value followed by *Oreochromis mossambicus* (15) in the later period.

Size class distribution of food of the Spot-billed Pelican among early and later periods showed significant variation from each other ($p<0.05$); length size varied between the two different rearing periods ($U=95$, $df=71$, $p<0.01$), so also width ($U=79$, $df=71$, $p<0.01$) and weight ($U=82$, $df=71$, $p<0.01$).

Totally 2493 records of activities of the Spot-billed Pelican over 144 hours of observation spread across a total of 12 days in 2008-09 and 2388 records over 120 hours of observation in 10 days in 2009-10 were obtained. I carried out continuous 5-minutes focal animal sampling on the chosen individual alternately with the instantaneous sampling (Altmann 1974). The activities were divided into six major categories such as domestic chore, social activity, feeding, feeding chick, movement, maintenance and resting.

To compare the proportion of time spent in each activity as determined from scan samples, each activity was aggregated for observation of one day. The proportion of scores in a given activity represented the time individuals actually engaged in that activity. Statistical analyses were conducted on proportions (Squires & Anderson 1997) and reported in percentage by adapting Mendiratta (2009).

The percentage time spent on each activity was estimated for each day as

$$T_a = 1/S \sum_{i=1}^{s} n_{ai}/N_i \times 100$$

The Spot-billed Pelican spent maximum time on domestic chore (43.37%) followed by maintenance (18.13%) and display (6.45%). The time spent on both domestic chore and maintenance varied significantly between the years ($t=-3.51$, $p<0.01$; $t=-2.26$, $P<0.05$ respectively). However, for display no marked difference was found ($t=0.85$, $p>0.05$). In Post South-west monsoon the Spot-billed Pelican Pelican arrived the breeding ground. The domestic chores was high (41.10%) followed by maintenance (23.07%). Among the grouped seasons post south-west monsoon showed high display activity (21.90%), but it was low in North-east monsoon, winter and summer. Comparison of time spent across seasons in various activities by the Spot-billed Pelican showed significant variation. Maintenance was the major activity through out the day for the adult. It was higher in the morning (20.27%) than during midday (13.27%) and the activity across the time blocks varied significantly ($x^2=20.215$, $df=3$, $p=0.000$). Feeding chick varied significantly among time blocks ($x^2=25.413$, $df=3$, $p=0.000$). The young Spot-billed Pelican spent most of the time for resting (16.62%) followed by maintenance (4.32%). Feeding was very less in after noon (2.71%). Time spent on various activities such as resting, maintenance, social, movement and feeding did not vary significantly across the 4 time blocks (resting $x^2=6.090$, $df=3$, $p=0.107$; maintenance $x^2=4.567$, $df=3$,$p=0.206$; social $x^2=0.189$, $df=3$, $p=0.979$; movement $x^2=4.137$, $df=3$, $p=0,247$; feeding $x^2=0.331$, $df=3$, $p=0.954$).

In adult significant variation was found in following activities, namely domestic chore $x^2=18.199$, $df=11$, $p=0.000$, movement $x^2=24.215$, $df=11$, $p=0.000$ and feeding $x^2=39.097$, $df=11$, $p=0.000$ and in young one resting, maintenance, social, movement and feeding showed marked difference among the hours of the day.

7.2 THREATS AND CONSERVATION IMPLICATIONS

In South India, population of *Pelecanus philippensis* had declined considerably in the recent past and a few recommendations have been given for its conservation, improving the nesting habitat of this species (BirdLife International 2001). Generalized recommendations for the conservation of water birds in natural and created wetlands have been elusive because studies are often of a local nature, and do not compare source data against those from other regions.

In this study geographically broad habitat relationships of the Spot-billed Pelican were examined to provide conservation prescriptions in four different sites in villages with huge nesting trees, irrigation tank or seasonal tanks with clumps of nesting trees. We develop models from our study in Uppalapadu, Telineelapuram, Nelapattu and Ramachandrapalayam. Numbers of breeding Spot-billed Pelican have dramatically increased in Andhra Pradesh, and the population may currently be restricted by breeding habitat. Safer nesting sites and readily available food during breeding season are linked to increased or strong site tenacity in traditional or newly emerged nesting sites and increased occupancy rate and abundance of the Spot-billed Pelican in colony sites. It is found that the Spot-billed Pelican prefers to nest in fishing tanks. So, protection of this species at the private fish tanks and protection of nesting trees should be provided as they were uprooted by the pond owners. Providing artificial tree structure is easily adapted by the nesting Pelican in Uppalapadu but not utilized in the Kolleru and Nelapattu (fig p & q). The nesting association with the Painted Stork is observed in Telineelapuram but not in Nelapattu sanctuary as they nest with Asian Openbills. In Uppalapadu, though the nesting association was correlated with nesting Painted Stork the decreasing population of Painted Stork had less effect on nesting Spot-billed Pelican. Several other species such as Asian Openbill and Painted Stork used the artificial structure for nesting. The management activity such as planting sapling,

placing tree guards, manual removal of *Eichhornia* and providing artificial nesting substrate and of changes in water regime were listed chronologically with birds breeding activity and provided recommendations, such as any above listed activity should be done in non-breeding season when the nesting activities are less and net conservation benefit can be realized from management action.

Major threats for the Spot-billed Pelican population of Uppalapadu that stem from the breeding site can be listed as: (Sheeba & Vijayan 2009 b).

(i) Nest disturbance by inhabitants or visitors (of nests on the outer fences and school building top in particular)

(ii) Nest deserted due to intrusion made by cleaning the pond or other management activity of planting saplings, mound strengthening, and removing water from the reservoir for management purpose.

(iii) Pollution of nearby wetlands and cultivable field by the pesticide use and by fish feed (although no negative effects were detected on breeding success a reduction in water quality is probable in the near future).

(iv) Intrusion by photographers and visitors.

(v) Hunting pressure and illegal fishing in and around bird habitat.

(vi) Pollution by bird excreta and their consequence such as foul smell.

7.3 MANAGEMENT SUGGESTIONS FOR UPPALAPADU

- Area adjacent to the bird reserve (maximum possible, at least 15 acres) may be acquired and added to the existing reserve and, protected and managed as a Community Reserve/ Conservation Area. Management actions may be taken keeping the following points in consideration:

(i) The nesting area should be inaccessible to mammalian predators and free of disturbance from humans, i.e., firewood collection in the fringe area.

(ii) Plant nesting trees species, namely *Barringtonia sp., Acacia nilotica, Pithecellobium dulce, Borassus flabellifer* on the mounds and bunds.

(iii) Some mounds without vegetation will facilitate resting of the fledged young and non- nesting birds.

(iv) Artificial nesting trees may be erected for immediate use by the Pelicans.

(v) Provide large open water area for feeding of pelicans and other birds.

(vi) Periodic replenishing of fish with fingerlings.

(vii) Have a combination of surface vegetation to provide extra habitat to attract other waterbird species such as wintering and resident ducks.

- Minimize disturbance level in school zone by renovating the barbed fences.
- Strengthening the villagers' support through education and awareness programmes.
- Eco-development programmes including eco-tourism with trained guides from the nearby villages.
- Stopping and even reversing attempts to drain wetlands to straighten the mounds or construction work inside bird habitat should be limited and monitoring the water quality in the future.
- Making local villagers more aware of the importance of the Spot-billed Pelican and the importance of their heronry for this species.
- Additional water supply to fulfill the need of the people who share their reservoir for birds.

7.4 MANAGEMENT SUGGESTIONS FOR OTHER SITES

The increase in the number of nesting birds in survey areas resulted from a number of factors mainly suitable and safer nesting sites and nearby foraging sites as reported by Hafner *et al.* (1986). After three decades the nesting activity at Kolleru was restored by destroying fish farms from the Sanctuary area in 2005. The colony was not sustained because of the recreational activity such as boating. The new colony at Uppalapadu was mainly of the population from Kolleru. Shift in sub-colony formation was due to high disturbance at breeding site. Since colonies move, protection of colonies (outside protected area) and foraging sites should be encouraged to shelter more birds. A species' conservation concerns will differ within the species' range and we should develop and implement a conservation programme based on a thorough understanding of the population dynamics, including size and trend and how survival and mortality constrain population stability (Kushlan 1992).

So, we recommend the conservation needs as given below (Sheeba & Vijayan 2009c):

- Kolleru: Restricting recreational activity at nesting sites and protection from poaching and contamination from fishery industries.
- Uppalapadu: Management activity should be done in non-breeding season without interrupting the habitat quality.
- Telineelapuram: Protection through community participation.
- Ramachandrapalayam: Protection of nesting trees through community participation.
- Nelapattu: Retain the water levels during breeding season.

7.5 CONSERVATION NEEDS AND CONCLUSION

The management of ecosystems rather than individual species is taking a forward position in environmental conservation (Kushlan 1993). Active management will probably need to include: protection and active manipulation of colony sites; protection, active manipulation, and even restoration of feeding habitat, and protection and active management of wintering sites. The ideal management plan would involve meeting the habitat needs of all cohabiting colonial wading bird species over an area sufficiently large to encompass the biological limits of each population. This process requires regional approaches to colony and habitat management. Wetland management should be designed to meet seasonal needs for a diversity of waterbird species that may use these restored habitats (Kaminski *et al.* 2006).

Understanding the potential of and constraints on such regionally-based conservation planning is an important area of research (Kushlan 1992). Decisions on the timing, frequency, duration and magnitude of environmental water allocations depend on sound knowledge of ecological thresholds, and indicators to measure success or failure of management interventions (Jenkins *et al.* 2009). As suggested by Klein (1993) visitors' attitudes especially school children were enhanced by effective nature education programmes such as bird- watching, explaining life history strategies of waterbirds.

Plate 2

CHIEF MANAGEMENT ACTIVITIES TOOK PLACE DURING STUDY PERIOD

7a. Connecting road was established from main road to the Bird protected habitat

7b. Planting artificial nesting tree (iron) in 2008

7c. Revetment of mounds by stone

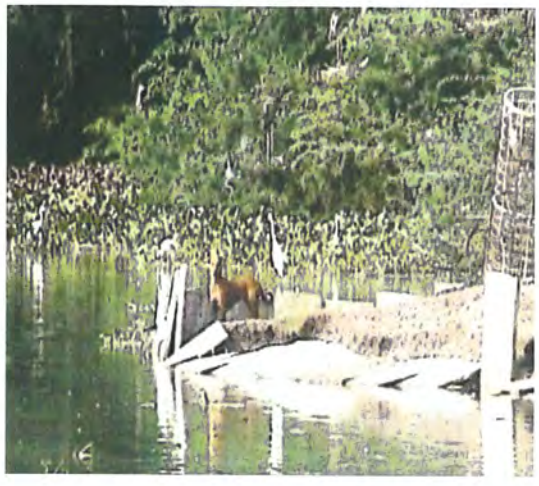
7d. Railing along the bund

7e. Watch tower and sheds for visitors

7f. Reconstruction of the entrance

Plate 3

DISTURBANCES OBSERVED AT UPPALAPADU



7g. Disturbance by stray dogs and monkey

7h. Egg predation by crow

7i. Recreational activity

7j Intrusion by photographers

7k. Cattle grazing

Plate 4

EDUCATION PROGRAMMES ORGANIZED AT UPPALAPADU

7l. Strengthening community participation

7m. DFO is explaining foreign visitors

7n. World Wetland Day 2009 Conducted by SACON

7o. World wetland day Celebration in 2010 (Talk by DFO. Guntur)

MANAGEMENT IMPLICATION IN OTHER PLACES

7p. Artificial nesting tree (iron) at Kolleru

7q. Wooden nesting platform at Nelapattu

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Appendix 1

Order	*Scientific name*	English name	Telugu name	Status
Podicipediformes	*Tachybaptus ruficollis*	Little Grebe	Munu-gudi-kodi	R
Pelecaniformes	*Pelecanus onocrotalus**	Great White Pelican	Chinkabatu	R
Pelecaniformes	*Pelecanus philippensis*	Spot-billed Pelican	Chinkabatu	LM
Pelecaniformes	*Phalacrocorax niger*	Little Cormorant	Neetikaki	R
Pelecaniformes	*Phalacrocorax fuscicollis*	Indian Shang		R
Pelecaniformes	*Phalacrocorax carbo**	Great Cormorant	Bontakaki	R
Pelecaniformes	*Anhinga melanogaster*	Darter	Pamubatu	R
Ciconiiformes	*Ardea cinerea*	Grey Heron	Narayana pachchi	R
Ciconiiformes	*Ardea purpurea*	Purple Heron	Yerra narayana pakshi	R LM
Ciconiiformes	*Casmerodius albus*	Great Egret	Pedda tella konga	R LM
Ciconiiformes	*Mesophoyx intermedia*	Intermediate Egret	Tella konga	R LM
Ciconiiformes	*Egretta garzetta*	Little Egret	Chinna tella konga	R LM
Ciconiiformes	*Ardeola grayii*	Indian Pond Heron	Guddi konga	R LM
Ciconiiformes	*Butorides striatus*	Little Green Heron	Dosi konga	R
Ciconiiformes	*Bubulcus ibis*	Cattle Egret	Samti konga	R
Ciconiiformes	*Nycticorax nycticorax*	Black-crowned Night Heron	Chinta wakha	R LM
Ciconiiformes	*Ixobrychus sinensis*	Yellow Bittern		R LM
Ciconiiformes	*Ixobrychus cinnamomeus*	Chestnut Bittern		R LM
Ciconiiformes	*Mycteria leucocephala*	Painted Stork	Yeru kala konga	R LM
Ciconiiformes	*Anastomus oscitans*	Asian Openbill	Galu konga	R LM
Ciconiiformes	*Ciconia episcopus***	Woolly-necked Stork		R V
Ciconiiformes	*Leptoptilos javanicus***	Lesser Adjutant Stork		R V
Ciconiiformes	*Threskiornis melanocephalus*	Black-headed Ibis		R LM
Ciconiiformes	*Plegadis falcinellus*	Glossy Ibis	That kankanam	R LM
Anseriformes	*Sarkidiornis melanotos*	Comb Duck	Juttu chiluwa	R LM

Anseriformes	*Anas crecca*	Common Teal		WV
Anseriformes	*Anas poecilorhyncha*	Spot-billed Duck		R OM
Anseriformes	*Anas acuta*	Northern Pintail		WV
Anseriformes	*Anas querquedula*	Garganey		WV
Anseriformes	*Anas clypeata*	Northern Shoveler		WV
Anseriformes	*Rhodonessa rufina**	Red-Crested Pochard		WV
Anseriformes	*Aythya ferina*	Common Pochard		WV
Gruiformes	*Amaurornis phoenicurus*	White-breasted Waterhen	Buda kodi	R
Gruiformes	*Porphyrio porphyrio*	Purple Swamphen	Nila bolli kodi	R LM
Gruiformes	*Gallinula chloropus*	Common Moorhen	Jumbu kodi, Bolli kodi	R PWV
Gruiformes	*Fulica atra*	Common Coot	Bolli kodi	R WV
Charadriiformes	*Hydrophasianus chirurgus*	Pheasant-tailed Jacana		R LM
Charadriiformes	*Metopidius indicus*	Bronze-winged Jacana		R
Charadriiformes	*Gallinago gallinago*	Common Snipe	Muku puredi	PR WV
Charadriiformes	*Himantopus himantopus*	Black-winged Stilt		R LM
Charadriiformes	*Vanellus indicus*	Red-wattled Lapwing	Yennapa chitawa	R
Charadriiformes	*Tringa glareola*	Wood Sandpiper	Chinna ulanka	WV
Charadriiformes	*Actitis hypoleucos*	Common Sandpiper	Polte ulanka	WV
Charadriiformes	*Calidris temminckii*	Temminck's Stint		WV
Coraciiformes	*Halcyon smyrnensis*	White-throated Kingfisher		R
Coraciiformes	*Alcedo atthis*	Small Blue Kingfisher		R
Coraciiformes	*Ceryle rudis*	Pied Kingfisher		R

Appendix 2

Order	*Scientific name*	English name	Telugu name	Status
Coraciiformes	*Upupa epops*	Common Hoopoe		R LM
Piciformes	*Dinopium benghalense*	Black-rumped Flameback		R
Falconiformes	*Circus aeruginosus*	Eurasian Marsh Harrier		WV
Falconiformes	*Accipiter badius*	Shikra		R
Falconiformes	*Ictinaetus malayensis*	Black Eagle	Adavi nalla gadda	WV
Psittaciformes	*Psittacula krameri*	Rose-ringed Parakeet	Chiluka	R
Cuculiformes	*Clamator jacobinus*	Pied Cuckoo		R
Cuculiformes	*Surniculus lugubris*	Drongo Cuckoo		BV
Cuculiformes	*Eudynamys scolopacea*	Asian Koel	Nalla kovela(M), Poda kovela (F)	R LM
Cuculiformes	*Centropus sinensis*	Lesser Coucal		R
Coraciiformes	*Coracias benghalensis*	Indian Roller	Pala pitta	R LM
Passeriformes	*Oriolus oriolus*	Golden Oriole	Vanga pandu	V
Passeriformes	*Dicrurus macrocercus*	Black Drongo	Passala poli gaud	R LM
Passeriformes	*Terpsiphone paradise*	Asian Paradise-Flycatcher	Toka pigilipitta	R LM
Passeriformes	*Corvus splendens*	House Crow	Manchi kaki	R
Passeriformes	*Hirundo rustica*	Common Swallow	Wana kovela	R
Passeriformes	*Hirundo daurica*	Red-rumped Swallow		WV
Passeriformes	*Prinia inornata*	Plain Prinia	Lota-kun-jitta	R
Passeriformes	*Pycnonotus cafer*	Red-vented Bulbul	Pigli-pitta	R
Passeriformes	*Orthotomus sutorius*	Common Tailorbird	Likka jitta	R
Passeriformes	*Acridotheres tristis*	Common Myna	Goranka	R
Passeriformes	*Sturnus pagodarum*	Brahminy Starling	Papata gorinki	R LM
Passeriformes	*Sturnus roseus*	Rosy Starling	Pariki pitta/Palisa	WV
Passeriformes	*Sturnus contra*	Asian Pied Starling	Venda gorinka	R LM
Passeriformes	*Nectarinia zeylonica*	Purple-rumped Sunbird		R

Passeriformes	*Nectarinia asiatica*	Purple-Sunbird	Thena-pitta	R LM
Passeriformes	*Ploceus philippinus*	Baya Weaver	*Parsupu pitta*	R
Passeriformes	*Motacilla maderaspatensis*	White-browed Wagtail	Sakala sarela-gadu	R
Passeriformes	*Motacilla flava*	Yellow Wagtail		WV

* Occasional visitors; R-Resident; LM-Local Migrant; V-Vagrant; WV-Winter Visitor;

** *Rare Visitors* ; PR-Partially Resident