Chapter 5

Habitat Utilisation by Storks

5.1 Foraging site selection in storks

5.1.1 Introduction

The term habitat utilisation has been used many times in the literature of birds and other animals for the assessment of their habitat requirements. Movement of the birds are also governed by the habitat quality and thus they distribute themselves in space and time. Habitat quality can be defined as the suitability of an area to support a reproducing population of a given species or group of species (Maures, 1986). The evaluation of habitat quality is a prime concern in development of management plans, impact assessments, mitigation studies and multiple resource use strategies. Cody (1985) stated that habitat use by birds is influenced by vegetation structure. I feel that the water birds are quite selective in this respect in order to enhance their foraging efficiency.

Many researchers have attempted to approach the assessment of habitat quality using multivariate statistical methods (James, 1971; Whitmore, 1975; Whitmore, 1977). Several studies on birds have considered partitioning mechanisms among coexisting heron species. Whitfield and Blaber (1979) found that segregation was achieved through a combination of prey size and wading depth among four different size herons in Lake St. Lucia, Natal, South Africa. Custor and Osborn (1978) found
that Great egrets (*Egretta alba*) fed in deeper water than did the smaller Snowy egret (*Egretta thula*) and Tricolored heron (*Egretta tricolor*). Willard (1977) working in fresh and salt water marshes in New Jersey found that larger herons ate larger fish and fed in deeper water than did smaller herons. These studies address the habitat utilisation by the an assemblage of storks for common resources in a tropical wetland ecosystem.

The habitat utilised can be in terms of nesting, foraging, roosting, resting or defining a territory for display. The present study was conducted to look for the habitats used by four species of storks for nesting, foraging and roosting. Habitat use with regard to foraging was studied for all the four species while habitat utilised for nesting and roosting habitat use was studied only for Whitenecked and Blacknecked stork.

5.1.2 Methods

Intensive vegetation sampling was done at all the feeding sites of each of the four species of storks. A systematic random sampling design was followed. At each sampling point, a 0.5 m x 0.5 m quadrat with 25 subdivisions of 10 x 10 cm each was used to record presence and absence of species and cover values. A total of 50 plots were sampled at each site. Plots were placed at 5 metres interval and at each sampling site, the following parameters were recorded:
i. Water level i.e., depth of water

ii. Percent vegetation cover by counting the subunits of the quadrat. The vegetation was classified into three classes;
   a. Floating vegetation
   b. Submerged vegetation and
   c. Emergent vegetation

The feeding sites of Whitenecked stork were shallow water bodies between forested areas. These sites were sampled for trees, shrub and ground cover of the different plant species. Point-centred-quarter (PCQ) method (Muller-Dombois & Ellenberg, 1974) was used to sample trees and shrubs. A total of 50 samples of trees and 50 points of shrubs were taken. At each point following parameters such as distance to nearest plant species for each quarter, girth at breast height (GBH), were recorded to calculate tree and shrub density. In each quarter distance to the nearest plant species was recorded; trees < 30 cm of GBH, height, tree species, shrub species.

Parker's two step method (Sale and Berkmuller, 1988) was used to sample ground cover which gives the percentage of ground covered by vegetation and the composition of that vegetation in terms of frequency of plant types or species.
5.1.3 Analyses

The Hierarchial cluster analysis was performed to classify the foraging sites of each species by using SPSS 6.1 (1994). The percent cover and relative frequency of the plant species encountered in each quadrat was calculated. PCQ method was used to calculate the density, frequency, dominance and diversity of the patches utilised for foraging by Whitenecked stork. Relative frequency, dominance and density were used to compute Importance value indices (IVI) (Mueller-Dombois & Ellenberg, 1974).

5.1.4 Results

The foraging sites were identified for all the four species- Whitenecked, Blacknecked, Openbill and Painted storks. The feeding behaviour and preference for prey species differs among the four stork species thus the area utilised for feeding in the Park. These sites were marked on the gridded map and later a detailed vegetation sampling was done. Since the feeding sites differed to a great extent between Whitenecked and rest of the stork species, the method of sampling varied. The data collection on the foraging ecology and the habitat utilised were started in 1994.

5.1.4.1 Foraging sites of solitary nesters

a. Blacknecked Stork

Four types of foraging sites of the BNS were seen during the study period. These sites were marked on the map and were sampled when the storks were absent in
these areas to avoid the disturbance. Total 13 plant species were recorded during the sampling of these sites. *Azolla pinnata, Spirodea polyrhiza, Wolffia globosa* and unidentified Algae were the dominant floating species, *Utricularia* spp., *Paspalum distichum, Ipomea aquatica, Hydrilla verticillata* were the submerged species while *Eleocharis dulcis, Eichornia crassipes, Cyperus rotundus, Echinocloa colonum* and *Paspalidium punctatum* were the dominant emergent species.

In E block (site 1) (see study area for block characteristics), the cluster analysis showed first grouping between *Spirodea polyrhiza* and *Wolffia globosa* which constituted the floating vegetation followed by *Hydrilla verticillata* and *Cyperus rotundus* assembling also with *Spirodea polyrhiza* and *Wolffia globosa*, Algae, *Paspalum distichum, Echinocloa colonum, Eleocharis dulcis* (Fig 5.1.1). The species structured at an increasing or higher euclidean distances in the hierarchial order were *Ipomea aquatica, Paspalidium punctatum, Utricularia* spp. and *Azolla pinnata*. The relative frequency of a *Azolla pinnata, Paspalidium punctatum, Ipomea aquatica, Utricularia* spp. was found to be highest and cover values of *Azolla pinnata* (28.6), *Paspalidium punctatum* (23.4) and *Utricularia* spp. (13.3) were high followed by rest of the species (Fig 5.1.2).

In D block (site 2), *Cyperus rotundus* and *Spirodea polyrhiza* showed first grouping followed by *Wolffia globosa* and *Hydrilla verticillata, Eleocharis dulcis, Paspalum distichum, Algae, Utricularia* spp., *Paspalidium punctatum* and *Azolla pinnata* (Fig
Fig 5.1.1 Association among the aquatic macrophytes at foraging site of Blacknecked Stork- E Block
Fig. 5.1.2 Relative frequency and cover of aquatic vegetation at Blacknecked storks' foraging site - E block

Aquatic Vegetation

- Azolla pinnata
- Paspalidium punctatum
- Ipomea aquatica
- Utricularia spp.
- Eleocharis dulcis
- Algae
- Echinocloa colonum
- Eichhornia crassipes
- Hydrilla verticillata
- Paspalum distichum
- Cyperus rotundus
- Wolffia globosa
- Spirodea polyrhiza

Legend:
□ Frequency
■ % Cover
5.1.3. The cover values of Azolla pinnata (29.3), Utricularia spp. (11.7) were high (Fig 5.1.4) and relative frequency of Azolla pinnata, Paspalidium punctatum, Ipomea aquatica.

The block K (site 3), Cyperus rotundus-Algae showed first grouping followed by Spirodela polyrhiza-Wolffia globosa, Utricularia spp.-Paspalidium punctatum (Fig 5.1.5). The Cover values of Paspalidium punctatum (27.4), Azolla pinnata (23.8) were high followed by rest of the species (Fig 5.1.6). The mean water depth recorded at the foraging site of Blacknecked stork was 40.24 ± 9.50 cm.

b. Whitenecked stork

A total of nine species of trees were recorded at the foraging sites of Whitenecked stork. The mean water depth at the foraging site was 10 ± 3.45 cm. The main tree species were Acacia nilotica, Mitragyna parvifolia, Ziziphus mauritiana, Syzigium cumini, Prosopis chilensis, Albizia lebbeck, Prosopis cineraria, Salvadora persica and Kiganelia reticulata. Acacia nilotica occurred in highest density 46.2 trees/hectare and was the most important species with an IVI of 180 and other dominant species which are in Table 5.1.1

Two species of shrubs were sampled at the foraging site of Whitenecked stork; Prosopis chilensis and Kiganelia reticulata. Kiganelia reticulata has the highest density 70.99 shrub/m², followed by Prosopis chilensis (Table 5.1.2).
Fig 5.1.3 Association among the aquatic macrophytes at foraging site of Blacknecked Stork- D Block
Fig. 5.1.4 Relative frequency and cover of aquatic vegetation at Blacknecked storks' foraging site-D block

Aquatic Vegetation

- Azolla pinnata
- Paspalidium punctatum
- Ipomea aquatica
- Utricularia spp.
- Paspalum distichum
- Algae
- Echinocloa colonum
- Eleocharis duloides
- Eichhornia crassipes
- Wolffia globosa
- Cyperus rotundus
- Spirodela polyrhiza

Legend:
- Frequency
- % Cover
Fig 5.1.5 Association among the aquatic macrophytes at foraging site of Blacknecked Stork - K Block
Fig. 5.1.6 Relative frequency and cover of aquatic vegetation at Blacknecked storks' foraging site—K block
<table>
<thead>
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<th>Tree species</th>
<th>Density</th>
<th>Relative Frequency</th>
<th>Relative Dominance</th>
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<tr>
<td>Acacia nilotica</td>
<td>91.4</td>
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<td>Mitragyna parvifolia</td>
<td>46.2</td>
<td>21.0</td>
<td>.60</td>
</tr>
<tr>
<td>S. persica</td>
<td>90</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Prosopis cineraria</td>
<td>22.8</td>
<td>9.4</td>
<td>.043</td>
</tr>
<tr>
<td>Albizia lebbeck</td>
<td>5.08</td>
<td>3.8</td>
<td>.05</td>
</tr>
<tr>
<td>Prosopis chilensis</td>
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<td>1.3</td>
<td>.13</td>
</tr>
<tr>
<td>Syzigium cumini</td>
<td>1.01</td>
<td>1.0</td>
<td>.01</td>
</tr>
<tr>
<td>Ziziphus mauritiana</td>
<td>15.2</td>
<td>9.4</td>
<td>.043</td>
</tr>
<tr>
<td>Kirgamine holiculata</td>
<td>7.7</td>
<td>1.3</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>19.0</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>9.4</td>
<td>17.2</td>
<td>.05</td>
</tr>
</tbody>
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Table 5.1: Tree density at foraging sites of Whenecked stork.
Table 5.1.2 Shrub density at foraging sites of Whitenecked stork

<table>
<thead>
<tr>
<th>Shrub species</th>
<th>Density</th>
<th>Relative Density</th>
<th>Frequency</th>
<th>Relative Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prosopis chilensis</td>
<td>.68</td>
<td>25.95</td>
<td>14</td>
<td>0.26</td>
</tr>
<tr>
<td>Kirganelia reticulata</td>
<td>1.86</td>
<td>70.99</td>
<td>38</td>
<td>71.69</td>
</tr>
</tbody>
</table>

Cynodon dactylon and Oxalis oxidentalis were the two dominant species encountered. The relative frequency of Cynodon dactylon was 75% and Oxalis oxidentalis 25%.

5.1.4.2 Foraging sites of colonial nesters

Like solitary nesters, foraging sites of the colonial nesters namely Painted and Openbill storks also differed in terms vegetation composition and feeding sites.

a. Painted Stork

I recorded 15 plant species at the foraging sites and placed them into three categories: Floating vegetation was constituted by Azolla pinnata, Algae, Spirodela polyrhiza and Wolffia globosa; submerged vegetation by Utricularia spp., Paspalum distichum, Ipomea aquatica and Hydrilla verticillata; and emergent by Panicum paludosum, Vetiveria zizanoides, Echinocloa colonum, Eleocharis dulcis, Eichhornia crassipes, Cyperus rotundus and Paspalidium punctatum.
First grouping was formed by *Paspalidium punctatum* which is an emergent species with *Eleocharis dulcis*, *Spirodea polyrhiza*, *Eichhornia crassipes*, Algae, *Cyperus rotundus* and *Echinocloa colonum* which are all emergent except for the two. This group forms an emergent assemblage of species. The second assemblage according to the hierarchial cluster is formed by *Vetiveria zizanoides* with all the above species and showed again an emergent assemblage. (Fig. 5.1.7). The group at the highest euclidean distance was formed by *Azolla pinnata* with *Panicum paludosum* and all the remaining species. *Azolla pinnata* (40), *Panicum paludosum* (18.7) and *Utricularia* spp. (14.6) had the highest cover whereas high values of the relative frequency were recorded for of *Azolla pinnata*, *Panicum paludosum* and *Hydrilla verticillata* (Fig 5.1.8).

The second foraging site (block E) showed two major clusters between *Paspalidium punctatum-Vetiveria zizanoides* and *Azolla pinnata* with rest of the species (Fig. 5.1.9). The percent cover of *Azolla pinnata* (45.5), *Paspalum distichum* (28) and *Echinocloa colonum* (17) was high while relative frequency of *Azolla pinnata*, *Paspalum distichum* and *Panicum paludosum* were high in comparison to other species found in the foraging sites (Fig 5.1.10). The mean water depth recorded at the foraging site of Painted stork was 21.83 ± 3.14 cm.

b. Openbill stork

Eight species of plants were recorded at the foraging site of Openbill stork located in L block. These species comprise *Azolla pinnata*, *Hydrilla verticillata*, *Panicum*
Fig 5.1.7 Association among the aquatic macrophytes at foraging site of Painted Stork - L Block
Fig. 5.1.8 Relative frequency of aquatic vegetation at Painted storks' foraging site - L block

Aquatic Vegetation

- Azolla pinnata
- Panicum colonum
- Hydrilla verticillata
- Utricularia spp.
- Wolffia globosa
- Paspalum distichum
- Ipomea aquatica
- Vetiveria zizanioides
- Paspalidium punctatum

Frequency
% Cover

Frequency
% Cover
Fig 5.1.9 Association among the aquatic macrophytes at foraging site of Painted Stork - E Block
Fig. 5.1.10 Relative frequency of aquatic vegetation at Painted storks' foraging site - E block.
paludosum, Vetiveria zizanoides, Algae, Paspalidium punctatum, Wolffia globosa and Utricularia spp.. The species formed two major clusters between Vetiveria zizanoides-Utricularia spp. and Azolla pinnata with rest of the species (Fig. 5.1.11). The relative frequency of Azolla pinnata, Panicum paludosum, Hydrilla verticillata and percent cover of Azolla pinnata (50.5) and Panicum paludosum (22.7) were high (Fig 5.1.12).

The second foraging site located in E block had three species associations Algae-Paspalidium punctatum, Utricularia spp.-Wolffia globosa-Paspalidium punctatum, Algae-Vetiveria zizanoides-Panicum paludosum forming another and the third association was of Azolla pinnata with other species (Fig. 5.1.13). Percent cover of Azolla pinnata (39) was higher than Panicum paludosum (22.7) while relative frequency of Azolla pinnata was higher than other species (Fig. 5.1.14). The water depth at the feeding site of Openbill stork was 19.21 ± 4.73 cm.

5.1.4.3 Differential habitat use pattern in solitary nesters

The foraging sites of Blacknecked and Whitenecked storks differ to a great extent in the composition of plant species. Wetland areas with more aquatic vegetation such as Paspalum distichum, Eleocharis dulcis, Echinocloa colonum and Cyperus rotundus were frequently utilised by Blacknecked stork. The foraging site of Whitenecked stork was dominated by tree species such as Acacia nilotica, Mitragyna parvifolia, shrubs such as Kirganelia reticulata and ground cover of Oxalis oxidentalis and Cynodon dactylon. No tree species was encountered at the
Fig 5.1.11 Association among the aquatic macrophytes at foraging site of Openbill Stork - L Block
Fig. 5.1.12 Relative frequency of aquatic vegetation at Openbill storks' foraging site - L block

Aquatic Vegetation

- Azolla pinnata
- Panicum colonum
- Hydrilla verticillata
- Utricularia spp.
- Vetiveria zizanioides

Frequency % Cover
Fig 5.1.13 Association among the aquatic macrophytes at foraging site of Openbill Stork- E Block
Fig. 5.1.14 Relative frequency of aquatic vegetation at Openbill storks' foraging site-E block.
foraging site of Blacknecked stork. There was significant difference ($X^2=34.75, p<0.001$) in mean water depth of the foraging sites of Blacknecked and Whitenecked storks.

5.1.4.4 Differential habitat use pattern in colonial nesters

There was slight difference in the feeding habitat of Painted and Openbill storks. All the feeding sites of Painted stork were characterised by areas where aquatic vegetation comprised of Algae, Ipomea aquatica, Hydrilla verticillata, Echinocloa colonum and Eleocharis dulcis whereas Openbill stork fed at the sites dominated by species such as Paspalidium punctatum and Vetiveria zizanoides. The mean water depth at the feeding site of Painted stork was $21.83 \pm 3.14$ cm while the feeding depth of water at Openbill's foraging site was $19.21 \pm 4.73$ cm. There was no significant difference ($X^2=1.66, p>0.05$) in the water depth of foraging sites of Openbill and Painted storks.

5.1.5 Discussion

Wetland ecosystems are one of the most dynamic and productive ecosystems. Wetlands with a higher nutrient content are more productive than those with a lower nutrient content (Cole, 1983 cited in Merendino and Ankney, 1994). I feel that the higher nutrient content is related to the hydrologic connectivity and openness of the wetland. Wetland choked with weeds like Eichhornia crassipes have low nutrient content than an open water body which allows free flow of sunlight to the different zones. A slight fluctuation in water level changes the species composition.
as some species prefer to grow in less water while some in deeper water levels. Vegetation structure has been the primary attribute measured to examine habitat selection by birds (James, 1971; Whittmore, 1977).

I found different kinds of composition of plant species at the foraging sites of all the four species of storks. The Openbill storks used more areas dominated by *Paspalidium punctatum* and *Vetiveria zizanoides* which probably grow in less water. *Paspalum distichum* was less in number which was the species occurred more at BNS site. As mentioned earlier, the Whitenecked stork preferred more forested areas with small pools for feeding. These sites had lot of ground cover and with high soil moisture which are probably favourable for insects. The Whitenecked storks were seen many times feeding on insects especially those found in small flooded grasslands. There was a clear resource segregation among these four species. It has also been proved by foraging ecology of the storks. This was quite well supported by Kushlan (1978, 1981) that species of wading birds within a community tend to partition resources and to show low overlap in habitat, time of feeding, prey size and feeding behaviour. Recher et al., (1983) have described differences in water depth and vegetation between foraging Australian heron; Hom (1983) found differences in prey, space, time and habitat, and Niethammer & Kaiser (1983) in prey in North America. Fasola (1986) studied the species pairs showing niche segregation in non-agricultural habitats (Night heron-Little egret & Grey-Purple herons) and which have the potential to compete for resources owing to morphological similarities.
Davis & van der Valk (1988) studied the vegetation structure of Keoladeo National Park (KNP) and reported the fast spread of *Paspalum distichum* with maximum cover followed by *Ipomea aquatica* then *Hydrilla verticillata*. Middleton (1992) discussed about the preference of *Paspalum distichum* dominated patches by the Greylag goose (*Anser anser*) and *Cynodon dactylon* patches by Barheaded goose (*Anser indicus*) in KNP. It was also clearly mentioned that the geese do not select sites within aquatic areas of the KNP based on the composition of plant community, therefore no generalisation can be made for encouraging a particular plant species in a particular habitat of the Park.

I feel that the presence of *Paspalum distichum* can attract a large number of waterfowl such as Greylag and Barheaded geese but birds such as storks and herons which need open, clear water to feed on fishes, growth of *Paspalum distichum* is not good. Besides *Paspalum distichum*, the other weed which is restricting the growth of other plants and movement of birds is *Eichhornia crassipes*. During the study period, I have observed the change of foraging site caused by the spread of *Eichhornia crassipes*.

There were certain sites which resembled in vegetation composition with the foraging sites but these sites were never utilised for foraging by Blacknecked stork. Probably the *Paspalum distichum* was too thick to wade for the species. It would have been interesting to sample the unused site only then it can be inferred with certainty which was not possible due to time constrain. The foraging sites of
Painted and Openbill stork are ephemeral in nature. The low level of water dries up quickly and the birds have to look for other potential sites which is the main reason for leaving Park in January as all the puddles and pools dry by that time.

Openbill and Painted storks are specialised feeders which require a certain level of water for efficiently foraging. Even a slight change in water level forces the birds to move to other sites. Blacknecked storks on the other hand are generalist, can feed on a variety of food items and have been observed in the Park all the year round. The four species can be seen utilising same sites only in June before monsoon, when the fishes gets concentrated in deeper pools (They face competition for a little time as the rain brings water which mean more fishes to the Park.).

I think that in order to have a good population of any species, habitat needs to be healthy in all possible ways. Food availability is the prime factor which governs the selection of site for breeding and other purposes. In KNP, fishes are abundant and distributed in the whole wetland but dense vegetation restrict the distribution of birds to utilise the habitat evenly.
5.2 Nest-site characteristics of solitary breeders

5.2.1 Introduction

Habitat selection involves the choice of particular habitat among the available habitats which results in non random distribution of birds in space. Partridge (1978) defined two factors for the selection and use of a particular area by an animal. Habitat selection can be in terms of territory selection, feeding site selection, roost-site selection or nest-site selection. There are two factors: proximate and ultimate which are important in the life of any organism. Proximate factors are used to evaluate a site. Proximate factor can be any characteristic of the environment that an organism uses as cue to behavioural or physiological responses. These can be understory, canopy spread, canopy height or slope. The presence or absence of animal of the same or other species as they may act as competitors or predators and may influence habitat use. Ultimate factors are the parameters that determine the success of an animal within a particular habitat like animals’ ability to reproduce, obtain food, and avoidance of predators.

Nest site selection involves selection of a site for construction of nest prior to egg laying. The selection of appropriate nest site is vital for the reproduction of birds because it determines the environment to which adults, eggs and altricial chicks will be exposed during critical periods. The site selection and making of nest provide the necessary protection against predation of eggs and nestling. The nest will be affected by environmental conditions such as exposure to the winds, protection from storms and nest architecture.
The selection of nest-site is a difficult task in solitary breeders. In colonial breeders, the birds follow other birds of the colony to the foraging grounds which act as information centre (Ward & Zahavi, 1973). Solitary breeders have different strategies for avoiding risk of predation and thus selection of safe nesting site is important for the successful breeding (Frederick & Collopy, 1989).

The nesting season of Whitenecked stork begins before the onset of monsoon while Blacknecked storks start breeding by the end of September-October (after the monsoon). Like other wading birds, the breeding success of Blacknecked stork depends on the amount of rainfall and time of water release inside the Park. Monsoon acts as triggering factor for the breeding and water brings tons of fingerlings, about 19 million (Vijayan, 1991) which grow up by the time Blacknecked stork starts nesting. Rejuvenation of insects and earthworms provide food for the Whitenecked stork.

5.2.2 Method

All the nests of the Blacknecked and Whitenecked storks were identified by following the adults collecting nesting material to the tree. Each nesting tree was sampled for knowing the detailed vegetation structure which can be later interpreted in terms of selection strategies. Sampling was done around each nesting trees by using belt transect of 6m (3m on both sides) width and 30 m of length in four directions from the nesting tree. All the trees within this transect were identified. Measurements were taken from each tree for GBH (girth at breast
height), height, tree species and canopy spread. Nest material and nest dimensions were also recorded. The variables used are as follows:

1. Nesting tree: Tree species selected for the nest.
2. Tree height: Height of the tree was estimated.
3. GBH: The diameter of the tree supporting nest at the height of 1.5 m.
4. Canopy: Canopy of the nesting tree.
5. Nest position: The position of nests was categorised into two types in relation to its orientation on the nesting tree i.e. distal and proximal.

In distal position nest is present on the main branch of the tree while proximal is at the side branch of the tree but nests were always on the top canopy in both the positions.

6. Water level: Level of water around the nesting tree.
7. Water source: Nearest unoccupied block with water that the birds use in the Park.
8. Park boundary: Shortest distance of the Park boundary from the nesting tree.
9. Water source outside the Park: Presence of any wetland outside the Park boundary.
10. Distance to road: Nearest road to the nesting tree.
11. Distance to nest: Distance to the nest of other nesting species which could be a potential predators such as raptors, owls, cats.
12. Nest height: The distance from the bottom of the nest to the water.
5.2.3 Analyses

Principal Component Analysis (PCA), an ordination technique was performed on the nesting data to find out important factor(s) responsible for nest site selection in Blacknecked and Whitenecked storks. All analyses was performed on STATA 5.0 (1997) and SPSS 6.1 (1994).

5.2.4 Results

During my study period, six pairs of Blacknecked stork were seen inside the Park. The breeding sites of Blacknecked stork for most of the pairs in KNP remained unchanged over the years. Total of 12 nests were constructed during 1994-1996 and all the nesting trees were located in water. Four species of nesting trees were identified: *Acacia nilotica*, *Mitragyna parvifolia*, *Prosopis cineraria* and *Acacia leucophloea*. *Acacia nilotica* was most commonly used among all the tree species. Some of the trees used for nesting were covered with climbers such as *Cryptostegia grandiflora*.

The status of Whitenecked stork has remained neglected in the past. This study was the first attempt to know about the nest-site selection in the species. Total 15 nests were counted during 1994-1996. Not much information on the nesting could be gathered during 1994 as the breeding was over by the time I started studies. *Mitragyna parvifolia* was used inside the Park for nesting while few nests were found outside the Park on *Dalbergia sissoo*. In both the species, nest-site selection involves a joint selection by male and female.
5.2.4.1 Blacknecked stork

a. Habitat Relationships

PCA performed on all the variables showed three main factors. The first three PC's explained 70% of the variation in nest site characteristics. Loading of nest site characteristic variables on the three components can be interpreted as relative importance of different factors. The first component accounted for 30% of the total variance. The first PC is highly positively correlated with canopy spread, GBH, and distance to road from the nesting tree. High values on the first component correspond to habitat with high basal area and canopy spread while distance to road gives protection and less disturbance. The second component accounted for an additional 27% of the total variance (Fig. 5.2.1). This component was negatively correlated with GBH and canopy spread and positively correlated with the land area and the Park boundary. The high values corresponds to increase in distance to land area and from the Park boundary to avoid the disturbance by villagers.

The third component accounted for 13% of the total variance. The water level is highly positively correlated third component but no single factor made a prominent contribution (Table 5.2.1).

b. Comparison between nesting and non-nesting trees

The t-test showed significant (p<0.0001) difference between height, canopy spread, GBH of nesting and non nesting tree (Table 5.2.3).
Table 5.2.1 Results of Principal Component Analysis of Blacknecked Stork’s Nest site characteristics

<table>
<thead>
<tr>
<th>Habitat Variables</th>
<th>Principal Components</th>
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</thead>
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<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
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</tr>
<tr>
<td>Tree Height (THGT)</td>
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<td>-0.592</td>
<td>0.196</td>
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<td>Girth at breast height (GBH)</td>
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<td>0.531</td>
<td></td>
</tr>
<tr>
<td>Canopy (CAN)</td>
<td>0.817</td>
<td>-0.130</td>
<td>0.101</td>
<td></td>
</tr>
<tr>
<td>Water source (WSOUR)</td>
<td>0.474</td>
<td>-0.330</td>
<td>-0.368</td>
<td></td>
</tr>
<tr>
<td>Land area (LAREA)</td>
<td>0.411</td>
<td>0.774</td>
<td>-0.252</td>
<td></td>
</tr>
<tr>
<td>Park boundary (PBOUN)</td>
<td>-0.247</td>
<td>0.827</td>
<td>0.039</td>
<td></td>
</tr>
<tr>
<td>Water source outside (WSOUT)</td>
<td>0.443</td>
<td>0.429</td>
<td>-0.567</td>
<td></td>
</tr>
<tr>
<td>Distance to road (DROAD)</td>
<td>0.612</td>
<td>0.677</td>
<td>0.144</td>
<td></td>
</tr>
<tr>
<td>Distance to nest (DNEST)</td>
<td>-0.633</td>
<td>-0.010</td>
<td>0.097</td>
<td></td>
</tr>
<tr>
<td>Water level (WLEV)</td>
<td>-0.132</td>
<td>0.544</td>
<td>0.671</td>
<td></td>
</tr>
</tbody>
</table>

Percent Variation 30.0 27.0 13.3
Cumulative Percent Variation 30.0 57.0 70.3
Fig. 5.2.1 Plot of nest-site variables for Blacknecked stork on PCA-1 and PCA-2
5.2.4.2 Whitenecked stork

a. Habitat Relationships

In Whitenecked stork, eigenvalues of three factors were greater than one. The first three PC's explained 98% of the variation in nest site characteristics. The first component accounted for 51% of the total variance. The first PC is highly positively correlated with GBH, water source outside the Park and distance to road from the nesting tree. High values on the first component correspond to habitat with high basal area while distance to road gives protection and less disturbance. The second component accounted for an additional 36% of the total variance. This component was negatively correlated with GBH, water source outside the Park and the Park boundary and positively correlated with canopy spread, distance to nest of other species and water source inside the Park. The high values corresponds to decrease in distance to feeding site and dense foliage (Fig 5.2.2).

The third component accounted for 11% of the total variance. The tree height is highly positively correlated while rest of the factors have no prominent contribution (Table 5.2.2).

b. Comparison between nesting and non-nesting trees

The t-test showed significant difference (p<0.0001) between height, canopy spread and GBH of nesting and non nesting trees (Table 5.2.4).
Fig. 5.2.2 Plot of nest-site variables for Whitenecked stork on PCA-1 and PCA-2
Table 5.2.2 Results of Principal Component Analysis of Whitenecked Stork’s Nest site Characteristics

<table>
<thead>
<tr>
<th>Habitat Variables</th>
<th>Principal Components</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
</tr>
<tr>
<td>Tree Height (TGHT)</td>
<td>-0.555</td>
</tr>
<tr>
<td>Canopy (CAN)</td>
<td>-0.017</td>
</tr>
<tr>
<td>Girth at breast height (GBH)</td>
<td>0.922</td>
</tr>
<tr>
<td>Water source (WSOUR)</td>
<td>-0.291</td>
</tr>
<tr>
<td>Park boundary (PBOUN)</td>
<td>0.960</td>
</tr>
<tr>
<td>Distance to road (DROAD)</td>
<td>0.898</td>
</tr>
<tr>
<td>Distance to nest (DNEST)</td>
<td>0.460</td>
</tr>
<tr>
<td>Water source outside the Park (WSOUT)</td>
<td>0.955</td>
</tr>
</tbody>
</table>

<p>| Percent Variation                  | 51.1     | 36.5     | 11.8      |
| Cumulative Percent Variation       | 51.1     | 87.6     | 99.4      |</p>
<table>
<thead>
<tr>
<th>Tree Variables</th>
<th>Nesting Tree*</th>
<th>Non-Nesting Tree*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Height</td>
<td>183.33 ± 20.55</td>
<td>104.93 ± 5.97</td>
</tr>
<tr>
<td>Tree GBH</td>
<td>908.3 ± 71.20</td>
<td>671.68 ± 23.61</td>
</tr>
<tr>
<td>Canopy Spread</td>
<td>761.6 ± 179.81</td>
<td>410 ± 29.24</td>
</tr>
</tbody>
</table>

*All values are in centimetres
Table 5.2.4 Comparison between nesting and non-nesting trees of Whitenecked stork

<table>
<thead>
<tr>
<th>Tree Variable</th>
<th>Nesting Tree*</th>
<th>Non-Nesting Tree*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree Height (cm)</td>
<td>329.66 ± 162.40</td>
<td>113.85 ± 184.59</td>
</tr>
<tr>
<td>Tree GBH (cm)</td>
<td>650 ± 151.65</td>
<td>208.88 ± 174.28</td>
</tr>
<tr>
<td>Canopy Spread</td>
<td>483.33 ± 421.50</td>
<td>642.22 ± 135.66</td>
</tr>
</tbody>
</table>

*All values are in centimetres
5.2.5 Discussion

The nesting of Whitenecked in KNP starts with the onset of monsoon and as reported by Ali & Ripley (1987) it differs in north and south India. The WNS breeds from December to March in south India.

The major factors for the selection of nesting site were found to be height of the trees, GBH and the canopy spread.

The Blacknecked stork used *Acacia nilotica* due to the presence of thorns nests were inaccessible to predators. Whenever *Mitragyna parvifolia* was selected as nesting-site, trees were either very tall and dense or covered by a climber *Cryptostegia grandiflora*. The nest was on an inaccessible branch and difficult for a ground predator to reach. An attempt was made to take nest dimensions of all the nests but presence of *Cryptostegia grandiflora* made it difficult for me to approach it.

All the nesting trees were tall with large GBH and dense canopy spread which provided protection from predation. The nests of Blacknecked stork were on the top canopy from where most of the surrounding area was visible and helped in easy takeoff and landing on the nest by the birds. This is absolutely in contrast to the Whitenecked stork which preferred to nest in the middle, dense and hidden strata of the tree.
The nesting trees of Whitenecked stork found inside the Park were *Mitragyna parvifoila* while *Dalbergia sissoo* was selected as a nesting tree outside the Park. The probable reason for this could be that the wood of *Mitragyna parvifoila* is used for many purposes and has a high value in the market so it is not so abundant in the unprotected areas. *Mitragyna parvifoila* was stolen several times for wood from the Park. The foliage of *Mitragyna parvifoila* is denser than *Dalbergia sissoo* which has the advantage of height only and probably that could be a reason for the available for this species outside the protected area.

Water level was significantly related to the nest-site selection as expected because one pair of Blacknecked stork was observed for two consecutive years attempting to nest in Ajanbund area at the time of monsoon. As soon as the water was drained, the pair abandoned the nest and selected another site. This observation lead to the conclusion that presence of water around the nesting tree may be important even inside the Park as it reduces the accessibility to local villagers who come frequently in the Park to cut grasses around the nesting tree.

Butler (1994) discussed about the food as a limiting resource during the breeding season in context with the colonial breeder. Birds prefer to nest within their feeding territory or feed within their nesting territory and thus reduce the number of trips and increase vigilance for predators. This was observed many times in case of Blacknecked stork which feed near the nest within their nesting territory, at a distance of just 25 m (n=30). In the case of Whitenecked stork, which is much
smaller than the Blacknecked and prefers comparatively shallow areas of water to
feed, nested near the Park boundary where water level remains at low level. Thus
explains the positive correlation between selection of nesting site closer to the Park
boundary. The water level outside the Park, especially in the numerous puddles,
used to be less thus providing an ideal habitat for the WNS to forage. Relationship
between water level changes and foraging of wading bird has been demonstrated
for a number of species (Kushlan, 1978). It was clearly observed in Wood stork
(Mycteria americana) (Kahl, 1964) which began to nest at a specific water level. In
Whitenecked stork, nest-site selection and egg-laying occur before the onset of the
monsoon when the water is ideal for foraging inside the Park but soon after the
rains when the area gets flooded, it affects the foraging site as it needs shallow
feeding grounds.

The vicinity of marshes as potential food sources and reduced risk of mammalian
predation in water are supposed to be the major factors for the nest site selection in
marsh nesting birds especially where these qualities overweigh the disadvantages
of competition for nest sites, avian predators and nest parasitism and mortality due
to sudden flood tides (Rosenzweig, 1981, 1985; Burger, 1982). Nest predation has
a significant role in evolution of many aspects of avian nesting behaviour (Lack,
1968; Burger, 1982). Among ciconiiformes, there is almost no group or individual
nest defence behaviour and even low predation apparently is capable of destroying
very large colonies (Baker, 1940; Sheilds and Parnell, 1986; Rodgers, 1987).
In Keoladeo National Park (KNP), the abundance of food and absence of raptors during summer and controlled regulation of water level in different blocks help in successful breeding of the birds every year. The nesting trees which were not surrounded by water, there was no potential predator for the birds except perhaps the Jungle cat (*Felis chaus*). I have never seen any mortality due to predation on these solitary breeders.

McCrimmon (1978) studied nest-site selection among five species of herons on the North Carolina Coast. PCA revealed four components of nest sites: vegetation structure, accessibility, protection and placement of the nests. McCrimmon’s heronry was in heterogenous vegetation and species segregated themselves within certain areas. In KNP, there was intra-specific competition for nest-site and the White-backed vulture (*Gyps benghalensis*) was the only species which had direct competition with storks for nest-sites. For two years, a pair of Blacknecked stork had to leave half constructed nest due to the presence of vultures. In the case of Whitenecked stork as well, it had been observed once where vultures succeeded in expelling out the pair from the selected site.

The selection of nest-site by the birds is for those sites which increase its reproductive success, protection from predators and relying on their past experience, birds re-use these nesting site like the colonial breeders (Butler, 1994). I also found that two nests were re-used by the Whitenecked and Blacknecked storks.
Bird populations are regulated by territorial behaviour (Lack, 1968; Fretwell & Lucas, 1970; Patterson, 1980). Based on the movement of marked individuals, I found that the BNS is a highly territorial bird and a pair would not allow any other pair or solitary individual in its territory. Almost a stable population of six adult pairs of BNS and a high 'floating' population, proves that all the potential territories are already occupied and there is a quick replacement if an individual or a pair disappears or dies.