9. NESTING

9.1. INTRODUCTION

Nest, the receptacle of eggs is a prerequisite for reproduction in birds. Although some sorts of nesting are found in many lower chordates true nesting and nest oriented parental care is almost integral part of reproduction in birds. The success of breeding in birds is tied intricately with the success of nesting because after the acquisition of homiothermy birds can no longer depend on the heat of the enviornment for hatching, as does their reptilian forrunners. As the embryonic development within the egg requires steady warmth, which the parents provide in the form of incubation, the receptacle of eggs i.e., the nest should be kept in an unaltered state for a longer period of time. And in case of altricial birds the nest has to be maintained for even a longer period. In order to maintain the tranquility of nests birds have developed different protective measures in the form of nestsite selection to active defence.

Nesting in birds is a long and elaborate process. Each step is associated with the ultimate success of breeding. For each nesting parameter costs and benefits can favour different life-history traits. For example, nest concealment affects the probability of predation (Nolan, 1978; Best & Best, 1985). So the trade off between this two factors will determine nestsite characteristics which in turn will affect the bird species differentially with different life-history traits.

Several factors play important roles in different nesting parameters like habitat selection (Hilden, 1965; Martin & Roper, 1988), nesting height (Marzluff, 1983; Dhindsa et al, 1986), nest defence (Trivers, 1972; Dawkins & Carlisle, 1976; Curio, 1987), etc. and these nesting parameters in turn influence the reproductive success (Skutch, 1949; Lack, 1968; Slagsvold, 1982; 1989; Wicklund, 1982). So the whole process of nesting is a very elaborate and sophisticated process in birdlife which makes proper adjustment between different enviornmental factors and the animal's fitness. This adjustment attains much more importance in colonial birds (see Wittenberger & Hunt, 1985). Coloniality obviously provides some advantages to the birds (Lack, 1968; Robertson, 1973; Ward & Zahavi, 1973; Krebs, 1974; Emlen & Demong, 1975; Parsons, 1976; Ydenberg et al, 1983; Robinson, 1985) but also demands greater adjustment with other members of the colony, both intraspecific and interspecific (Lowe-McConnell, 1967; Jenni, 1969; Schoener, 1974; Burger, 1978; Hafner, 1980; Martin, 1985; Stauffer & Best, 1986).

So to make a comprehensive study on nesting of a colonial bird like openbill stork various life process like competition, food limitation, predation, etc. and several physical factors and historical constraints should be taken into account. Storks in particular are more selective to their nesting and many factors like water level, habitat destruction, human interference have been found to seriously impair its nesting (Kahl, 1964; Robertson & Kushlan, 1974; Kushlan _et al_, 1975; Ogden & Nesbit, 1979; Ogden _et al_, 1980; Browler, 1984; Rodgers, 1987; Rodgers _et al_, 1987; Verheugt, 1987) and thus the breeding as a whole. The worldwide decline of stork population is mostly tied with the nestsite destruction (Cramp, 1977; Ogden & Nesbitt, 1979; Rodgers _et al_, 1987; Verheugt, 1987). So the nesting of openbill stork, which breed here in a huge mixed-species congregration, deserves a comprehensive study with minute details. Although the openbill stork is the commonest stork species of the Indian subcontinent no detailed account of its nesting ecology is known. However, Ali (1953), Ali & Ripley (1968), Kahl (1970b, 1972d), Mukhopadhyay (1980) and Stanley & Breeden (1982) provided some useful preliminary information on nesting of this species.

9.2. METHODS

Ecological and behavioural data on nesting were collected all through the season. The spatial and behavioural data were recorded instantaneously (Altmann, 1974) as far as possible. Nest-site characteristics were measured after the emergence of first batch of hatchlings, when the number and position of nests became quite stable due to the completion of nesting by most pairs. Nesting tree height and nest height were measured by meter-stick. However, some exceptionally long trees were measured by ocular estimation. Some of the habitat characteristics like canopy cover of nesting trees, distance of nesting tree from nearest waterbody, etc. were, however, measured just before the arrival of birds in the sanctuary. Thickness of canopy cover was indexed by estimating the percent foliage cover which was calculated from the percentage of dark and light areas of the canopy shadow during the sunny midday hours when the sun attained the topmost position. Nest concealment was indexed by estimaiting percent foliage cover in a 25cm circle centered on the nest from a distance of 0.5m from above and from the side in each of the four cardinal directions.

In each season some nests were marked with labelled alluminium plates placed at the under surface of the supproting branch for identification at any part of the season. Nests of particular bird species were identified mostly by watching the presence of the owners and in some cases by egg colour and nest characteristics. In order to determine the distance covered by the birds for nest material collection from ground a number of colour-marked nesting materials were placed at different distances and were recovered from specific nests after few hours.

In each season some nests were marked with labelled alluminium plates placed at the under surface of the supporting branch for identification at any part of the season. Nests of particular bird species were identified mostly by watching the presence of the owners and in some cases by egg colour and nest characteristics. In order to determine the distance covered by the birds for nest material collection from ground a number of colour-marked nesting materials were placed at different distances and were recovered from specific nests after few hours .

Members of the nests were identified by marking as it has been described earlier. Nests that were attended by territorial birds or lodged at least one egg was considered as active. To detect predation by Bengal monitors trunks of some nesting trees were covered with a thin uniform coating of mud. This coating imposes no disturbance to the monitors for climbing and also it is not an unfamiliar object to that animal as they pass most of their time in the ditches. Any predatory attempt to clutches or broods by this climber should therefore easily be traced back by its footprints or at least scratching lines on muddy coating and subsequent observation of the nests of those trees. Selected trees were located in inundated areas where monitors moved in abundance.

9.3. RESULTS AND DISCUSSIONS

9.3.1. Selection of Nest-site

After arrival in the heronry openbill storks do not immediately engage themselves in finding a nest-site. At first they settled on some lofty trees which are not their usual nesting trees. In the first one or two days the few hours that they spent in the sanctuary were engaged mostly in resting state on those trees. A few birds, however, flew around for a short course and rejoined to their roosting assemblage. No territoriality or nesting behaviour was observed upto this point. Thereafter birds came down to the trees which were usually used for nesting. At that period they frequently changed their position from one tree to another. So far birds spent most of their time outside the sanctuary. In next one or two days they spent more time in the sanctuary. Gradually their movement concentrated to a few trees and territoriality appeared (Fig. 9.1.). At that point they were even found to leave the possession of a spot which was held and defended for more than hour and settled on another spot. So before the final choice they obviously follow a period of appetitive searching for nest-site. During this period birds try to find out the best available site which often determines their ultimate fitness (Preston & Norris, 1947; Tinbergen et al, 1967; Calder, 1971; Schafer, 1980; Walsberg, 1981; Best & Best, 1985).

Although nest-site selection plays a vital role in influencing the number and quality of young that can be fledged successfully there is considerable variation in different parameters of this selection. Such variation probably is a function of different conflicting attributes (e.g. Lawton & Lawton, 1980). Severel characteristics of the immediate vicinity of nest (Calder, 1971; Walsberg & King, 1978; Keppie & Herzog, 1978; Nolan, 1978; Walsberg, 1981; Best & Best, 1985) and of the habitat patch surrounding the nest (Bowman & Harris, 1980; MacKenzie & Sealy, 1981; Petersen & Best, 1985) influence the choice of nest-site which will be discussed later on in this chapter. Some other associated factors are discussed here.

9.3.1.1. Time of appetetive searching

Although birds are selective about their potential nest-site and spend a considerable time in searching; the time between their arrival in nesting tree and final selection of a particular spot varies greatly among individuals, particularly among different bird groups. Usually birds who come earlier to the sanctuary take longer time to settle on a particular spot (Fig. 9.1.). It indicates that the early comers are more selective or are in a position to afford more time than the late comers. Early comers spent lot of time in nest-site selection probably because they had sufficient time to rear a brood and also plenty of options to choose the best site with minimum competition. On the other hand, as the season progressed both the favourable period of the breeding season and potential nesting sites decreased with increasing intraspecific competition for space. These variables probably dictate nest-site selection as it is a product of different conflicting factors.

9.3.1.2. Nesting synchrony

Openbill storks of a particular group, as identified by their date and time of arrival, were more interested to nest in a clumped area. Whereas, two different groups which arrived on the same day were found to nest in distant areas. It is obvious that although individuals of a particular group nested in a particular portion of the heronry consisting of a few trees, certainly all of them are not enjoying the same sort of site-oriented advantage as a tree provides severel nesting sites with differential nest heights, overhead cover, exposure, etc. Why then the individuals of a particular group who get low grade nest-sites do not go to other areas of the heronry for better nesting sites ? Probably the storks make a sacrifice in their nest-site selection in response to their kinship with neighbouring individuals. This nesting synchrony of the same group members seems to be advantageous because of better intra-individual adjustment developed during the nonbreeding assemblage which help the birds to withstand the adverse forces like predation and also minimizes the intra-individual conflicts. Thus the trade off between costs and benefits of intra-individual relation also probably plays a significant role in nest-site selection.

9.3.1.3. ROLE OF SEXES

In all the observed cases the male's choose the nest-sites. Such male biased behaviour is common to most species of storks. The male took all sorts of initiative to find out a suitable nesting site in all the cases. In no instance females accompanied the process of searching. And it was the male who took the first decision to settle on a spot from where he attracted the mate and in most cases (83.6%) that spot was used for nesting after the acquisition of a mate. But in 16.4% cases male was found to exhibit pair forming displays from his selected site for hours with no response from any female. On failing to attract any mate from that spot it finally deserted the spot. I found 6 such males to consort with mates from different spots within two or three days. So the final selection of a nest-site seems not to be the sole choice of the male rather it also depends to some extent on the females' response.

Contrary to the above mentioned situation in 4 instances males were found to attract the females from unusual spots which was liable for nesting and after pair formation they shifted to the final nesting spot. In two cases the displaying spots were the rachis of a coconut leaf and in other cases it was a straight unforked branch. In no case it was possible to construct nest on these spots. In all the cases the final nesting spot was placed in the inner or lower part of the tree which was almost concealed by the overhead cover of foliage. All these incidents were observed at the later part of the breeding season. Probably at the prevailing pressure of nest-site scarcity the birds adopted a round about way of nest-site selection. As the openbill storks use the nest-site for dual purpose of mate attraction and nesting, only those sites should be considered as suitable which provided proper support to the nest as well as easy access and clear visibility of other conspecifics for the purpose of mate attraction. Probably at the end of the season with the scarcity of suitable nest-site those birds selected two separate sites to serve the two major purposes. Firstly, they choose an open vantage position for mate attraction and after that they finally choose the nesting site with proper basal support irrespective of its overhead cover. The whole process starting from female response to final nest-site selection took only 56 to 192 minutes.

9.3.2. Begining Of Nest-building

Nest-building starts after a few days of pair formation. After pair formation both the members of a pair pass most of their time at the nest-site and exhibit pair maintenance displays from time to time. During this period the frequency of twig swaying behaviour gradually increases. The rate of the twig swaying behaviour of male increased (1.26/10min) almost two times more than the pre-mating period (0.68/10min). The other important development of this behaviour was that in all cases of twig swaying the birds pull down the twig to touch the base of the nest-site which was uncommon during pre-mating phase. Also from time to time, mainly the male, placed twigs to the nesting spot collecting from the nest-site. However, it should not be treated as true nesting as the birds were not really careful in placing these materials in the nesting spot and actually all of them fell down within a period of 2 to 7 minutes. During this period birds were reluctant to go far away or to pass long time outside the nest. All their activities were nest-site oriented but not actually devoted to nest material collection.

After this comparatively less active period suddenly nesting activity increased. Although before this period a few twigs were placed to the nesting spot, this sudden hike of nest material addition to the nest-site indicates the initiation of true nesting (Fig. 9.2.). From this point birds were more kin to anchor the nest materials at the nesting spot and only 13.4% twigs fell down after this period. With the begining of nesting both the members actively assisted one another in placing the nest materials to the nest which was not so elaborative and a joint affair before this period. Practically the pre-nesting behaviour of a pair was directed towards the establishment of better adjustment and coordination between the mates which suddenly turned towards the establishment of a nest at the begining of nesting.

The interval between pair formation and initiation of nesting varied among individuals, nesting at different parts of the season. As the season progressed this interval rapidly diminished and at the end of the season birds started nesting almost immediately after pair formation (Fig. 9.3.). Such variability was probably correlated with the demand of the situation. At the start of the breeding season there was sufficient time and resources like food to rear a successful brood so birds probably paid more attention in finding out the best available mate which required a great deal of time for testing through different behavioural traits before investing further on nesting. Whereas, at the end of the season both time and resources were at a crucial stage of depletion which forced the birds to complete the breeding process as early as possible . This trade off between time and resources and the and the selectivity probably was better adjusted through gradual cut down of the interval between pair formation and nesting.

9.3.3. Process Of Nest-building

It takes a considerable time to construct a nest which consists of three distinct phases as follows :

9.3.3.1. Preparatory stage

In this step birds actually prepare the nest-site for nest construction. At first they pluck the twigs existing at the nest-site and place them to the nest which in one hand makes the nest-site more suitable for free movements and other activities and on the other provides a supporting base to the developing nest. In most cases the attendant bird/birds place the twigs in the spot and hold them with their feet. As the nest-sites are usually located at the interjunction of branches it is convenient for the birds to hold the twigs with their toes against a fork. After addition of new twigs at the interjunction of the branches the mesh of the twigs do not require any further care to stick on to the spot. Such anchored twig-mesh now acts as a supporting platform. During this stage birds exhibit no special nesting behaviour other than collection and adding of nest materials. Twigs were placed one over others with gentle swaying and downward pushing by the bills. Nest materials consisted exclusively of twigs probably because those flexible objects were more suitable to make an interweaven structure. Besides, the twigs were available within a close range which enables the birds to stay at the nest avoiding absence from it over long periods during nestmaterial collection. There may be other advantages of using fresh twigs as nestmaterial, as it contains a higher percentage of moisture and gets withered and wrinkled on even brief exposure to hot day periods. For this reason when the twigs are heaped together at the interjunction of branches get glued to one another forming an anchored mesh-work of considerable strength.

All through this preparatory stage at least one partner of a pair remain upright upon the nesting material. It takes variable time and number of nest materials to form a supporting base depending mainly on the structure of the nest-site. Usually 14 to 20 twigs are required for this phase of construction.

9.3.3.2. Construction of floor and side

On completion of a supporting structure the main nesting starts. At the begining of this stage only twigs and fresh branches are used. All these materials are light, flexible and have severel leaves attached to them. On a number of occassions shrubs were also used, particularly in nests which were started at the later part of the season. May be it was a good substitute of fresh branches which were extensively used at the earlier season and thus became more scarce at the later period. After the construction of a circular structure of about 0.20m diameter, hard structures were gradually added to the nest in large number. These materials included long fresh branches, dead branches and sticks which measured about 30cm to 60cm in length and 40 to 80gm in weight. These material confered strength to the nest to withstand the heavy weight of the incubating birds and the nestlings. In some nests shrubs were also added by this time. These shrubs and the branches with abundant leaves were mostly placed to the periphery of the nest. On an average about 60 to 80 such nest materials are added so as to form a thick circular pad having a rather small cup height of about 1 to 2.5cm. At the begining of this intensive construction birds usually placed the nestmaterials from a position outside of the nest border but at about the middle of this period they used the nest as a platform. At this stage the nest looks like a full grown one but its texture is still loose, the platform is spongy and the constituent nesting materials are easily separable from one another.

9.3.3.3. <u>Lining</u>

Openbill storks used a wide variety of materials such as aquatic weeds, grasses, shrubs, dry leaves, rotten submerged leaves, twigs, etc. instead of using any particular lining material. Soft lining in one hand provides a better surface for the incubating birds and on the other prevents harsh touch of hard nesting materials to the tender eggs and youngs. The nesting materials collected from waterbodies add extra moisture which probably helps decomposition of inner soft parts. The decomposed inner parts actually serve as a cementing material to hold the hard parts together. Lining of the centre of the nest is made mainly with soft and light materials such as leaves, grasses and aquatic weeds while for the periphery heavier materials like tender branches, shrubs, etc. are used. Thus at the end of this phase the nest appears as a thick and tight circular pad with a diameter of 0.32m ($n = 76$; $SD = 0.043$) and cup height of 3 to 4cm.

Although a nest is completed within a few days the birds kept on adding nesting materials regularly throughout the season (Plate 9.1). This is quite common not only in this species but also in other storks (Kahl, 1971c; Cramp, 1977; Thomas, 1986). Such continued addition of nest material takes place at least upto the fledging of youngs and in many cases it continued even after that period. On an average 5-7 nestmaterials were added everyday into the nest upto 70 days after formal completion of nest. Nest material addition was done irrespective of any damage to the nest. It was actually a routine activity. Maintenance of nest over a long time period is necessary here as the fledglings not only use the nest for roosting at dates way beyond their fledging but also nests provide necessary surface to regurgitate on and feed the youngs. The direct effect of adding nest material is evident from a remarkable increase of nest area after the early hatchling period. After the attainment of final size at the end of initial nest construction the size of the nests almost remain constant upto the 7-day age of last hatchling. During this period birds mainly concentrate on lining the nest. After that period long branches or sticks were used at an accelarated rate and in 74.2% cases the nest size increased considerably. Whereas, in 19.2% cases nest size remained almost constant at this stage and only in a few cases (6.6%) the nest size decreased during that period (Fig. 9.4.). In all these cases where nest size decreased or remained almost the same during the interval between hatching and fledging the nest-site was not suitable to bear a larger nest. Either the supporting structure was liable to withstand the larger nest or the neighbouring nest was too close for further increase in nest area. So the openbill seems to be interested to increase its nest size with the increase of hatchlings' age. And actually this idea attains more support when we find that the nests with larger number of nestlings are significantly larger in size than those having smaller number of nestlings (Table 9.1.). In two cases nests even developed a two stair pattern as it continued to increase from its original position to a lower branch which happened to exist close by. It was as if a portion of the original nest gradually spilled over to a closeby lower branch which was subsequently developed by addition of fresh twigs. So the whole nesting process is not really a simple affair in this species rather it takes huge attention of the birds over a very long period in order to achieve ultimate breeding success.

9.3.4. Use Of Nest Materials

Though in a few instances I found clothes, papers, plastics and jute fibers in their nests openbill storks used mostly natural resources like fresh twigs and branches, dry branches, sticks, grasses, dry leaves, shrubs, aquatic weeds and submerged rotten leaves. Although they used fresh twigs and branches of almost all the available trees in this sanctuary relative use (indexed as plucking of twigs/tree/hour) of Lagerstroemia flosregnae, Barringtonia acutangula, Dalbergia sisso, Eucalyptus sp., Ailanthus excelsa and Alibizzia lebbeck species were much more in comparison to other trees. Of all the nesting materials used about 46% consisted of fresh twigs and branches, 13% were mostly dried materials collected from ground and 41% materials from waterbodies. At the initial stage they used exclusively twigs. Thereafter fresh branches were used at greater rate which continued to be used at a moderate rate all through the nesting period. Sticks and dried branches were used mostly at the middle stage of nest construction. Whereas, aquatic materials were used at higher rate at the later phase and continued to be added over a very long period (Fig. 9.5.). Most of the materials used for nesting weighed not more than 80gm. However, in one case a bird was found to carry a 5'6'' long bamboo stick weighing 168gm from a distance of about 150m to its nesting tree but finally the stick felt down.

9.3.5. Collection Of Nest Materials

Openbill spent a lot of energy to collect nest materials from various sources. To pluck a twig or a branch from trees or to collect shrubs from ground or aquatic weed from a huge colony they exerted only pulling force and even went back for a few steps and flexed the neck backwards holding the material with the bills to apply effective force in case of a tightly fixed material. Bills are the only means to collect and carry the materials. Smaller materials, particularly submerged leaves, were collected severel at a time. Submerged leaves were collected through pecking movement of bills under the water as done during foraging. Collection of aquatic materials were made mostly during midday hours (Fig. 9.6.).

Most of the ground materials were collected within a range of 30m, particularly during the initial nest construction period. It, however, depends mostly on the availability of the materials. One interesting thing is that the birds like to collect materials from a particular spot for a few successive occassions if it offers abundant suitable materials irrespective of its distance from the nest. On the first phase of nesting i.e., within 2 days of nest initiation 68.5% materials were collected within a distance of 10m of the nest. Experiments with colour marked sticks and branches points towards their preference of ground material collection within the range of 15 to 25m from the nesting tree. However, on many occassions (16.6%) materials were collected beyond the 30m range. To collect aquatic materials birds exploited those sites which offered the shortest course of flight from its nest and it was not neccessarily the nearest waterbody from the nest.

9.3.6. Use Of Greenery And Its Role

Openbill storks used a huge number of green materials in their nesting. These materials were used almost allthrough the breeding season. Severel avian species use greenery in their nests and in many cases it serves more than a construction material such as concealment of eggs and nestlings (Welty, 1962; Collias & Collias, 1984), shading of eggs and nestlings (Bush & Gehlbach, 1979), nest sanitation (Orians & Kuhlman, 1956; Newton, 1979), advertisement of nest occupation (Newton, 1979), insulation of eggs and nestlings (Merteus, 1977; Newton, 1979;

Collias & Collias, 1984), and also as ectoparasite repelent (Johnson & Hardy, 1962; Sengupta, 1981; Wimberger, 1984; Clark & Mason, 1985; 1988). Openbills added a considerable amount of green nest materials regularly in their nest starting from the initiation of nesting to 30-40 days after fledging. The major portion of these green materials consisted of twigs and fresh branches of woody plants available in the sanctuary. The use of other green materials like grasses, shrubs, etc. was probably not of great importance as they were used at a very small percentage and sporadically without accentuating at any particular phase of breeding. However, at least more than 7 twigs or branches were added in every nest per day upto the 3rd week age of nestlings (Fig. 9.7.).

Rarely eggs were found covered with greenery (1.9%; n = 3085 nest visits) and in even fewer cases hatchlings were found concealed under greenery (0.7%; n = 4418 nest visits). So concealment or shading of eggs or nestlings is probably not a function of greenery use in this species. Actually parents defend their eggs or youngs by active presence at the nest and shade the nest contents with their body and outstretched wings during the warm part of the day. Although youngs, particularly at early age, and in few cases adults defecate in the nest but greenery does not solve the purpose of nest sanitation. I agree with Rodgers et al (1988) in this point. Furthermore, it prevents the guano to pass through the dried nesting materials as a result the nestlings get soiled with the guano which surely contradicts its nest sanitation function.

The greenery probably also does not act as an ectoparasite repelent because in that case its use should have been on the increase with the hatching of youngs. But actually use of greenery slows down at that period. Again many ectoparasites (mites) are hematophagus, expectedly they will lower haemoglobin content of affected birds. If greenery restricts ectoparasites, the haemoglobin content of youngs of nests with and without greenery should vary significantly. But in no cases haemoglobin level was found to differ significantly. ($F = 1.5$ (7day old); 3.1 (15d); 2.5 (30d); df = 2, 78; $P > 0.05$) among youngs reared in controled nests, greenery added nests and in greenery removed nests (Fig. 9.8.).

Rodgers et al (1988) advocated that greenery in wood stork nest acts to maintain internal temperatures above ambient temperature. According to them greenery coupled with guano plugs the holes of the nest to act as an insulator. Such plugging is also found in openbill stork's nest. May be by their nature they act as an insulator but openbills here probably did not use this material to accomplish insulation. Because if it served to maintain higher than ambient temperature during incubation then birds should have added higher percentage of greenery during incubation period as was found in the study of wood stork (Rodgers et al, 1988). But here openbill storks added major portion of greenery before the initiation of incubation (Fig. 9.7.). Secondly, the question of plugging of the nest holes may be effectively solved with aquatic weeds and submerged rotten leaves. Moreover, maintenance of higher than ambient temperature is not necessary in this warmer part as it was in case of wood storks of north and central Florida in Rodgers et al's (1988) study. So the use of greenery should not be regarded as critical in relation to nest insulation.

The use of huge amount of greenery is probably a function of its easy availability and mainly served as construction material. However, any function of greenery other than its suitability for nest construction may be associated with pair formation and maintenance. Because green twigs or branches are associated with many ritualised pair forming and pair maintaining displays. Often the males were found to get busy with twigs even before the initiation of nesting and during the early periods of pair formation males always handed over the collected twigs or branches to the females. Moreover, the frequency of greenery use (Fig. 9.7.) fits quite well with this demand.

9.3.7. Nesting In Relation To Water

Colonially nesting wading birds, particularly openbill storks, usually nest in trees situated in or surrounded by water (Baker, 1929; Kahl, 1970; Kushlan, 1976; Clark, 1978; Bancroft *et al*, 1988). In this sanctuary also birds nested in a number of trees which were situated in submerged areas (Zone I in Fig. 3.1.). However, a greater proportion of trees (78.7%) were on areas free of water logging at any part of the season except on occassional floods. Of the later category a large number of trees were quite isolated (Zone III) for the major part of breeding session being surrounded by water on more than three sides. On the whole, a major portion (52.3%) of nesting trees were placed neither in water nor were surrounded by water on more than two sides. Of the 5-year study period only in 1989 and 1991 low lands with nesting trees experienced water logging at the onset of nesting and in the other three years (1987, 1988, 1990) water logging occurred during the laying period. A major portion of that inundated area was under 15 to 25cm water for more than 70 days period during July, August and September (Table 9.2.). After mid-September the water dried up speedily and by the end of October about 90% of that area was already dry. The ditches or canals of the sanctuary, however, contained sufficient water at the onset of nesting to prevent easy access to the nesting zone. from all sides.

vital role in determining nesting site nor the surface water condition of nesting zone is vital to trigger initiation of nesting. However, openbill storks were found to use water for various breeding purposes allthrough the breeding season. So the presence of waterbodies in near vicinity in the present study site essentially serve purpose other than its protective value. Probably the manifold importance of water in their breeding restricted them to nests within a maximum range of 20m from the nearest waterbody.

9.3.8. Nesting Synchrony

It was found that neighbouring birds nested almost at a time. In more than 65% cases nests on a particular tree were initiated within a range of 2 weeks. Only in 18% cases nests on particular trees were initiated over a period of one month or more. Nesting asynchrony was a prevalent feature of peripheral zone. In four cases the interval between the initiation of first and last nest in a particular tree was more than 75 days and all these trees were situated at the peripheral zone. However, in more than 80% cases nearest neighbours initiated nesting within 8 days ($\bar{X}$ = 3.65; n = 868; SD = 1.88).

Such nesting synchrony was reported in many other bird colonies (Nelson, 1970; 1978; Burger, 1974; 1979). Nesting synchrony probably helps to reduce aggression (Hunt &

Hunt, 1975; Burger, 1980; Fetterolf, 1984). At least it reduces the level of intraspecific interference (Nelson, 1970; 1978), may be due to their prior familiarity in the nonbreeding foraging group or due to the similar reproductive drive in space of time (Fetterolf, 1983).

9.3.9. Nesting Failure

Despite huge parental investment and care nest may be destroyed all on a sudden due to various reasons. Average nesting failure over the five year study period was 11.2%. Although predation is the main cause of nest failure in most bird species (Ricklefs, 1969; Clark & Wilson, 1981). it is not true in this sanctuary. The three main causes of nesting failure in almost all the study years were as follows:

Intraspecific fighting

This factor played the most vital role in nesting failure in this sanctuary. Intraspecific fighting for space and mate is very common in this species. During the long course of fighting on many occassions the nest became destroyed even when with eggs or hatchlings. Of all the nesting failure this particular type alone covers 71.3%.

Unusual nesting spot

In some cases birds were found to nest in some unusual spots where they conventionally do not nest. Usually openbill storks nest at the junction of two or more branches but in a few occassions (4.3%) nests were found to be constructed at the junction of a straight branch and the cut end of another branch. Besides nests were sometimes placed at apical portion of branches which were totally unsuitable for bearing the weight of full grown broods or clutches. All these nests at unusual sports faced the same fate of failure but the end came at different stages of reproduction ranging from 7 days of nest initiation to nestling stage. In all these cases nesters were young and probably inexperienced thus made the fatal mistake in selecting the nestsite. Details on this will be discussed in appropriate chapter.

Unidentified causes

Apart from these three main causes of nesting failure a considerable number of nests (16.1%) were found abandoned due to some unknown reasons. In most such cases (65.2%) intact nests were found unguarded for a long time and finally other nesting birds stole the nest materials. In 26.1% cases unguarded nests were found with intact or partially lost clutch. In only 8.7% cases nests were found with dead nestlings and the nests were found intact without any attendant birds.

Moreover, devastating natural calamities like flood and storm accounted for several nest loss. Over the five year study period the sanctuary experienced flood on three occassions. It was possible for me to visit the sanctuary just after the day of start of flood in the years 1987 and 1989. In 1987 I observed as many as 13 nests to float in the water even with eggs and hatchlings and as per reasonable assumption not less than 200 nests got washed away in that flood. But no nest was found or reported to be washed away in the 1989 flood. However, storms inflicted considerable loss in almost all the years. I found a total of 114 nests to fall down in 5 occasions of storm with the highest loss in 1990 when two nesting trees fell down resulting destruction of 69 nests.

As the main cause of failure was the attack of conspecific birds the best method of nest defence was to guard the nest which may also subserve the purpose of mate guarding. Both the members of a pair were found to guard the nest over a rather long period. It starts with the nest-site selection and runs upto the late nestling period. However, the intensity of nest defence decreases rapidly after early nestling period. No nests were found unguarded until the nestlings were 10 day old unless it was disturbed by some external factors wuch as human interference or loud mechanical noise.

Predation

The Bengal monitor, Varanus bengalensis, has been reported to steal eggs from lower branches of trees situated in submerged area. Though the Bengal monitor has a reputation as a good climber I never found any one of them to steal eggs from nests. However, they were found to gather in this heronry in a large number particularly during the breeding season of openbills and were found to eat stork eggs which fell on the ground. Whether or not the Bengal monitor steals eggs from nests, they probably assemble in the heronry in search of food and certainly the fallen eggs are part of it. Even if the report of egg stealing by Bengal monitor is true it never amounted to a significant level as the nesting failure in the lower branches of submerged zone ($\bar{X}$ = 10.28%) was neither heigher than that in the upper branches of that zone ($\bar{X}$=10.67%) nor in the lower branches of dry zones ($\bar{X}$ = 11.14%).

The most important predator was the house crow, Corvus splendens. Actually crows were not true predators rather they scavange nest contents. In no case they were found to attack or drive away the adult birds, rather they wait for a long time for oppurtunities to steal eggs or hatchlings in absence of the parents. The total clutch/brood loss due to such scavenging leads to the desertion of pairs which ultimately causes the total destruction of nests. Although crows were active for a very long period of over 80 days they caused only 7.7% of total nesting failure.

Table 9.1 : Size of nest at different phases of breeding with differential brood size

No. of nestlings	n	Area of nest at hatching (cm^2)	Area of nest at fledging (cm^2)	Percentage of nest area increase between hatching and fledging
1	21	774.72	929.83	20.02
2	40	791.58	995.83	25.33
3	56	829.95	1257.20	51.48
4	38	824.85	1425.95	72.88

Table 9.2 : Average depth of water logged area at nesting Zone I during different parts of the season

Year	Average depth of water (cm)							
	20 June	1 July	15 July	1 Aug.	15 Aug.	1 Sep.	15 Sep.	1 Oct.
1987	00	06	13	27	31	29	33	17
1988	00	05	12	20	26	30	18	00
1989	08	11	16	23	17	15	18	13
1990	00	01	07	09	13	04	08	09
1991	11	08	10	09	07	05	35	21

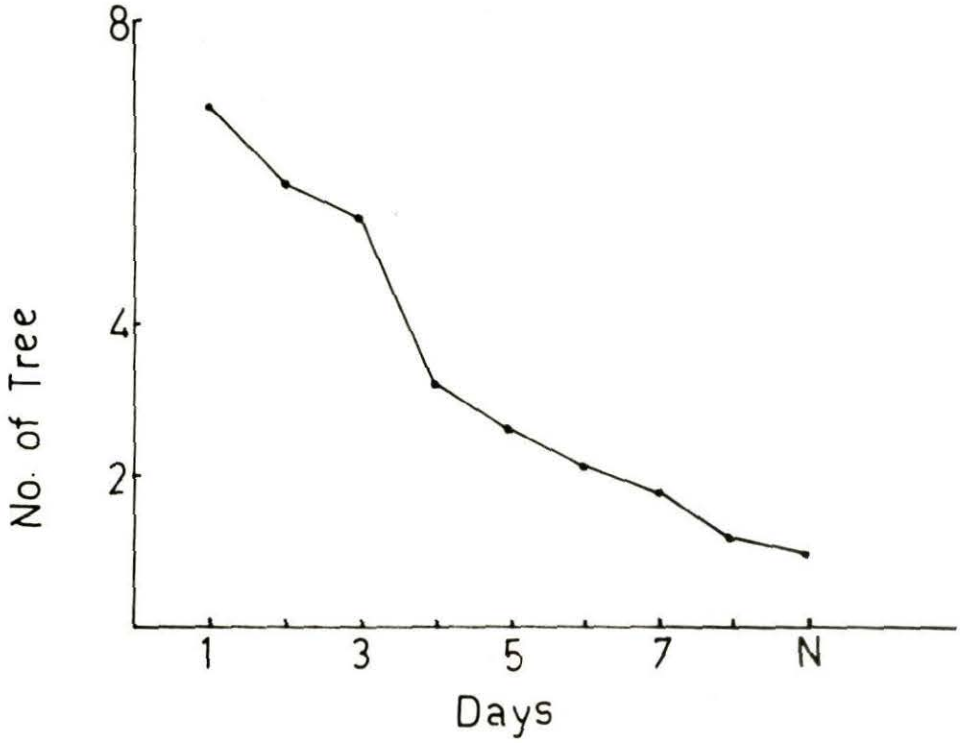

Fig. 9.1 : Number of tree used to exhibit nest-site territoriality before the initiation of true nesting ('N')

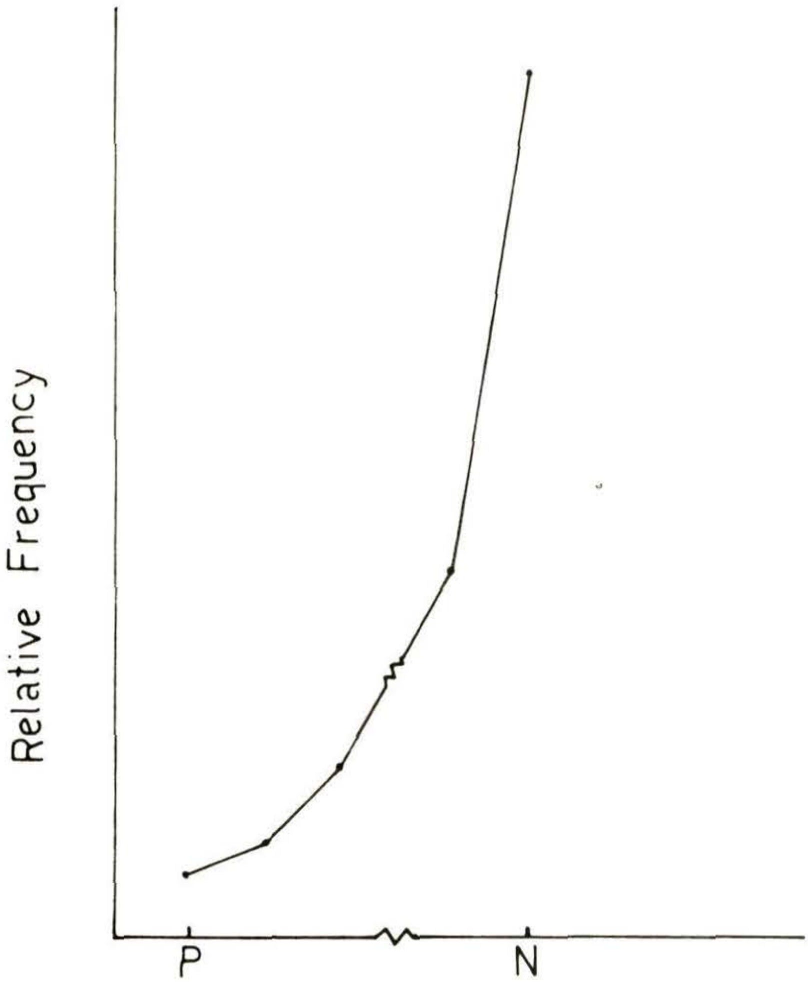

Fig. 9.2 : Frequency of nest material placement in nest-site within pair-formation and nesting. P, day of pair-formation; N, day of nest initiation

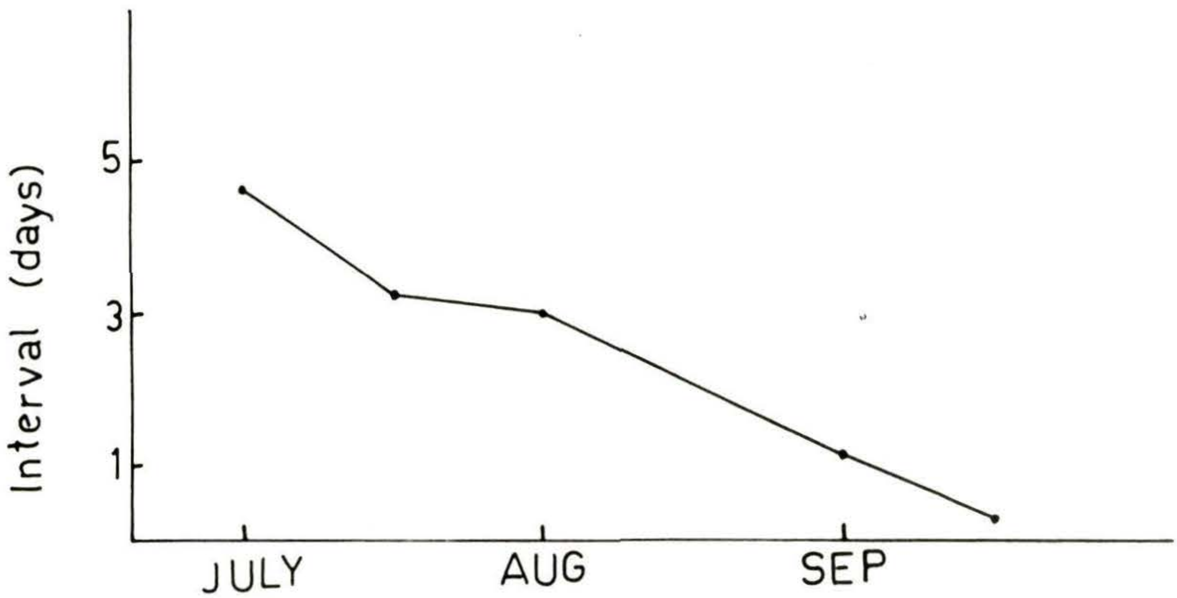

Fig. 9.3 : Interval between pair-formation and nest initiation at different parts of the breeding season

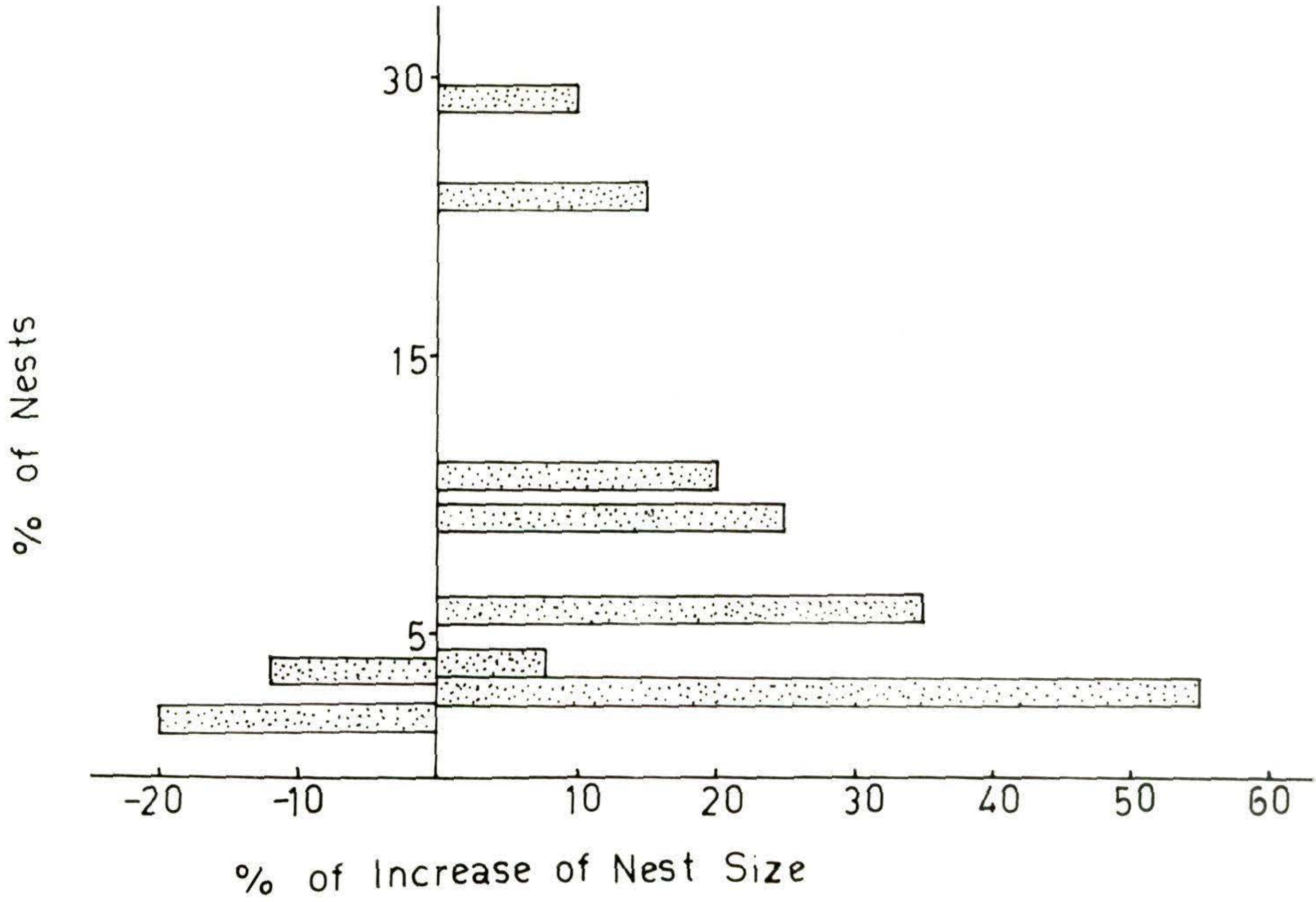

Fig. 9.4 : Frequency of nest size increment within the period of hatching and fledging

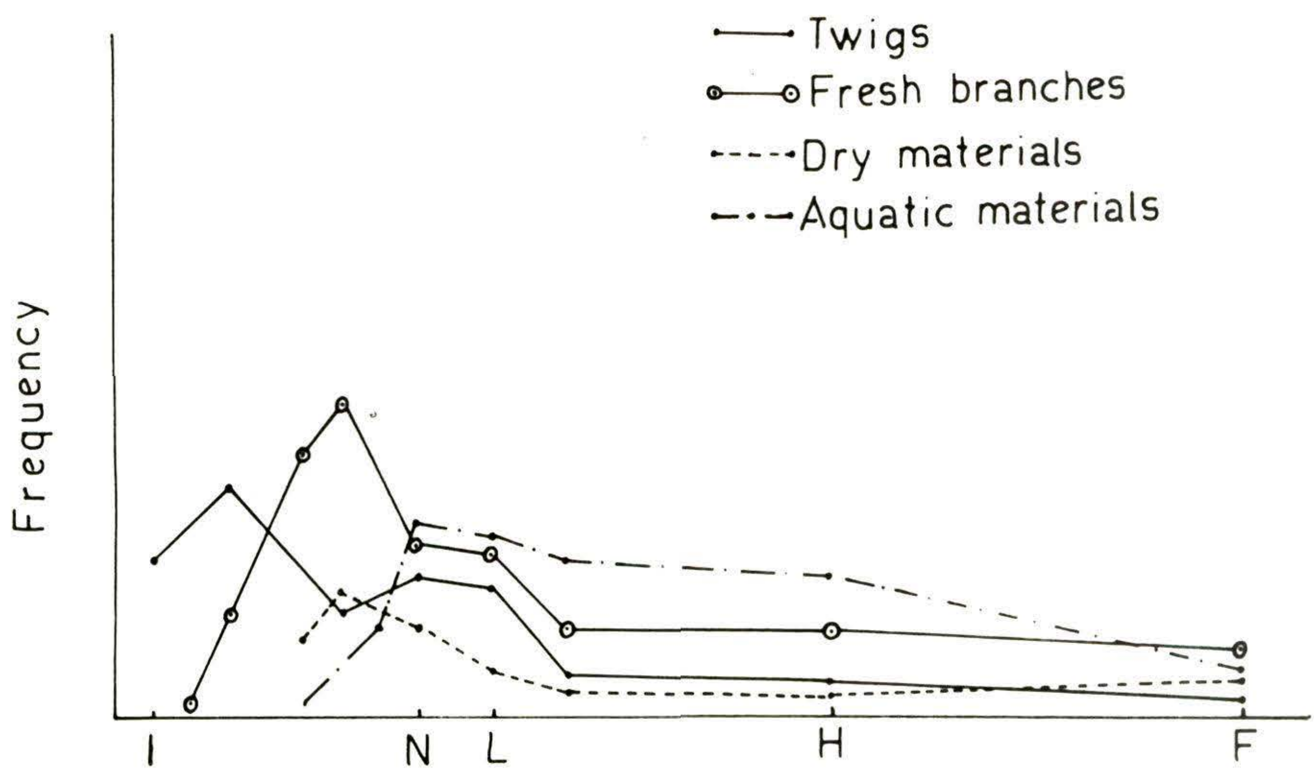

Fig. 9.5 : Frequency of different nest materials used during the breeding cycle. I, initiation of nest; N, completion of nesting; L, initiation of laying; H, hatching; F, fledging

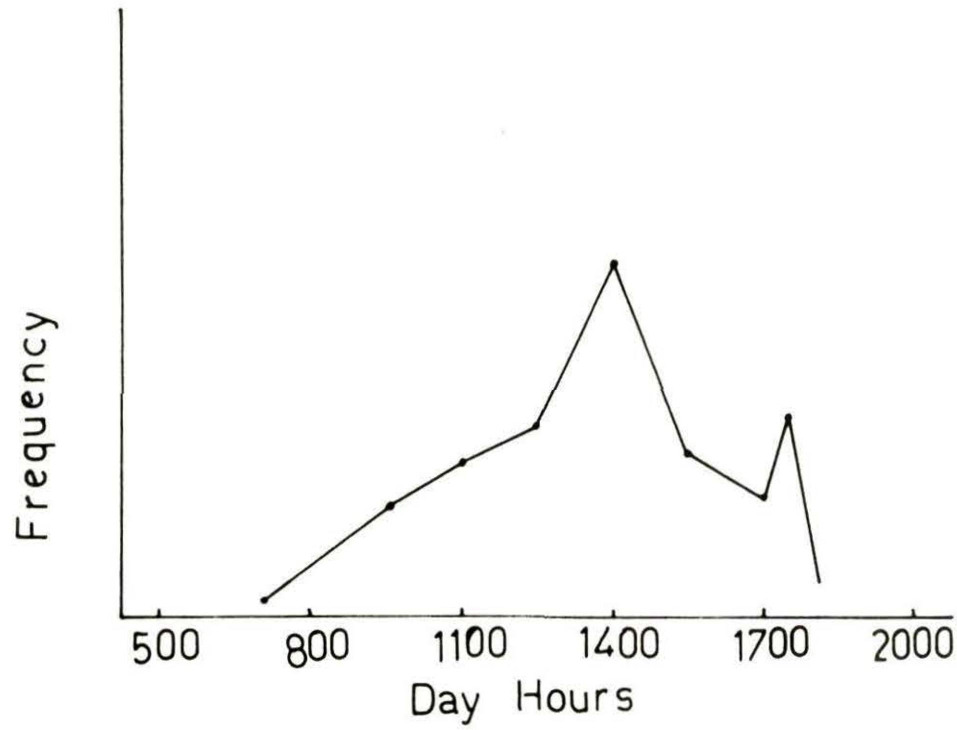

Fig. 9.6 : Frequency of aquatic material collection

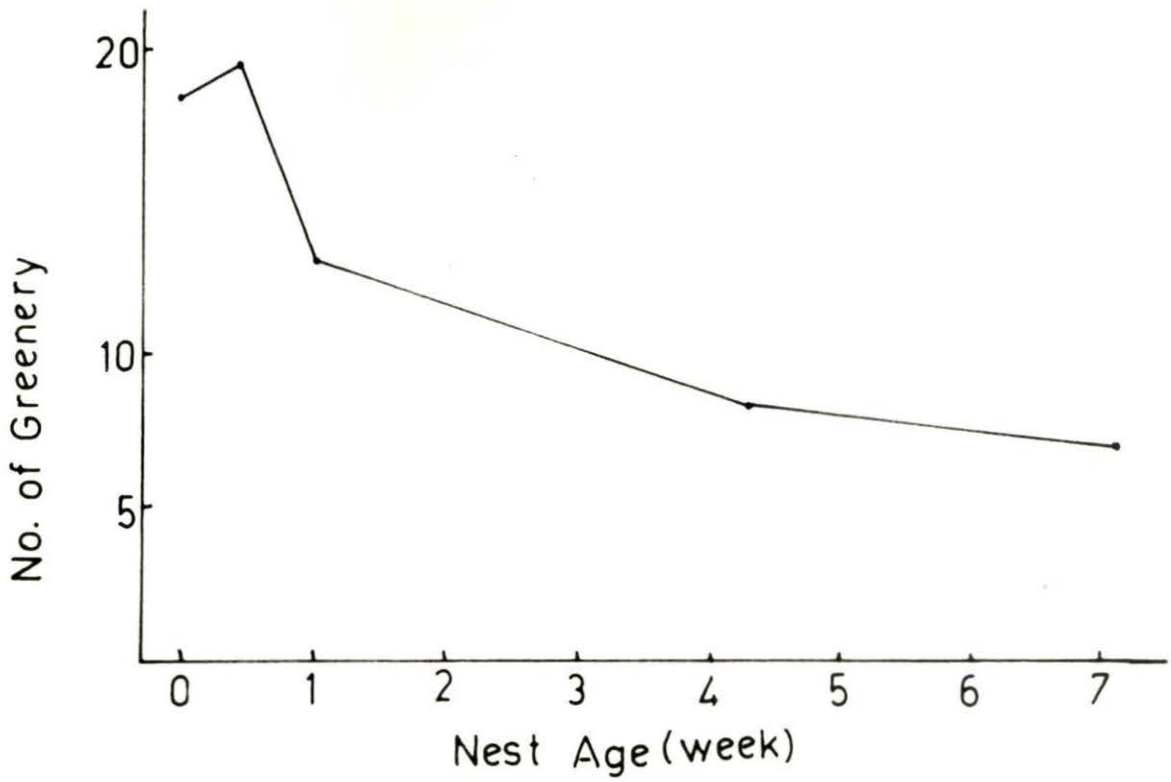

Fig. 9.7 : Use of green nest materials through out the breeding stage

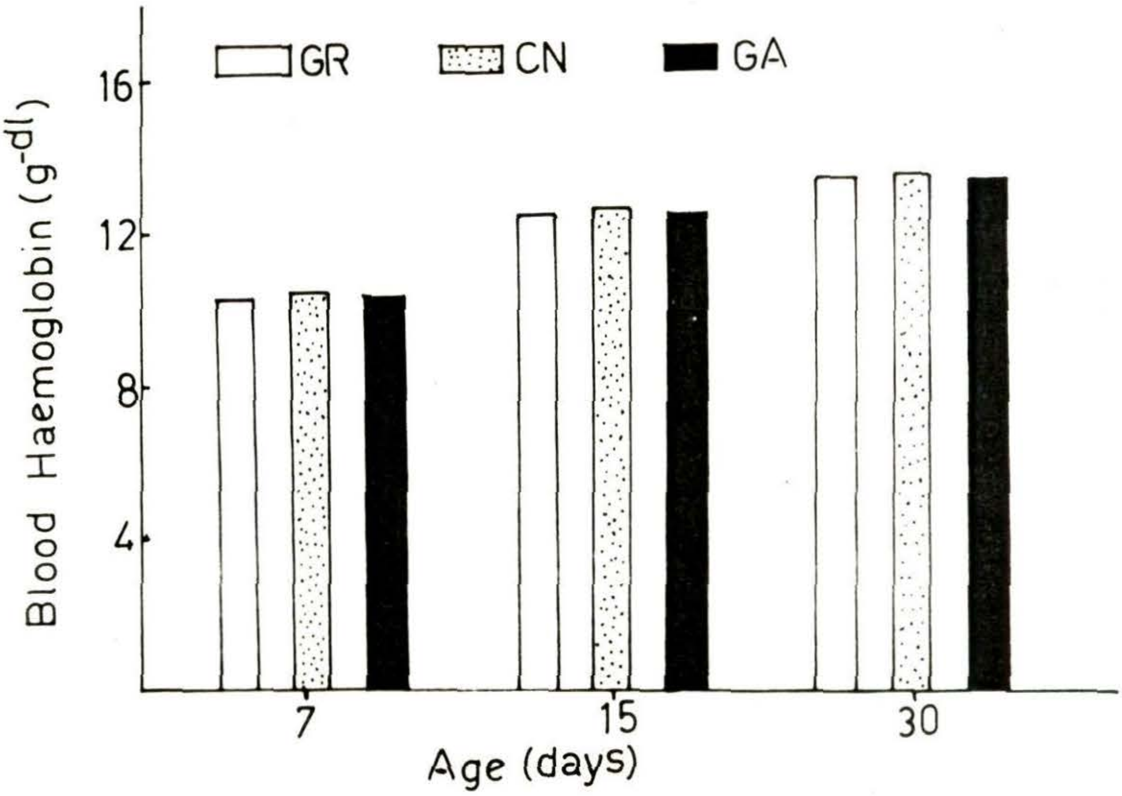

Fig. 9.8 : Mean haemoglobin content of nestlings exposed to three different type of nests. CN, controlled nest; GR, greenery removed; Ga, greenery added

Plate 9.1 : Addition of fresh branch to a nest with grown-up nestlings.

Plate 9.2 : Collection of nest material from ground.