

Resting and roosting requirements of the near - threatened spot-billed pelican *Pelecanus philippensis* Gmelin 1789, in Pulicat Lake, Andhra Pradesh, India

Vaithianathan Kannan

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Abstract

Habitat requirements for resting and roosting of the near-threatened spot-billed pelican *Pelecanus philippensis* is very important for conservation of the species. Pulicat Lake holds a significant population of spot-billed pelican. The requirement for rest and roost habitats for the species is needed to strengthen effective conservation measures. Field based observational studies were conducted from October 2010 to September 2012 on the species at Pulicat Lake to understand its resting and roosting requirements. The mudflat habitat was largely used for resting (66.3%) and roosting (54.2%). However, abandoned crop fields were found to be preferred by pelicans for roosting in Pulicat Lake. The nearest feeding distance ranged from 5 to 6.5 m from rest site and 3 to 6 m to its roost site. Pelicans observed to have association with painted stork, caspian tern, brown-headed gull and oriental white ibis at rest site, whereas, at roost it has association with spot-billed duck, spoonbill, grey heron, shovellers and garganey. A total of 10 roost sites were regularly monitored and found to be used by pelicans at Pulicat Lake. However, the arrival of pelicans at the roost sites was highly variable.

Key words: Habitat requirement, India, Pulicat Lake, Resting and roosting ecology, Spot-billed pelican

INTRODUCTION

All birds need undisturbed places for rest and roost during the day and at night to avoid predation or stress (Weller, 1999). Roosting is a general term for nocturnal resting of individual flocks at specific sites whereas in day time it is termed as loafing. Some species have very specific requirements for rest sites. Many species rest and roost along bare shorelines or mudflats, or on islands where they are protected from ground predators at night. Social tolerance is the

offset for higher alertness for predators. Water birds like the coots, cranes and geese apparently sit on mats of submerged vegetation, open sheet-water to roost overnight (Tachaet *et al.*, 1994). Loons are known to 'roost' together at night but disperse and defend feeding areas during the day (McIntyre, 1978). Wintering Lesser Snow Geese on the Gulf of Mexico coastal plain, use of a region which seems to depend upon the availability of their preferred roost area, and birds may come and go at night if feeding conditions or disturbance patterns demand (Newton, 2006). Ground roosters like northern harriers may be subjected to predation by great-horned owls (Weller *et al.*, 1955), but still larger perchers like herons and ospreys use snags or posts in conspicuous places but are large enough to escape aerial predators.

Several bird species roost in groups of hundreds or thousands. These roosting flocks may be composed of a single species or of several species. Birds that commonly roost in large numbers include starlings, house sparrows, crows, grackles, gulls, purple martins, red-winged blackbirds, pigeons, vultures and wading birds. Roosting sites may involve trees and shrubs for herons and passerines, emergent vegetation for night herons, swallows, and blackbirds, and a vegetated site like waterlilies or lotus beds,



Vaithianathan Kannan

email: kannan.vaithianathan@gmail.com

PG and Research Department of Zoology and Wildlife Biology, A.V.C. College (Autonomous), Mannampandal - 609 305, Mayiladuthurai, Tamil Nadu, India.

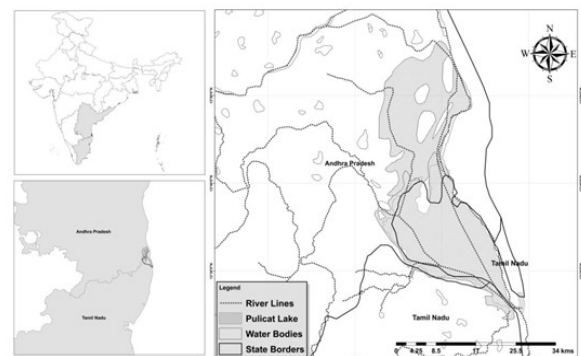


Fig. 1. Map of the Pulicat Lake

flooded shrubs, or forest canopy for swimmers like woodducks (Hein and Haugen, 1966; Martin and Haugen, 1960). Roost sites are an essential ingredient of the home range of such species and may be related to the location of food, spaced at a minimal distance. There are a lot of studies on mixed-species roosting in herons, egrets, blackbirds, swallows, gulls and dabbling ducks (Ehrlich *et al.*, 1988). These studies state that protection from predators and location at an energy-saving distance from foraging sites are the advantages of such roosts. The more interesting idea about roosts and other flocking is to gain visual or vocal cues to the location of food resources. This was termed as Information Center Hypothesis, but some researchers have concluded that herons and egrets gain information and even follow successful birds to daytime feeding areas (Krebs, 1978). Unlike the resting, roosting usually takes place on the same sites on sandbars, small islands, jetties and is frequently traditional sites, which are used year after year. Communal roosting habits were observed in a diverse array of bird species (Allen and Young, 1982; Eiserer, 1984) and are common among Falconiiformes (Anderson and Patterson, 1988; Steenhof, 1984), especially in the family Cathartidae (vultures), and may occur in association with rare and unpredictably distributed food resources, such as carrion (Rabenold, 1987; Thompson, *et al.*, 1990). In most species, group foraging is associated with communal roosting or colonial breeding. An alleged advantage of communal roosting and colonial breeding in terms of foraging is given by the information center hypothesis (Ward and Zahavi, 1973), according to which animals at a roost of a colony may transfer information about the location of new ephemeral food sources (Ward and Zahavi, 1973; Allchin, 1992; Barta and Szep, 1995; Mazluff *et al.*, 1996; Bayer, 1981; Mock *et al.*, 1988; Richner and Heeb, 1995). Alternatively, roosts or colonies, as assemblages of many individuals, may facilitate local enhancement (Thrope, 1963) to find food (Brown, 1988; Buckley, 1996). The role of flock foraging in the evolution of avian coloniality has thus often been discussed (Horn, 1968; Ward and Zahavi, 1973; Wittemberger and Hunt, 1985; Brown and Brown, 1996; Richner and Heeb, 1996).

Spot-billed Pelicans (*Pelecanus philippensis*) breed in colonies, feed in groups and roost in flocks. In general the birds rest and roost in a variety of natural areas and man-made structures (Mainwaring, 2015). Natural roosting sites can include trees in urban parks and residential areas, haystacks, hedgerows and marshy areas. Man-made structures were chosen for roosting and often include barns, ledges, chimneys, attics, flat roofs, airport hangers and runways. Observers may see various waterbirds fly during the day, some land in the water to drink, to feed and some

land on a mudflat or a snag, by disturbing other individuals or species to find a place to rest. The ecological requirement for resting and roosting of spot-billed pelicans are not known. Social gatherings require special habitat and certain conditions within that habitat to meet the needs of a species or mixed flock. On the other hand, not much is known on roosting ecology of Indian birds (Gadgil, 1972), Gadgil and Ali (1975) described the function of mixed roosts and information on communal roosting in Indian birds. After which studies have been conducted on roosting habits of common myna *Acridotheres tristis* (Sengupta, 1973), bank myna *Acridotheres ginginianus* (Khera and Kalsi, 1986), weaver birds (Ambedkar, 1968; Dhindsa and Toor, 1981), pariah kite *Milvus migrans* (Mahabal and Bastawade 1984), rosy pastor *Sturnus roseus* (Mahabal and Bastawade, 1980) and green bee-eater *Merops orientalis*. Hence, the requirements of the resting and roosting ecology of the spot-billed pelican in Pulicat Lake were studied to understand the factors that determine safe resting and roosting for pelicans in the Pulicat Lake.

MATERIALS AND METHODS

Study area

The study was confined in Pulicat Lake. Pulicat Lake (13° 33' 34.19" N 80° 10' 17.40" E) the second-largest brackish water lake after Chilika (Orissa) in India covering an area of 720 km² and one of the most important refuges for waterbirds in southern India (Scott, 1989). Because of its importance to waterbirds, Pulicat has been identified as an IBA (Important Bird Area) site of India by BirdLife International and Bombay Natural History Society (Islam and Rahmani, 2004) and has also been proposed for inclusion as a Ramsar Site of Wetland of International Importance by Wetlands International (Figure 1).

Pelicans are amongst the most distinctive of birds and thus are instantly recognizable (Ali and Ripley, 1978; Elliott, 1992). The family Pelecanidae comprises of only one genus, *Pelecanus*. At present, eight species are recognized (Sen Nag, 2019). The Spot-billed Pelican (*Pelecanus philippensis*) is distributed over a range of territory between 129,000 and 181,000 km² in South-east Asia (BirdLife International, 2000; 2001). The strongholds of the species are in India, largely distributed and confined to southern and north-eastern India (BirdLife International, 2000; 2001; Kannan and Manakadan, 2005), Sri Lanka, Cambodia (Thomas, 1964; Archibald, 1992; Scott, 1992; Carr, 1993; Mundkur and Taylor, 1993), Sumatra (Silvius, 1986; Verheugtet *et al.*, 1993), Thailand (Boonsong and Round, 1991), Philippines (Weerd and Der Ploeg, 2004). Historically the species was reported in Java, Pakistan, Bangladesh, Indonesia, Nepal, Turkey, Laos,

Malaysia, Korea, Thailand, China, Vietnam and the Philippines (Aarestrup *et al.*, 1971; Johnsgard, 1993; Grimmer *et al.*, 1999b; Stattersûeld and Capper, 2000; Hutchins *et al.*, 2003; BirdLife International, 2004a; 2005; UNEP-WCMC Species Database, 2005). Due to the decline over time and much-reduced distribution range besides other factors, the Species Survival Commission (SSC) and the Pelican Specialist Group have strongly urged for studying the species in depth in India (Crivelli and Schreiber, 1984; Elliott, 1992; Collar *et al.*, 1994; Crivelli and Anderson, 1996; BirdLife International, 2003; Crosby and Chan, 2006; Kannan and Pandiyan, 2013). The species is notified as Near Threatened (BirdLife International, 2005; BirdLife International, 2019).

Methodology

Pelicans are very social and usually found in flocks. Observations were conducted throughout the Pulicat Lake. Data were collected from the flocks; the individual birds were not observed due to the difficulty in following the individuals. Pelicans were observed from a maximum of 100 m distance using a spot-scope and binoculars. They were not approached closer to avoid disturbance by the observer. Whenever the pelicans were sighted, the following parameters were recorded: time of observation, habitat type in which sightings were made, associated species, number of birds present, number of days roost used, distance from shore, distance from road, nearest feeding distance, distance from water, and distance

location was marked in the map. After this those sites were re-visited during the night to confirm whether the site is used throughout the night. At each roost, counts were done just before the dusk and if the roost sites were close by, daily visits were also made to make sure pelicans were present at the roost site. In addition to this, fishermen were also enquired to confirm the birds and the number of days the roost site is used or disturbance caused, if any.

RESULTS

Resting Requirements

A total of 202 observations were made on resting pelicans in Pulicat Lake. Five major habitat types were used by the pelicans such as mudflat, in water, stone, vegetated grassy island, and edge of the waterbody. Of the total observations, the mudflat habitat (66.3%) was largely used (the highest number of birds was recorded), followed by in water and vegetated grassy island (5.9%) and the edge of the waterbody (4.0%). In addition to this, pelicans were observed to have rested on the stones smudged in the water along the culvert paths (Figure 2).

At the rest site, the flock size of the Spot-billed Pelicans was the highest in the edge of the waterbody (108.3±15.9) followed by mudflat (94.4±52.2), on stone (94.1±25.7) and in the vegetated grassy island (90.7±18.9) and in water (84.7±40.2). Distance from the resting site to the shore was the highest while resting on stones (18.1±9.3), followed by the edge of the waterbody (16.6±11.0), in water (13.0±7.6), mudflat (11.6±8.2) and the mean distance from the resting site to shore was 9.7±9.8 m in the vegetated grassy island. However, the maximum mean distance from the road to the resting site was the highest while resting on stones (23.6±8.5) and the lowest was in the vegetated grassy island (16.2±14.0). On the whole, in all habitat types recorded for resting the nearest feeding distance

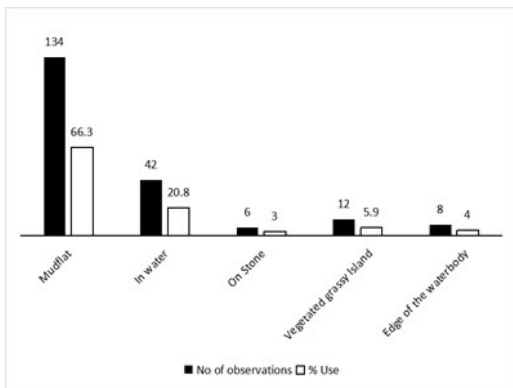


Fig. 2. Resting habitat used by the spot-billed pelican based on the number of observation

from bush. Resting observations were taken at different times of the day. Roosting records and sites of the pelicans in Pulicat Lake were done before the sunset and sites were marked in the map for regular monitoring. Two-year (October 2010-September 2012) data were used in this analysis. Visits were made all over the Pulicat Lake during the evenings (1700hrs – 1800hrs) to find the roost site. During all the visits if the pelicans are found using a site for roosting, the

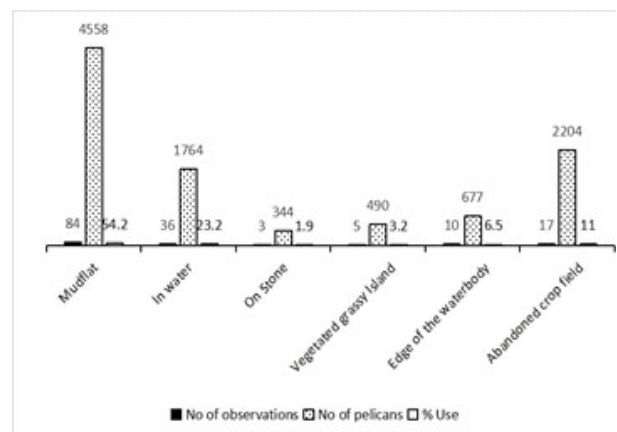


Fig.3. Roosting habitat used by spot-billed pelican based on the number of observation across number of pelicans counted

Table 1. Flock size and mean distance from the major disturbance parameters from the rest sites of the Spot-billed Pelican

Habitat	No of pelicans (Mean \pm SD)	Distance from shore (m)	Distance from road (km)	Nearest feeding distance (m)	Distance from water (m)	Distance from bush (m)
Mudflat	94.4 \pm 52.2	11.6 \pm 8.2	20.0 \pm 13.6	5.4 \pm 2.7	1.9 \pm 0.8	8.2 \pm 4.7
In water	84.7 \pm 40.2	13.0 \pm 7.6	20.7 \pm 13.7	6.3 \pm 2.4	-	10.0 \pm 6.3
On Stone	94.1 \pm 25.7	18.1 \pm 9.3	23.6 \pm 8.5	6.5 \pm 2.6	2.3 \pm 0.8	7.5 \pm 2.0
Vegetated grassy Island	90.7 \pm 18.9	9.7 \pm 9.8	16.2 \pm 14.0	5.8 \pm 3.2	2.0 \pm 0.8	9.6 \pm 6.3
Edge of the waterbody	108.3 \pm 15.9	16.6 \pm 11.0	16.6 \pm 18.8	5.0 \pm 2.9	2.1 \pm 0.6	5.7 \pm 2.6

Table 2. Correlations between the disturbance factors and the number of pelicans at different rest sites

Habitat	Mean no. of pelicans	Shore distance	Road distance	Feeding site distance	Water distance	Bush distance
Mudflat	94.4	-0.46	0.062	-0.115	0.081	-0.062
In water	84.7	0.114	0.303	0.114	-	-0.054
On Stone	94.1	0.684	0.211	-0.442	0.434	-0.421
Vegetated grassy Island	90.4	-0.338	-0.53	0.093	-0.269	-0.666*
Edge of the waterbody	108.3	0.491	0.161	-0.236	-0.761*	0.474

*Correlation is significant at the 0.05 level (2-tailed).

Table 3. Flock size and mean distance from the major disturbance parameters from the roost sites of the spot-billed pelican

Habitat	No of pelicans (Mean \pm SD)	Distance from shore (m)	Distance from road (km)	Nearest feeding distance (m)	Distance from water (m)	Distance from bush (m)
Mudflat	54.5 \pm 32.9 (n=84)	12.3 \pm 7.9	19.7 \pm 12.8	5.4 \pm 2.8	2.0 \pm 0.8	8.5 \pm 5.5
In water	48.1 \pm 36.0 (n=36)	16.0 \pm 8.3	21.0 \pm 13.7	6.0 \pm 2.2	-	9.3 \pm 6.1
On Stone	117.5 \pm 3.5 (n=3)	26.0 \pm 3.6	28.3 \pm 7.2	5.3 \pm 3.0	1.6 \pm 1.1	10.3 \pm 4.5
Vegetated grassy Island	100.7 \pm 6.8 (n=5)	10.8 \pm 10.5	17.2 \pm 12.6	5.0 \pm 3.7	2.0 \pm 0.8	6.5 \pm 2.2
Edge of the waterbody	63.3 \pm 50.3 (n=10)	20.0 \pm 8.8	15.4 \pm 13.8	5.3 \pm 2.3	2.3 \pm 0.4	7.3 \pm 5.2
Abandoned crop field	134.5 \pm 52.5 (n=17)	13.1 \pm 8.9	23.0 \pm 10.0	5.4 \pm 2.9	2.8 \pm 0.3	7.7 \pm 3.2

ranged from 5 m to 6.5 m. Apart from resting in water, the mean distance from the resting habitat to water is approximately 2 m. There is no relationship between the pelican rest site to the bush distance though the mean distance from the rest site to the bush was the highest in water (10.0 \pm 6.3) and the lowest while

resting on the stone which is adjacent to the roads (7.5 \pm 2.0) (Table1).

The distance from the mudflat rest site to the road distance ($r = 0.062$; $p < 0.596$) and water distance ($r = 0.081$; $p < 0.353$) were positively correlated whereas the shore distance, nearest feeding area distance and bush distance is negatively correlated. In water rest

site to the shore distance, road distance, and feeding area distance were positively correlated whereas the bush distance ($r = -0.054$; $p < 0.734$) was negatively correlated. Since pelicans were resting in water, the water distance was not taken as a parameter in this analysis. However, the nearest feeding area distance to bush distance was significantly correlated at the 0.05 level ($r = -0.314$; $p < 0.043$). Pelican's resting on stones was positively correlated with shore distance; road distance and water distance, the nearest feeding area distance and bush distance were negatively correlated. The nearest feeding area distance and water distance was significantly correlated at 0.05 level ($r = -0.827$; $p < 0.42$). Pelicans resting in the vegetated grassy island positively correlated only with the nearest feeding area distance ($r = 0.093$; $p < 0.773$) while other parameters showed negative values whereas the number of pelicans and the bush distance was significantly correlated at 0.05 level ($r = -0.666$; $p < 0.018$). Similarly, pelican's resting at the edge of the waterbody was significantly correlated to water distance at 0.05 level ($r = -0.761$; $p < 0.028$) (Table 2).

Overall the correlation analysis showed that there is no significant relationship between the number of the pelicans and major disturbance factors from the rest sites. At rest sites, the spot-billed pelicans were observed to have an association with painted stork *Mycteria leucocephala*, caspian tern *Sterna caspia*, brown-headed gull *Larus brunnicapillus* and oriental white ibis *Threskiornis melanocephalus*.

Roosting Requirements

A total of 155 observations were made on the roosting pelicans in Pulicat Lake. Unlike the resting sites, pelicans used six major habitat types such as mudflat, in water, on a stone, vegetated grassy island, the edge of the waterbody and abandoned crop field. Of the total observations, the mudflat habitat (45.4%) was largely used and the highest number of birds was recorded followed by abandoned crop field (22.0%) and in water (17.6%). In addition to this, pelicans were observed to have roosting on stony areas in the mudflat vegetated grassy island and at the edge of the waterbody (Fig. 3).

At the roost site, the flock size of the spot-billed pelican was the highest in the abandoned crop field (134.5 ± 52.5) followed by vegetated grassy island (100.7 ± 6.8), on stony areas (117.5 ± 3.5) and at the edge of the waterbody (63.3 ± 50.3) and in mudflats (54.5 ± 32.9). From the roosting site to the shore was the highest while roosting on stony areas that are present along the Sriharikot road (26.0 ± 3.6) followed by the edge of the waterbody (20.0 ± 8.8), in water (16.0 ± 8.3)

and in the abandoned crop field (13.1 ± 8.9). However, the maximum mean distance from the road to the roosting site was the highest while roosting on stony sites (28.3 ± 7.2) and the lowest was in the edge of the waterbody (15.4 ± 13.8). On the whole, in all habitat types recorded for roosting the nearest feeding distance ranged from 3 m to 6 m. Apart from roosting in water, the mean distance from the roosting site to water is approximately 2 to 3 m. Similarly, for the resting sites of spot-billed pelicans, there is no relationship between the roosting pelican and roost site to the bush distance though the mean distance from the roost site to the bush was the highest while roosting on stony areas (10.3 ± 4.5) and lowest in water (6.5 ± 2.2) (Table 3).

In all habitats where spot-billed pelican roosted was similar from the shore distance ($r = 1.000$). The road distance from the water roosts, the edge of the waterbody and abandoned crop field was negatively correlated. Pelican numbers roosting in the vegetated grassy island were significantly correlated ($r = 0.839$; $p < 0.018$) with distance to roads. The distance to feeding areas were negatively correlated with water roosts ($r = -0.009$), on stone ($r = 0.817$; $p < 0.391$), the edge of the water body and in the abandoned crop field ($r = 0.451$; $p < 0.191$). Except for the water roost the mudflat, edge of the water body and in the abandoned crop field the water distance was negatively correlated. Although there is no exact relationship between bush distance to roost site, the habitats in water, on a stone and in vegetated grassy island roost were negatively correlated (Table 4).

This shows that the pelicans select the sites for roosting with natural features, which are protecting where predators and other disturbances cannot approach easily. On the other hand, at the roost sites, the pelicans observed to have an association with spot-billed duck *Anas poecilorhyncha*, eurasian spoonbill *Platalea leucorodia*, grey heron *Ardeacinerea*, northern shoveller *Anas clypeata* and garganey *Anas querquedula* as they were recorded with pelicans at the roost site. Apart from the duck species the grey heron and eurasian spoonbill were found in pelican roost site and this could be due to food, which was disgorge by the pelicans. A total of 10 roost sites were regularly monitored and found used by pelicans at Pulicat Lake. The time of arrival of pelicans at the roosts was highly variable. The maximum number of birds used abandoned crop field followed by stony habitats for roosting. The roost site at Moolah - I in the abandoned crop field was used for a long period (35 days) followed by the mudflat habitat near Venadu

Table 4. Correlation between the disturbance factors and the number of pelicans at different roost sites

Habitat	Mean no of pelicans	Shore distance	Road distance	Feeding site distance	Water distance	Bush distance
Mudflat	54.5	1	0.128	0.078	-0.028	0.159
In water	48.1	1	-0.04	-0.009	-	-0.118
On Stone	117.5	1	0.307	-0.817	0.961	-0.338
Vegetated grassy Island	100.7	1	0.839*	0.121	0.135	-0.23
Edge of the waterbody	63.3	1	-0.076	-0.451	-0.181	0.187
Abandoned crop field	134.5	1	-0.076	-0.451	-0.181	0.187

*Correlation is significant at the 0.05 level (2-tailed).

Table 5. Site name, habitat type and number of days the roost sites occupied by the Spot-billed Pelicans in Pulicat Lake during the study (October 2010-September 2012)

Site name	Habitat type	Mean number of birds	Months used for roosting	Number of days roost occupied
Venadu	Mudflat	98	Oct; Jan; Feb	25
Kudiri wetland	In Water	6.6	Jan	13
Sriharikota Road	On a stone	114.6	May	15
Moolah - I	Abandoned crop field	129.6	July	35
Moolah - II	Mudflat	62	Apr; Sep; June	8
Moolah - III	In water	23	Feb; Mar	11
Moolah - IV	Edge of the waterbody	67.7	March	15
Moolahwetland - V	In water	52.2	Jan; May	15
Beripeta - I	Mudflat	62.7	Apr; May, June, Mar; Oct; Jan; Feb	15
Beripeta - II	In water	83.6	Jan; May	10

(25 days). Other locations were used based on the water level and local conditions (Table 5).

DISCUSSION

Pelican's communal roosting provides several advantages to the species as well to other species of birds because of their highly developed skills of fish-eating birds in food finding. The food finding phenomenon provides an opportunity to the associated species especially fish-eating birds to find suitable food patches. On the other hand, less experienced members or the new recruitments of the same species of the roost can follow other birds to known feeding sites. The adaptive significance of communal roosting in birds is not well-understood (Keister *et al.*, 1985; Beauchamp and Guy, 1999). Pelicans resting and roosting in a mudflat, in water, on a stones, vegetated grassy island, the edge of the waterbody and abandoned crop field could be due to favourable micro-climates and surrounding areas aids in thermoregulation and energy conservation.

The pelicans began congregating at dusk (sunset was approximately 1800 h), making short flights from main foraging site to roost site. Pelicans arrive mostly one by one or in a large influx of birds to the roost site. In all roost sites, it was observed that there is no major vegetation surrounding near to the roosts except the *Prosopis* clumps. Other birds roosted with pelicans are Grey Heron *Ardea cinerea* and Eurasian Spoonbill *Platalea leucorodia*. No aggressive interactions were noted between any of the species at the roosts. However, the pelicans gurgle when disturbed at night, and leave the site one by one or all at once if the disturbance is strong. At roost sites, the pelicans sleep with the bill tucked in scapular feathers, which was the predominant behaviour of pelicans at their stand roost (Pavlovic *et al.*, 2018).

Members in pelican roosts, are likely to be non-breeders (mostly immature birds) during the breeding season because an active nest requires frequent visits. Hence, most of the breeders probably limit their foraging and roosting activities within home ranges.

Therefore, non-breeders are expected to comprise a disproportionate number of the individuals at roosts in the breeding season. However, the observations could not be compared to the overall distribution of pelicans in the area due to their large size. In poor-weather, the pelicans may stay all day at their roosting sites or even several days if the weather remains bad. Unlike the geese, cranes and ducks, the pelicans were silent at the roost.

Pelicans breed in tropical and temperate regions (Elliott, 1992). The presence of suitable resting and roosting sites is often important in determining the successful foraging and breeding of pelicans. The two-year study at Pulicat Lake was not adequate to reveal the impact of on the resting and roosting ecology of the spot-billed pelican. No pelican was seen resting and roosting on the trees in Pulicat Lake during the study period. Due to its large size and their strong gregarious tendencies, pelicans need an abundant supply of fish, a requirement that restricts the potential range of most species. The spot-billed pelican obviously need safe and undisturbed sites for resting and roosting. Resting and roosting sites of the spot-billed pelican indicates that the foraging habitat has to be safe in such case; the pelicans can fly far from their roost site for feeding.

Inter-species association of resting and roosting birds has been reported widely. Association among co-occurring species at the roosts reduce predation and alertness among the birds is well known. Protection of resting and roosting sites of the spot-billed pelican is essential by minimizing the disturbance caused by the fishermen. At one roost it was observed that the pelicans were roosting over the bund at a abandoned crop field, birds such as ducks, other wading birds roost at the middle portion of the same site, and the pelican flock seems to be less exposed to predators. In three instances during the study period the author came across the remains of the spot-billed pelican's carcass possibly predated by Jackal *Canis vulpes* at the abandoned crop field (near Moolah) roost site. In addition, on two occasions it was also observed that the Jackals were chasing the resting pelicans along the Sriharikota road. During the study period, the spot-billed pelicans almost used the same sites for roosting. However, some of the regularly used roost sites are temporarily abandoned due to disturbance possibly caused by the fishermen movements during the night in Pulicat Lake. Spot-billed Pelicans in Pulicat Lake observed to have an association with two different bird species in their roost sites. Interestingly the painted storks and egrets that associate with pelicans while feeding were not found at the observed pelican roost sites.

In Pulicat Lake, Spot-billed Pelicans fly as far as 10 km to roost. This represents less energy expenditure of the pelicans for energy savings. During severe conditions, the pelicans stay mostly around the Beripeta area adjacent to the Sriharikota Island to compensate for the energy lost in flying from the feeding locations to the roost. The shortest distance between any roost and a feeding area is 1 km. Therefore, communal roosting behaviour by pelicans in Pulicat Lake can be explained solely because of energy savings. In fact, roosts that are more than 50 km from the feeding area can create energetic demand to the communally roosting pelicans. Kelty and Lustick(1977), reported that European Starlings selected favourable micro-climates provided by pinewoods to reduce the daily existence metabolism. Bald Eagles near the Nooksack River in Washington conserved energy by roosting in coniferous forests as compared with deciduous riparian areas (Stalmaster 1981; 1983). All these suggest that the thermal significance attributed to the selection of nocturnal roost (Calder, 1973; Calder and King, 1974; Kelty and Lustick, 1977). Therefore, it can be concluded that although pelican's roosts had favourable local weather conditions over the Pulicat Lake, energy savings were valid by the cost of flying to these roosts, and the adaptive significance of such behaviour could be to gain information regarding the location of the feeding sites.

Roosting of pelicans at Pulicat Lake was highly variable. This variability may be due to seasonal requirements for breeding, moult and migration. When the high temperature or strong winds occurred, roosting flocks arrive early even before the sunset. Departure from the roost sites during the morning could be more closely related to overnight starvation than the sunrise. When a predator appeared or disturbance occurred near the stand roost site, the typical response was the alert posture and looking for the immediate danger. The alert bird leaves the area or flies over the roost site. Immediately other alert birds also join and do the same unless their safety is assured. When the roosting flock was in the early stages of formation or late stages of departure, part or all of the flock sometimes leave the roosting site. The temperature and the wind are the most important factors governing the roosts of the pelican (Newton, 2006).

The water level and wind speed are another most important factors governing the rest and roosts of pelicans. Most studies of coastal shorebirds have reported close relationships between tides and movements to and from the feeding areas, primarily because of the effect of tide level on availability of prey and foraging space (Evans, 1976; Burger *et al.*, 1977; Connors *et al.*, 1981; O'Connor, 1981; Cramp and

Simmons, 1983; Burger, 1984; Myers, 1984; Zwartset al., 1990). No evidence has been found of pelicans foraging on vegetated habitats during high water, although a small proportion of the pelicans observed feeding at the roost site itself on few occasions. Food resources on coastal lakes in tropics decline sharply as summer progresses, and this decline is probably an important determinant of the timing of pelicans shift to the southern portion of the Pulicat lake for foraging during summer and after breeding. Pelicans departing from evening flew predominantly in the direction of main feeding areas as the water level increases. During such conditions, other large wading birds such as painted stork *Mycteria leucocephala* and grey heron *Ardeacinerea* take advantage of the site for feeding. One such incident during the night visits confirmed this, and the pelicans were found to be roosting whereas the storks and herons were found feeding (Kannan and Manakadan, 2007).

Pelican's feeding activity had been found to follow primarily a diurnal periodicity rather than tidal. Crepuscular movements to and from the roost regardless of the stage of water level were unanticipated. Not only did dawn and dusk influence the formation and dispersal of roosting flocks at low water levels, when we expect pelicans to be foraging on shallow water flats, but interactions of the timing of sunrise and sunset with the timing of high water also served to extend the number of time the pelicans spent at the roosts. Crepuscular formation of roosts is typical of shorebirds using inland habitats (Hamilton, 1959; Swinebroad, 1964; Brooke, 1972; Atkinson, 1976; Myers and Myers, 1979; Myers, 1980) and has been documented for a few species of coastal dwelling shorebirds (Goss-Custard, 1969; Hartwick and Blaylock, 1979; Hockey, 1985; Myers *et al.*, 1985; Jaques, 1994). From flight directions and synchronous movements of the departing birds, it is inferred that pelicans flew to an area of mudflats that was not going to be submerged at high water, to some unknown roost site inland, or to join a roosting flock in the central portion of the lake. In addition to that, during extensive searches of pelicans in the lake I found concentrations of droppings or moulted feather were found which is an indication of where pelicans might have roosted. During nights, it may have been advantageous for pelicans to roost at sites other than those occupied regularly during the day to decrease the risk of predation by ground predators.

On days of winds greater than 25 km/h, pelicans tended to form large, compact roosting flocks or to disperse into islands and high bunds. Roosting pelicans in Pulicat Lake are crowding together during heavy winds. The wind has a strong effect on the insulative quality of plumage (Robinson *et al.*, 1976),

and heat loss in dunlins is thought to be accelerated by wind (Evans, 1976). Communal roosting may have afforded some thermal benefits because the wind speed is lower in the middle of shorebird roosts than at the edge (Whitlock, 1979; Ydenberg and Prins, 1984). Strong winds also affected attendance at particular roost sites. The flexibility to use several traditional roost sites interchangeably, depending on local roosting or feeding conditions, may allow pelicans to minimize energetic expenditures during the period of high demands.

CONCLUSIONS

From the study it has been found that the lake itself is a vulnerable wetland harboring significant number of near-threatened spot-billed pelicans. The study also revealed the key sites and habitat requirements of spot-billed pelican for resting and roosting in the Pulicat Lake. This is likely to occur in many other habitats, but the availability of this type of mudflat habitat is rapidly declining at Pulicat Lake due to lime-shell mining. The finding that disturbance by predators may determine the choice of roost underlines the importance of minimizing all sources of disturbance at rest and roosts had been abandoned and access to them was quite difficult. In Pulicat Lake, human disturbance is high which is likely to have an effect similar to that of potential predators, and ultimately force birds to change their selection of roosting site. The results also highlight that the need for high protection to those sites and habitat used by pelicans for resting and roosting in the Pulicat Lake. However, human disturbance appears to be higher in the Pulicat Lake, suggesting that this factor may be the determinant in the choice of rest and roost of spot-billed pelican. Thus, it may be concluded that habitats under investigation were under stress and perturbed which needs to be quantified.

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