Breeding ecology of the Sacred Ibis *Threskiornis aethiopicus* in the Free State, South Africa

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Studies on the breeding ecology of the Sacred Ibis *Threskiornis aethiopicus* were carried out at a few colonies in the Free State province, South Africa, but were focused on one colony at Wolwekop, Dewetsdorp district, in an extensive farmland in the Transitional *Cymbopogon-Themeda* grassland. In the Free State a 2-3 fold increase in the Sacred Ibis breeding population took place during the years 1972-1995, attributed to the intensification of agriculture practices and the creation of new dams. Sacred Ibis nests were built mainly of sticks and twigs, but quite often greenery was used. Nests were situated relatively low in the tree, and in each colony they were subdivided into smaller groups. If a colony was situated on an island, some nests, or all, were placed on the ground. Hatching and fledgling success varied in relation to season and locality. Two peaks occurred in daily activity of adult birds: one between 7h00and 10h00, and other between 17h00and 18h00. Chick's growth form hatching to the age of 22 days were also investigated.

Key words: Breeding ecology, Sacred Ibis *Threskiornis aethiopicus*, Free State, South Africa.

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Introduction

The Sacred Ibis *Threskiornis aethiopicus* is one of 32 species of the family *Threskiornitidae*, 11 of which occur in Africa (del Hoyo *et al.* 1992; Hancock *et al.* 1992). It is the most widespread and the commonest member of this family on this continent (Brown *et al.* 1982).

The Sacred Ibis is a colonial breeding species, and from the earliest times has been very well adapted to man-modified habitats. Despite this, its ecology is still not well known. Clark & Clark (1979) studied its diet, movements (Clark 1979a) and pesticide contamination (Clark 1979b) in an intensive farmland near Pretoria. Diet of the Sacred Ibis nestlings was also analysed in an extensive farmland and in a nature reserve in the Free State, South Africa (Kopij *et al.* 1996), while reproductive performance has only been investigated in natural habitats in Ethiopia (Urban 1974) and Kenya (Parson 1977).

The present study focused on reproductive performance in populations breeding in both man-modified and natural habitats, where, in contrast to previous studies (Urban 1974; Parson 1977), predation pressure was expected to play no significant role.

Studied sites

Studies were focused on a colony established *c.* 30 years before, in a tree belt on a dam wall, 100 m from buildings of the farm Wolwekop, Dewetsdorp district, Free State, South Africa (29°27'S, 26°40'E). Besides Sacred Ibises, 1 218 pairs of the Cattle Egrets *Bubulcus ibis*, 30 pairs of the Reed Cormorants *Phalacrocorax africanus* and a few pairs of Black-headed Herons *Ardea melanocephala* and Little Egrets *Egretta garzetta* nested in the colony (Kopij 1996a, 1997b).

The area around the Wolwekop colony was utilised as pastures with scattered cultivated (arable) fields, dams and farmsteads. Natural vegetation in this area is represented by the Transitional *Cymbopogon-Themeda* Veld, in a semi-arid zone, where mean annual precipitation is lower than 550 mm (Earle & Grobler 1987), with rain falling mainly (80%) during the summer (October-March, with a peak in February).

In the second half of November 1995 studies were also carried out at a colony at Willem Pretorius Game Reserve (WPGR) in the Winburg/Senekal districts, Free State (28°20'S, 27°20'E). The mixed heronry with 6 020 Cattle Egret nests, 155 pairs Sacred Ibis nests and 155 nests of other members of Ciconiiformes and Phalacrocoracidae was situated on an island in the large Allemanskraal Dam which is surrounded by natural vegetation of Transitional *Cymbopogon-Themeda* Veld (Kopij 1996b). WPGR borders on subhumid zone (annual precipitation 600-700 mm, Earle & Grobler 1987). During 1995/96 breeding season the water level in the dam was so low that the island had a very wide connection to the land. Preceeded by a drought, heavy rains fell in this area in December (cf. Kopij 1996b).

Methods

During the breeding season November 1972 – April 1973 an inventory of some ciconiid species, including the Sacred Ibis, was carried out in the Free State. This was repeated during the years 1993-1996. Eleven of the biggest Free State dams were surveyed on a monthly basis. Some farmers were also interviewed in order to detect ibis breeding colonies on farm dams (Kopij 1997a).

The colony at Wolwekop was studied during two seasons: 1976/77 (observations were made every week) and 1993/94 (observations were made 2-3 times a week). Each nest was

checked at least four times at regular intervals to determine clutch size and breeding success. As ibis chicks were able to leave their nests relatively early (14 days of life) and congregated together in one place, it was difficult to determine fledging success for a particular nest, this was, therefore, calculated for each tree only, and for the entire colony.

In two other colonies, namely at WPGR (Kopij 1996b) and at Sandveld Nature Reserve 27°40'S, 25°40'E (Kopij & Nuttall 1996), observations were made on nest location, their construction, clutch size, and hatching success.

The following terms have been used to determine breeding success: hatching success – percentage of chicks hatched in relation to the number of eggs laid; fledging success – percentage of fledglings in relation to the number of hatchlings; reproductive success – percentage of fledglings in relation to the number of eggs laid; nest success – percentage of nests with fledglings in relation to the number of nests with eggs. A fledgling is assumed as an entirely feathered chick, able to leave the nest, i.e. approximately 20 day old.

Nestlings were weighed (to the nearest 0.1 g) using a Pesola scale, and measurements (to the nearest 0.5 mm, using a vernire calliper) were taken at the same time of day (between 10h00 and 11h00), at 1-3 day intervals from the time chicks hatched.

Activity in the colony at Wolwekop was studied by recording all birds departing and arriving, their flock sizes and flight directions, from 04h00 until 20h00. This was done on three sunny days: 1 December 1993, and 14 and 20 January 1994, when most pairs had nestlings, and on one cloudy day (17 November 1993).

Results

Breeding population

In the Free State, the Sacred Ibis is absent in the south-western areas, probably because of the lack of sufficient breeding sites. Inventory of breeding sites, carried out during the years 1972/73, showed existence of 170 breeding pairs in eight colonies in this province (Table 1). During 1995 breeding season at WPGR, 155 pairs nested, while at Sandveld Nature Reserve 105 nests were found. It is likely that Sacred Ibises nested colonially also at Krugersdrift Dam, Kalkfontein Dam, Vaal Dam and in the Gold Fields near Welkom during the 1995 breeding season. The total Free State population in that season, therefore, may be estimated at 300-500 pairs, giving a 2-3 fold increase during last 23 years.

Nest construction

The Sacred Ibis nest comprises a platform, 27-37 cm in diameter ($\bar{x}$ = 30.9 cm; n = 25) and 10-15 cm in height ($\bar{x}$ = 13.3 cm; n = 8). It is composed mainly of sticks, 10-140 cm in length and 0.2-2.5 cm in diameter (n = 422; Table 2), with a mixture of weed stems, their roots and grass clumps. In some nests artificial items, such as nylon rope (*c.* 30 cm), two wires (*c.* 60 cm) and a cable (40 cm) were found.

Table 1 Number of occupied nests in Sacred Ibis colonies in the Free State during 1972/73 breeding season (after L. P. Stoltz & B. Geyser, unpubl. data)

Locality	N
Memel Adhalia	30
Machbela	19
Vaal Dam	5
Allemanskraal Dam	15
Worsal	38
Eureka	33
Wolwekop	26
Montgomery Halt	4
Total	170

Table 2 Nesting material of Sacred Ibis nests

Nesting material	F	N	$\bar{N}$	SD
Twigs	25	86	10.8	23.4
Weed stems	100	76	9.5	13.4
Sticks	100	188	23.5	8.0
Protasparagus sp.	100	98	12.3	7.4
Weed roots	25	21	2.6	5.4
Salix babylonica	100	44	5.5	3.2
Other plants*	88	12	1.6	1.7
Artefacts**	50	5	0.6	0.7
Average	100	530	66.4	60.3

*Othre plants: *Cirsium* sp.(6), *Rhus pyroides* (3), *Acacia karroo* (2), clumps of grass (2); **artefacts: plastic rope (2), cable (1), wire (2).

Many sticks of *Protasparagus* sp., *Salix babylonica* and *Rhus lancea* were used in the nest construction at Wolwekop, as these were commonly available in the vicinity of the colony. At WPGR, although sticks were used as main nesting material, large proportions of dry stems of *Chaenopodium murale* were also found. Dry parts of *Opuntia* sp. were recorded as main nesting material in nests situated on the ground. Both the *Chaenopodium murale* and *Opuntia* sp. were growing in large quantities inside and around the colony.

At Wolwekop, seven analysed nests were composed of 38-66 items ($\bar{x}$ = 53; Table 2). The nest material was loosely bound, resulting in nests falling into pieces towards the end of the breeding season. Of 70 nests at Wolwekop only nine (12.9%) were still intact one week after the last fledglings left the colony.

Greenery was quite often brought to the nests by Sacred Ibises. On 30 November 1993 (incubation/hatching phase) all nest at Wolwekop were surveyed for the presence of these. Mainly grasses collected on the dam banks and leafy willow twigs gathered from a tree standing nearby were recorded.

These items were often seen in the nests during the incubation and nestling phases. A similar survey conducted at WPGR in the end of November 1995 (hatching period) showed that greenery was also used (Table 3).

Table 3 Greenery found in Sacred Ibis nests

Plant species	Wolwekop	WPGR	Total	%
Salix babylonica	22	3	25	24.0
Poaceae sp.	19	3	22	21.2
Nidorella resedifolia	-	15	15	14.4
Paspalum dilatatum	4	11	15	14.4
Pseudognapholium luteoalbum	5	-	5	4.8
Salix + *Protasparagus*	3	-	3	2.9
Chenopodium murale	-	2	2	1.9
Water plants	1	1	2	1.9
Altermanthera sessilis	2	-	2	1.9
Protasparagus denudatis	2	-	2	1.9
Asteracae sp.	2	-	2	1.9
Paspalum dilatatum	1	-	1	1.0
Protasparagus cooperi	1	-	1	1.0
Lycopodium sp.	1	-	1	1.0
Cyperus eragrostis	1	-	1	1.0
Cyperus sp.	-	1	1	1.0
Eucalyptus sp.	-	1	1	1.0
Unidentified	-	3	3	2.9
Total	64	40	104	100

Nest location

In colonies studied, most nests were grouped in smaller subcolonies. The subcolony size ranged from 2 to 43 nests ($\bar{x}$ = 13.3; n = 16). At Wolwekop eight such clumps were established in 1993, their size ranged from 2 to 17 nests ($\bar{x}$ = 8.5), with only two pairs nested solitary. At WPGR no nest was sited on its own; all were clumped in eight groups comprising three to 43 nests ($\bar{x}$ = 18; n = 155).

Within the subcolony, nests were situated close (0.3-3 m) to one another. In larger groups (10 or more nests) those nests placed in the centre were so close to one another (30-60 cm, $\bar{x}$ = 47; n = 52) that they formed a kind of common platform. Five such platforms at Wolwekop and six at WPGR were established.

At Wolwekop most (n = 42) nests were located on *Acacia karroo* and the remainder on *Rhus lancea* (n = 7) and *Rhus pyroides* (n = 21). In 1993, nest height varied from 1 to 5.2 m ($\bar{x}$ = 2.6 m; n = 33) and in 1976 the average nest height was similar ($\bar{x}$ = 2.7 m) ranging from 1.9 to 3.2 m (n = 15). Most nests located on *Acacia karroo* were above 2 m in height, while most of those on *Rhus pyroides* were below 1.5 m. Nests on *Rhus lancea* were the highest above the ground.

At WPGR 43 nests were situated on *Acacia karroo*, 43 nests on *Ehretia rigida*, 33 nests on *Rhus brucei*, seven on *Rhus pyroides* and 18 on the ground around and on top of *Protasparagus* sp. Nest height varied from 0 to 3.5 m ($\bar{x}$ = 2.0 m; n = 155), with most being between 1.5 and 2.5 m.

At Sandveld Nature Reserve all 105 nests were located on *Acacia erioloba*, 3-5 m above the ground. At Kalkfontein Dam (C. A. van Ee, pers. comm.) and Krugersdrift Dam (J. Marx, pers. comm.) all nests were found on the ground, on small islands.

Timing of breeding

Egg laying started at Wolwekop in the beginning of October and ended, with a peak, at the end of this month in 1976/77. However, in the second half of November other birds started laying eggs, completing their clutches in the middle of December. The last fledglings, therefore, left the nests at the end of February (Figure 1).

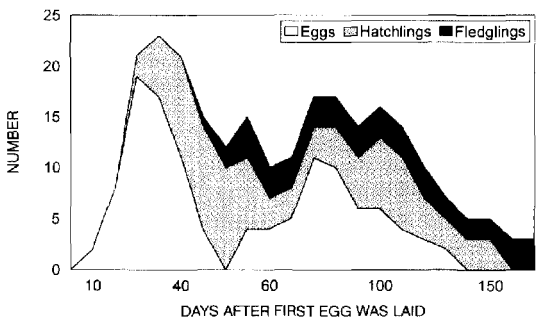

Figure 1 Timing of breeding of the Sacred Ibis at the Wolwekop colony during the 1993/1994 breeding season. Day 0 = 25 September, Day 160 = 1 March.

At the same colony breeding activity was better synchronised in 1993/94. Eggs were laid between 15 October and 15 November, with a peak around 20-27 October (65.7% pairs). At WPGR the breeding activity was synchronised to a similar extent, two thirds of females laid eggs between 20 and 30 October, i.e. approximately five weeks before the rains. In the same season, at Sandveld Nature Reserve the birds began to lay eggs c. 7-9 weeks later, i.e. 1-2 weeks after the rains began.

Clutch size

Mean clutch size at Wolwekop and at WPGR were similar (χ^2 = 1.82; p>0.05). Likewise, no statistical difference in mean clutch size was found between the breeding season of 1976 and 1993 at Wolwekop colony (χ^2 = 0.12; p>0.05). Overall mean clutch size for 251 nests was 2.36 (Table 4). Most clutches contained 2-3 eggs (82%). The mean clutch size at WPGR was higher at the beginning of incubation (at least 2.69), than at the end of the incubation phase (2.40), when many eggs were ejected or dropped from the nests (χ^2 = 2.18; p>0.05). A total of 52 such eggs were found on the ground below the nests, 32 of which were examined: 16 (50%) contained embryos, another 16 (50%) were without embryos (some infertile, in others embryos might have died .in an

Table 4 Clutch size in the Sacred Ibis

Site	Season	Clutch size 1	2	3	4	Number of nests	Mean clutch size	SD
Wolwekop	1976	4	11	24	1	40	2.55	0.71
Wolwekop	1993	16	23	28	-	67	2.18	0.80
WPGR	1995	21	58	62	3	144	2.40	0.10
Total		41	92	114	4	151	2.36	0.96

early stage of the embryogeny). No difference between the clutch size and nest height location has been recorded

Three Sacred Ibis nests at Wolwekop and six nests at WPGR were shared with Cattle Egret. There were usually single eggs of the Sacred Ibis and 2-3 eggs of the Cattle Egret in those mixed clutches. Although all Sacred Ibis eggs failed to hatch, Cattle Egret eggs did hatch in those mixed clutches.

At WPGR in 1995 the mean clutch size for the subcolony on the ground was only slightly higher ($\bar{x} = 2.56$) than that in the entire colony ($\bar{x} = 2.40$) ($\chi^2 = 0.68$; $p>0.05$). L. P. Stoltz (in litt.) found one colony on the bare ground on a small island, in a dam in the Gold Fields near Welkom; there were at least 20 breeding pairs, with the mean clutch size of 2.30.

At Machbela, in 1972 the mean clutch size was 1.6 ($n = 19$ nests), at Worsal – 2.5 ($n = 38$ nests) and at Wolwekop – 2.2 ($n = 26$) (L. P. Stoltz & B. Geyser, unpubl. mat.)

Hatching

One or two days before hatching the chick made a small hole (*c.* 5 mm in diameter) and often uttered a weak call. Hatching was asynchronous, with chicks in a clutch hatching at 1-3 (usually one) day intervals. Hatching took place throughout the day, with an apparent peak during the afternoon. At WPGR, at least 25 chicks partly deliberated from egg shells or just hatched (wet) were seen between 15h00 and 16h00. Egg shells were usually ejected on the ground below the nests, but sometimes only onto the rim of the nest.

At Wolwekop, the mean number of hatchlings per nest with eggs was 1.7 and the average number of hatchlings per nest with hatchlings 2.3 ($\chi^2 = 3.30$; $p>0.05$); hatching success was 66%. (Table 5). Only clutches of two and three resulted in hatching. At WPGR the mean number of hatchlings per nest with eggs and per nest with hatchlings was 1.6 and 2.3 ($\chi^2 = 0.07$; $p>0.05$ and $\chi^2 = 0.00$; $p>0.05$) respectively, with hatching success being calculated at 88.4% (96.0% if eggs ejected from nests are excluded in calculation). The average number of hatchings in the subcolony situated on the ground at WPGR was higher, i.e. 2.6 ($\chi^2 = 4.47$; $p = 0.05$) and 2.5 ($\chi^2 = 0.04$; $p>0.05$) hatchlings per nest with eggs and hatchlings respectively); hatchling success was calculated here at 89.9%; only two infertile eggs were found around the subcolony.

Fledging success

In 1976/77 at Wolwekop the average number of fledglings per nest with eggs was 1.5, the average number of fledglings per nest with hatchlings 1.9 and the average number of hatchlings per nests with fledglings 2.1. Fledging success was calculated there as 57.8%. At the same colony in 1993/94 the fledging success was 51.4% and the average number of fledglings per nest with eggs 1.1 ($\chi^2 = 8.00$; $p = 0.01$).

Table 5 Hatching success of the Sacred Ibis in Willem Pretorus Game Reserve in 1995

Number of hatchlings per nest	1	2	3	4	Total
Number of nests	16	42	40	1	99
Total number of hatchlings	16	92	120	4	232
Percentage of nests	6.9	39.7	51.7	1.7	100

Of 33 chicks found dead, 13 dropped from the nests and died on the ground from starvation, nine were found dead in their nests, four were found drowned in the dam water, two were dead on branches, and one chick showed possible evidence for cainism.

Nestling growth

Just after hatching the chicks weighed *c.* 40 g with culmen *c.* 16 mm in length, skull – 38, forearm – 20 and tarsometatarsus – 18 mm. They were covered with delicate whitish down, except for the head which was black. The beak was blackish at the base and reddish towards the top.

During the first three weeks of life the growth curves of all parameters were similar among older and younger chicks (Figure 2), after 5-6 days the tarsometatarsus grew more rapidly. At the age of 20 days, when the fledglings left their nets, their culmens and skulls were four fold and tarsometatarsus five fold longer, in comparison with these measured at hatching.

During the first three weeks of life, chick's weight increased exponentially, although marked differences among the chicks were recorded. By 4-5 days their mass had doubled and by 8-9 days exceeded 10 times their natal mass. At age 22

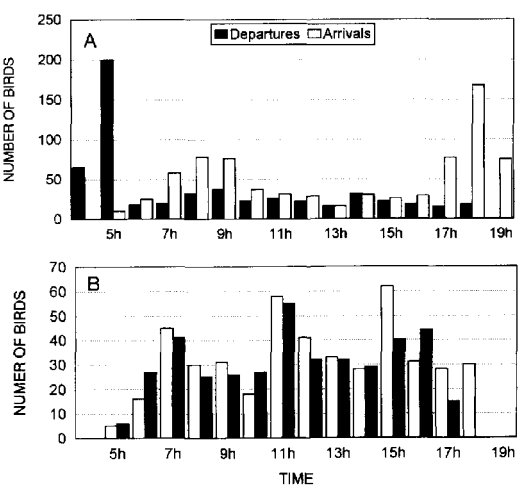

Figure 2 Diurnal flight pattern of the Sacred Ibis at the Wolwekop colony during the 1993/94 breeding season. A – sunny days, B – cloudy day.

days they weighed approximately 1000 g and thereafter the growth slowed down.

First primaries emerged at five days, while the shafts erupted 1-2 days later. The proportion of the shafts to the vane was more or less equal by 17 days, but at 22 days the shaft length already markedly exceeded that of the vane. First retrices were noted at age of seven days, and at 14 days the proportion of the shaft to the vane in the retrices was equal, while at 22 days the shaft length was twice as long as that of the vane.

Activity

At Wolwekop, first Sacred Ibises departed from the colony at *c.* 4h30 (i.e. approximately half an hour before sunrise); last birds arrived between 19h15 and 19h30 (i. e. approximately half an hour after sunset). Two peaks of this activity occurred: one between 7h00 and 10h00 and 17h00 and 18h00 (Figure 3). During an overcast day, the pattern was erratic: birds were less active in the morning and more active around the noon (Figure 3).

Sacred Ibises flew singly (60%) or in flocks, comprising usually of 2-10 birds (96%). Birds departed more often in flocks (47.8%), while they arrived more often singly (63.6%) (Figure 4). They clearly preferred (78% of all records) an easterly direction when departing for food, where a river was situated 4-5 km away. Some of the ibises (16.2%) flew to a larger dam c. 5 km south of the colony.

Discussion

At the beginning of the 20th century, the Sacred Ibis was regarded as a non-breeding winter visitor in South Africa (Anderson 1997). Although in Zimbabwe first colonial breeding was recorded in 1978 (Anderson 1997), in the Free State, this breeding strategy was already quite widespread during the years 1972/73 (Table 1). The breeding population in the Free State has also shown a marked increase in the last few decades. This may be attributed to the increase of dams and agricultural practices, which has created feeding places such as rubbish dumps, dung heaps, sewage farms, carcasses, etc. The increase in Sacred Ibis numbers have probably caused a decline of the sympatrically breeding African Spoonbill *Platalea alba,* as both the species have similar feeding habitat preference (Kopij *et al.* 1996; Kopij 1997a). In 1972/73 120 breeding pairs of Spoonbills in 10 colonies (Kopij 1997a) and 170 pairs of Sacred Ibises in eight colonies (this study) were recorded in the Free State, while twenty years later, in the central part of the province alone, at least 200 breeding pairs of Sacred Ibises (this study) and no more than 20 breeding pairs of the Spoonbills (Kopij 1997a) were recorded.

In the Free State, Sacred Ibises build their nests in discrete groups (subcolonies). This has also been found at Lake Victoria in Kenya (Parson 1977), at Lake Shala in Ethiopia (Urban 1974) and in western Tanzania (Stromach 1968). Parson (1977) showed that the Fish Eagle *Haliaeetus vocifer*, main predator in his study area, did not select small subcolonies in preference to larger ones, therefore the percentage of egg loss due to predation was inversely correlated with a subcolony's size. In other words, natural selection can favour subcolonies of a larger size. The larger subcolonies may 'swamp' a predator with prey over a limited period of time, moreover larger number of birds in the larger subcolonies are involved in behavioural defence. Parson (1977) assumed that older females breed in larger subcolonies, but since the mean clutch size, which depends on female age, does not differ significantly between smaller and larger subcolonies (Parson 1977, and this study), it can be expected that, like in the Kittiwake *Rissa tridactila* (Coulson 1968), larger subcolonies are occupied by males of better physical quality. It is known that in migratory ciconiid species the male arrives at the nesting site occupied by him in a previous breeding season a few days before the female's arrival (e.g. Hancock *et al.* 1992).

In the Free State incubation begins after the first egg has been laid, similar to what was recorded in Ethiopia (Urban 1974) and in Tanzania (Stromach 1968). However, in Kenya incubation begins when the entire clutches have been completed (Parson 1977). In the Ethiopian and Free State colonies predation did not markedly affect reproductive success, while at the Lake Victoria in Kenya very high Fish Eagle predation

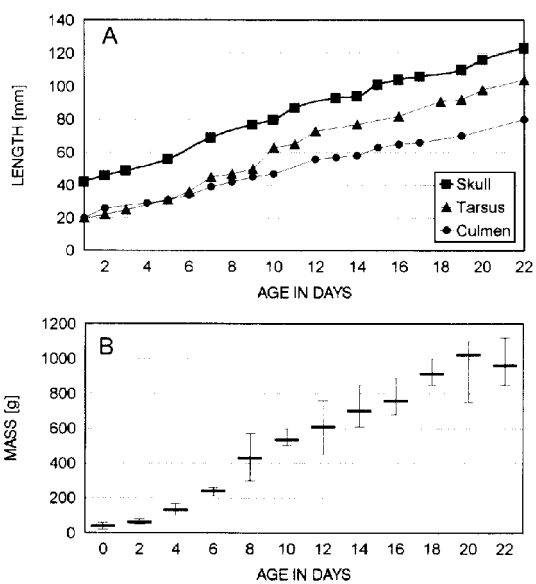

Figure 3 Growth rate of Sacred Ibis chicks. A – culmen, skull and tarsometatarsus; B – body mass.

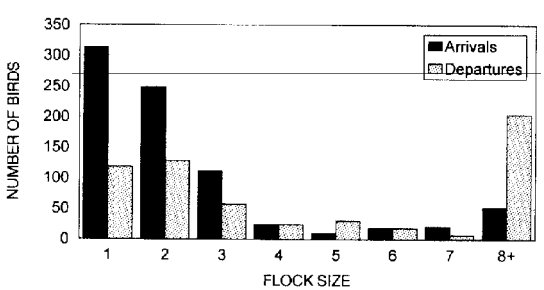

Figure 4 Flock size of Sacred Ibises departing and arriving to the Wolwekop colony.

was recorded. This suggests that synchrony hatching may switch on under such conditions, when 'swamping' a predator with prey might be an effective antipredator strategy.

Breeding success of colonial nesting ciconiid species appears to markedly fluctuate in relation to the season, habitat and geographical locality (Urban 1974; Miller & Burger 1978; Kopij 1997a; Rogers & Schwikert 1997). In the Sacred Ibis, a few factors control chick mortality (Stromach 1968, Urban 1974, Parson 1977, Tomlison 1979), namely heavy rains or drought, predation and falling from the nests to the ground (these factors are linked with nest height and wind velocity). None of these factors played an important role in this study, hence the high breeding success recorded there.

Although many Sacred Ibis nestlings that fell from trees often become caught in thorns and died, nests situated on the ground probably suffered heavier mammalian and reptilian predation, hence both hatching and fledging success in the WPGR was only slightly higher in nests situated on the ground than those in trees.

Heavy rains are important in the initiation of breeding in the Sacred Ibis (Urban 1974; Brown *et al.* 1982; Anderson 1997). Although in this study they did start to breed after heavy rains at Sandveld Nature Reserve, at Wolwekop, they began to breed during a prolonged drought (*c.* 2 months before rains fallen) at WPGR. Around the large dam, where they nested, very low water level exposed small and shallow bays, preferred by the birds as feeding places. Such places may resemble a flooded area where Sacred Ibises are known to breed also in dry season (del Hoyo *et al.* 1992).

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