A PRELIMINARY INVESTIGATION INTO THE STATUS, DISTRIBUTION AND SOME ASPECTS OF THE FORAGING ECOLOGY OF THE SOUTHERN GROUND HORNBILL (Bucorvus cafer) IN NATAL

by

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PREFACE

The experimental work described in this thesis was carried out in the Department of Biology, University of Natal, Durban, from January 1989 to December 1990, under the supervision of Mr Colin W. Sapsford, Dr Alan C. Kemp and Mr Bruce R. Page.

These studies represent original work by the author and have not been submitted in any form to another University. Where use was made of the work of others it has been duly acknowledged in the text.

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This project could not have been conducted without the support and help given by farmers throughout Natal. I wish to acknowledge the help of those farmers who reported sightings of B.cafer, especially those who agreed to complete data sheets.

A special thanks is due to all the farmers of the Eston and Mid Illovo districts. Too many people from these districts supplied endless help, encouragement and support, to mention each personally. Their support and permission to use their land, is most appreciated. I would especially like to thank Mr Malcolm Stainbank and Mr Carlson for their help, and permission to use their properties so much during the nesting period. I also thank Mr Pete Carlson for his help during the initial stages of the field work. I thank Mr Gavin Roe-Scott for the loan of a 20 megahertz radio. I would also like to thank the Eston and Mid Illovo Conservancies, and particularly the Chairmen, Mr F.Keiser, Mr K.Smith and Mr.E. Holtz, for their enthusiasm and support of this project.

A very special thanks is due to the families of Phoenix Wattle Company, Mike and Marie Byrne, Anthony and Robyne Gibbs, and Mike and Sue McNeil. They offered an incredible amount of support, encouragement and help throughout the project. I thank them for the use of their cottage and the many wonderful meals they supplied. I will always be grateful for the many hours of help and encouragement they gave and most of all, I thank them for the friendship which saw me through the difficult stages of the project. Their support, more than anything else, was responsible for the success of this project.

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ABSTRACT

A study on the distribution, status and selected aspects of the foraging ecology of B. cafer in Natal, was undertaken from January 1989 to December 1990.

A census was initiated to assess the distribution of B. cafer in Natal. 436 sightings were reported from 187 locations. B. cafer occurs throughout Natal, except in the far northwestern regions. A population estimation based on this census suggest that between 300-350 B. cafer individuals exist in Natal, excluding KwaZulu regions. The large area occupied by KwaZulu and the protection of this species by Zulu folk law, suggest that the population may be considerably larger.

Selected aspects of the foraging ecology of the two study groups in the Natal midlands were examined, focusing on the role that individuals play in provisioning the nestling, nest bound female and fledgling.

B. cafer are predominantly carnivorous. They are able to utilise habitats used for a wide variety of agricultural practices. The major criteria, in terms of habitat selection, being a short (<0.5 m) or sparse ground cover. Younger birds were less successful than older individuals at digging and probing for food. Foraging success rate of the juvenile increased from 7.2% prior to nesting, to 51.2% during nesting. The acquisition of foraging skills, particularly digging and probing, takes time and experience.

Frogs were the major food item fed to the nestling and nest bound female. The presence of helpers reduced the amount of feeding by parent birds. Helpers in the Stainbank group supplied 25% of food bundles to the nest. The juvenile did not act as a helper. Subadults helped most during the periods when the demand for food delivery to the nest was highest, and at the end of the nesting period. Helpers reduced the amount of time that the dominant female spent away from the nest during incubation and early nestling phase. Once the female left the nest, the male reduced his food delivery rate. An abundance of frogs, close to the nest, enabled a single pair to adequately provision a nestling. The parent birds provisioned the fledgling until the following breeding season.

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CHAPTER ONE

INTRODUCTION

Two species of Ground Hornbill of the genus Bucorvus (Aves: family Bucerotidae) inhabit African savannas (Bucorvus abyssinicus (Boddaert) (Abyssinian Ground Hornbill) and Bucorvus cafer (Schlegel) (Southern Ground Hornbill)). B.abyssinicus is restricted to Africa north of the equator, while B. cafer is the southern African species (Clements, 1981). B. cafer is a large, ground foraging cooperatively breeding bird (Kemp and Kemp, 1980), and is one of at least 222 known cooperatively breeding bird species in the world (see Brown (1987) for details).

Cooperative breeders are characterised by the presence of non-breeding adult helpers at the nest. Skutch (1961) defined a helper as "a bird which assists in the nesting of an individual other than its mate, or feeds or otherwise attends a bird of whatever age which is neither its mate nor its dependent offspring". Explanations for why offspring delay breeding, and remain with the group and act as helpers in the breeding process are numerous (see Brown (1987) for review). Fry (1972) stated that there is no one set of circumstances, or single common selective factor, which has led to the parallel evolution of cooperative breeding in birds. Two of the most widely adopted models on the evolution of cooperative breeding are the ecological constraints model (Emlen, 1982a) and kin-selection model (Lack, 1968; Brown, 1974; Ricklefs, 1975). Emlen's (1982a) model, emphasises ecological constraints that limit the possibility of personal, independent breeding. He states that selection will favour delayed dispersal when severe ecological constraints occur. Kin selection was invoked by Lack (1968) to explain not the presence of nonbreeders, but their behaviour; specifically their role in assisting in the production of offspring not their own. Kin selection explanations of cooperative breeding rely heavily on Hamilton's (1963) ideas of inclusive fitness. Hamilton (1963) included the effects of a behaviour on nondescendent kin, and not just the effects of parents on their offspring, into his inclusive fitness theory.

Emlen (1982a&b) stated that retention of immatures, reduced dispersal of non-breeding birds, and delayed maturity and breeding, are a result of a decreased probability of a dispersing bird obtaining a breeding position, due to saturation of suitable habitat, or a lack of suitable habitat for breeding, brought about by a fluctuating environment. Stacey and Ligon (1987), suggest that a yearling can produce more offspring during its lifetime by remaining in a high quality territory for one or more years as a nonbreeding helper than to disperse and attempt to breed in a low quality territory. Emlen and Wrege (1989), summarise the advantages for a non-breeding bird to delay breeding and remain as a helper in a group, into four categories; (i) Improved probability of survival to the following breeding season, (ii) enhanced probability of becoming a breeder in the future, (iii) increased reproductive success when it does become a breeder, and (iv) increased production of non-decendent kin. The first three points imply improved direct fitness, while the final point implies an increased indirect fitness. For a recent review on the advantages and disadvantages for both helpers and breeders in cooperative systems see Brown (1987).

Essential to the understanding of cooperative breeding, is the assessment of the role that helpers play in the activities of the group. Studies of the foraging ecology of cooperatively breeding birds have focused primarily on provisioning of chicks at the nest, and particularly on the role that helpers play in this process (Brown, 1970; Ligon, 1970; Woolfenden, 1975; Brown, 1978; Emlen, 1978; Stallcup and Woolfenden, 1978; Ligon and Ligon, 1979; Kemp and Kemp, 1980; Hooper and Lennartz, 1981; Emlen, 1982a; Emlen, 1982b; Wilkinson and Brown, 1984; Austad and Rabenold, 1985; Zack, 1986; Hunter, 1987; Lennartz Hooper and Harlow, 1987; Kemp, 1988; Ligon and Stacey, 1989). Chapter Four deals with this topic in detail.

As mentioned previously, <u>B. cafer</u> is the largest avian cooperatively breeding species (Kemp and Kemp, 1980). In South Africa, studies on this species have been restricted to a population in the central district the Kruger National Park, South Africa (Kemp and Kemp, 1978; Kemp and Kemp, 1980; Kemp, 1988; Kemp Joubert and Kemp, 1989). Kemp (1988), noted that the population structure of <u>B. cafer</u> is typical of many cooperative breeding birds, with high survival of fledglings to adulthood, even in this the largest known avian cooperative breeder. The lifespan of <u>B. cafer</u> is not known, but thought to be in excess of 20 years (Kemp, 1988). They live in groups of 2-11 individuals, in mutually exclusive territories which are occupied throughout the year (Kemp and Kemp, 1980). There is only one breeding pair per group, and breeding attempts are usually made annually, but only 23 of 215 group breeding seasons (11%) recorded in the Kruger National Park, resulted in independent young (Kemp, 1988). Ground Hornbills are the largest of the hornbill species, and the only hornbills not to seal the female into the nest, and among the few not to undergo the characteristic simultaneous flight feather moult of the breeding female (Kemp and Kemp, 1980). They are also reported to be the only entirely carnivorous hornbills, foraging on foot in cohesive groups (Kemp and Kemp, 1978). Kemp (1988) believes that limited breeding vacancies is the key to explaining the advantages of cooperative breeding, helping, male territoriality, female dominance and obligate siblicide shown by B. cafer in the Kruger National Park.

Habitat utilisation by B. cafer, outside of the relatively pristine environment of the Kruger National Park, has not been assessed. A study of B. cafer in Natal was prompted by the Natal Parks Board, as little was known about the populations in Natal, much of which lives outside natural reserve areas, and it was thought that perhaps numbers of B. cafer were declining.

An initial aim of this study, therefore, was to update the distribution records for this species in Natal, and attempt to assess its status.

The conservation of any species requires a sound understanding of its biology and life strategies. I hypothesise that, all factors being equal (nest sites, mortality factors etc.), in large ground foraging species such as B. cafer, choice of habitat, social structure, breeding biology, and ultimately survival, revolves around the foraging strategy and ability to not only provide for themselves, but to allow for successful breeding. It was therefore decided that the focus of this study would be on selected aspects of the foraging ecology of B. cafer in agricultural areas, and more specifically, on the role that different group members play in provisioning the chick, nest bound female and fledgling.

Two B. cafer groups were chosen in the Natal midlands as study groups. Only one of the groups had helpers in the 1989/90 breeding season, which made it possible to compare the foraging ecology and breeding biology of a group which contained helpers with one which did not.

CHAPTER TWO

STUDY AREA AND GROUPS

2:1 STUDY AREA

2:1:1 The Greater Natal Region

As stated previously, this study attempts first to assess the status and distribution of B. cafer throughout Natal, and second, focuses on certain aspects of the foraging ecology of two groups.

Natal is situated on the east coast of South Africa (Fig.2:1) rising from the Indian Ocean in the east to the Drakensberg mountain range in the west. The greater Natal region is divided into KwaZulu and Natal (Fig.2:2). KwaZulu regions cover a total area of 19907 km^2, which is approximately 28% of the area of the greater Natal region (Central Statistical Services pers. comm.[1]). For the purpose of this study, KwaZulu was considered to be part of Natal, however, a lack of data for KwaZulu regions necessitated their exclusion from many of the analyses shown in Chapter Three.

The farming regions of Natal, excluding game reserve areas and KwaZulu, cover an area of approximately 50 355 km^2 (Fotheringham, 1981). Figure 2:3 shows the major farming types in each area. A summary of the proportion of Natal under each type, as defined in Fotheringham (1981), is given in Table 2:1.

[1] Central Statistical Service. Escoval House. Smith St. Durban

FIGURE 2:1 Map of Natal, with major place names, and its location in Southern Africa, and the location of the study area. (after Cyrus and Robson, 1980).

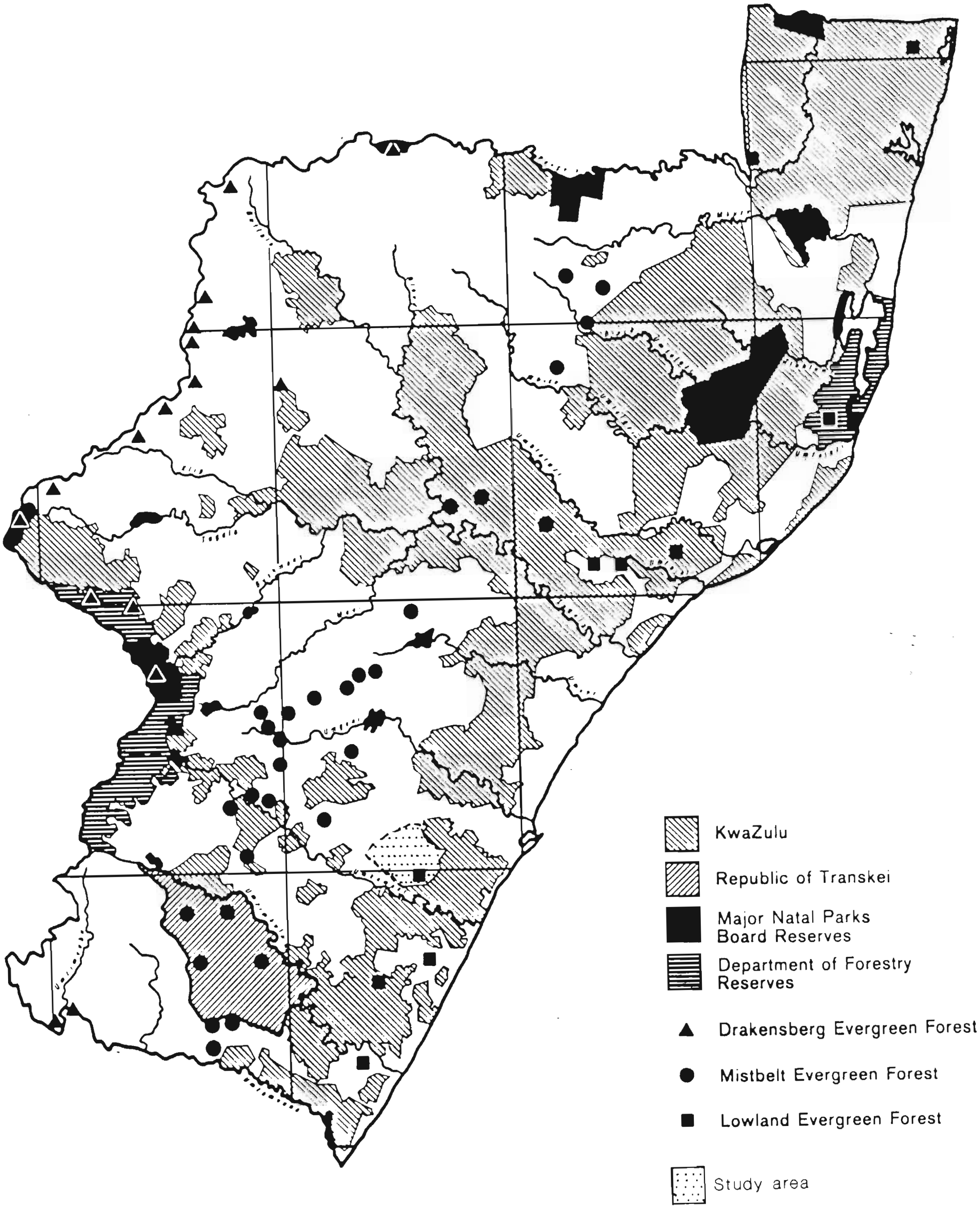

FIGURE 2:2 KwaZulu and Major conservation areas, forests and rivers in Natal (after Cyrus and Robson, 1980).

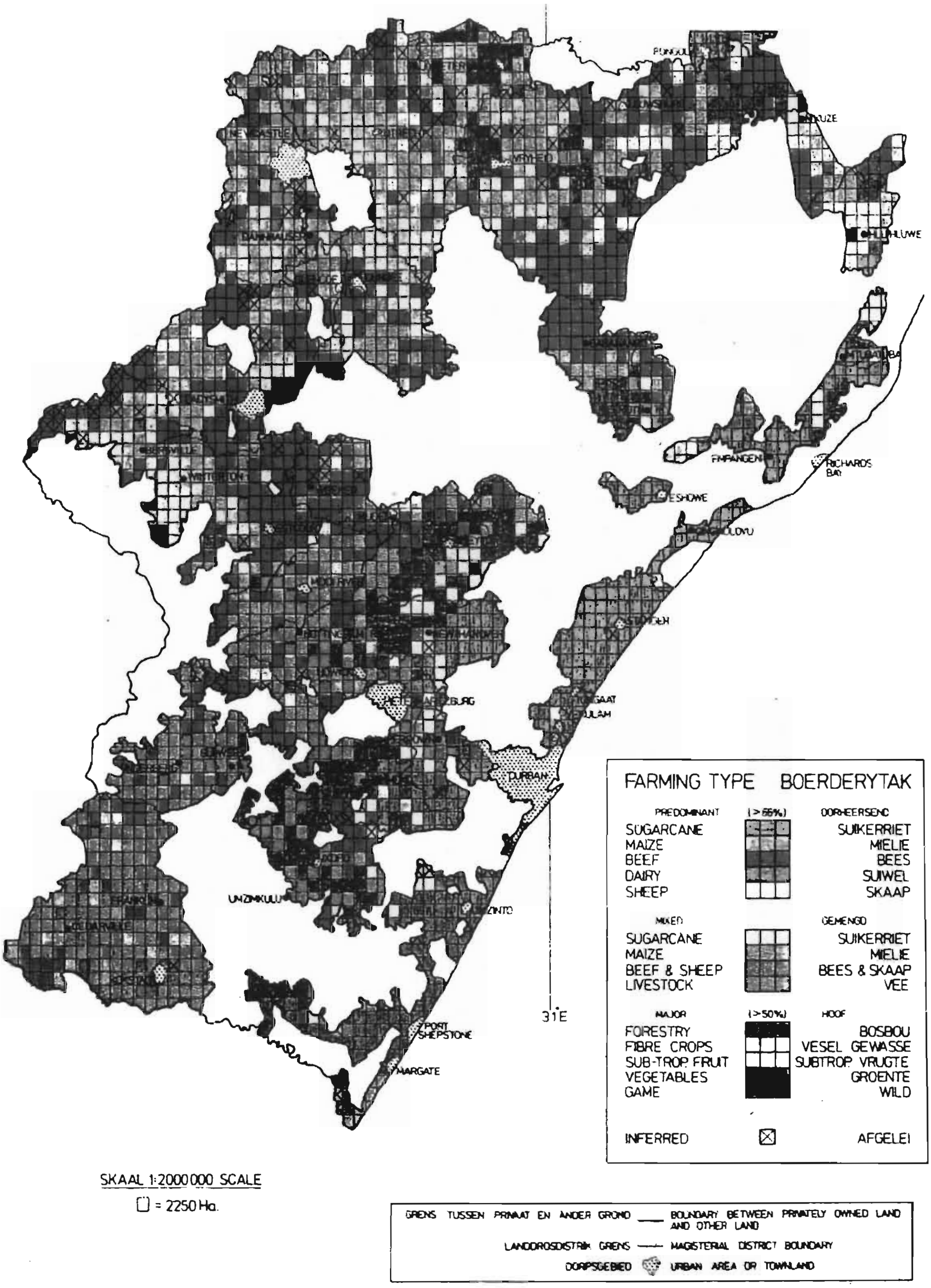

FIGURE 2:3 Map of farming types in Natal (after Fotheringham, 1981).

2:1:2 Choice of study area

To select a suitable study area an excursion was undertaken through a selected area of Natal during April and May 1989. Based on the first 55 reported sightings, it was decided that ten groups in the Natal midlands would be investigated as suitable study groups (Fig.2:4).

TABLE 2:1 Land use summary for farms in Natal, based on Fotheringham (1981).

BROAD LAND USE AREA	TOTAL AREA (km^2)	% OF SURVEY
Veld	36 374	72.2%
Dryland Crops	7 102	14.1%
Plantations	4 025	8.0%
Dry Pasture	1 047	2.1%
Irrigated Crops	836	1.7%
Irrigated Pasture	248	0.5%
Dry Orchard	40	0.1%
Irrigated Orchard	63	0.1%
Unclassified	3 321	6.6%

Two days were spent in each of the ten selected areas, during which time each area was assessed as a suitable study area. This assessment was based on accessibility and proximity to Durban, terrain and vegetation type, and the ease with which the area could be covered using a motorcycle and on foot. In addition the possibility of setting up a permanent base camp and the general response to the study by

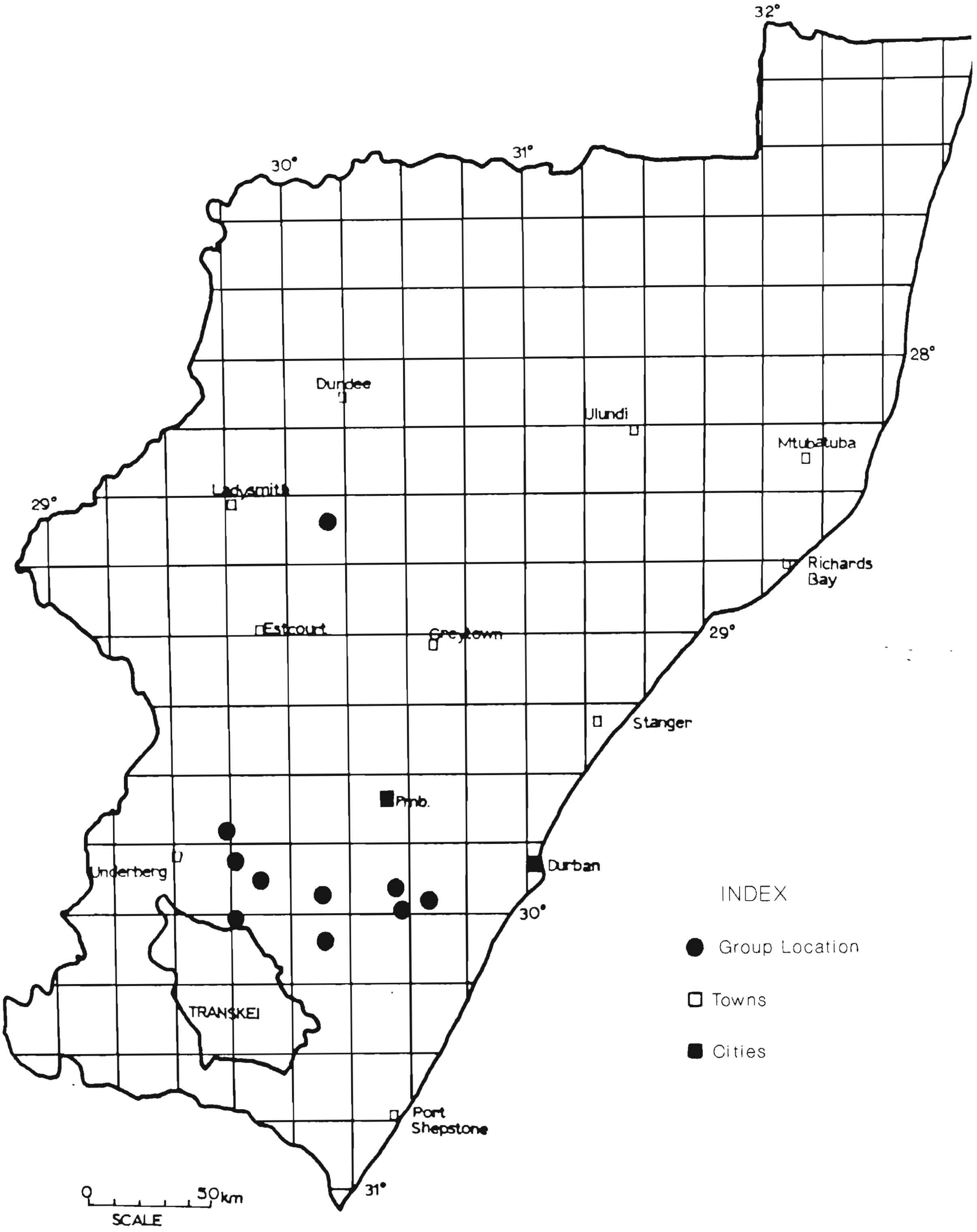

FIGURE 2:4 Location of groups that were assessed as possible study groups.

farmers in the area was assessed. During these visits the following data were collected when the groups of B. cafer were observed: group size and composition, the tameness of the group, and the ease with which they could be followed.

Based on the above criteria it was decided that the three groups in the Eston and Mid Illovo districts would be most suitable for study purposes.

2:1:3 Description of the Study Area

The Eston and Mid Illovo districts are situated in the Natal Midlands, approximately 38 kms from the coast (Fig. 2:1).

The study area is at an altitude of 300-900 m above mean sea level, and experiences a mean annual rainfall of 900-1200 mm (Cyrus and Robson, 1980). Mean daily temperatures for January are 21-22^{0}C, and for July 14-15^{0}C (Cyrus and Robson, 1980).

The predominant natural vegetation of the region is open bush (Pentz, 1945; Yates, 1966). The eastern edge of the study area is at the limit of the coastal evergreen bush and the southern regions comprise dry thornveld (Pentz, 1945; Yates, 1966).

Data on agricultural land use, collected from the postal survey of Agricultural Land Use (Agriquest : Fotheringham, 1981), conducted by the Department of Agriculture and Fisheries (Natal Region) is presented for the magisterial districts of Camperdown and Richmond in Tables 2:2 and 2:3.

TABLE 2:2 Land Use summary for the magisterial districts of Camperdown and Richmond (after Fotheringham, 1981).

Land Use Summary	No. Farms	Total Area(km^2)
Veld	775	626
Plantations	222	523
Dryland Crops	332	366
Dry Pasture	340	69
Irrigated Crops	172	47
Irrigated Pasture	104	22
Dry Orchard	135	7
Irrigated Orchard	68	5
Unclassified	775	245
TOTAL AREA	775	1909

TABLE 2:3 Summary of major enterprises for the magisterial districts of Camperdown and Richmond (after Fotheringham, 1981).

Major Enterprise	No. Farms	Total Area (km^2)
Gums and Pine	189	455
Sugar Cane	157	290
All Pastures	326	75
Irrigated	243	71
Maize	258	65
Wattle Forest	102	55
Vegetables	220	22
Misc. Fodder Crops	151	13
Potatoes	83	6
		Mean No. Of Head
Beef Cattle	291	28813
Dairy Cattle	239	13833
All Sheep	128	9854

Eston and Mid Illovo form part of the Camperdown and Richmond magisterial districts respectively. These data show land use and major enterprises for the two districts. Agriquest covered 775 farms, which accounted for 72.9% of the total area of the district.

Both the Eston and Mid Illovo districts have active wildlife Conservancies, with a total of ten game guards patrolling the two regions.

2:2 STUDY GROUPS

Three groups of B. cafer in the study area were initially chosen for study, although only two groups were used for the foraging and breeding studies. However, the movements and breeding success of the third group was monitored sporadically. The three groups were neighbouring groups and there were at least two other groups in the area (Fig 2:5). The estimated territorial boundaries of each group were based on sightings and recorded movement patterns from August 1989 to January 1990 only, and may therefore change during the winter months. Territory sizes were estimated using a 200 m by 200 m grid, on a 1:250 000 map. No correction was made for topography when calculating these areas. This, together with the fact that territory boundaries were based on movements of the birds in only six months of the year, mean that the areas depicted represent minimum territory size. The mean distance between the three nest sites was 10.1 kms (S.D. 0.49 km), and thus similar to the mean distance of 8.9 km (S.D. 3.2 km) between eight nest sites in the Kruger National Park (Kemp and Kemp, 1980).

The three groups were named after the land owner or farm on which nest sites were located, and will subsequently be referred to as the Stainbank and Carlshaven groups which

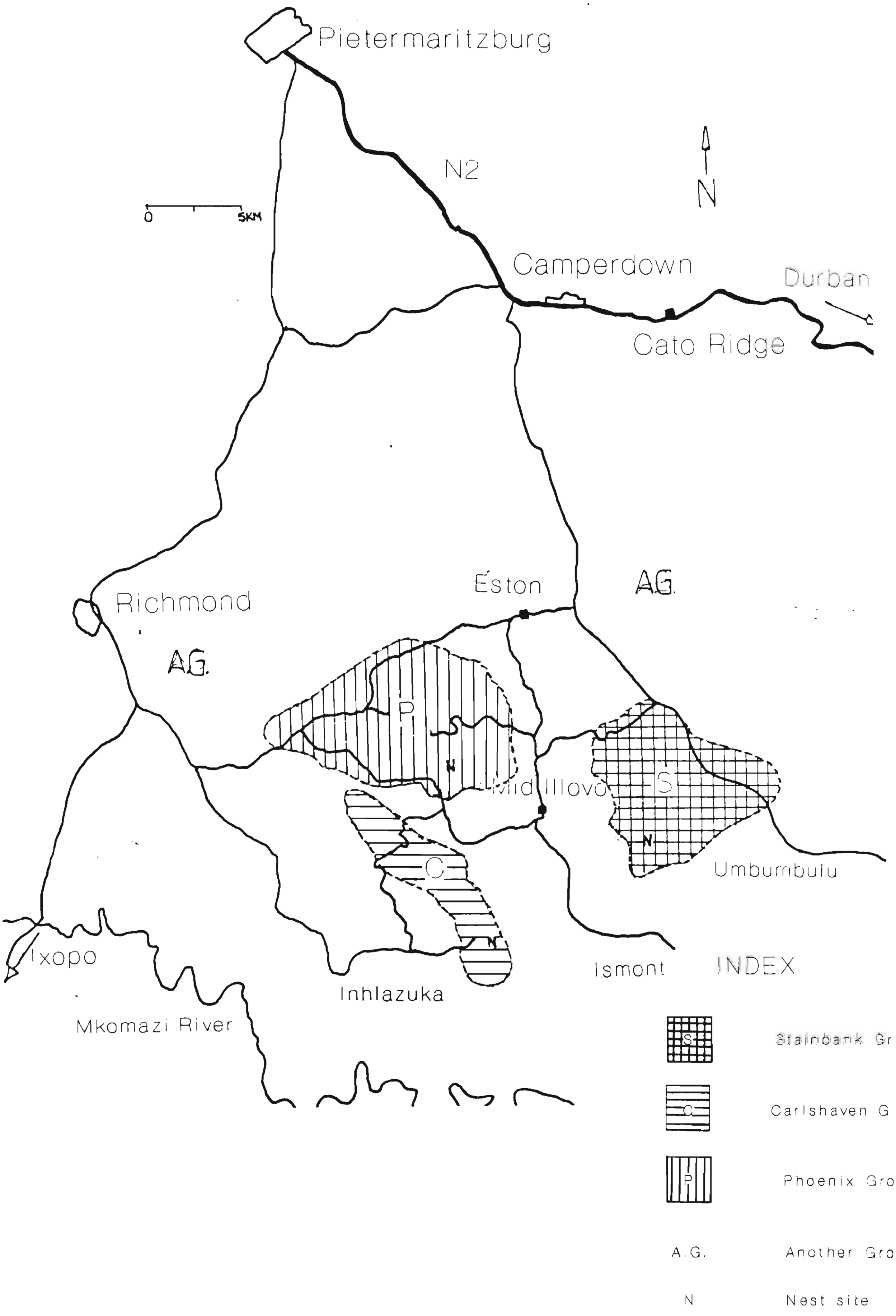

FIGURE 2:5 Map of study area showing the location of the study groups.

formed the focus of the study. The third group was the Phoenix group (Fig 2:5).

2:2:1 Stainbank Group

In March 1989 this group consisted of five birds, including two adults, two subadults and a three month old fledgling. One of the subadults was almost fully mature, while the second had a yellow border to the red wattle, which had almost disappeared by August 1990. Based on descriptions of birds of known age (Kemp pers. comm.[2]), these two birds were estimated at 4-5 years and 3-4 years respectively. It must be stressed however that wattle colour is not necessarily a reliable indicator of age. The two adults are referred to as the dominant male and female, and the two subadults as subadult 3 (older bird) and subadult 4. The juvenile was a fledgling from the 1988/89 breeding season. Based on group size and the estimated ages of each individual, and assuming that the subadults and juvenile were kin from previous breeding attempts by the adults, this group probably bred successfully at least three times in the six years prior to the study. During the breeding season of 1989/1990, the group successfully reared a nestling to fledging, and by September 1990 the group consisted of six birds.

Very little is known of the previous history of this group although numerous reports suggest that for the last five or six years the group consisted of 4 to 5 birds. This suggests that birds may have left the group or natural mortalities occurred within this period.

[2] Alan Kemp. Dept. of Birds. Transvaal Museum. Pretoria.

The birds occupied a territory of approximately 43 km^2, in an area which is predominantly under sugarcane (Fig. 2:5). From three previous reports (Stainbank pers. comm.[3]) it appears that they have utilised the same nest site for at least ten years. The nest is situated on a cliff face at the south eastern edge of the territory (Fig.2:5), and is approximately 10 m from the top of the cliff. The nest consists of a rock ledge with an overhang and is shielded in the front by two large boulders (Plate 2:1). Behind the boulders are two interlinked chambers, 70 cm X 50 cm and 80 cm X 36 cm respectively. The height of the chamber overhang is approximately 1.5 m. The two shielding boulders are approximately 60 cm in height. The nest was lined with leaves and twigs. The birds utilised a large tree 3-4 m from the nest as a perch from which the nest was approached. Two birds could be accommodated in the nest simultaneously.

2:2:2 Carlshaven Group

In March 1989 the Carlshaven Group consisted of two adults, a young female, and a subadult. The dominant female was driven from the group by the young female at the start of the breeding season in late September, and was only seen with the group on one day during the nesting period. This old female was seen on her own within the territory on three separate occasions. Assuming that the old female was the dominant bird in the 1988/89 season, the young female participated in breeding for the first time in 1989/1990, and mated with the dominant male. On 3 September 1989, the subadult, which was estimated as a four year old bird, was found dead in an orange orchard with suspected Aldicarb poisoning. This reduced group size to two for the breeding

[3] Malcolm Stainbank. P.O. Eston. Natal.

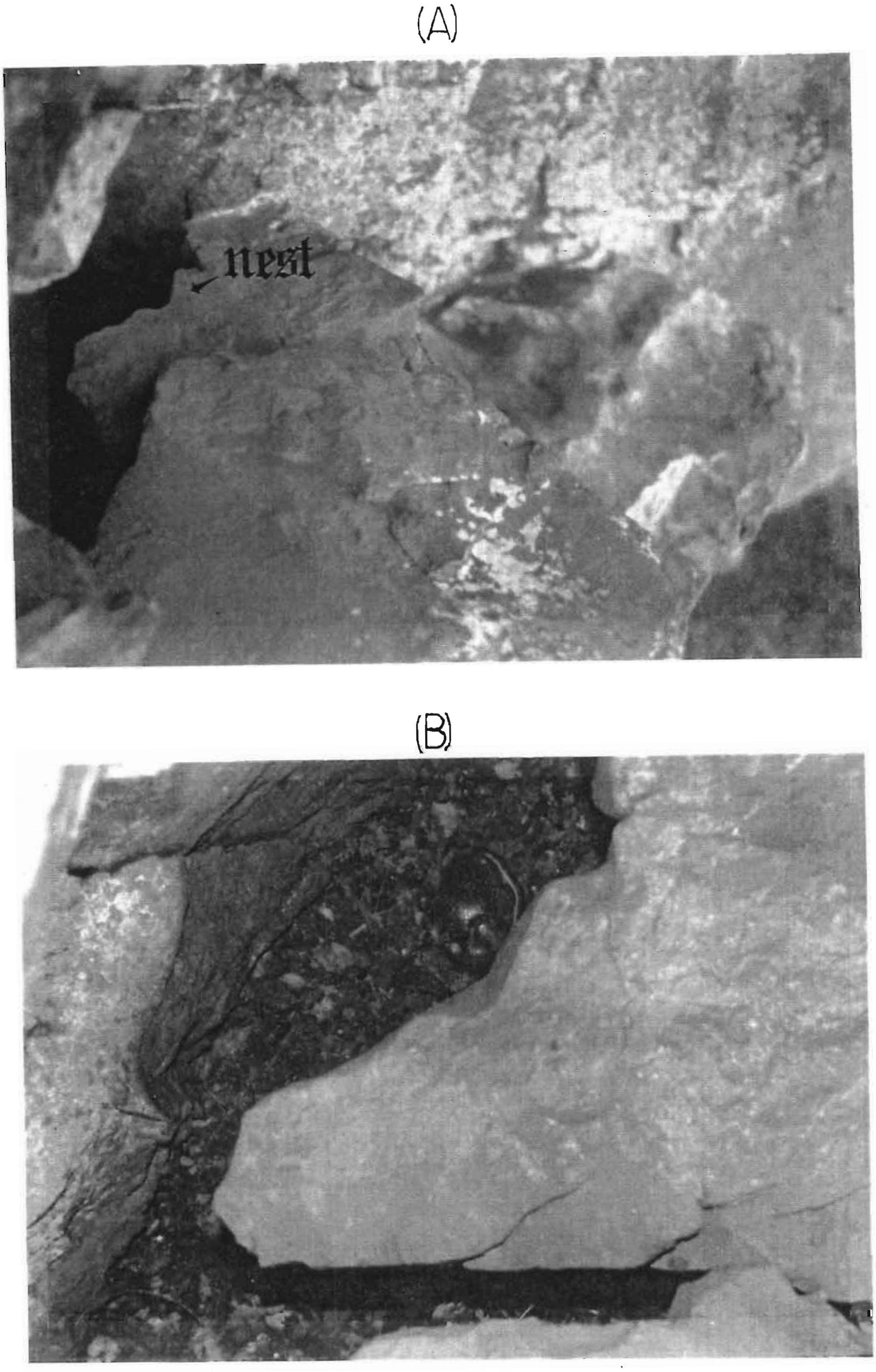

PLATE 2:1 Stainbank nest as viewed from the outside (A), and from above (B).

season. In January 1990 a subadult (subadult 50) joined the group. The origin of this bird was unknown, and although initially chased by the pair it was eventually accepted as a member of the group. This bird did not however, provision for the chick. A chick was successfully reared during the 1989/1990 season and at the end of 1990 the group consisted of four birds.

The previous history of the group is largely unknown, but unconfirmed reports suggest that group numbers fluctuated between four and six birds.

This territory was approximately 22 km^2, with 10% of the territory located in an African location. The farms in the territory are predominantly cattle, fruit or timber farms with very little sugar cane.

From previous reports it appeared that the group used the same nest site for many years. At the beginning of the 1989/1990 season however, they were observed visiting a new nest location on three occasions, before returning to use the original site. This nest site was very similar to the Stainbank nest, in that it consisted of a rock cavity in a cliff face, shielded by boulders in the front (Plate 2:2). The nest cavity was 165 cm long and 65 cm wide and the height from the floor to the overhang was 54 cm. The shielding boulders were approximately 35 cm high, and the entrance to the nest was approximately 20 cm wide. The nest was situated about 5 m from the top of the cliff and the birds used a tree close to the nest as a perch from which the nest was approached. The birds foraged in lands above and below the cliff face.

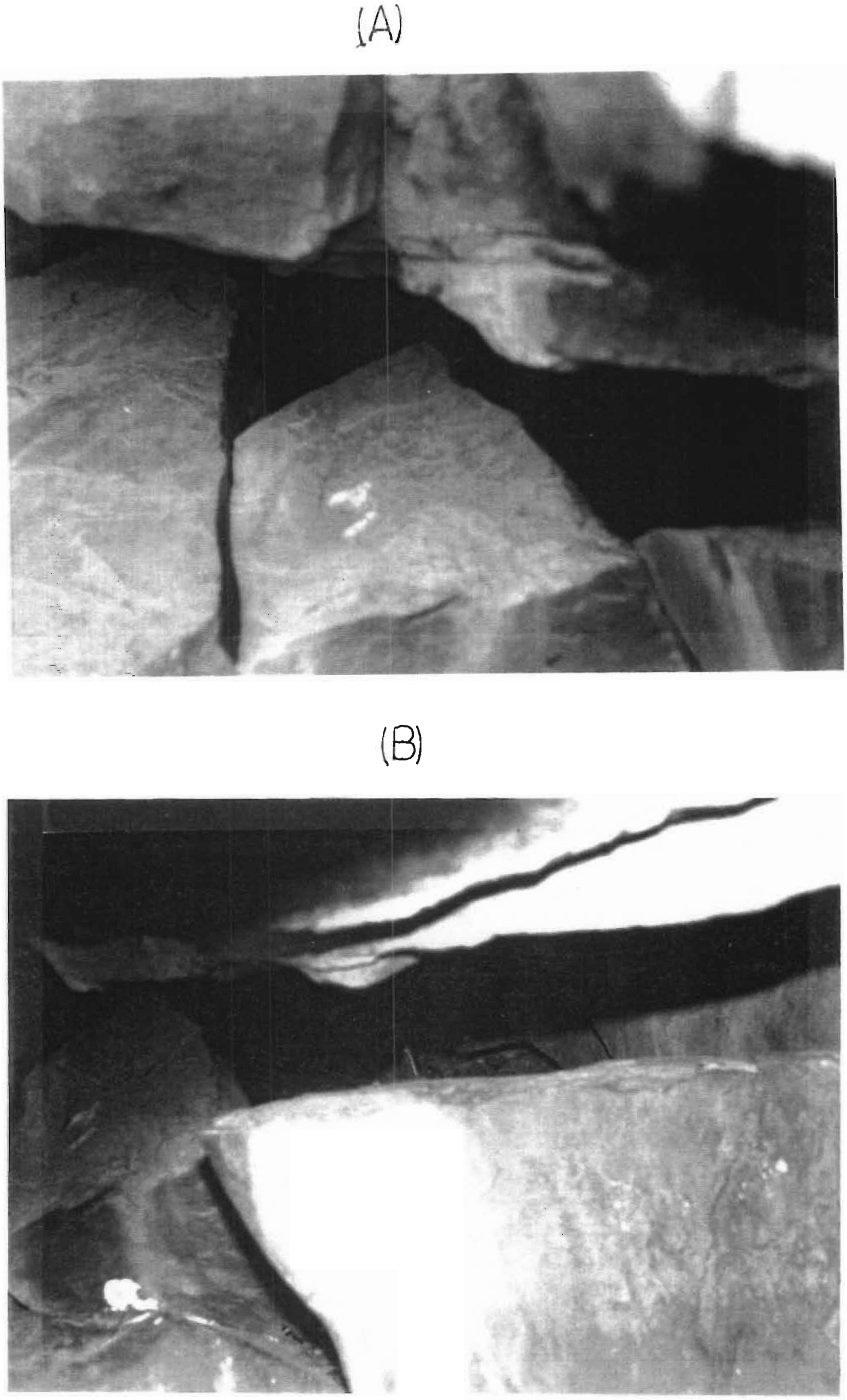

PLATE 2:2 (A) and (B) Carlshaven nest as viewed from the outside.

2:2:3 Phoenix Group

In March 1989 the group consisted of a dominant male and female, and two subadults. The latter were approximately four and three years old respectively. Although the group was not as closely monitored as the Stainbank or Carlshaven groups, the movements and breeding success of the group was documented. In April 1989 one of the subadults disappeared from the group. Between March and June 1990 the other subadult left the group and was sighted on its own but within the territory. The bird did not appear to have developed female colouring and the reason for leaving the group is not known. While with the group, this bird seldom foraged closer than 10 m from the pair. The birds attempted to breed in the 1989/1990 season, but left the nest in late December. The reason for the unsuccessful breeding attempt was not known.

Group size increased from five birds in December 1987, to six birds in December 1988. By March 1989, however, group size was four birds (Byrne pers. comm.[4])

The nest sight of the Phoenix group consisted of a cavity in a cliff face. It differed slightly from the Stainbank and Carlshaven nests in that it was a definite cavity rather than a ledge and did not have shielding boulders in front of it (Plate 2:3).

The territory covered an area of approximately 70 km^2 (Fig. 2:5). The farms in the territory are predominantly sugarcane and timber farms.

[4] Mike Byrne. P.O.Box 3. Eston. Natal.

PLATE 2:3 Phoenix nest site as viewed from the outside.

CHAPTER THREE

STATUS AND DISTRIBUTION

3:1 INTRODUCTION

The Southern Ground Hornbill, B. cafer, inhabits African savannas south of the equator (Kemp and Kemp, 1980), and in southern Africa, occurs from Damaraland, eastwards through northern Botswana, Zimbabwe, Mozambique, northern and north eastern Transvaal, Natal and the north eastern Cape (Ginn McIlleron and Milstein, 1989).

The most recent distribution records in Natal were published by Cyrus and Robson in 1980. Very little is known, however, about the population density of birds, group sizes, or the past history of the species in this region. One of the objectives of the present study therefore, was to update distribution records and assess the status of B. cafer in Natal.

The Kruger National Park is the only region in southern Africa where the status and distribution of B. cafer has been well documented (Kemp & Kemp, 1980; Kemp Joubert and Kemp, 1989). Aerial surveys conducted over 90% of the Park and ground surveys conducted in the Satara area, were used to assess its status and distribution (Kemp et al., 1989). A comparison of aerial data and ground counts indicate that aerial surveys record only about 60% of the birds in a given area (Kemp et al., 1989). These surveys do, however, suggest that B. cafer can be expected to occur throughout the 19 485 km^2 of the Kruger National Park (Kemp et al., 1989). This supports the hypothesis that habitat saturation may occur for _B. cafer_ in the reserve (Kemp, 1988). Fourteen neighbouring groups were monitored during 1973, and their density was approximately one group per 100 km^2 (Kemp & Kemp, 1980). These figures were determined for a relatively undisturbed habitat, and no similar data are available for areas outside of the Kruger National Park, and in particular, areas influenced by intensive agriculture.

Territory size has never been accurately determined, although the mean inter-nest distance for eight nest sites of neighbouring groups was 8.9 kms (Kemp and Kemp, 1980). Group size was monitored in the Satara region of the Kruger National Park between 1969 and 1986. For 971 groups, group size ranged between two and eleven birds with 72% consisting of 3 to 5 birds (mean group size 3.51)(Kemp _et al_., 1989). Based on these data, a density of between 3 to 5 birds per 100 km^2, or one group per 100 km^2, can be expected for an environment in which habitat saturation occurs.

The data for the Kruger National Park support the hypothesis that large carnivorous birds, such as _B. cafer_, will have large territories or home ranges and will consequently occur at relatively low densities (Calder, 1984).

The distribution of groups within the Kruger National Park showed no obvious correlation with vegetation or climatic gradients within the reserve (Kemp _et al_., 1989). Their distribution was however similar to that of some large herbivores in the reserve (Kemp _et al._, 1989). The factors influencing distribution outside the Kruger National Park have not been previously evaluated.

The objectives of this part of the study were:

(1) To update the distributional records of this species in Natal.
(2) To assess its status in Natal.

3:2 METHODS

B. cafer is a large, easily identifiable ground-foraging Hornbill which lives in cohesive groups on exclusive territories which are occupied throughout the year (Kemp and Kemp, 1980). Thus the most effective and practical means of estimating numbers in Natal, was to initiate a census in which the general public were encouraged to report sightings throughout Natal.

Public awareness of the programme was stimulated by eleven articles on this species, published in various magazines and newspapers (Appendix 1), which were aimed largely at the farming community, to report sightings. The census was also advertised through The Natal Bird Club, The Wildlife Society of South Africa (Natal branch), and various Natal Conservancies.

Where possible the following data were recorded for each report; (i) date, (ii) an accurate location for the group, (iii) the number of birds in the group, (iv) the number of juveniles present, if these could be identified. Each sighting was then plotted on 1:500 000 maps of Natal.

A data sheet was then sent to each person who reported a sighting. These data sheets (Appendix 2), allowed observers to report ten different sightings, after which the sheet was returned. Another data sheet was then returned to the sender on receipt of a completed data sheet. The data required for each sighting were as follows; (i) date, (ii) the time of day, (iii) number of birds in the group, and the number of juveniles if these could be identified, and (iv) the accurate location of the group. In this way, group size and breeding success could be assessed. By comparing sighting dates and other data for farms in the same area, the number of groups in each area could be established with some confidence. Data sheets were also sent to 81 Natal Parks Board field rangers.

Location data obtained in this way were plotted on a quarter degree grid map of Natal. Farms for which there were more than one record were only represented by a single map point. If multiple reports were received from large areas, such as game reserves and National Parks, each sighting was plotted independently. Personal sightings were included for all groups outside the study area, while personal sightings of the study groups were not used in this survey.

Group size for each farm was based either on a single report or on multiple data sheet reports where these were recorded. If group size changed during the year, the most recent group size was plotted. If no report was received for a particular farm in the period following breeding (1989/1990 season), no assessment of the breeding success of the group in that year was attempted.

Group size could often be used to determine the number of groups present in a particular area where birds were sighted on more than one farm. However, care had to be taken, since the number of birds in a particular group could vary due to emigrations, mortality (natural and unnatural), females incubating or attending a chick on the nest at the time of sighting, the splitting up of groups for short periods, or successful fledging of a chick. Thus differing group sizes reported at different times of the year from neighbouring farms, did not necessarily imply separate groups.

In assessing the number of groups in a given area, circles representing a land area of 120 km^2 were used. Each circle represented a group territory and although the area was greater than that calculated for territories of the study groups (Chapter 2) and greater than that indicated by a density of one group per 100 km^2 (Kemp and Kemp, 1980), the dimensions of this area were chosen as it separated the seven known groups in the Midlands area, and made allowance for territories of non-uniform shape. These theoretical territories made it possible to assess, at a rather gross level, which sightings were too far apart to be for the same group. Using these analyses and sighting data, the number and size of groups reported in Natal could be established with some confidence.

Distribution data throughout Natal was then superimposed on maps showing the location and extent of Conservancies, Natal Parks Board Reserves, and KwaZulu areas, in order to assess their possible influence on distribution records. In addition distribution data were superimposed on a map of Natal which depicted the major farming types.

3:3 RESULTS AND DISCUSSION

436 sightings of B. cafer were reported from 187 locations. Sightings were reported from 135 locations in 1989, and from only 20 in 1988, 20 in 1989 and 1990, and 12 in 1990. Only five records were received for sightings prior to July 1988.

These five sightings were not included in the study as the exact dates, location, and number of birds were not recorded. Detailed records of each sighting are shown in Appendix 3. Ground Hornbills remain in cohesive groups on exclusive territories whose boundaries, at least in the Kruger National Park, appear to remain stable over long periods (Kemp et al., 1989). For this reason 1988 data were used in certain areas where more recent data were not collected. However, the possibility exists that a group may have disappeared in a particular area since 1988 and that no reoccupation of the territory had occurred. Group sizes recorded for these locations may well have changed too.

The distribution of B. cafer in Natal, based on actual sightings, is shown in Fig.3:1. These data show that records were obtained throughout Natal except in the far north-western and north-eastern regions. The high concentration of sightings in grids 29^{0}45' 30^{0}15' and 29^{0}45' 30^{0}30' do not necessarily indicate particularly high concentrations in this area but rather that this area was the study area and therefore sampled more intensively. Although personal sightings of the study groups were not included, all farmers in the area were aware of the research programme and consequently reported sightings. Two locations for the Transkei (30^{0}15' 29^{0}45' and 30^{0}30' 29^{0}15') were included since these birds were sufficiently close to the Natal border that their territories may have extended into Natal.

The distribution data for B. cafer for this study was compared with that from the Natal Bird Atlas (Cyrus and Robson, 1980)(Fig.3:2). The major differences in the two distribution maps occurred in northern Natal and KwaZulu, north of 28^{0}15'. It is not possible to assess whether the species moved away from some areas or invaded others during the period between surveys or whether differences are a result of

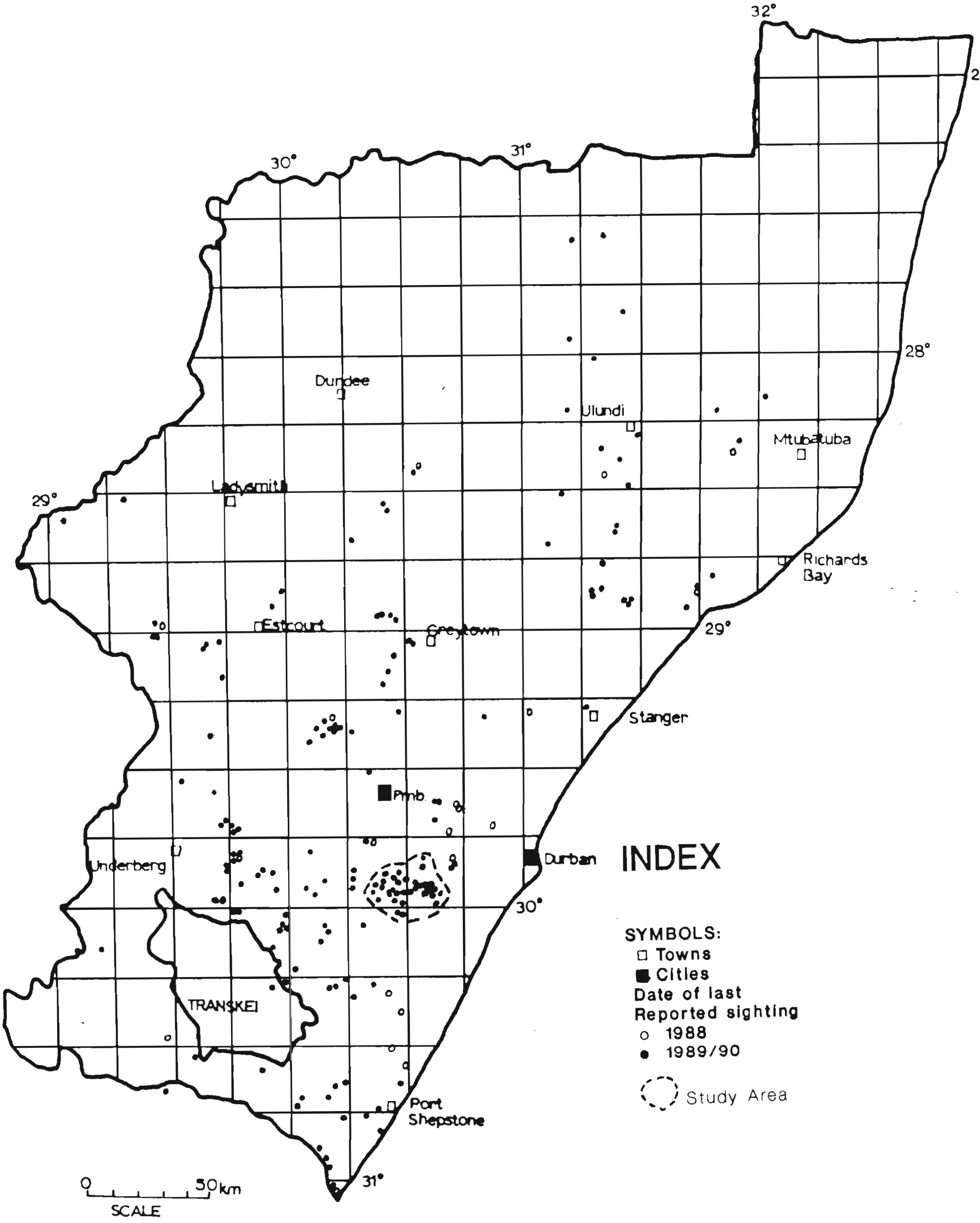

FIGURE 3:1 Distribution records for B.cafer in Natal (this study).

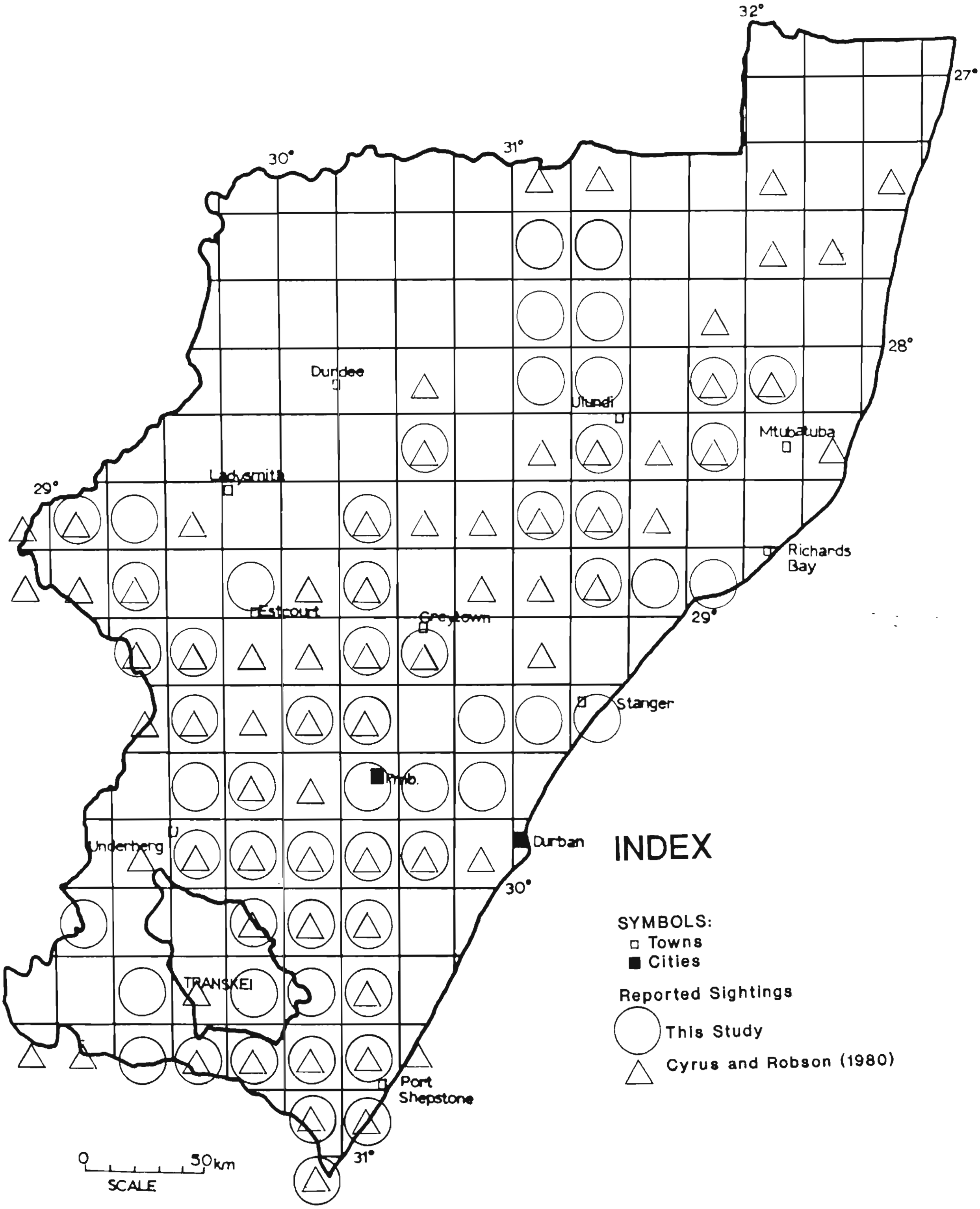

FIGURE 3:2 A comparison of distribution records for B.cafer for this study and the Natal Bird Atlas (after Cyrus and Robson, 1980)

incomplete sampling during the surveys. Reports from Mkuzi Game Reserve ($32^{0}0'$ $27^{0}30'$) (Goodman *pers. comm.*[1]) and Itala Game Reserve ($31^{0}0'$ $27^{0}15'$ and $31^{0}15'$ $27^{0}15'$) (Sandwith *pers. comm.*[2]), suggest that birds had moved out of these reserves, since they have not been seen in either since 1987. They were, however, heard in the Mkuzi reserve in March 1990 (Goodman *pers. comm.*). Unusually tall grass growth in Itala Game Reserve may have caused the birds to leave this region (Sandwith *pers. comm.*).

Of the 91 grids in Figure 3:2 in which birds were sighted in either survey, sightings were recorded in only 39.6% from both surveys. In 60.4% of the grids sightings were recorded from only one of the surveys. This comparison clearly shows the dangers of assuming the apparent distribution of a species collected by such a survey, to be representative of actual distribution.

Interpretation of distribution data is complex due to inadequacies in the sampling methods. To accurately assess distribution, each grid should be censussed at the same intensity and time. The distribution of newspapers and magazines in which articles were published results in sampling bias. KwaZulu areas were poorly sampled since a large proportion of the population in these areas were not aware of the survey or did not have the means to report sightings. By superimposing the distribution map on a map of Natal, it is clear that 86.6% of sightings were confined to areas outside of KwaZulu (Fig. 3:3). Because the Zulu people are superstitious about *B. cafer* and seldom kill this species, and the observation that one of the study groups (Carlshaven

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[1] P. Goodman. Mkuzi Game Reserve. P.Bag X550. Mkuzi. 3965.

[2] T. Sandwith. Itala Game Reserve. P.O.Box 42. Louwsberg. 3150

Group - Chapter Four) foraged in a KwaZulu area on numerous occasions without being harmed, it seems unlikely that the apparent absence from these areas necessarily reflects a low population density in KwaZulu. KwaZulu comprises 28% of the greater Natal region, covering an area of 19907 km^2 (Central Statistical Services pers. comm.). The above data effectively mean that the census covers only 72% of Natal. Due to the lack of data for KwaZulu, further analyses will exclude the KwaZulu region.

The influence of Natal Conservancies on public awareness must also be considered when interpreting distribution data. Areas which experience a constant input from such organisations are more likely to be conservation conscious and become aware of research programmes such as this. Figure 3:4 compares distribution of B. cafer with the location of Natal Conservancies and Natal Parks Board reserve areas. Table 3:1 compares the number of conservancy areas and the number of reported sightings. For this analysis, Natal, excluding KwaZulu regions, was divided into three regions of approximately equal surface area, estimated by weighing pieces cut from maps of the region. These data serve only as a guideline since the area covered by each conservancy was not known. Only four locations were plotted for the three study groups in an attempt to reduce any error due to the high intensity of sampling in this area.

Although this comparison is simplistic, there is clearly a greater concentration of sightings in the areas with the highest conservancy densities.

The above discussion suggests that there are many considerations that should be taken into account when attempting to interpret distribution data of this type, and shows clearly

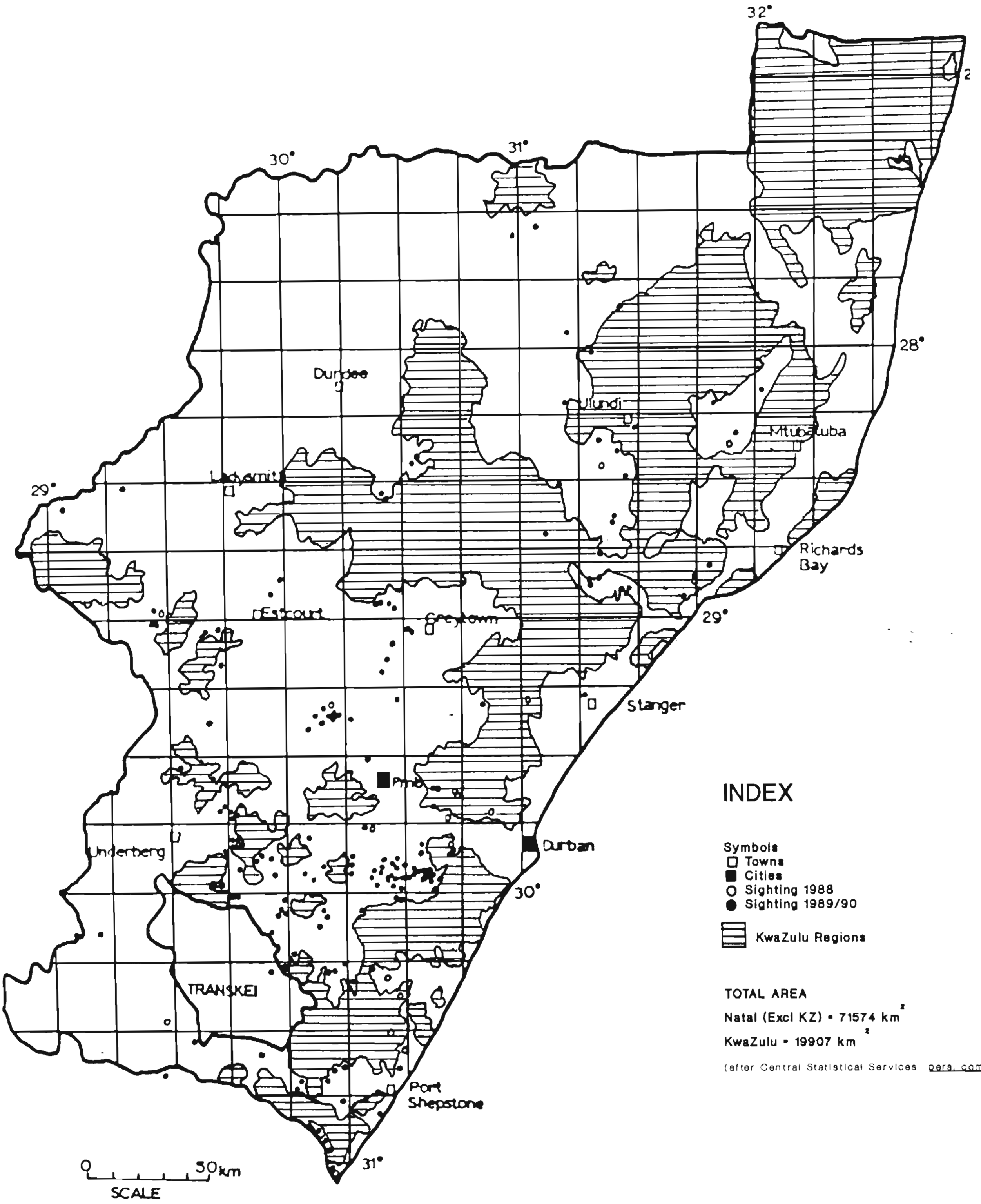


FIGURE 3:3 Comparison of the apparent distribution of <u>B.cafer</u> in Natal with the location of KwaZulu controlled areas in Natal (after Cyrus and Robson, 1980).

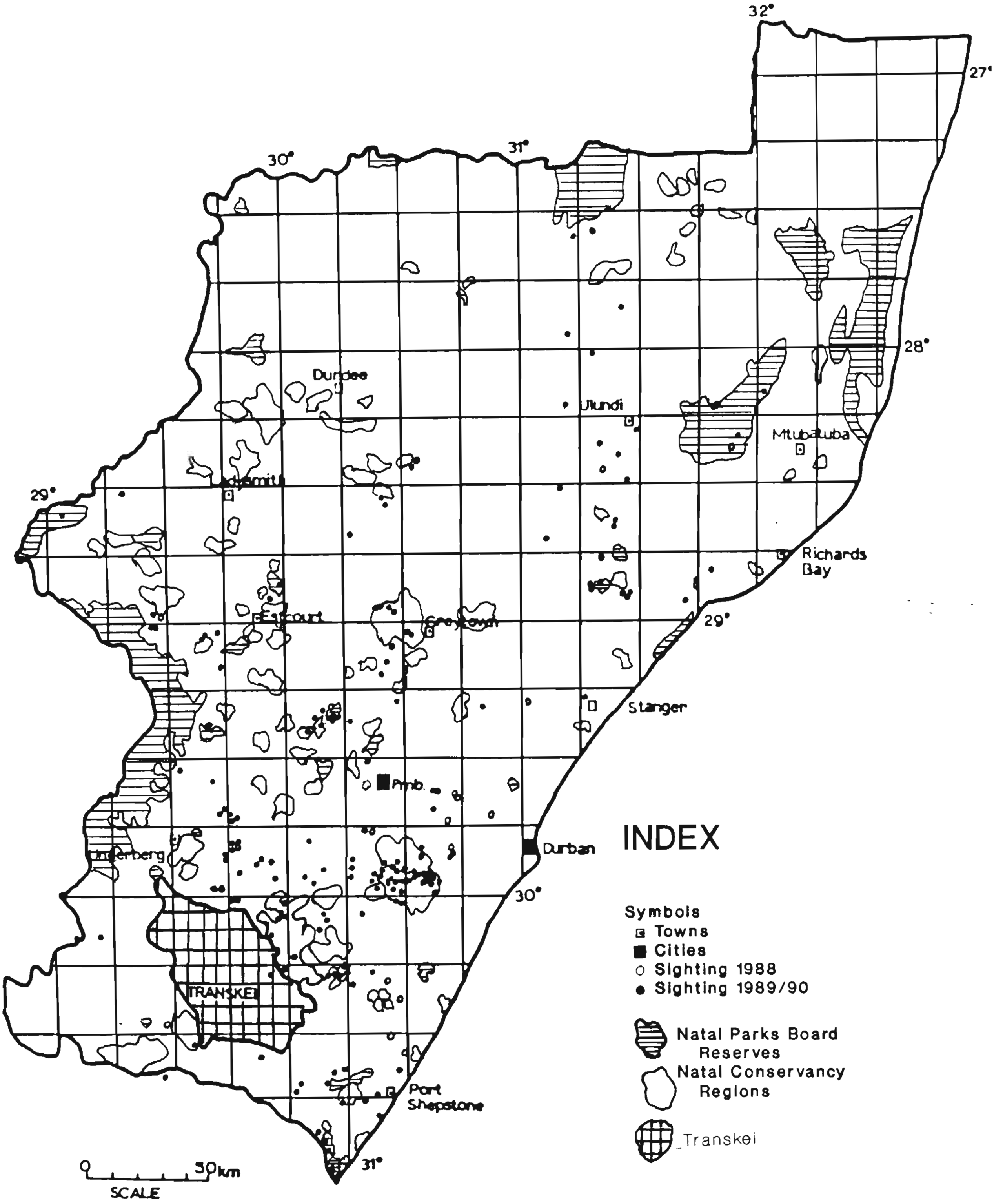


FIGURE 3:4 Comparison of the apparent distribution of <u>B.cafer</u> in Natal with the location of Natal Conservancy and Natal Parks Board reserves in Natal (after Natal Parks Board)

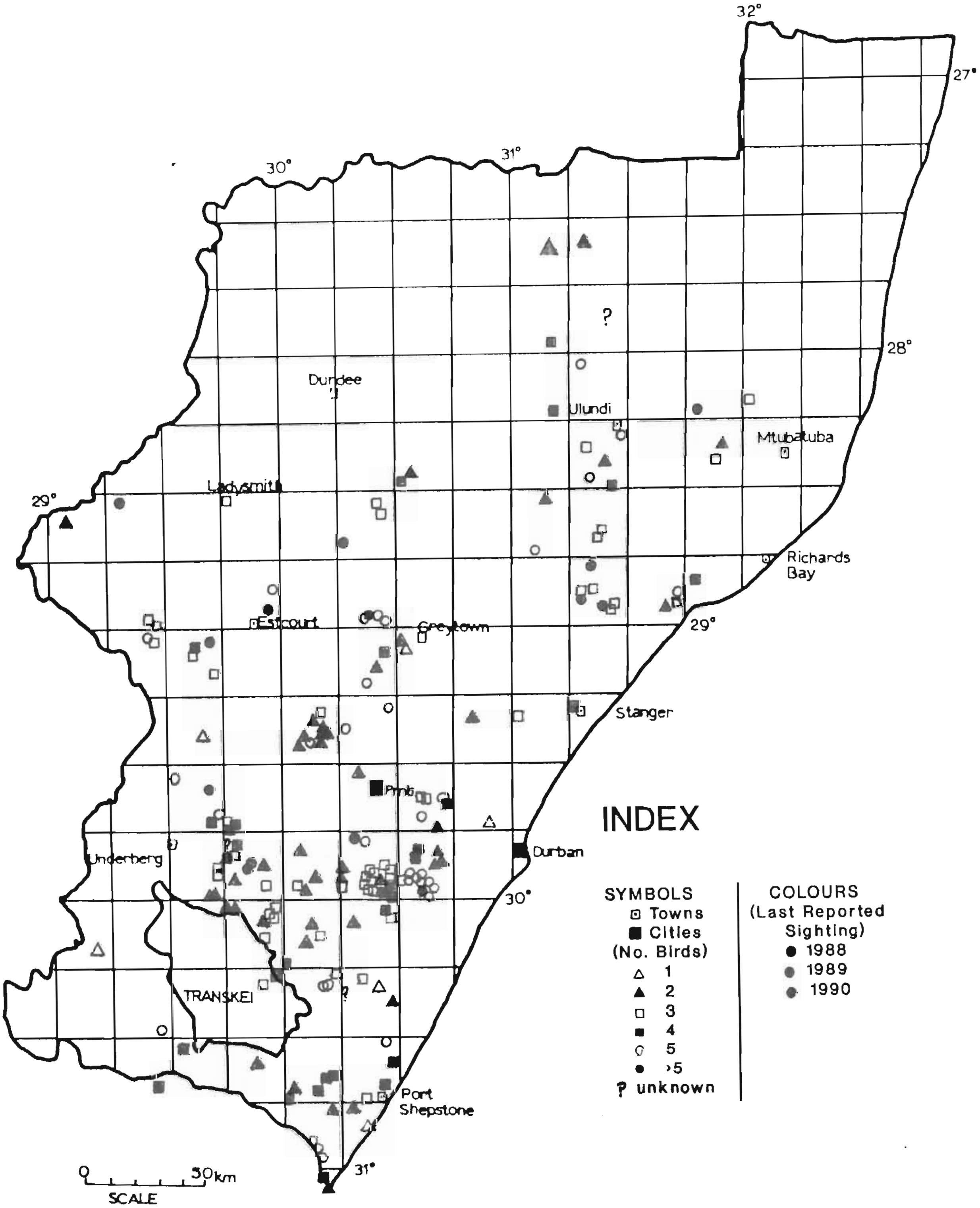


FIGURE 3:5 Estimated number of birds in each group at each sighting location, based on the most recent figures obtained for each location.

that the recorded distribution may not represent actual distribution.

TABLE 3:1 A comparison of distribution data with the distribution of Natal Conservancies.

AREA COVERED	No. of CONSERV.	No. of SIGHTINGS	RATIO SIGHTINGS: CONSERVANCIES
North $28^{0}15'$S	17	7	0.4
$28^{0}15'$-$29^{0}15'$S	35	43	1.2
South $29^{0}15'$S	38	90	2.4

A provisional estimate of the number of birds in Natal can be made based on group sizes reported at each location (Fig.3:5) and on the estimated number of groups (Fig.3:6). Group sizes indicated for each location cannot be considered as the actual group size at the end of 1990, as numerous factors may have resulted in both underestimations and overestimations of group sizes. For example, 69% of reports are based on a single sighting and may therefore underestimate the number of birds in the group as some of the birds may have been absent or not visible at the time. Sightings in the months October to February may also underestimate group size since reports seldom indicated whether or not the female was with the group or in the nest at the time. The breeding success of groups for the 1989/1990 breeding season was only reported for 22 locations, or 15 estimated groups, and this may result in the underestimation of group sizes of remaining groups. There were also records of birds leaving parent groups and joining other groups (pers. observ.).

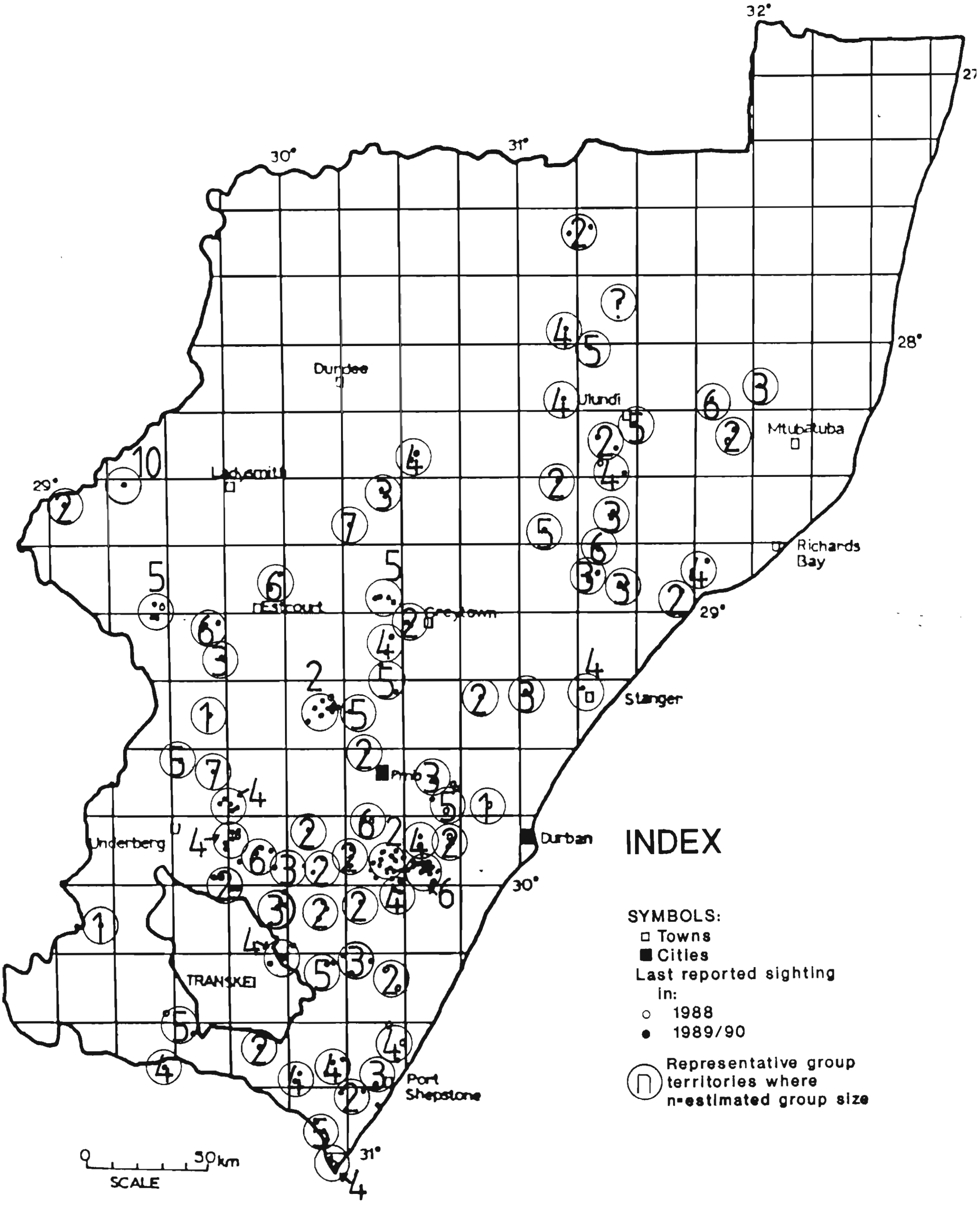


FIGURE 3:6 Estimated number of reported groups and the estimated number of birds in each group at the time of the last reported sighting of each group.

Natural and unnatural mortality, and emigration of individuals away from parent groups may have resulted in an overestimation in the size of a group, if these changes were not recorded. Since the beginning of 1989, three dead birds with suspected poisoning, were found, which suggests that more birds may have died due to unnatural causes.

Single birds which did not belong to any known group were occasionally observed within the territory of an established group or in the interface between territories (pers. observ.). Kemp and Kemp (1980) monitored 19 groups in the Satara area of Kruger National Park in 1976, and found that 5.5% of the population in this area were single birds. From aerial surveys of the entire Kruger National Park (Kemp et al., 1989), it was determined that 2% of the population in the reserve were single birds. In the Eston and Mid Illovo areas no single birds were ever reported by the farmers and yet two different individuals were personally observed on six different occasions during the study. It therefore seems likely that in some territories, additional single birds, which were not reported, may have been present. In the case of single bird sightings (Fig 3:5), it is not known whether these birds formed part of a larger group, or were indeed isolated birds in the territory of another group.

The average group size of 3.7 birds (Fig. 3:6) compares favourably with the average of 3.51 birds reported by Kemp et al. (1989) for the Kruger National Park. Group size distribution was similar for both studies (Fig.3:7), although there was a greater percentage of groups in Natal consisting of only two birds.

Although some of the problems in interpreting distribution data have been identified, the data obtained in this study form a foundation for future studies aimed at assessing the status and distribution in Natal in more detail. Comparing the data collected in this survey and that in the Natal Bird Atlas (Cyrus & Robson, 1980)(Fig 3:2), and the sampling bias discussed, it is clear that not all groups were accounted for in this study. This, together with the fact that the population of single birds cannot be determined, makes it impossible to predict the number of groups and number of birds in Natal with any degree of certainty. However, based on the data presented in Figure 3:6 an estimate of at least 85 to 90 groups existing in Natal may be realistic. If this is so then the total number of birds in Natal, excluding KwaZulu regions, may exceed 300. It is impossible to estimate the total number of birds in KwaZulu from the data collected in this study. It is therefore essential for future studies to collect data on B. cafer numbers and distribution in KwaZulu, if an accurate assessment of the status and distribution in the greater Natal region is to be made. Further studies would have to be conducted before the number of groups and birds in Natal could be estimated with any confidence.

No historically reliable records exist to assess the status of this species in the past. There are however, reports of groups numbering 15 birds and one report of a group of 20 birds on Table Mountain near Pietermaritzburg in the 1920's. Since these reports cannot be confirmed, it is impossible to assess whether the Natal population are on the decline or incline. Since each group contains only one breeding pair and the remaining birds are usually related (Kemp and Kemp, 1980), a comparison of group sizes recorded during this study with data for the Kruger National Park (Kemp and Kemp, 1980)(Fig.3:7) suggests that the Natal groups, are breeding as successfully as birds inhabiting the more pristine environment of the Kruger National Park.

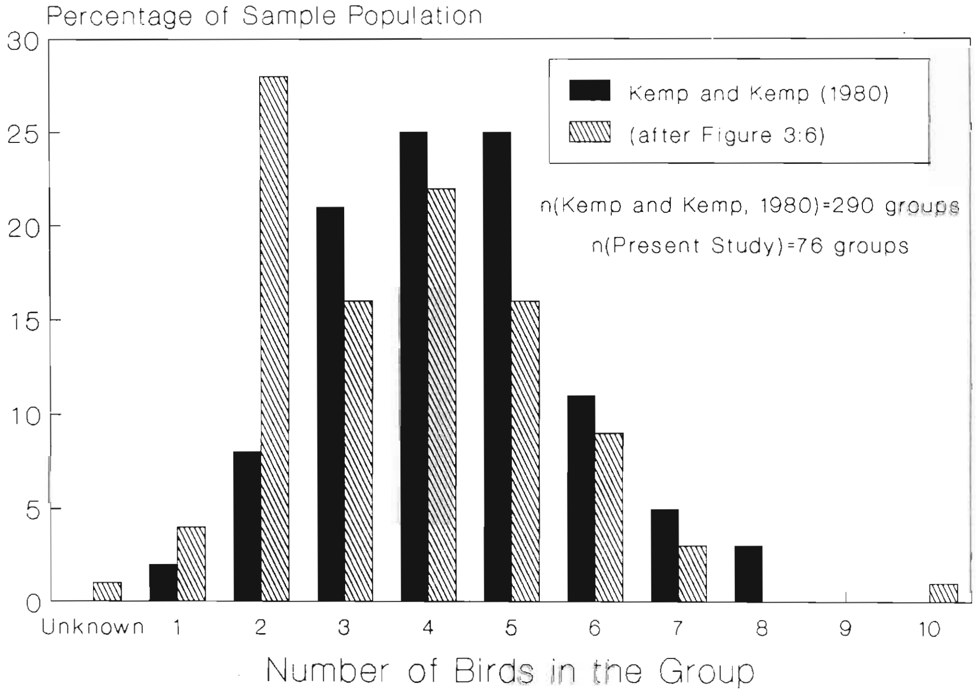


FIGURE 3:7 Frequency histograms of group size for <u>B.cafer</u> in the Kruger National Park (after Kemp and Kemp, 1980), and the present study.

Habitat saturation has been reported for the Kruger National Park. It is difficult to assess whether habitat saturation occurs in Natal, as it is uncertain whether observed gaps in the distribution are real or due to sampling bias.

A comparison of observed distribution pattern with farming types is shown in Figure 3:8. The number of sightings which occurred in each farming type are given in Table 3:2.

TABLE 3:2 The number of sighting locations in each farming type (after Fig.3:8).

FARMING TYPE	NUMBER OF SIGHTINGS
PREDOMINANT (>66%)	
Sugarcane	54
Maize	8
Beef	27
Dairy	9
Sheep	3
MIXED	
Sugarcane	8
Maize	
Beef and Sheep	1
Livestock	12
MAJOR (>50%)	
Forestry	38
Fibre Crops	
Sub-tropical Fruit	2
Vegetables	3
Game	
Unclassified	25

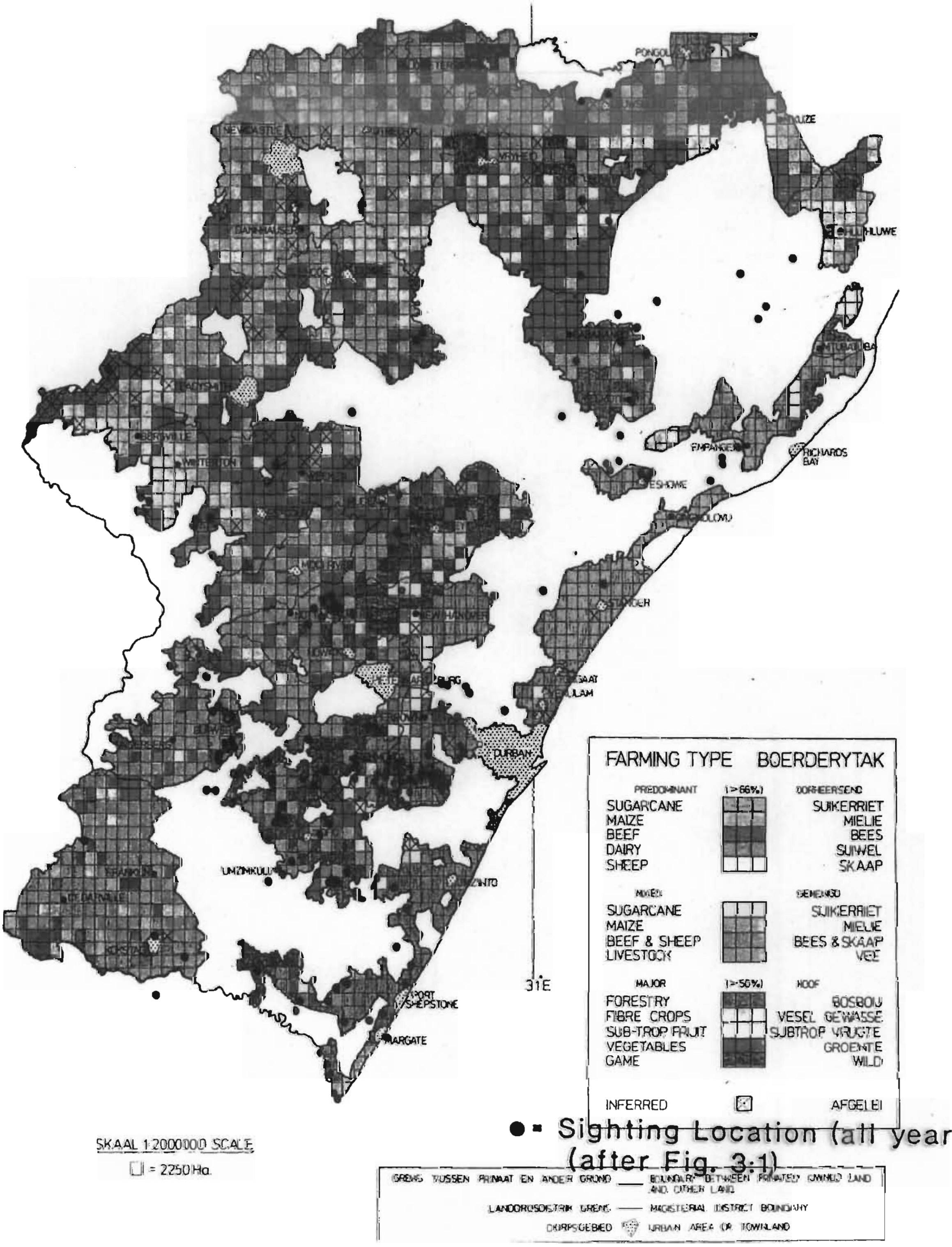


FIGURE 3:8. Comparison of the apparent distribution of B.cafer in Natal with the farming types used in Natal (after Fotheringham, 1981).

Unfortunately, the total area covered by each farming type in Figure 3:8 is not supplied in Fotheringham (1981). Grouping of similar farming types given in Figure 3:8 (eg. beef, sheep, livestock, dairy), were done in order to compare the number of sightings with the area cover by each farming type, based on the summary of major enterprises on each farm (Fotheringham, 1981) (Table 3:3)

93.8% of all sightings occurred in sugarcane, forestry, or livestock areas. This may be expected since the area covered by these three farming types accounted for 88.3% of the recorded area in Natal, excluding KwaZulu regions (Table 3:3). However, the area per sighting (Table 3:3) for each farming type, indicates that B. cafer occur more frequently in regions dominated by sugarcane and forestry, than in livestock farming areas. Although vegetable and fruit farming is only undertaken in 0.4% of Natal, it is apparent from Table 3:4 that B. cafer are able to utilise areas that are used for such farming practices. Although insufficient data have been collected to assess which farm lands can be used by B. cafer for foraging, it is apparent from Table 3:4 that they are able to utilise farms which practice a wide variety of agricultures. A more detailed examination of the use of farm lands by the two study groups in the Natal midlands will be presented in Chapter 4.

Care must be taken in interpreting these results, as the distribution data presented are not complete. Areas, particularly the northern and north western regions of Natal, which are most likely to have been sampled to a lesser degree, for reasons stated earlier, are also the regions in which livestock farming occurs (Fig.3:8).

TABLE 3:3 A comparison of the number of sightings in each farming type (after Fig.3:8), and the approximate extent of each farming type in Natal (after Fotheringham, 1981).

FARM.TYPE	No. SIGHTING	EST. AREA COVER IN NATAL (km^2) (After Fotheringham, 1981)	% TOTAL RECORDED AREA	AREA PER SIGHTING
Sugarcane	62	3903	8.0	6294.9
Livestock	52	34968	72.0	67246.6
Forestry	38	4025	8.3	10593.2
Maize	5	2168	4.5	43368.2
Vegetables	3	89	0.2	2954.7
S/T Fruit	2	103	0.2	5148.5

No attempt has been made to compare the distribution of <u>B. cafer</u> to any topographical, or climatic gradients in Natal. Kemp <u>et al</u>. (1989) found that in the Kruger National Park no correlation could be found between <u>B. cafer</u> density and topographical or climatic gradients except perhaps a slight concentration along the major rivers in the area.

In conclusion, from the data collected, it is apparent that <u>B. cafer</u> are found throughout Natal, with the exception of the far northwestern regions. Their occurrence outside of the Natal Parks Board reserves, indicate that they are able to utilise areas which experience a wide range of agricultural uses. Although this study does not provide an accurate estimation of the number of birds in Natal, indications are that the species is not under any real threat of extinction in this region. The data presented serve as a foundation for a future, more complete, study on the distribution and status of B. cafer in Natal. There is a great need for data on the distribution of B. cafer to be collected in KwaZulu regions. A more long term and extensive survey should be initiated so that a more accurate assessment of the status and distribution of B. cafer in Natal can be made, and incorporated into a conservation policy for this species.

CHAPTER FOUR

SELECTED ASPECTS OF B. CAFER FORAGING ECOLOGY

4:1 INTRODUCTION

Studies of the foraging ecology of cooperatively breeding birds, have focused primarily on provisioning of chicks at the nest, and particularly on the role that helpers play in this process (Brown, 1970; Ligon, 1970; Woolfenden, 1975; Brown, 1978; Emlen, 1978; Stallcup and Woolfenden, 1978; Ligon and Ligon, 1979; Kemp and Kemp, 1980; Hooper and Lennartz, 1981; Emlen, 1982a; Emlen, 1982b; Wilkinson and Brown, 1984; Austad and Rabenold, 1985; Zack, 1986; Hunter, 1987; Lennartz Hooper and Harlow, 1987; Kemp, 1988; Ligon and Stacey, 1989). For example, it has been shown in some cases, that helpers reduce nestling feeding rate by parent birds (Brown, 1970; Ligon and Ligon, 1979; Wilkinson and Brown, 1984; Austad and Rabenold, 1985; Zack, 1986; Hunter, 1987). However, although breeding success may be enhanced (Woolfenden, 1975; Austad and Rabenold, 1985; Zack, 1986; Lennartz et al., 1987), helpers do not necessarily contribute to breeding success (Brown, 1978). Reproductive success is not only correlated with the number of helpers, but with other factors such as habitat quality, home range size, and the experience of parent birds (Brown, 1978; Zack, 1986; Leonard Horn and Eden, 1989; Ligon and Stacey, 1989).

The influence of group foraging behaviour, and particularly its effect on the time spent in vigilance, have been documented by various authors (Pulliam, 1973; Krebs, 1974; Rabenold and Christensen, 1979; Heinsohn, 1987; Petit and Bildstein, 1987; Waite, 1987; Francis Hailman and Woolfenden, 1989; Valone, 1989; Packer and Abrams, 1990). The two most widely accepted benefits of group foraging are increased probability of locating or exploiting a suitable food resource (Krebs, 1974; Valone, 1989) and decreased vulnerability to predation (Pulliam, 1973; Petit and Bildstein, 1987; Francis et al., 1989).

Southern Ground Hornbills spend most of the active day on the ground, but are also strong flyers (Kemp and Kemp, 1980). Morphological adaptations for terrestrial existence, include long stout legs, walking on tiptoes and a short tail (Kemp, 1979). B. cafer also have broad wings, and fifteen cervical vertebrae instead of the normal fourteen found in other Hornbill species. They are one of the largest avian carnivores in Africa (Kemp and Kemp, 1978), and are also the only entirely carnivorous Hornbills (Kemp and Kemp, 1980).

In the Kruger National Park, B. cafer are most commonly associated with well grazed savannas around watering points for large mammals (Kemp and Kemp, 1980). They forage on foot, usually in groups, and scan the ground and surrounding vegetation for prey while walking. They are capable of killing prey as large as hares, but in the Kruger National Park, reptiles, insects, amphibians and land snails form the basis of their diet (Kemp and Kemp, 1978). Kemp and Kemp (1978) found that 62% of all food items were picked up on the surface, while 38% were obtained by scratching or digging. They may dig holes up to 40 cm in depth in search of toads (Kemp and Kemp, 1978). In addition they make more use of digging as a foraging method in dry periods when surface reptiles and grasshoppers are least abundant (Kemp and Kemp, 1978)

Although they generally forage as individuals, they occasionally cooperate in catching larger food items (Kemp and Kemp, 1978). Prey are swallowed whole and hard items are 'nipped' repeatedly to soften them before swallowing. Soft prey such as snails, caterpillars and toads are repeatedly wiped against the ground before being eaten. They may also chase large raptors from perches, presumably to pirate any food items which may be dropped (Kemp and Kemp, 1978).

During incubation and the early part of nesting, the female and nestling are fed by members of the group. A proportion of larger food items captured during group foraging are carried to the nest. One year old birds have never been observed to deliver food to the nest (Kemp and Kemp, 1980). Two year old individuals have been observed to provision the nestling and nest bound female, once the eggs have hatched (Kemp and Kemp, 1980). Fledglings are dependent on the adults for food for at least 6 - 12 months (Maclean, 1985), and in some cases for longer (Kemp and Kemp, 1980).

I hypothesize that, in a large ground foraging, cooperatively breeding bird such as B. cafer, choice of habitat, social structure, breeding biology, reproductive success and ultimately survival, largely centres around their foraging strategy and ability, not only to provide for the individual, but to allow successful breeding. One of the major objectives of this study therefore, was to examine selected aspects of the foraging ecology of B. cafer in the Natal midlands and assess the development of foraging techniques in juveniles and the role which different group members play in provisioning for the nest bound female, nestling, and fledgling in the group.

In order to address these objectives the following questions were asked;

(1) What constitutes the diet in the Natal midlands, and how do they obtain food?
(2) In order to obtain food, what habitats are utilised?
(3) How successful are different group members at foraging?
(4) Who provides food for (i) the incubating female, (ii) the female and the nestling during the early nestling phase, (iii) the nestling during the late nestling phase, and (iv) the fledgling?
(5) How does food demand by the nestling change during development?
(6) At what stage in the breeding cycle is the demand for food the greatest? Is there a change in the contribution of group members at this time?

Two study groups were selected in the Natal midlands (Chapter Two). The Stainbank group contained five birds, while the Carlshaven group comprised a single pair during the 1989/90 breeding season, and an additional bird who joined the group in January (see 2:2:2 for details). This group choice made it possible to compare the foraging ecology and breeding biology of a group which contained helpers with one which did not.

4:2 METHODS

4:2:1 Locating Study Animals

During the non-nesting period, when birds did not return regularly to a nest site, they were located by listening for territorial calls early in the morning. On a still morning, these could often be heard over a distance of four to five kilometers, but this distance decreased sharply during windy periods. Several stations, each on a vantage point from which I listened for territorial calls, were chosen in each territory. If a group had been seen in the 48 hour period prior to such a search, a vantage point in the vicinity of the latest sighting was chosen. If the group had not been seen during the previous 48 hour period, a vantage point was chosen in the centre of the territory.

Calling sessions usually lasted approximately 10 minutes, which enabled a fix on the position of the group to be obtained. If the group was not located before calling stopped, the immediate area was extensively searched. These searches were undertaken on a motorbike.

If calling was not heard within an hour of sunrise, three or four farms, within the territory but and more than 5 kms from the vantage point, were systematically searched. This involved choosing routes which covered the area as extensively as possible. Areas of known suitable habitat were searched more thoroughly than others. At any location where large areas could be viewed, a telescope was used to scan the surroundings. If birds were not located once all the farms had been searched, a second search was conducted over the same farms. Each search lasted two to three hours depending on the size and number of farms chosen.

Radio contact was maintained with farmers in the study area, and any sightings reported by them were immediately investigated. Such reports often resulted in the location of groups.

During the nesting period, locating groups was easier since they returned to the nest with food three to four times a day. At first light the group generally joined the female in territorial calling. If the roosting site was not known, the group was located by waiting at the nest from half an hour before first light. If the roosting site was known, the birds were followed from this site when they commenced foraging in the morning. If a group was lost while being watched, a search was conducted in the immediate area for approximately half an hour. If unsuccessful, I returned to the nest and waited for the group to deliver food and then followed them again when they left the nest.

4:2:2: Group Tracking and Data Recording

Each group was followed on foot and viewed through a telescope. Initially they could be approached to within 200 - 300 m, but within two to three months they could be followed at a distance of 50 m. In order to reduce disturbance, they were, however, seldom followed from closer than 100 m. Each group was followed for as long as possible each day. The birds were, however, often lost when they entered thick vegetation or flew long distances to cross valleys. If the birds in the group split up while being followed, the largest of the subgroups was always followed.

All data were recorded using a tape recorder, and later transcribed onto data sheets. Data on general behaviour, and more specific foraging behaviour were recorded simultaneously.

(i) RECORDING OF ACTIVITY BUDGETS AND HABITAT SELECTION

As the group were followed, the activity of each bird was recorded using the activity categories defined in Table 4:1.

TABLE 4:1 Definition of activity types.

ACTIVITY TYPE	DEFINITION
Calling	Deep booming territorial call or loud contact call
Foraging	Actively searching for food by walking and scanning the surround'gs
Flying	In flight
Preening	All preening behaviours including allopreening
Inactive	Included activities such as perching sunbathing, standing still,lying down
Visiting nest	A temporary return to the nest
Sitting in Nest	A return to the nest for an extended period, usually for the purpose of incubating the egg or caring for the nestling
Playing	Behaviour deemed to be play
Unknown	used if the exact activity was not known

The activity of each individual within a given group was recorded. The duration of each activity was recorded to the nearest minute, with the exception of flying and calling episodes, which were timed to the nearest second using a stop watch. The movements of the group were constantly mapped on transparency overlays on 1:50 000 maps of the study area.

The vegetation type in which the group occurred, was also recorded using the vegetation classification given in Table 4:2. The vegetation type occupied at any particular time was decided by the position of the majority of the group, and was not recorded for each individual. A circle, of approximately 1 m radius, around each bird was used to define the vegetation type at any particular time. The time of entry into a new vegetation type, and the duration, to the nearest minute, spent in that vegetation type were recorded.

(ii) RECORDING FORAGING BEHAVIOUR

The following two types of foraging records were collected. Single foraging attempts were recorded if the foraging of more than one individual at a time was being recorded. These are referred to as 'spot records'. When foraging records involved observing one individual continuously for more than 45 seconds, and recording all consecutive foraging attempts, they are referred to as 'observation records'. During an observation period, every foraging attempt was recorded in the same way as a spot record. In addition, the duration of the observation period and the average number of steps taken per minute (walking rate) were recorded. Observation periods lasted between 45 seconds and 10 minutes, depending on the visibility of focal birds, and the rate at which it moved. Observation records were preferred to spot records as foraging and movement rates could be determined. Spot records were only taken if the vegetation obscured the viewing of individuals. For both observation and spot records, the following were recorded for each foraging effort; the individual making the foraging attempt, the foraging method utilised (Table 4:3), the duration of the attempt, and the success of the attempt.

TABLE 4:2 Categories used to define vegetation type.
(* = after Edwards (1983))

BROAD VEGETATION TYPE	DETAILED VEGETATION CATEGORY	CHARACTERISTICS
(A) FORESTS	Open Natural Forest *	< 75% canopy cover
	Closed Natural Forest *	> 75% canopy cover
	Open Riverine Forest *	< 75% canopy cover
	Closed Riverine Forest *	< 75% canopy cover
	Wattle Forest (Mature)	Average tree height >1m
	Wattle Forest (Immature)	Average tree height <1m
	Pine Forest (Mature)	Average tree height >1m
	Pine Forest (Immature)	Average tree height <1m
	Eucalyptus Forest (Mature)	Average tree height <1m
	Eucalyptus Forest (Immature)	Average tree height >1m
	Forest Edge	Interface between forest & other veg.
(B) GRASSLANDS	Short Natural Grassland *	Average grass height <0.15m
	Medium Natural Grassland *	Average grass height 0.15m-0.4m
	Tall Natural Grassland *	Average grass height 0.4m-0.6m
	Very Tall Natural Grassland *	Average grass height >0.6m
	Burnt Grassland No Regrowth	No grass regrowth
	Burnt Grassland Small Regrowth	Regrowth height <0.15m
	Burnt Grassland Medium Regrowth	Regrowth height 0.15m-0.3m
	Pasture Grassland	All planted pasture grasslands
	Grassed Road Between Cane Fields	-
	Grassed Road Between Maize Lands	-
	Grassed Road Between Bananas	-
	Grassed Road Between Other	between any fields other than above
(C) SAVANNAS	Short Grassed Savannas *	Average grass height <0.15m
	Medium Grassed Savannas *	Average grass height 0.15-0.4m
	Tall Grassed Savannas *	Average grass height 0.4m-0.6m
	Very Tall Grassed Savannas *	Average grass height >0.6m
(D) HERBLAND	Short Herbland *	Average herb height <0.15m
	Medium Herbland *	Average herb height 0.15m-0.4m
	Tall Herbland *	Average herb height 0.4m-0.6m
(E) SUGAR CANE FIELDS	Cleared Cane Field, no regrowth	Cane height = 0
	New Cane	Cane height <0.1m
	Very Young Cane	Cane height 0.1m-0.3m
	Young Cane	Cane height 0.3m-0.5m
	Immature Cane	Cane height 0.5m-0.8m
	Mature Cane	Cane height >0.8m
	Dead Sprayed Cane	Dead cane height <0.5m
(F) MAIZE FIELDS	Immature Maize	Maize height < 0.5m
	Mature Maize	Maize height > 0.5m
(G) FRUIT PLANTATIONS	Immature Banana Plantation	Average banana tree height <0.5m
	Mature Banana Plantation	Average banana tree height >0.5m
	Immature Orange Orchard	Average tree height <0.5m
	Mature Orange Orchard	Average tree height >0.5m
(H) OTHER VEG. TYPES	Cleared Wattle Forest	
	Cleared Pine Forest	
	Cleared Eucalyptus Forest	
	Ploughed Open Land	
	River Bed	
	Cliff Face	
	Farm Yard	
	Dirt Road	

TABLE 4:3 Foraging techniques.

METHOD	DEFINITION
Picking	A single strike with the bill to pick up an item
Digging	Removing soil with a 'pick-like' action of the bill
Probing	Probing a hole with the bill
Scraping	The removal or surface litter (eg. leaves or grass) with a sweeping sideways motion of the bill. If a pick followed such a movement, the foraging attempt was recorded as a scrape.
Jumping	Jumping in order to capture a prey item
Turning Over:	
(1) Plant matter	Turning over a large item of plant matter in search of food
(2) Stone	Turning over a stone & looking under it for food
(3) Animal matt.	Turning over animal remains/faeces
(4) Other	Turning over objects not classed in 1 - 3 above, in search of food
Being Fed	Receiving food from another indiv.
Snapping at flying insect	Snapping at flying insects
Breaking up:	
(1) Mud Clump (2) Sugar Cane (3) Plant Matt.	Breaking up (1), (2), or (3) with the beak in order to search for food within
Caught during flight	Flying after flying insect
Picking in dig of other bird	Picking in a hole dug by another bird
Caught while running	Running after flying insect or any other fast moving prey item
Robbing	Robbing another <u>B. cafer</u> or another species of a food item
Foragė Meth. unknown	-

The duration of each foraging attempt was estimated by recording the time from initiation, until the food item was either caught or the attempt abandoned. Any attempt shorter than three seconds was recorded as a two second foraging attempt.

Food items were identified by observation. In most cases they were too small and were eaten too quickly to allow positive identification. However, in those cases where they could be identified, this was done to at least phylum level and, where possible, to class or species level.

Prey body length was estimated to the nearest 2 cms. Based on estimated prey body length, identified food items were allocated to one of four size classes for the purpose of analysis (Table 4:4). These size classes were not utilised for the examination of the size distribution for different prey items (Fig. 4:7). For these analyses size classes were chosen for each species independently.

TABLE 4:4 Size classes of food items

CLASS	FOOD ITEM LENGTH (cm)
1	0 cm - 2 cm
2	2 cm - 5 cm
3	5 cm - 10 cm
4	>10 cm

The fate of each food item was recorded according to the following categories (Table 4:5)

The vegetation type in which each foraging attempt occurred was recorded using the vegetation classification given in Table 4:2. For the reasons mentioned earlier, the vegetation code recorded for each foraging attempt for a given individual was not necessarily the same as the vegetation type recorded for the group at that particular time.

TABLE 4:5 Categories used to define the fate of each food item.

FATE	DESCRIPTION
Eaten	Eaten immediately
Lost	Dropped, lost after being put down in order to catch another food item or robbed by another individual
Given Away	Fed to another individual (not in the nest)
Carried to Nest	Not eaten but carried back to the nest

(iii) RECORDING NEST ACTIVITIES

The following data relating to nest activities were recorded:

The time spent waiting at the nest for the birds to return with food was added to the contact time, and gave the total time that nest visits and the amount of food returned to the nest, were monitored.

When a group or single bird returned to the nest, the following were recorded;

(a) Group composition. Birds that did not land at the nest, were not deemed to have visited the nest, even though they had walked back to the nest area with the rest of the group. They were however included in the group structure.

(b) For each bird that returned to the nest the following were recorded;

(i) bird identity.
(ii) food delivery (Yes/No).
(iii) nesting material delivered (Yes/No).
(iv) total time spent at the nest.

(v) estimated length and breadth of the bundle of food and/or nesting material delivered.
(vi) the identification and size of known food items in each bundle.

(c) Any activities observed at the nest (see Table 4:1), the individuals involved, and the duration of the activity.

The exact dates of egg laying and hatching were not recorded. Nestling age on the 28th November was estimated by comparing colour photographs of each nestling with descriptions of nestling development (Kemp and Kemp, 1980). From this comparison, chick hatching dates were estimated.

4:2:3 Data Analysis

VP Planner, Statgraphics, DBxL, Quatro Pro, and Harvard Graphics were used to analyse data. Macro facilities on DBxL were utilised to write analytical programmes for foraging data. One way analysis of variance tests (Scheffes tests-Statgraphics) were used to test for significant differences. A 95% confidence level was used.

4:3 RESULTS

A total of 118.23 and 81.13 contact hours were accumulated between August and January for the Stainbank and Carlshaven groups respectively. The Carlshaven and Stainbank females laid eggs in the last week of September and the first week of October respectively, and thus data for the period prior to nesting were limited, with only 40.2 contact hours for the Stainbank group and 13.14 hours for the Carlshaven group (Table 4:6). Contact time with each individual in the Stainbank group prior to nesting, and with individuals of the Carlshaven group during nesting, was concentrated in the middle of the day (Fig. 4:1). Contact time with each individual in the Stainbank group during nesting was spread more uniformly throughout the day (Fig. 4:1).

TABLE 4:6 Number of contact hours for each group between August and January.

MONTH	STAINBANK GROUP (Hrs)	CARLSHAVEN GROUP (Hrs)
AUGUST	13.9	0.36
SEPTEMBER	26.3	12.78
OCTOBER	19.58	18.18
NOVEMBER	22.04	20.68
DECEMBER	19.76	16.77
JANUARY	16.65	12.36
TOTAL	118.23	81.13

1608.5 and 1112.2 observation minutes were accumulated for the Stainbank and Carlshaven groups respectively. Total observation times for each individual in each group are shown in Table 4:7. Since the Carlshaven group consisted of only two birds during the first three months of the nesting period, the male was the only bird foraging for most of the active day, while the female was incubating or attending the nestling. This resulted in more time being accumulated for the dominant male in the Carlshaven group, than for any

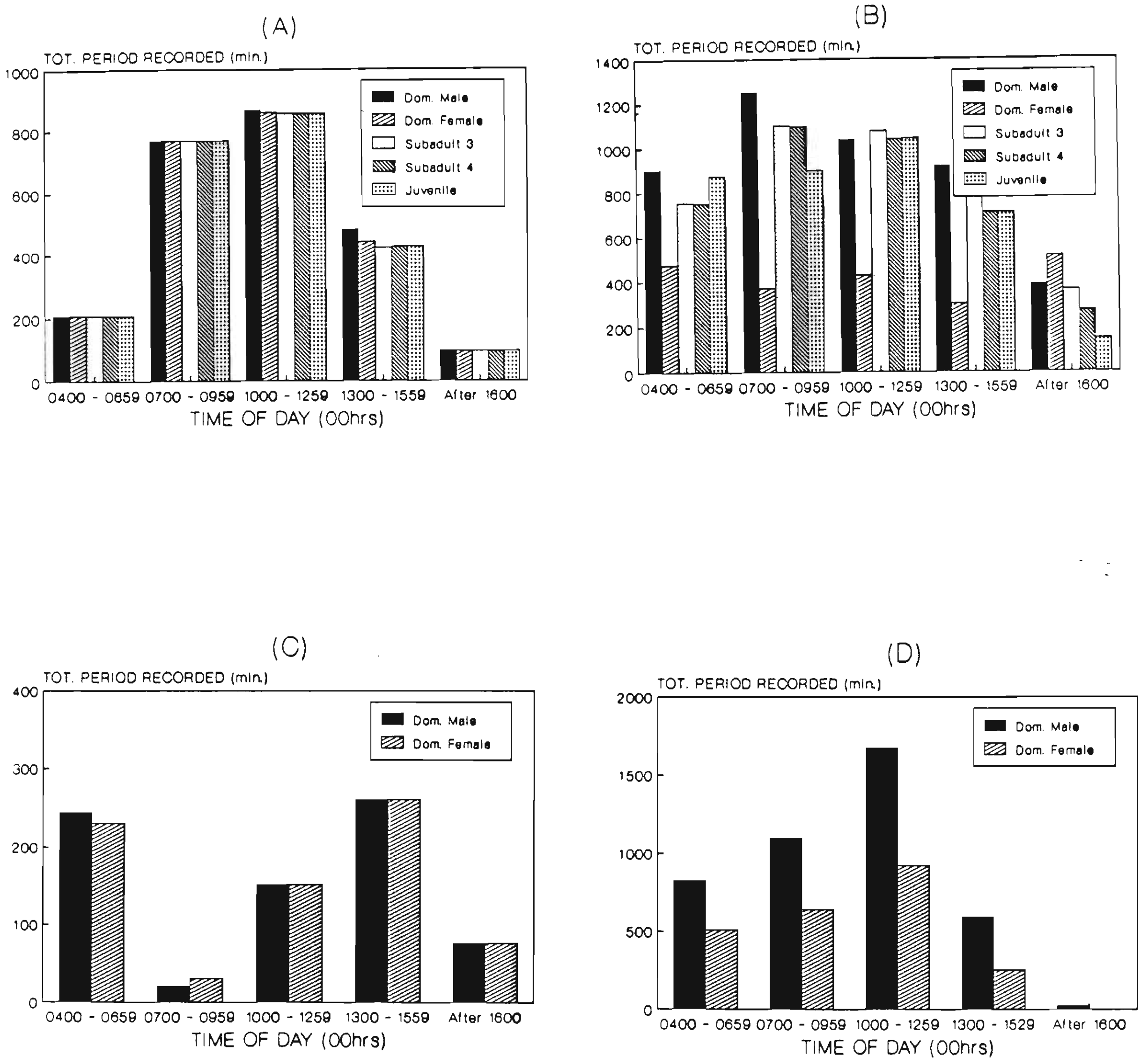


FIGURE 4:1 Contact time with each bird, within each three hour period of the day. ((A)=Stainbank group prior to nesting; (B)= Stainbank group during nesting; (C) Carlshaven group prior to nesting; (D) Carlshaven group during nesting).

other individual in either group.

TABLE 4:7 Time spent in observation periods on each individual.

STAINBANK GROUP		CARLSHAVEN GROUP	
BIRD IDENTITY	TOT.OBSERVATION PERIOD (Min)	BIRD IDENTITY	TOT.OBSERVATION PERIOD (Min)
Dom. Male	374.9	Dom. Male	666.6
Dom. Female	240.4	Dom. Female	284.0
Subadult 3	360.6	Old Female	119.5
Subadult 4	334.5	Subadult 50	42.1
Juvenile	298.1		
All Birds	1608.5	All Birds	1112.2

The amount of time spent in observation periods on each individual for each hour of the day, are given in Figure 4:2.

4:3:1: Activity Patterns

The percentage of total contact time, before and during nesting, spent in each activity by individuals, were determined for each group (Fig.4:3 and Fig.4:4). The data for the dominant females from both groups were based only on the time that the female spent out of the nest. The percentage of contact time that each female spent out of the nest during incubation and early nesting is detailed in section 4:3:6.

For individuals in both groups, the percentage contact time spent foraging, was 16-35% greater in the period prior to nesting. Foraging time for Stainbank individuals was 94.1-97.3% of total contact time prior to nesting and 66.8-80.9% during nesting. The pattern was similar for the Carlshaven

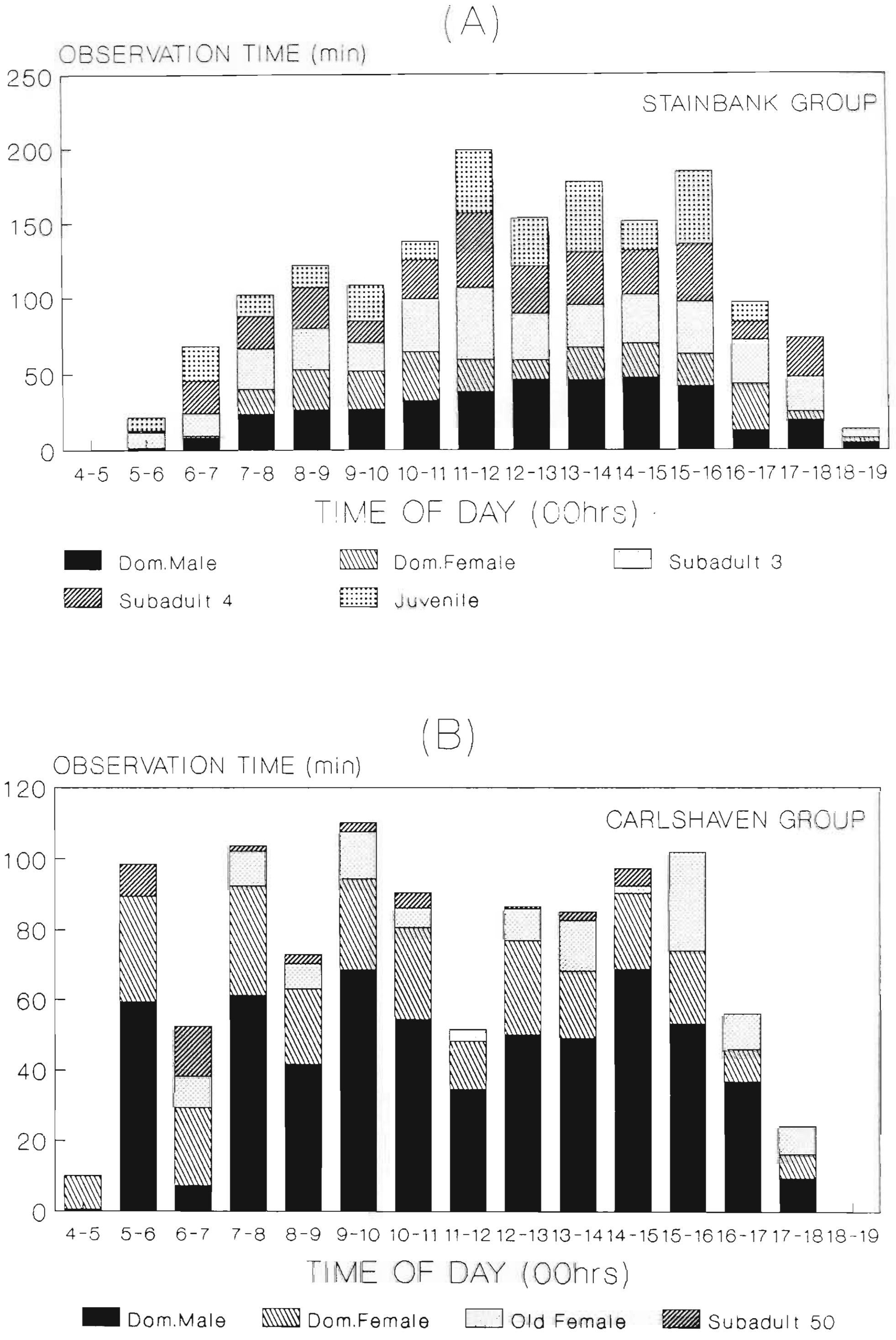


FIGURE 4:2 Time spent in observation watches on each bird of the Stainbank (A) and Carlshaven (B) groups, for each hour of the day.

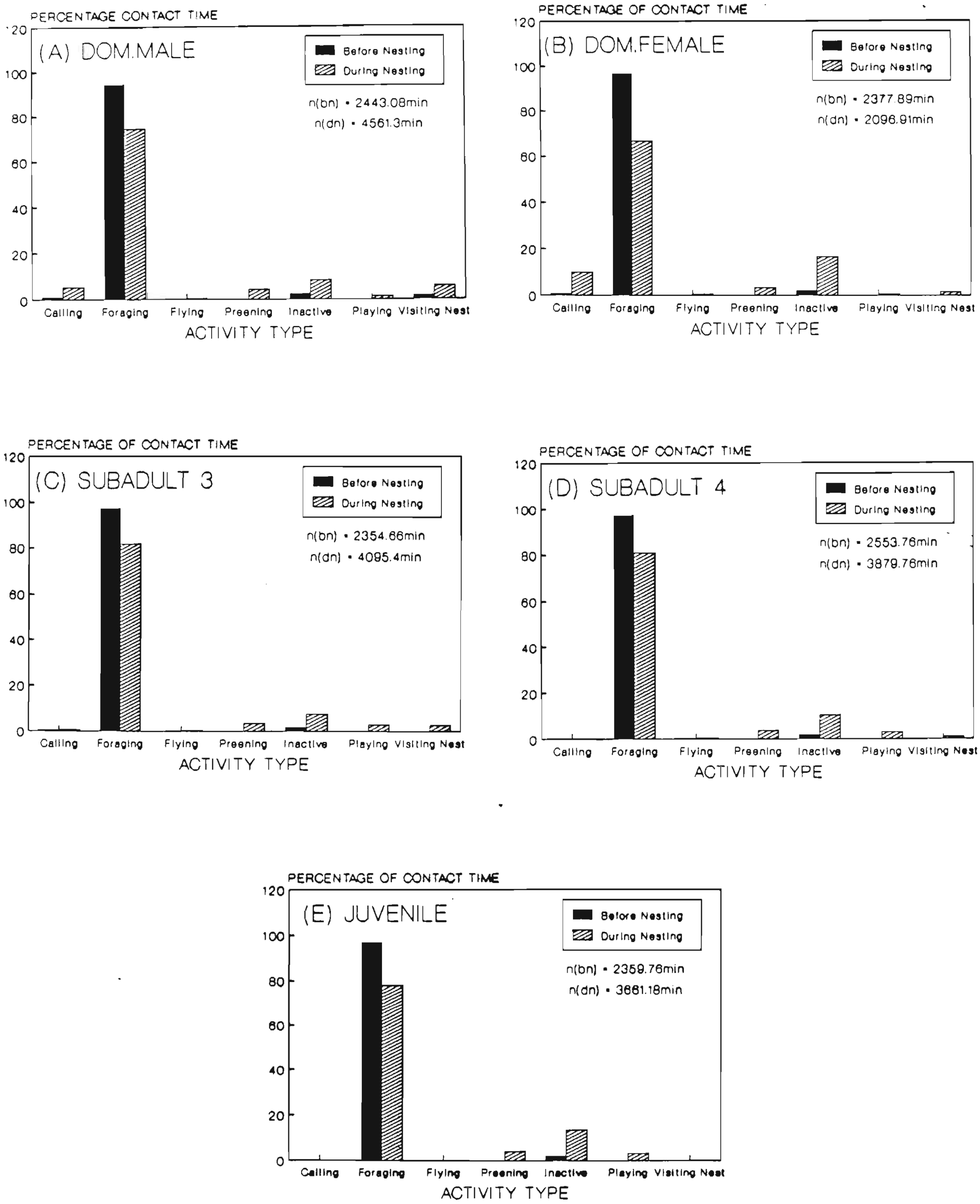


FIGURE 4:3 Activity analysis for each bird in the Stainbank group prior to and during nesting.

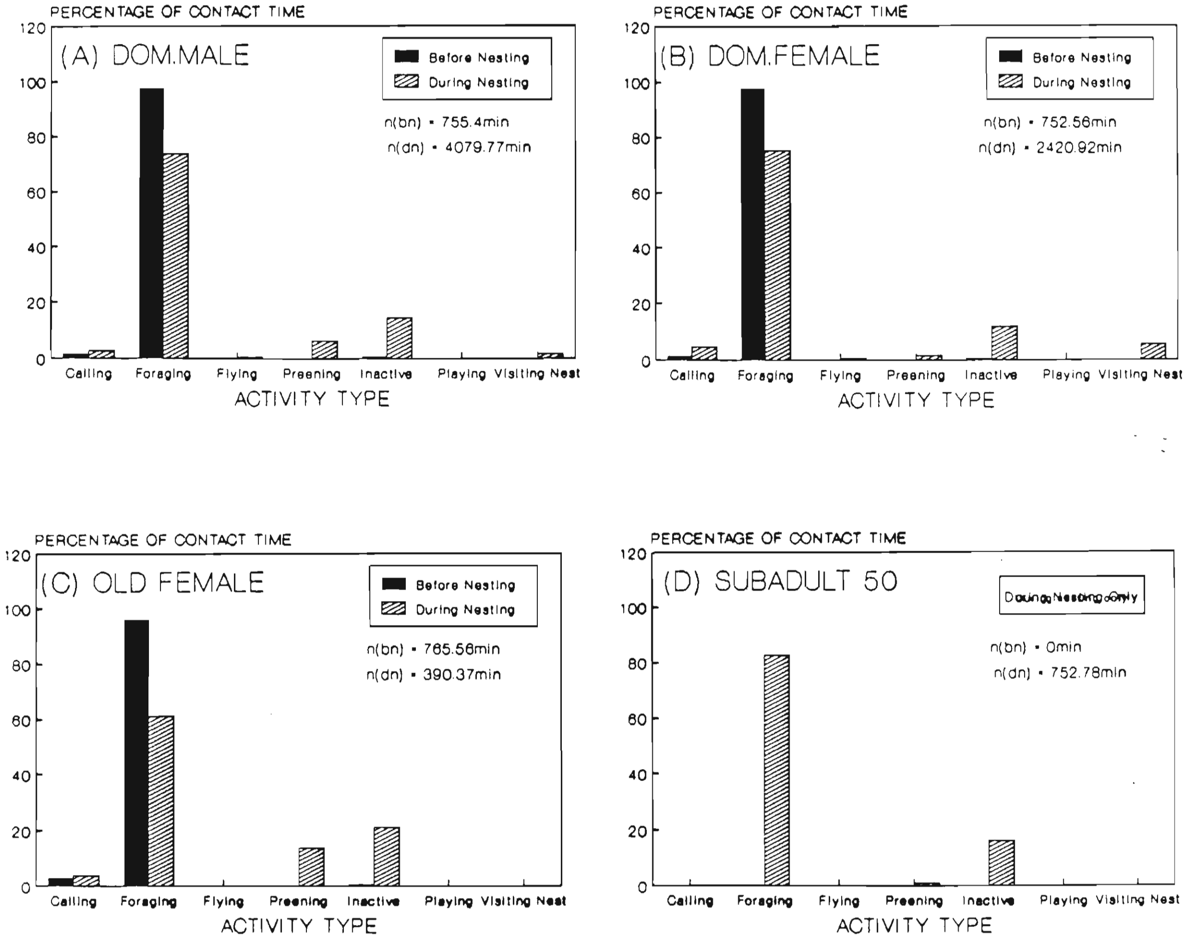


FIGURE 4:4 Activity analysis for each bird in the Carlshaven group prior to and during nesting.

birds, where foraging constituted 96.1-97.8% of total contact time prior to nesting and 61-82.5% during nesting.

Birds became active approximately 45 minutes before sunrise and returned to roost approximately half an hour after sunset. Thus active time for each day was estimated using mean monthly sunrise and sunset times, plus 75 minutes for the periods active prior to and following sunrise and sunset respectively. Sunrise and sunset for September were used for calculating activity periods prior to nesting, while sunrise and sunset for October to January were used for determining active periods during the breeding season (Department of Environmental Affairs <u>pers. comm.</u>[1]). Based on these data, mean daily activity time was 788 minutes prior to nesting and 888 minutes during nesting. Since a mean of 97% of the active day was spent foraging prior to nesting, and 75% during nesting (Figs. 4:3 & 4:4), daily mean foraging time prior to nesting was 764 minutes, while during nesting a mean of 666 minutes was allocated to foraging. The above data show that despite 12.7% increase in daylength during the nesting phase of the breeding cycle, they foraged for approximately 100 minutes longer each day prior to nesting. The observation period prior to nesting was, however, restricted to August and September, and foraging time during June and July may have been less than that recorded during the nesting period.

There were no marked differences in activity patterns between individuals in the period prior to nesting for either group or during the nesting period for the Carlshaven group. The following differences occurred in the activity patterns of individuals in the Stainbank group during the nesting period (Figs.4:3). The dominant male spent 5.4% of contact time calling, and the dominant female 10%. Playing occurred predominantly in the younger birds. 2.9% and 3.1% of the

[1]Dept. of Environmental Affairs. Louis Botha Airport. Durban

contact time was spent in play by subadult 3 and subadult 4 respectively. The juvenile spent 3.3% of the contact time playing. The dominant male and female only spent 1.4% and 0.7% of total contact time playing, respectively. Nest visiting (detailed in section 4:3:6) was conducted predominantly by the breeding pair and the oldest of the subadults (subadult 3).

Prior to nesting 2-2.5% of total contact time was spent inactive, while 7.7-16.8% was spent inactive during nesting. No preening was observed prior to nesting, but 3.3-4.3% of total contact time during nesting was spent preening. Only 0.3-0.6% of total contact time was spent in flight.

No play behaviour was ever observed in the Carlshaven group, which consisted only of adults. Calling was undertaken by the breeding pair and the old female, who was the dominant female in the period prior to nesting (Fig.4:4).

For the Carlshaven group, 0.7% of total contact time prior to nesting was spent inactive, while 11.9-21.5% was spent inactive during nesting. No preening was observed prior to nesting, but 1.1-13.8% of total contact time during nesting was spent preening. Only 0.2-0.6% of total contact time was spent in flight.

The percentage contact time spent foraging by each individual during each three hour period of the day was determined in order to assess whether the data presented in Figures 4:3 and 4:4 were representative of the time spent foraging throughout the day (Figs.4:5 and 4:6). This was only done

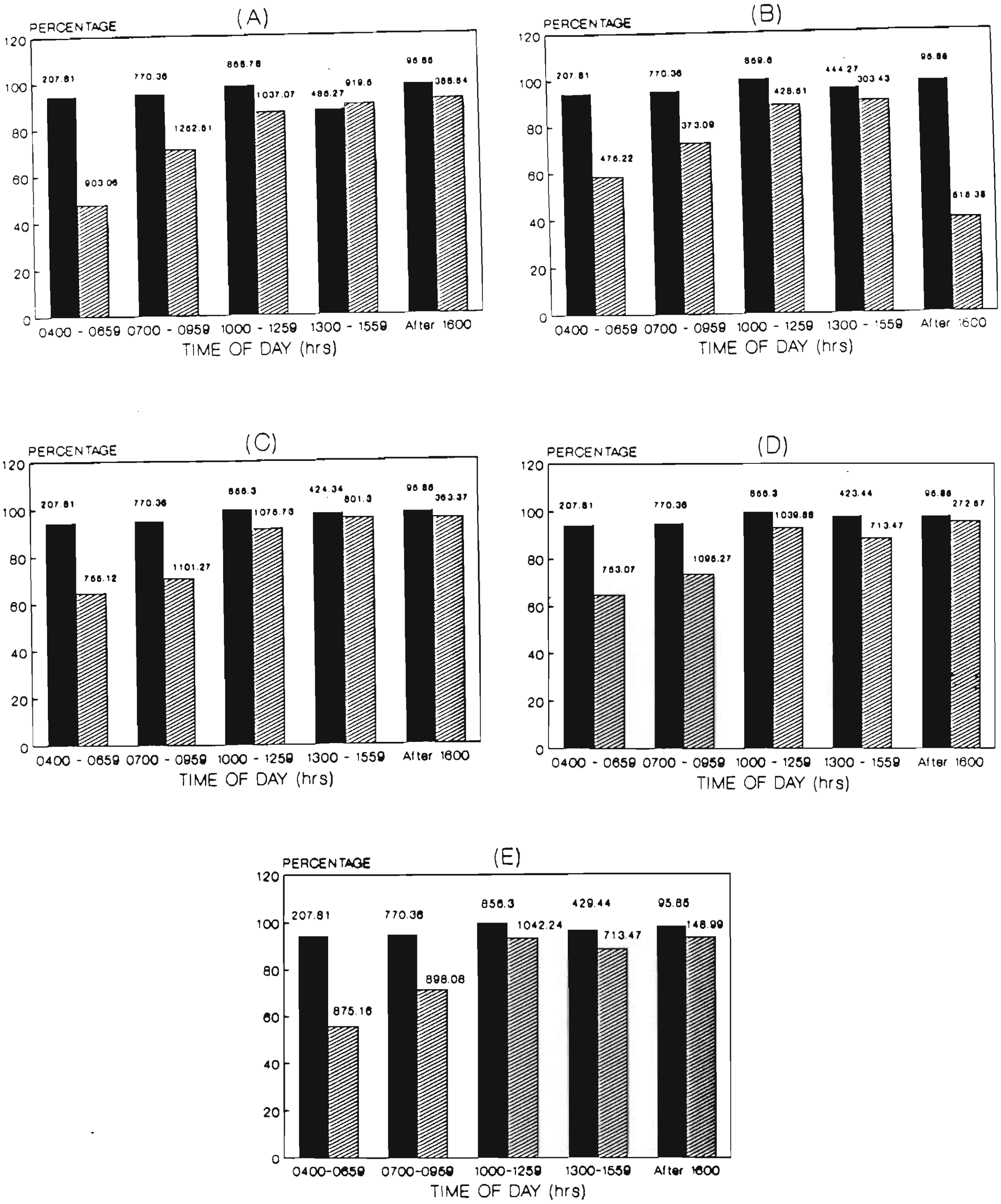


FIGURE 4:5 Proportion of the total contact time spent foraging for each bird in the Stainbank group prior to and during nesting. ((A)=Dom.Male; (B)=Dom.Female; (C)=Subadult 3; (D)=Subadult 4; (E)=Juvenile; Solid bars=Prior to nesting;hatched bars=During nesting).

(Numbers above each bar indicate total number of contact minutes)

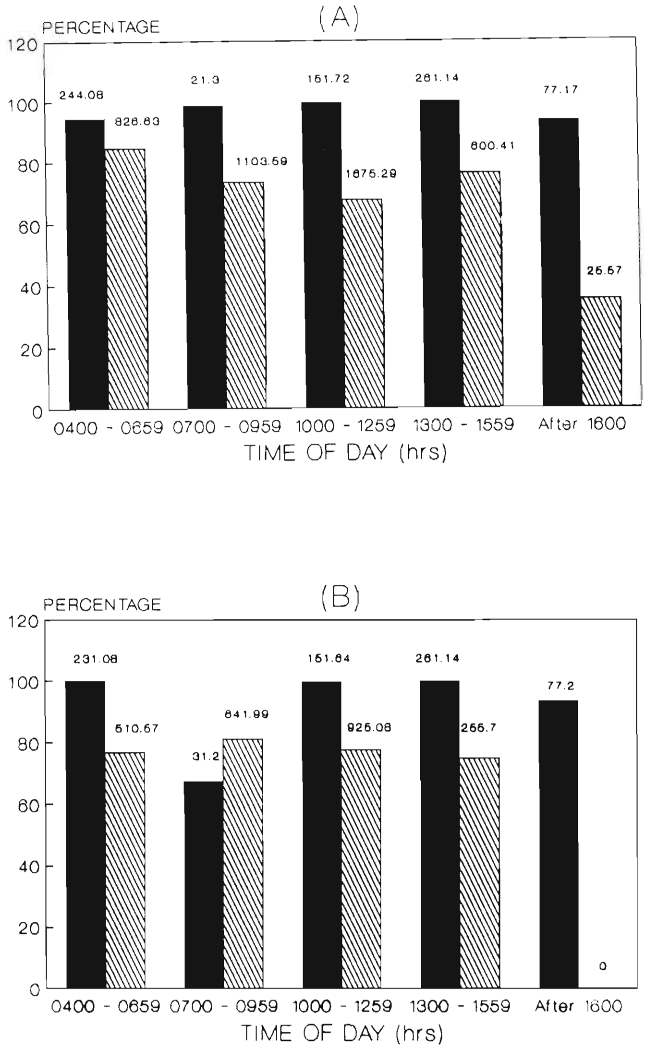


FIGURE 4:6 Proportion of the total contact time spent foraging for the dominant pair in the Carlshaven group prior to and during nesting. ((A)=Dom.Male; (B)=Dom.Female;Solid bars=Prior to nesting;Hatched bars=During nesting).

(Numbers above each bar indicate total number of contact minutes) for the dominant pair in the Carlshaven group as insufficient data were available for the other two birds. Prior to nesting, the birds of both groups spent approximately the same proportion of every three hour period foraging. During the nesting period, the proportion of contact time spent foraging by Stainbank individuals was 22-46% lower in the early morning and reached a peak during midmorning. Between 04h00 and 07h00 foraging time ranged from 47% of contact time for the dominant male to 65% for subadult 4, while the percentage of contact time spent foraging between 10h00 and 13h00 ranged from 87% for the dominant male to 93% for the juvenile. By contrast in the Carlshaven group the proportion of time spent foraging in each three hour period remained relatively constant throughout the day. Prior to nesting, 93.3-100% of contact time was spent foraging in each three hour period, with the exception of the dominant female between 07h00 and 09h59. During nesting, 67.6-84.6% of contact time in each three hour period prior to 16h00 was spent foraging. After 16h00 the percentage of contact time spent foraging by the dominant male, decreased to 35.2%.

4:3:2: Dietary Analysis

Table 4:8 shows the numbers of each identified food type caught by each group. For the purpose of analysis, the following prey types were recognised; unidentified, Orthoptera, Caterpillars, other Insects (other than the two mentioned), Annelids, Molluscs, Frogs, Snakes, Lizards, Rodents, and Sugarcane. 72.7% and 83.8% of the food items of the Stainbank and Carlshaven groups respectively, were too small and eaten too rapidly to be positively identified. Table 4:9 shows the number of food items caught in each of the above categories for both groups.

Based on identified items (Table 4:8), it is likely that the

TABLE 4:8 Classification of food items caught by both groups

FOOD SPECIES	NUMBER OF ITEMS CAUGHT STAINBANK GRP.	 CARLSHAVEN GRP.
UNIDENTIFIED	1129	1134
PHYLUM MOLLUSCA		
Unidentified snail	6	1
Slug	2	
PHYLUM ANNELIDA		
Unidentified		16
Common Earth Worm	8	1
Natal Earth Worm	1	
PHYLUM ARTHROPODA		
CLASS INSECTA		
Unidentified	29	1
ORDER Orthoptera		
Crickets	3	11
Grasshoppers	19	39
ORDER Coleoptera		3
ORDER lepidoptera		
Caterpillars	39	32
Moths	1	2
CLASS CHILOPODA Centipedes	1	
CLASS DIPLOPODA Millipedes	5	
PHYLUM CHORDATA		
CLASS REPTILIA		
Sub-Order Serpentes (Snakes)		
Unidentified	5	3
Bitis arientans Puff Adder	1	1
Lamprophis fulginosus House S.	1	1
Philothamnus natalensis N.Green S.	1	
Sub-Order Sauria (Lizards)		
Unidentified	3	1
CLASS AMPHIBIA		
Unidentified	42	76
Bufo spp	16	26
Breviceps spp	1	2
Strongylopus spp		3
CLASS MAMMALIA		
Fam. Muridae (rats and mice)		
Unidentified	1	1
Mus minutoides	1	
Fam. Chrysochloridae (moles)		
Amblysomus hottentotus	1	
SUGAR CANE PULP	237	

TABLE 4:9 Dietary composition based on feeding observations in the field. (A) includes and (B) excludes, data from the two days in which sugarcane was eaten.

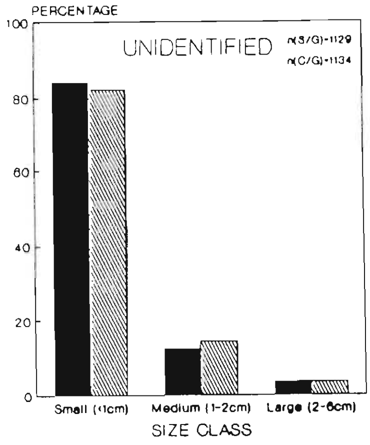
FOOD CLASS	CARLSHAVEN GROUP		STAINBANK GROUP (A)		STAINBANK GROUP (B)	
	No.	% of Identified Items	No.	% of Iden. Items	No.	% of Iden. Items
Orthoptera	50	22.7	22	5.2	18	11.3
Caterpillars	32	14.5	39	9.2	38	23.8
Other Insects	6	2.7	36	8.5	22	13.8
Annelids	17	7.7	9	2.1	5	3.1
Molluscs	1	0.4	8	1.9	8	5.0
Frogs	107	48.6	59	13.9	56	35.0
Snakes	5	2.3	8	1.9	7	4.4
Lizards	1	0.4	3	0.7	3	1.9
Rodents	1	0.4	3	0.7	3	1.9
Sugarcane	0	-	237	55.9	0	-

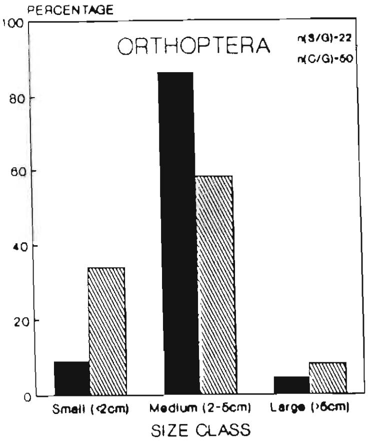
majority of unidentified items were small insects. Sugarcane constituted 55.9% of all the identified food items for the Stainbank group. This is however, misleading since the group foraged on sugar cane only during three observation periods. On all three occasions they ate numerous pieces of cane in a short period of time. Column B (Table 4:9) shows the percentage of identified food items in each category for the Stainbank group, but excludes the data from the two days where individuals ate sugarcane.

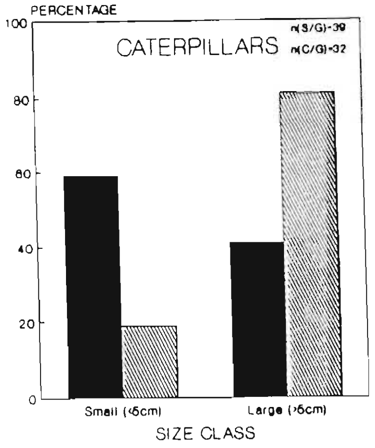
Frogs were the commonest identified animal caught by each group. They comprised, a greater percentage of the diet of the Carlshaven group. Orthopterans, other insects, and caterpillars were the next most commonly identified food items.

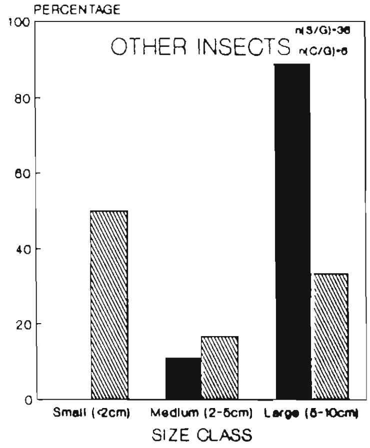
Each identified food item was allocated a size class, based on estimated body length. These size classes were chosen for each food category independently. Figure 4:7 shows the percentage of food items in each size category, for each food

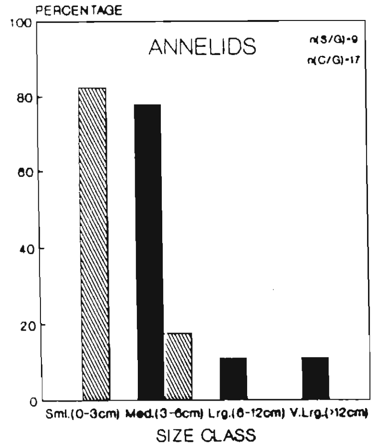
FIGURE 4:7 Size class distribution for different prey items
(Solid bars = Stainbank group; Hatched bars = Carlshaven group)

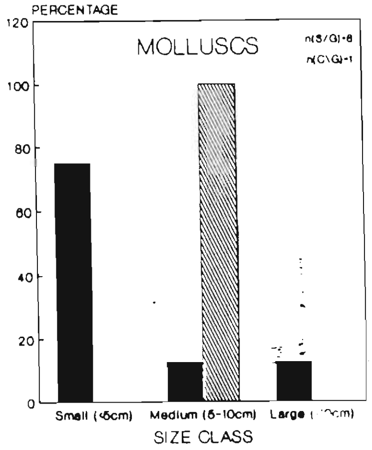

PERCENTAGE
UNIDENTIFIED
n(S/G)-1129
n(C/G)-1134
0
20
40
60
80
100
Small (<1cm)
Medium (1-2cm)
Large (2-6cm)
SIZE CLASS

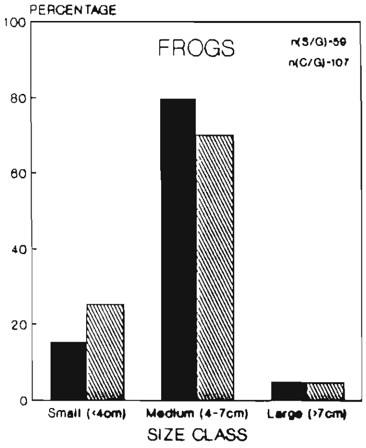

PERCENTAGE
ORTHOPTERA
n(S/G)-22
n(C/G)-60
0
20
40
60
80
100
Small (<2cm)
Medium (2-5cm)
Large (>5cm)
SIZE CLASS

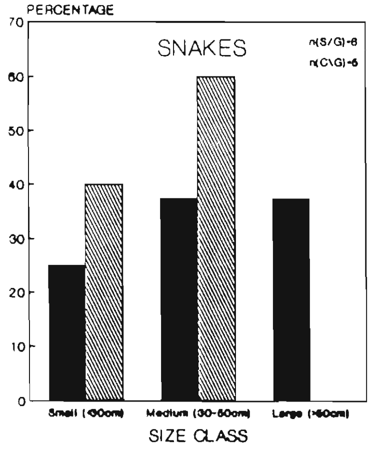

PERCENTAGE
CATERPILLARS
n(S/G)-39
n(C/G)-32
0
20
40
60
80
100
Small (<5cm)
Large (>5cm)
SIZE CLASS

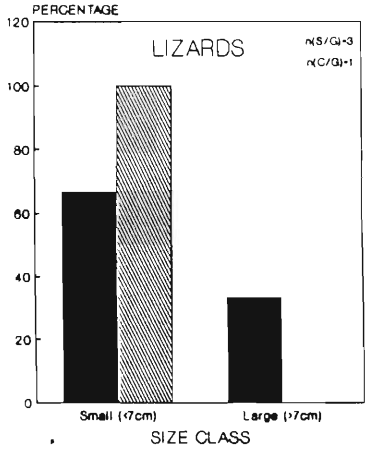

PERCENTAGE
OTHER INSECTS
n(S/G)-36
n(C/G)-6
0
20
40
60
80
100
Small (<2cm)
Medium (2-5cm)
Large (5-10cm)
SIZE CLASS

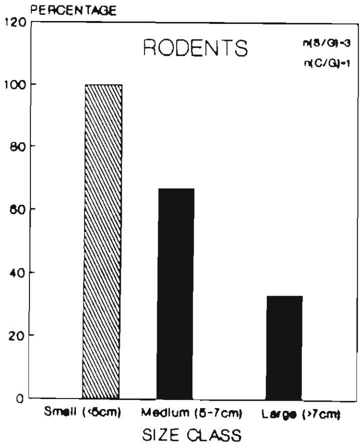

PERCENTAGE
ANNELIDS
n(S/G)-9
n(C/G)-17
0
20
40
60
80
100
Sml.(0-3cm)
Med.(3-6cm)
Lrg.(6-12cm)
V.Lrg.(>12cm)
SIZE CLASS


PERCENTAGE
MOLLUSCS
n(S/G)-8
n(C\G)-1
0
20
40
60
80
100
120
Small (<5cm)
Medium (5-10cm)
Large (>10cm)
SIZE CLASS


PERCENTAGE
FROGS
n(S/G)-59
n(C/G)-107
0
20
40
60
80
100
Small (<4cm)
Medium (4-7cm)
Large (>7cm)
SIZE CLASS


PERCENTAGE
SNAKES
n(S/G)-8
n(C\G)-5
0
10
20
30
40
50
60
70
Small (<30cm)
Medium (30-60cm)
Large (>60cm)
SIZE CLASS


PERCENTAGE
LIZARDS
n(S/G)-3
n(C/G)-1
0
20
40
60
80
100
120
Small (<7cm)
Large (>7cm)
SIZE CLASS


PERCENTAGE
RODENTS
n(S/G)-3
n(C/G)-1
0
20
40
60
80
100
120
Small (<5cm)
Medium (5-7cm)
Large (>7cm)
SIZE CLASS

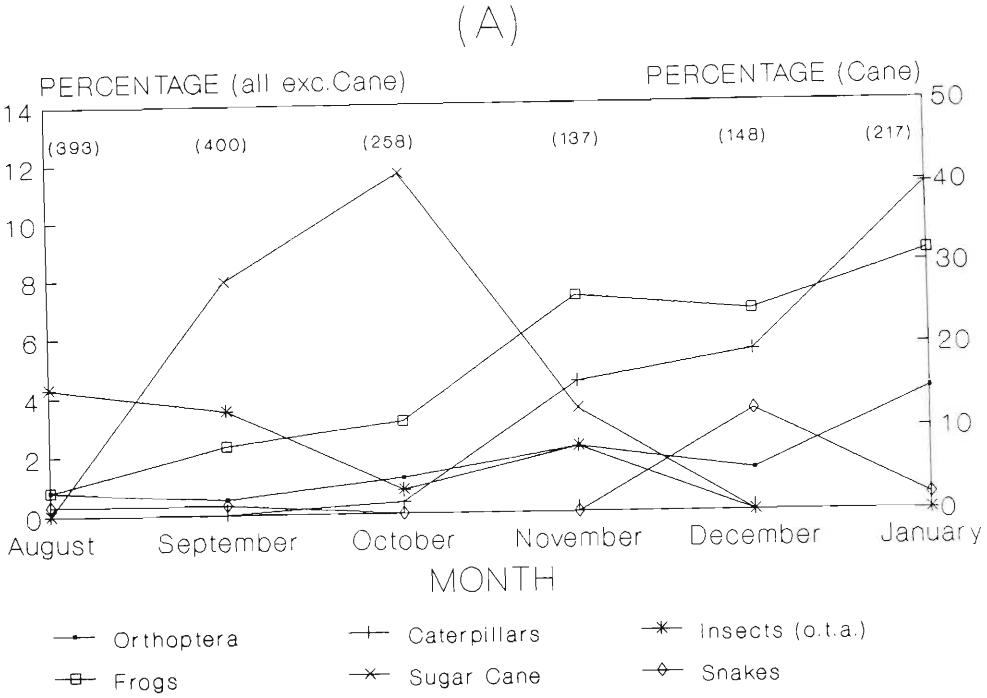
type. The percentage of frogs in each size class where similar for both groups, with 79.7% and 70.1% between 4-7 cm in length for the Stainbank and Carlshaven groups respectively. 86% of the orthopterans caught by the Stainbank group were similar in size (2-5 cm), while those caught by the Carlshaven group exhibited greater variability. 81% of the caterpillars caught by the Carlshaven group were greater than 5 cm in length, while 59% of the caterpillars caught by the Stainbank group were less than 5 cm in length. A large proportion (88.9%) of other insects caught by the Stainbank group were large (5-10 cm). 77.8% (28 individuals) of these were an unidentified large pupae (6-10 cm) obtained by digging in the soil in sugarcane fields.

The proportion of items in each food category for each month showed seasonal trends in food availability (Fig.4:8). Sugarcane was utilised by the Stainbank group in late winter and early summer when cane-cutting occurred. Frogs and caterpillars constituted a greater proportion of the diet of the Stainbank group in the summer months. Snakes were only caught during December.

Frogs were more abundant in the diet of the Carlshaven group during November and December while orthopterans were more abundant during September and October. Annelids were only caught in December and January.

4:3:3: Foraging techniques

Four major foraging techniques accounted for 97.6% and 97.5% of the foraging attempts for the Stainbank and Carlshaven groups respectively (Table 4:10). Picking was the major technique used by both groups. The Stainbank group used scratching, digging and probing to a greater degree, than the Carlshaven group.



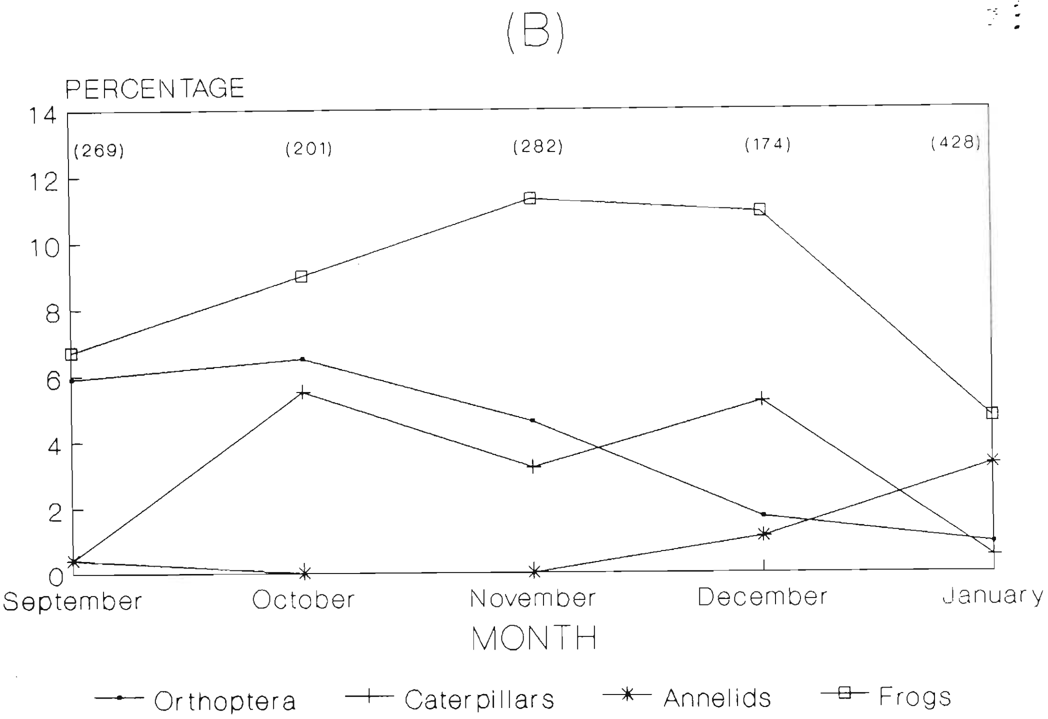


FIGURE 4:8 The proportion of each major food type, expressed as a percentage of the total number of food items caught for each month by the Stainbank (A) and Carlshaven (B) groups.

(Bracketed number indicate total number of food items recorded in each month)

TABLE 4:10 The relative importance and success rates of the four major foraging techniques.

FORAGING METHOD	STAINBANK GROUP No. of Attempts	% of Total Att.	Success %	CARLSHAVEN GROUP No. of Attempts	% of Total Att.	Success %
Picking	1553	46.2	78.4	1252	60.7	82.8
Scratching	1186	35.3	10.6	610	29.6	27.2
Digging	426	12.7	20.9	117	5.7	33.3
Probing	119	3.5	18.5	32	1.6	34.4

Foraging success for picking was 50-68% higher than any of the other methods (Table 4:10). Scratching was least successful in both groups. The Carlshaven group was 4-17% more successful for each of the four methods.

The mean duration of foraging attempts using each of the four major foraging techniques is shown in Table 4:11 for each group. The mean duration of picking scratching and probing were not significantly different ($p<0.05$) from each other in either group. Digging episodes, however, lasted significantly longer ($p>0.05$) than either of the other three techniques, in both groups. The mean duration of digging was 8-9.7 seconds longer than for picking, scratching or probing.

TABLE 4:11 Mean duration of foraging attempts using each major foraging technique.

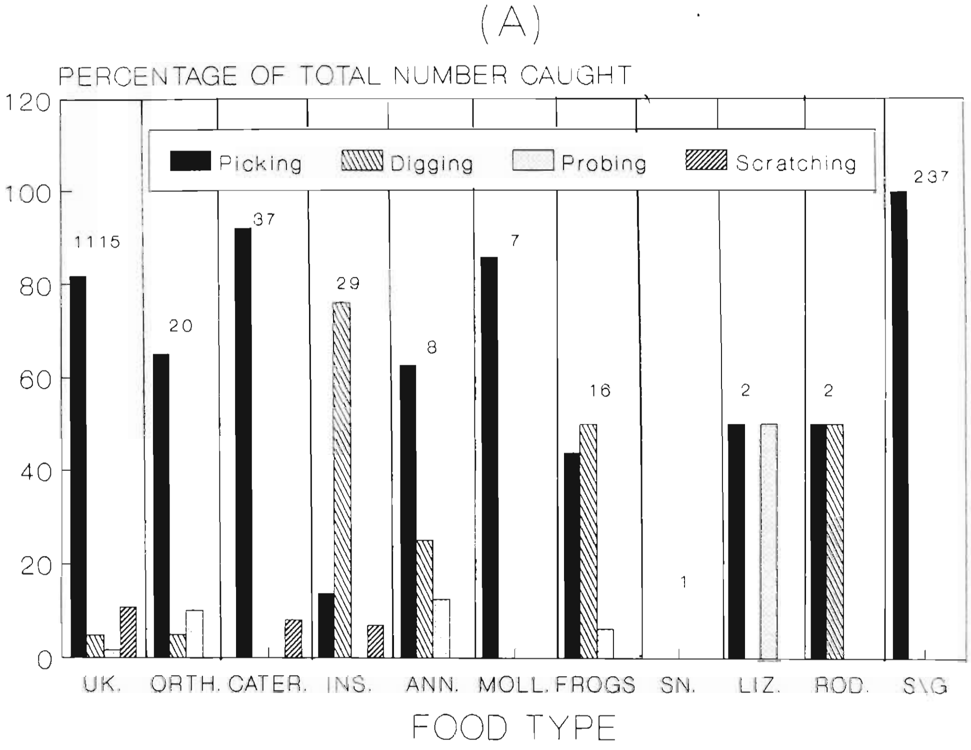
FORAGING METHOD	NUMBER OF ATTEMPTS STAIN.	CARLS.	MEAN DURATION (s) STAINBANK mean	S.D.	CARLSHAVEN mean	S.D.
Picking	1553	1252	2.2	(.18)	2.2	(.24)
Scratching	1186	610	2.3	(.20)	2.7	(.3)
Digging	426	117	10.9	(2.4)	11.9	(2.1)
Probing	119	32	2.9	(1.4)	3.1	(1.7)

Figure 4:9 shows the relationship between prey type and foraging technique. 50% of all frogs caught by the Stainbank group and only 19.2% by the Carlshaven group were obtained by digging. 63.5% of frogs caught by the Carlshaven group were captured on the surface. Picking was the major technique used to capture prey from all food categories by both groups, except in the case of frogs and other insects captured by the Stainbank group. For the Carlshaven group, 13.4% of unidentified food items, 16.1% of caterpillars, 20% of other insects and 13% of frogs were caught by scratching. For the Stainbank group only 10.7% of unidentified food items, 7.9% of caterpillars, 8.9% of other insects and 5.9% of frogs were caught by scratching. The high percentage (75.9%) of other insects captured by digging by the Stainbank group is due to the fact that 77.8% of other insects captured were unidentified large pupae found in the soil of sugarcane fields.

4:3:4: Habitat Utilisation

(i) TERRITORY UTILISATION

Figures 4:10 and 4:11 show the territories of the two groups and where birds were sighted prior to and during nesting. Territory boundaries were drawn along vegetation or topographical changes. The greater number of sightings by farmers prior to nesting was due to an appeal for sightings during this period to aid in locating groups. Insufficient time was spent with either group prior to nesting to adequately assess territory utilisation during this period. From the limited data available it does, however, appear that both groups utilised a far greater proportion of their territories during the non-nesting period. For example, during the nesting period, the Stainbank group foraged within a 4.5 km radius of the nest, and the Carlshaven group, within a



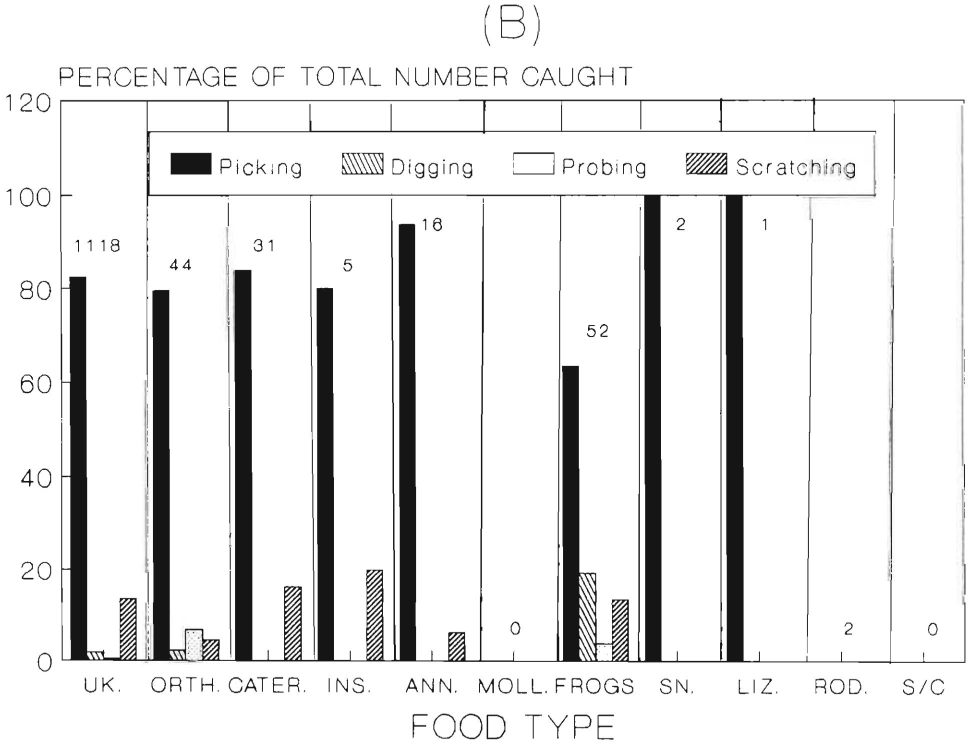


FIGURE 4:9 The relationship between prey type and foraging technique for all food items captured by the birds of the Stainbank (A) and Carlshaven (B) Groups.

(Numbers above each histogram indicate the total number of food items captured in each category)

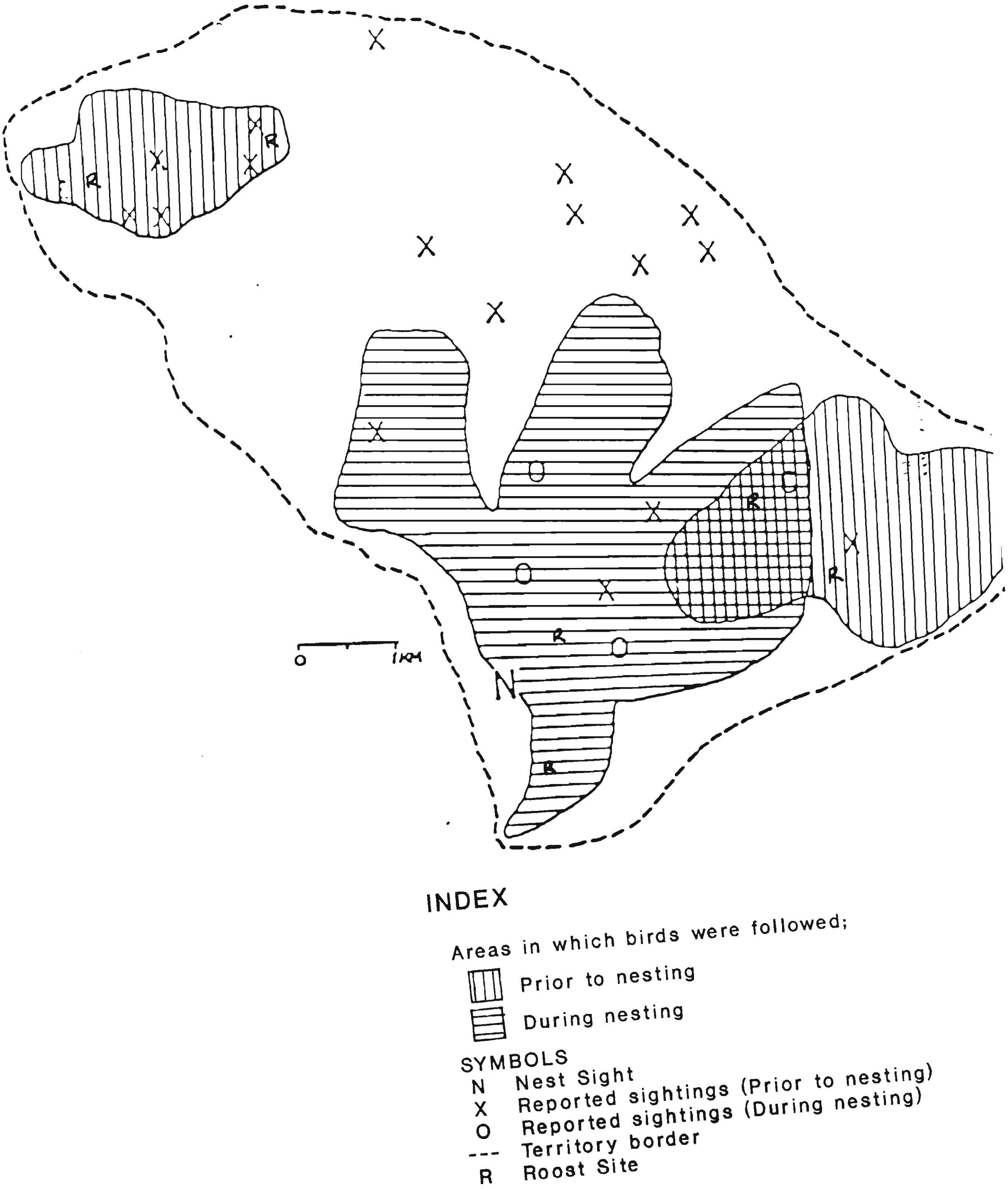


FIGURE 4:10 Areas within the estimated home range of the Stainbank group where the birds were sighted prior to and during nesting.

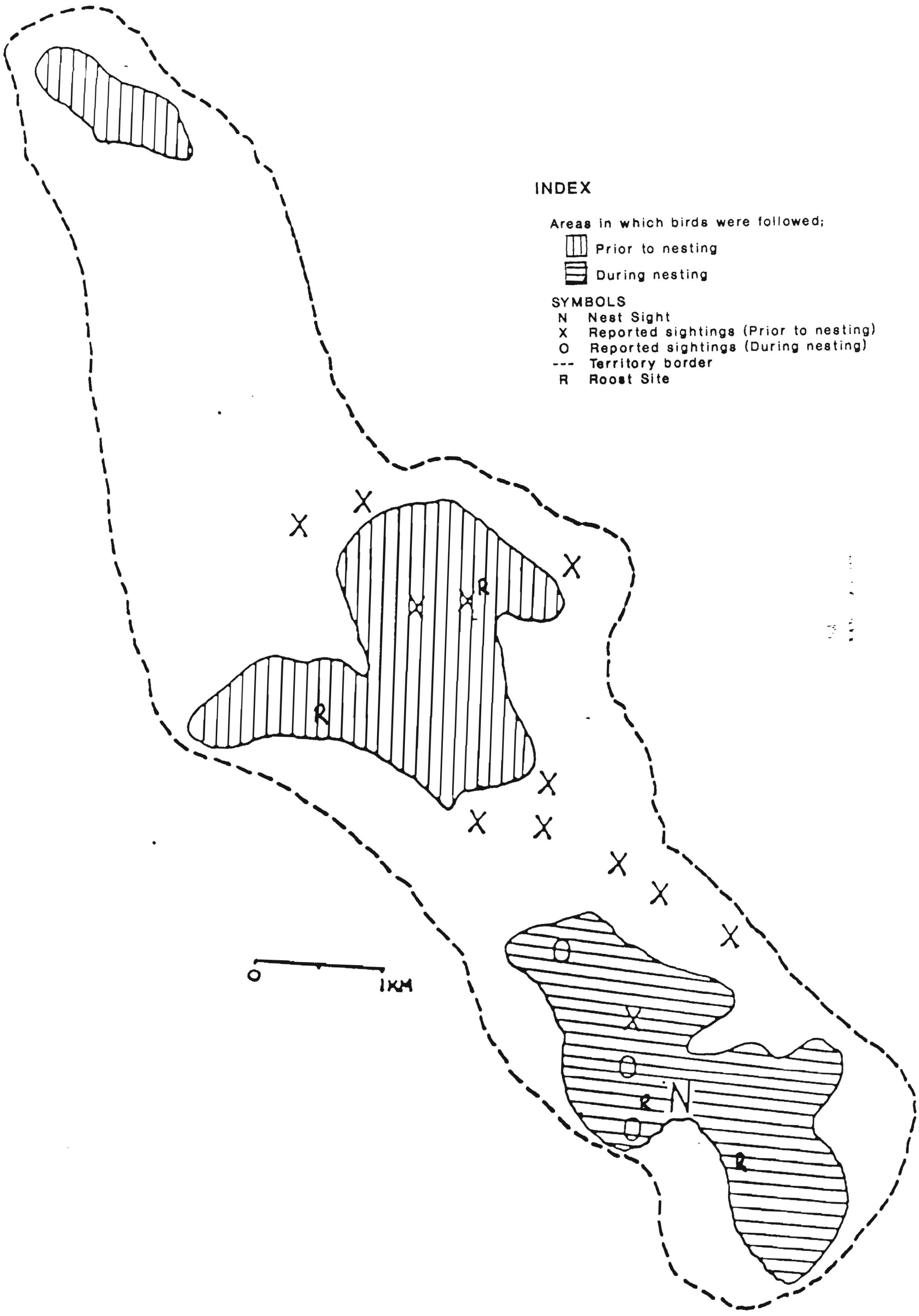


FIGURE 4:11 Areas within the estimated home range of the Carlshaven group where the birds were sighted prior to and during nesting.

1.5 km radius of the nest. This meant that the Stainbank group utilised approximately 12.5 km^2 of the territory during the nesting period, which is approximately 29% of the estimated minimum territory size (Chapter Two). The Carlshaven group, however, only utilised 14% of the estimated territory area (Chapter Two) during the nesting period; an area of approximately 3 km^2.

(ii) WALKING RATES

In order to assess distances covered by birds during foraging excursions, the mean number of steps taken per minute (walking rate) for each bird during observation watches were determined for the periods prior to and during nesting (Table 4:12).

There were no significant differences ($p>0.05$) in walking rate for the Stainbank individuals during either the pre-nesting or nesting period. The mean walking rates of each individual in the Stainbank group were higher during the nesting period, but only those of subadult 3 and the dominant male were significantly higher ($p<0.05$).

No significant difference in walking rate ($p>0.05$) was observed for Carlshaven individuals in either the pre-nesting or nesting period. There were also no significant differences ($p>0.05$) between walking rates of birds from the Stainbank and Carlshaven groups during either period.

Although walking rates were not significantly different during either period for either group, there was a trend for for all individuals to show a higher walking rate during breeding.

TABLE 4:12 Mean number steps per minute taken by each individual.(B.N.=before nesting, D.N.=during nesting)

BIRD IDENTITY	TOTAL OBSERVATION TIME (min) B.N.	D.N.	MEAN STEPS PER MIN. + (Std. Dev.) B.N.	D.N.
STAINBANK G.				
Dom. Male	178.5	196.5	49.2 (21.0)	67.4 (19.2)
Dom.Female	201.6	38.8	49.1 (23.8)	69.6 (10.7)
Subadult 3	180.8	179.8	41.2 (23.6)	65.6 (22.0)
Subadult 4	146.8	187.6	50.0 (15.7)	62.3 (16.5)
Juvenile	147.0	151.1	44.8 (15.7)	61.9 (17.5)
CARLSHAVEN G.				
Dom. Male	79.1	587.5	44.0 (14.5)	50.2 (18.5)
Dom. Female	62.3	221.7	43.4 (9.8)	56.0 (15.9)
Old Female	86.8	32.7	51.6 (12.9)	47.9 (12.7)
Subadult 50	-	42.1	-	44.7 (18.5)

Assuming that an individual bird takes an average of 50 steps per minute, it would cover approximately 600 m per hour while foraging (stride length = 20 cm (Kemp and Kemp, 1978)). Thus during an active foraging day of approximately 700 minutes the birds could walk up to 7 kms.

(iii) HABITAT SELECTION

The percentage of total contact time spent by each group in each major vegetation type (see Table 4:2) for the total period, and prior to and during nesting, are given in Tables 4:13 and 4:14. The Stainbank group spent 72% of contact time prior to nesting in sugarcane fields (Table 4:13). 32.8% and 20.5% of contact time during nesting were spent in grasslands and forests respectively, compared to only 14.2% and 2.1% prior to nesting.

The Carlshaven group spent 53.3% of total contact time in grasslands (Table 4:14). Prior to nesting, 86.9% of contact time was spent in grasslands. 14.1% and 12% of contact time during nesting, was spent in forests and fruit plantations. Savannas and herblands were also utilised more during the nesting period.

TABLE 4:13 Vegetation utilisation by the Stainbank group prior to and during nesting

VEGETATION TYPE	BEFORE NESTING		DURING NESTING		TOTAL PERIOD	
	Minutes	% of [a]	Minutes	% of [b]	Minutes	% [c]
Sugarcane	1843.9	72.0	999.5	21.0	2843.4	38.9
Grasslands	364.0	14.2	2033.4	42.7	2397.4	32.8
Forests	53.0	2.1	1446.5	30.4	1499.5	20.5
Savannas	-	-	121.0	2.5	121.0	1.7
Maize	36.0	1.4	32.0	0.7	68.0	0.9
Herbland	-	-	21.0	0.4	21.0	0.3
Fruit Plant.	-	-	-	-	-	-
Veg. other than above	262.0	10.2	109.2	2.3	371.2	5.1
All Veg.types	2558.9[a]		4762.6[b]		7321.5[c]	

TABLE 4:14 Vegetation utilisation by the Carlshaven group prior to and during nesting

VEGETATION TYPE	BEFORE NESTING		DURING NESTING		TOTAL PERIOD	
	Minutes	% of [a]	Minutes	% of [b]	Minutes	% [c]
Grasslands	601.0	86.9	1842.5	47.3	2443.5	53.3
Forests	7.0	1.0	642.3	16.5	649.3	14.1
Fruit Plant.	-	-	553.0	14.2	553.0	12.0
Savannas	37.0	5.4	353.0	9.1	390.0	8.5
Herbland	-	-	365.5	9.4	365.5	8.0
Maize	36.0	1.4	32.0	0.7	68.0	1.0
Sugarcane	-	-	-	-	-	-
Veg. other than above	47.0	6.8	113.2	2.9	160.2	3.5
All veg. types	692.0[a]		3897.5[b]		4589.5[c]	

For each of the major vegetation types most utilised by each group, the percentage of contact time spent in each category within each vegetation type was calculated (Figs. 4:12 and 4:13).

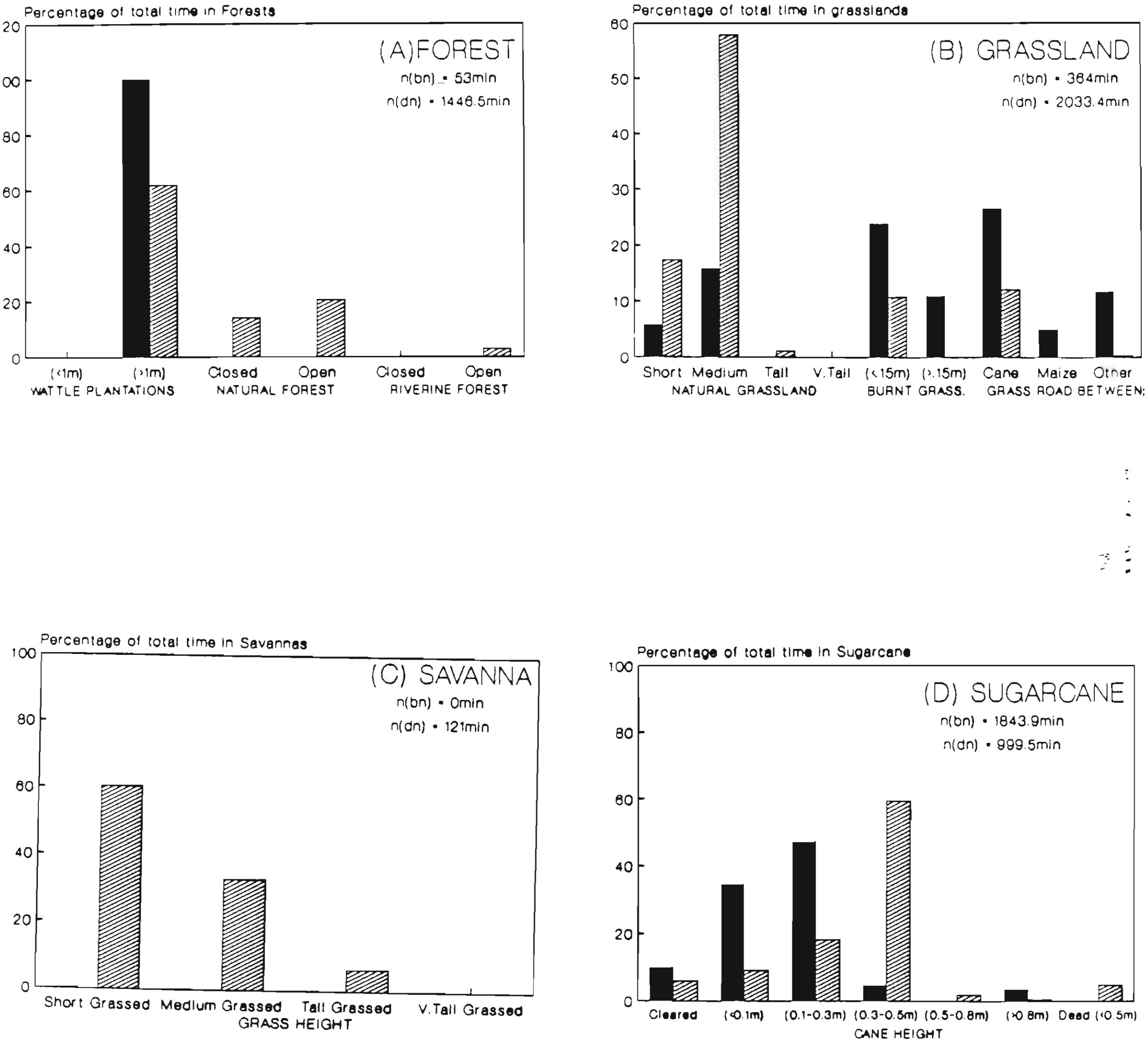


FIGURE 4:12 Percentage contact time in each vegetation type within each general vegetation category (Table 4:2) in which more than 100 recording minutes were accumulated for the Stainbank group. (Solid bars = before nesting; Hatched bars = during nesting)

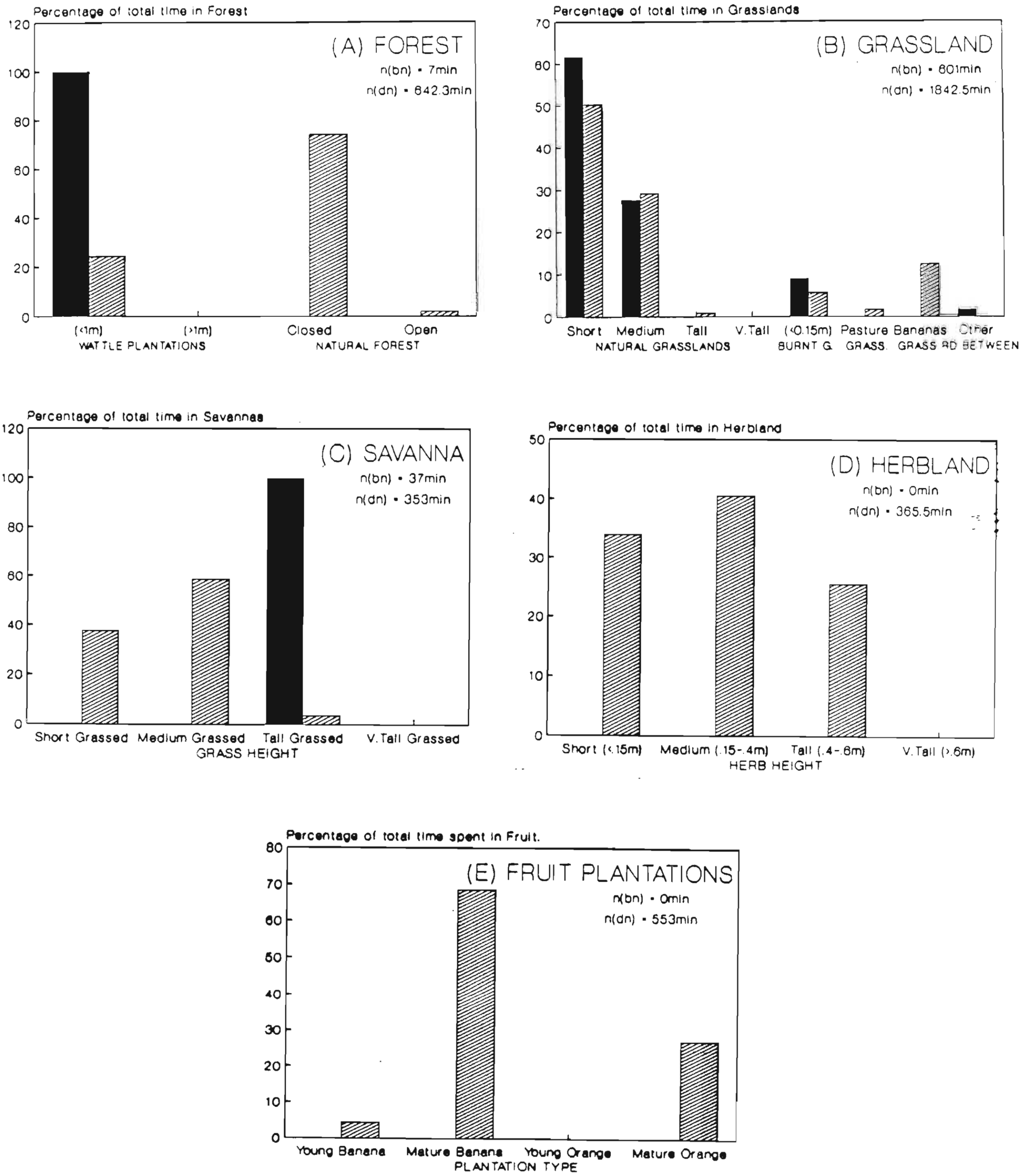


FIGURE 4:13 Percentage contact time in each vegetation type within each general vegetation category (Table 4:2) in which more than 100 recording minutes were accumulated for the Carlshaven group. (Solid bars = before nesting; Hatched bars = during nesting)

The only cultivated forests utilised to any extent by the Stainbank group were Wattle forests, in which 65.2% of the contact time in forests was spent (Fig.4:12). During nesting, 34.8% and 3% of the time in forests was in natural forest and riverine forest respectively. In the grassland category, 67.2% of contact time was spent in natural grassland, with 76% of that spent in grassland with grass height of between 0.15 m and 0.4 m. Only 1% of contact time in grasslands was spent in grass with a height of 0.4-0.6 m, and the birds never utilised taller grasslands. 34.9% and 26.7% of contact time in grasslands prior to nesting was in burnt grasslands and grassed roads between sugarcane fields respectively. During nesting, however, only 10.8% and 12.1% of contact time was spent in burnt grasslands and grassed roads between cane fields respectively. Of the contact time in savannas, 60.3% was in short grassed savannas, and 33.1% in medium grassed savannas. Prior to nesting, 91.7% of contact time in sugarcane was in fields where cane was less than 0.3m tall. During the nesting period, however, 59.3% of contact time was in fields where cane was 0.3-0.5 m tall. Fields where cane exceeded half a meter in height were seldom utilised.

The only cultivated forests utilised to any extent by the Carlshaven group were Wattle, in which 3.5% of the contact time in forests was spent (Fig. 4:13). During the nesting period, 73.84% of contact time in forests was spent in closed natural forest. 82.43% of the time in grasslands, was spent in natural grassland, with 64% of that in short natural grassland (grass height <0.15 m). Only 0.9% of contact time in grasslands was in tall grassland (grass height 0.4-0.6 m) and the birds never entered taller grasslands. This was also the case for savanna habitats, where savannas of different grass heights occurred. 87.18% of time was spent in savannas where grass was less than 0.4 m. 68.54% of contact time in fruit plantations was in mature banana plantations and 27.12% in orange orchards.

(iv) FORAGING TECHNIQUES AND SUCCESS RATES IN DIFFERENT HABITATS

Mean foraging rates (attempts per minute) in the most commonly utilised vegetation types and the percentage foraging success in each of these vegetation types are given for each group, in Table 4:15.

TABLE 4:15 Foraging and success rates for vegetation types most utilised by each group.

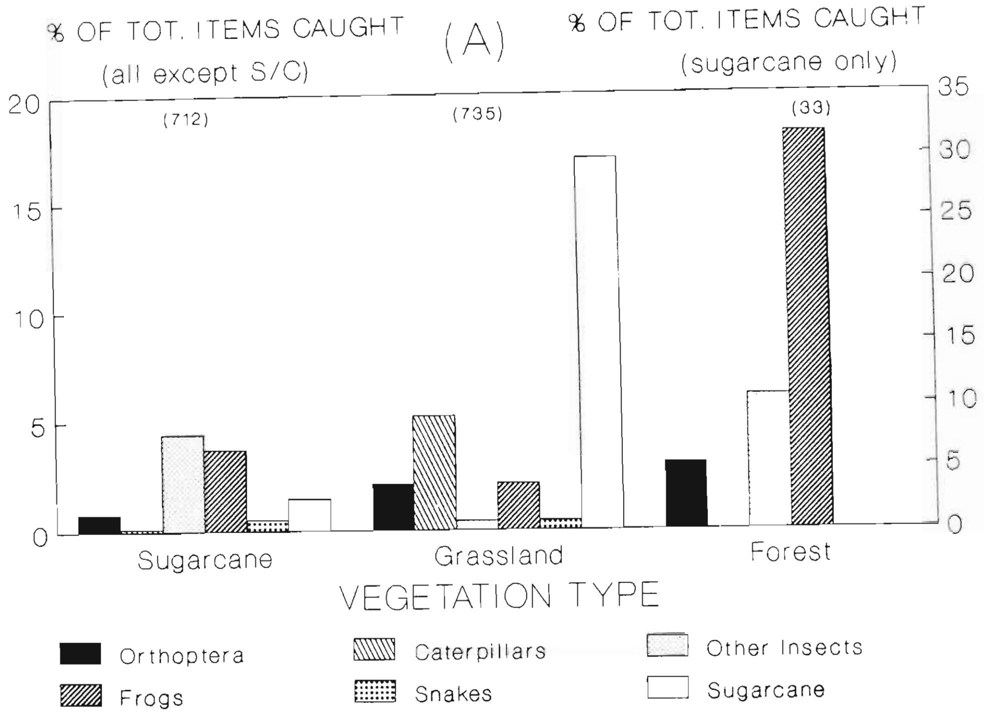
VEGETATION TYPE	TOT. OBSERVATION TIME (min)	AVE.FORAGING ATTEMPTS PER MINUTE ±(SD)	FORAGING SUCCESS %
STAINBANK GROUP			
Wattle Forest (>1m)	36.7	1.26 ±(1.26)	40.9
Short Natural Grass.	49.9	1.89 ±(1.15)	53.0
Medium Natural Grass.	213.3	1.83 ±(1.13)	63.5
Fire Break (<0.15m)	84.8	2.06 ±(0.74)	36.4
Grass Road btn. Cane	62.8	3.37 ±(3.78)	82.3
Sugarcane - cleared	80.1	1.58 ±(0.87)	33.9
Sugarcane (<0.1m)	337.4	1.81 ±(0.98)	24.6
Sugarcane (0.3-0.5m)	384.4	1.85 ±(2.04)	26.2
Sugarcane (0.5-0.8m)	183.8	1.38 ±(1.22)	35.2
Ploughed Land	31.0	1.43 ±(0.66)	22.9
CARLSHAVEN GROUP			
Wattle (>1m)	49.6	0.69 ±(0.55)	52.8
Short Natural Grass.	443.4	1.41 ±(1.22)	66.3
Med. Natural Grass.	143.4	1.56 ±(1.04)	42.0
Short Herbland	73.6	1.30 ±(1.30)	84.6
Medium Herbland	45.6	0.47 ±(0.65)	34.1
Mature Banana Plant.	72.1	5.03 ±(6.55)	80.6
Mature Orange Plant.	90.8	1.45 ±(0.85)	58.9

For the Stainbank group, the lowest rate of 1.26 attempts per minute occurred in Wattle forests, while the highest rate of 3.37 was recorded on grass roads between cane fields. There was, however, no significant difference (p>0.05) between mean foraging rates for the Stainbank group in any of the vegetation types listed in Table 4:15. Although mean foraging rates for grasslands and sugar cane were not significantly different (p>0.05), the foraging success rates in grasslands were between 18-39% greater than the success rate in sugarcane fields.

The lowest foraging rate for the Carlshaven group was 0.47 attempts per minute, recorded in medium height herbland. The highest foraging rate, of 5.03 attempts per minute, was recorded in mature banana plantations, which was significantly higher (p<0.05) than the rates in all the other vegetation types listed in Table 4:15, with the exception of short herbland. The differences in foraging rates for the other vegetation types, were not significant (p>0.05). Although there was no significant difference between mean foraging rates in the two grassland categories, foraging success in short natural grassland was 24.3% higher than that recorded in medium grassland. This was also true for the herblands, where foraging success in short herbland was 36.1% higher than in medium herbland.

The proportion of food items in each category, captured in the most commonly utilised vegetation types (Fig. 4:14), gives an indication of the relative abundance of each food type in each vegetation type. For the Stainbank group, sugarcane was the most abundant identified item in the diet when the birds foraged in grasslands. The sugarcane eaten, consisted of pulp left by labourers on grass roads between cane fields. Frogs predominated more in the diet when birds foraged in forests, and constituted approximately the same proportion of the total number of items caught in cane fields and grasslands.

Frogs constituted a greater proportion of food items captured by the Carlshaven group in savannas and were least



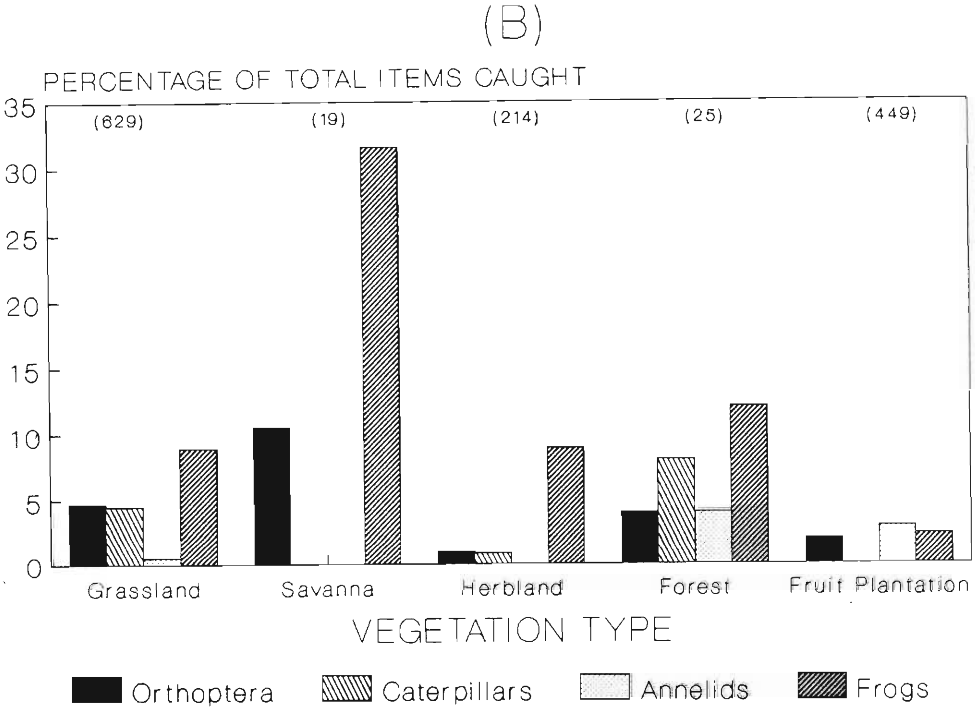


FIGURE 4:14 The percentage of each major food type captured in vegetation types most commonly utilised by the Stainbank (A) and Carlshaven (B) groups.

(Bracketed number indicate total number of food items recorded in each vegetation type) abundant in the diet in fruit plantations. Orthopterans predominated more in the diet when birds foraged in savannas, while caterpillars were more abundant in the diet when birds foraged in forests.

The foraging methods used in each vegetation type, in which more than 40 foraging attempts were recorded, are shown for the Stainbank and Carlshaven groups in Figures 4:15 and 4:16. Picking was the major technique used by the Stainbank group in grasslands and maize lands (Fig.4:15). In forests and cane fields scratching predominated. Digging and probing were seldom utilised in grasslands and maize fields.

Picking was the major technique used by the Carlshaven group in all four vegetation types, particularly in herblands and fruit plantations (Fig. 4:16). Scratching and probing were utilised to a similar degree in grasslands and herblands. Digging was used more frequently in forests and least in fruit plantations.

In tall grassland, the Stainbank group used picking more often than digging, while in short grassland 35% of foraging attempts involved digging (Fig. 4:17). This was not the case for the Carlshaven group, where the percentage of picking decreased from 59.2% to 50.4% with change in grass height from less than 0.15 m to 0.15-0.4 m, but increased to 54.5% in tall grassland (grass height 0.4-0.6 m) (Fig. 4:18). Digging, however, increased from 6% of all foraging attempts in short grassland, to 27.3% in tall grassland. As cane growth increased (Fig. 4:17), picking increased from 27.2% to 38.1% of all foraging attempts, and digging decreased from 21.2% to 13.2%. Scratching attempts remained relatively constant at approximately 45% of all foraging attempts, in all cane fields except those which had been recently cleared. Scratching was used more in banana plantations (31.4%) than

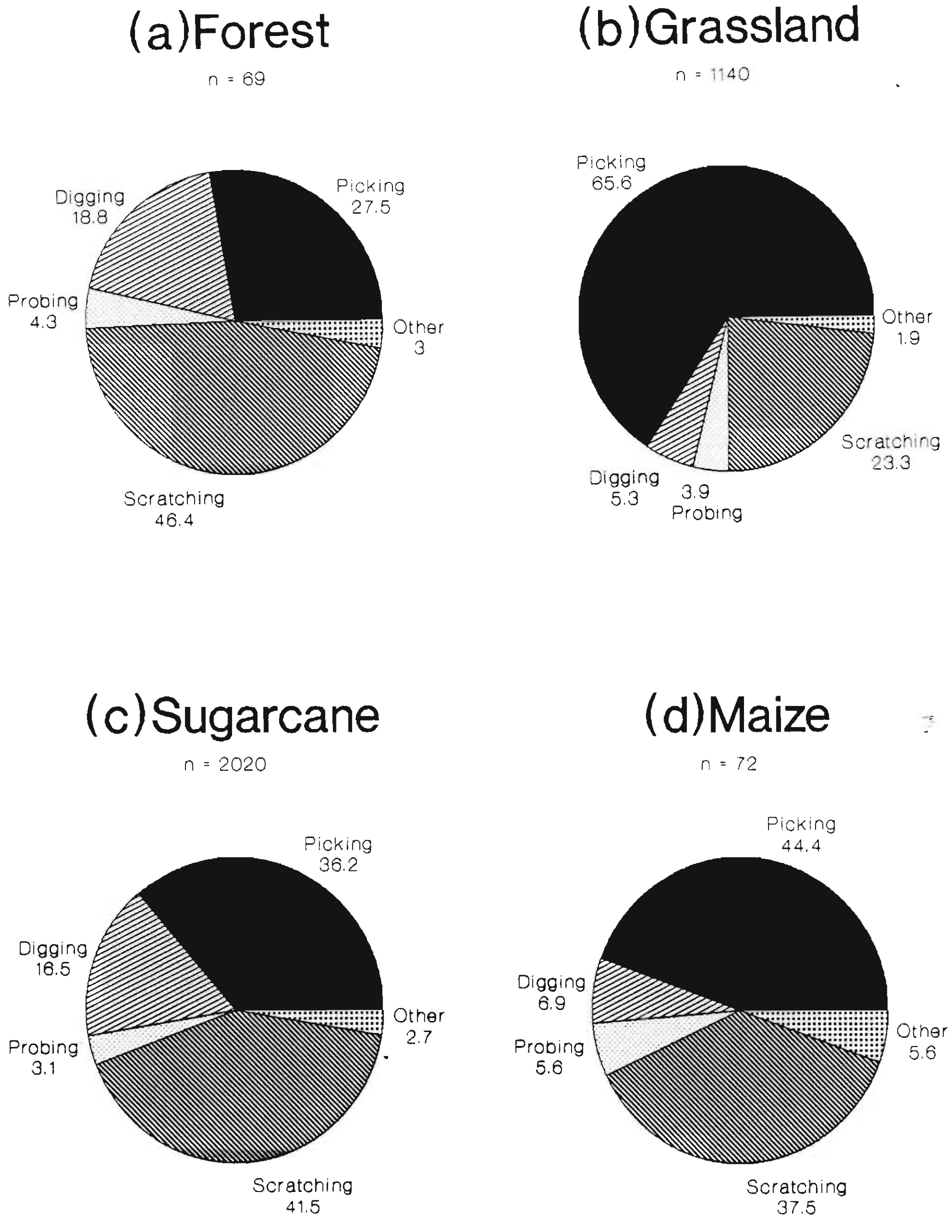


FIGURE 4:15 Stainbank group: The percentage of all foraging attempts in each vegetation type in which more than 40 foraging attempts were recorded, utilising each of the four major foraging methods (see Table 4:3 for other foraging methods).

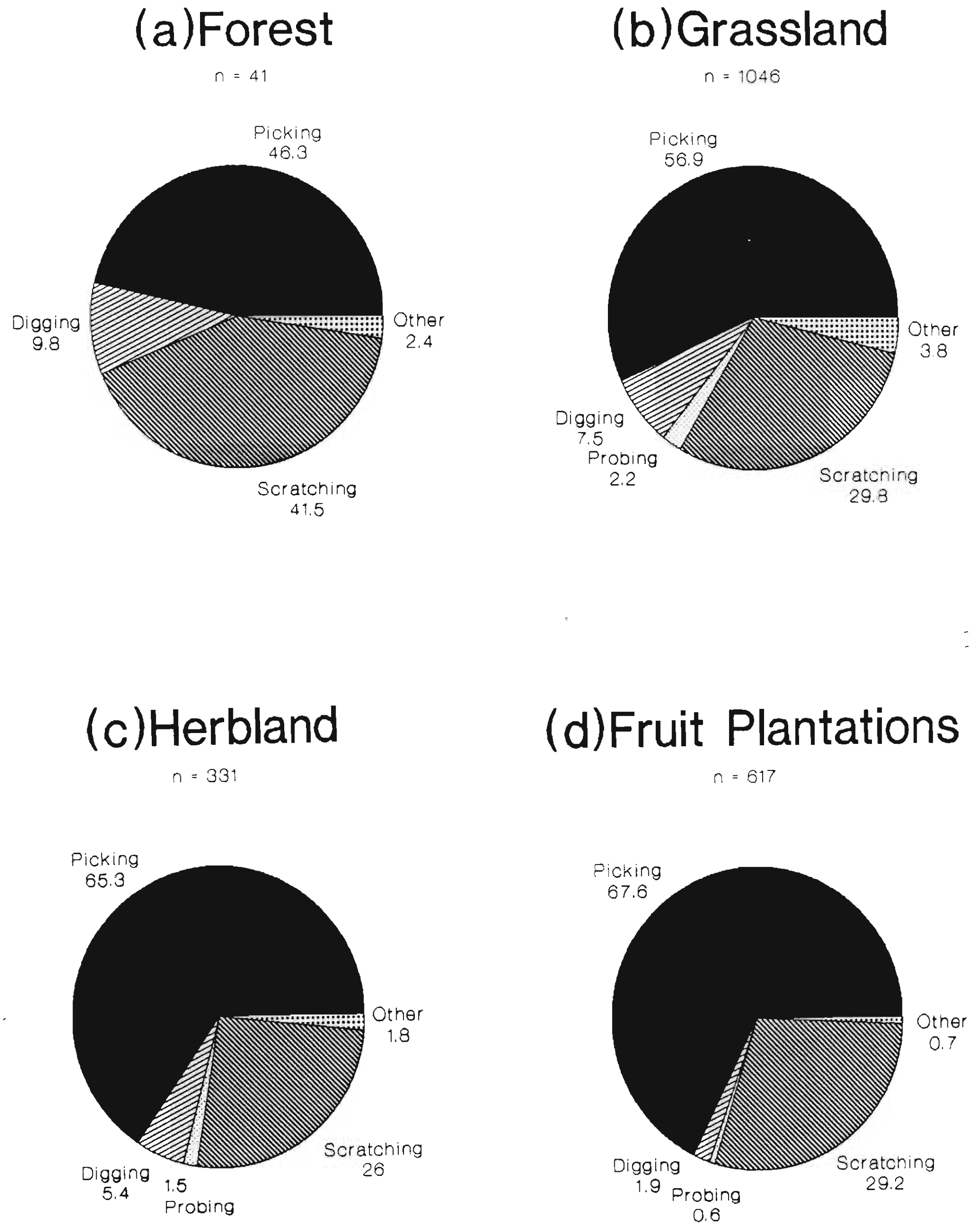


FIGURE 4:16 Carlshaven group: The percentage of all foraging attempts in each vegetation type in which more than 40 foraging attempts were recorded, utilising each of the four major foraging methods. (see Table 4:3 for other foraging methods).

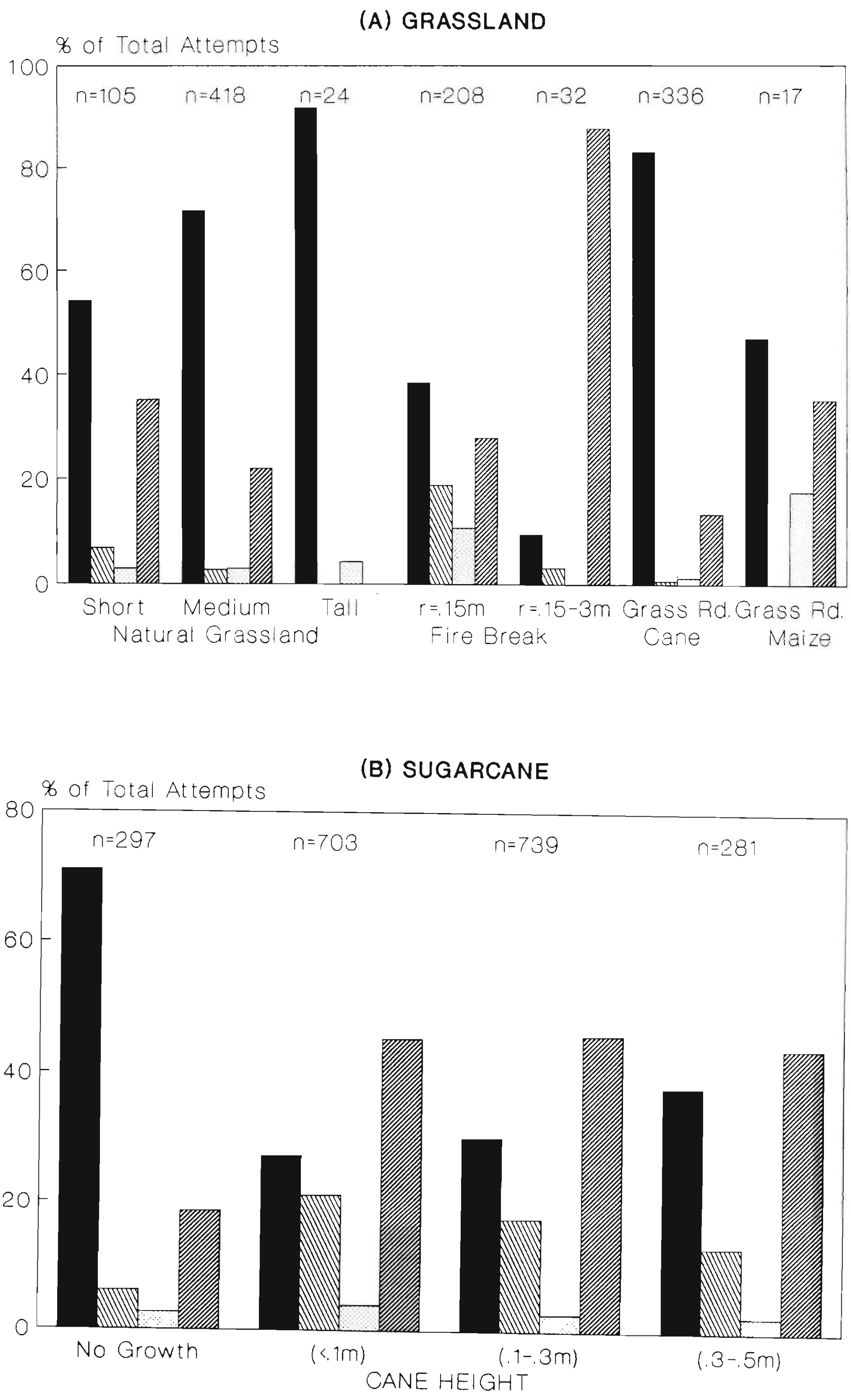


FIGURE 4:17 Stainbank Group: The percentage of foraging attempts utilising each of the four major foraging method for each vegetation category of (A) grassland, (B) sugarcane.

■ Picking ▧ Digging ☐ Probing ▨ Scratching in orange orchards (18.5%), where digging accounted for 5.4% of the foraging attempts (Fig. 4:18).

4:3:5: Foraging success of different individuals

The mean foraging rate and foraging success rate for all foraging attempts by each individual prior to and during nesting are given in Table 4:16. There was no significant difference (p>0.05) between foraging rates of individuals in either group prior to or during nesting. Success rates of the subadults and dominant pair in the Stainbank group, were 9.4-15.6% higher during the nesting period than during the pre-nesting period. The juvenile exhibited a success rate of 7.2% prior to nesting, and 51.2% during the nesting period. During both periods, the dominant male exhibited the highest success rate in the Stainbank group, while subadult 3 was the next most successful. The dominant female and subadult 4 exhibited similar success rates in both periods.

With the exception of subadult 50, the Carlshaven group exhibited success rates 18-39% higher than the Stainbank group prior to nesting, and between 1% and 21% higher during nesting. Unlike the Stainbank group, success rates for the Carlshaven birds were 0.3-7.7% lower during the nesting period compared with the rates prior to nesting. No marked differences were observed between success rates of individuals of the Carlshaven group.

Foraging success rates for each individual in the Stainbank group, for each month (Fig. 4:19), show a marked increase in the success rate of the juvenile at the start of the nesting period in October. The success rates of the two youngest birds, the juvenile and subadult 4, were similar between November and January.

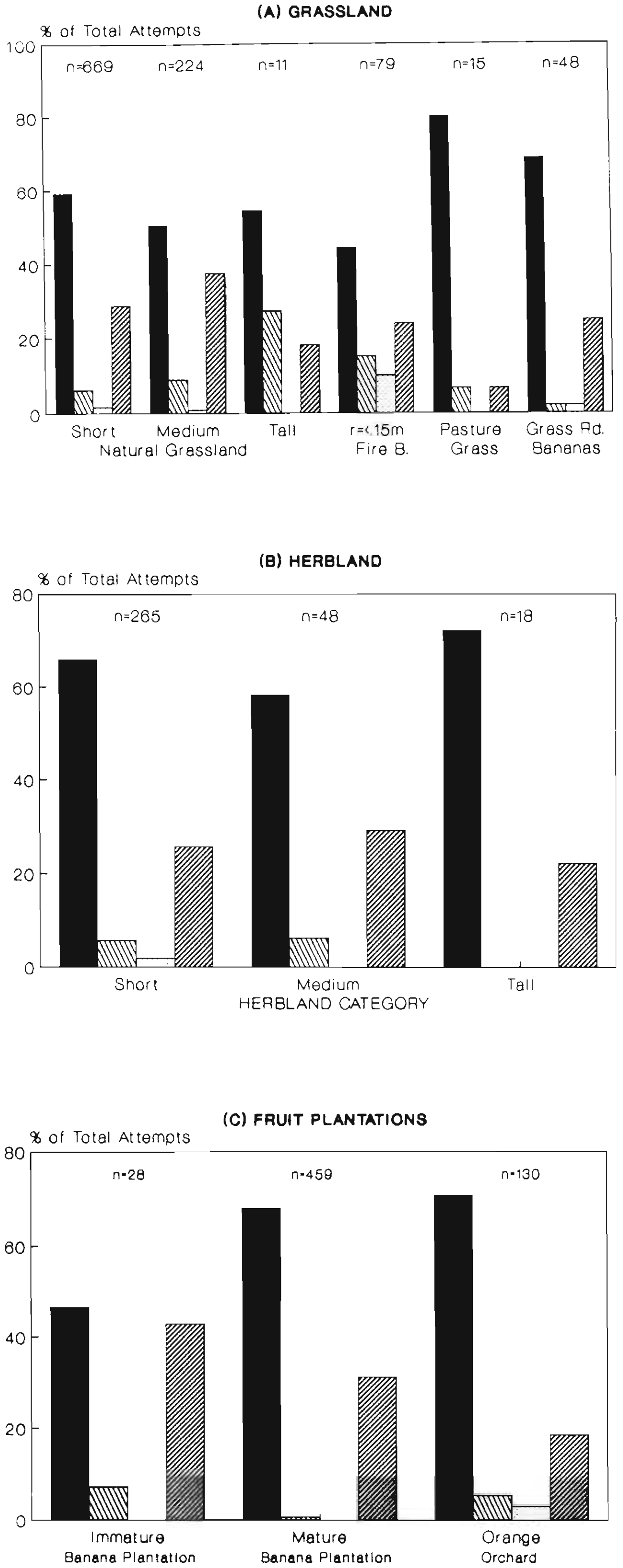


FIGURE 4:18 Carlshaven Group: The percentage of foraging attempts utilising each of the four major foraging method for each vegetation category of (A) grassland, (B) herbland, and (c) Fruit plantation.

■ Picking ▧ Digging ☐ Probing ▨ Scratching

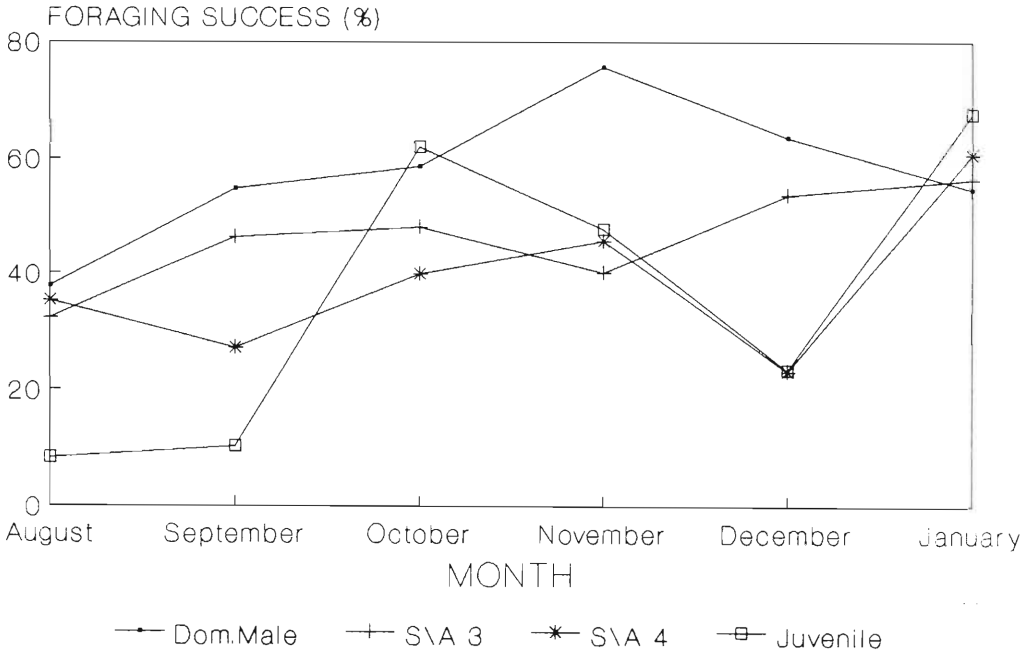


FIGURE 4:19 Foraging success rates for each individual (except the dominant female) in the Stainbank group for each month.

TABLE 4:16 Foraging and success rates for each individual. (B.N.=before nesting, D.N.=during nesting)

BIRD IDENTITY	TOTAL OBSERV. TIME (Min)		MEAN FORAGING RATE (FOR.ATTEMPTS PER MIN. ± (SD))		FORAGING SUCCESS %	
	B.N.	D.N.	B.N.	D.N.	B.N.	D.N.
STAINBANK						
Dom.Male	178.5	196.5	1.89 (1.46)	1.36 (1.44)	45.5	61.1
Dom.Female	201.6	38.8	2.39 (2.74)	1.47 (1.42)	33.3	44.4
Subadult 3	180.8	179.8	2.19 (2.59)	1.81 (1.22)	40.7	50.1
Subadult 4	146.8	187.6	2.14 (1.36)	1.73 (0.99)	31.3	41.7
Juvenile	147.0	151.1	1.64 (0.84)	1.84 (1.23)	7.2	51.2
CARLSHAVEN						
Dom.Male	79.1	587.5	2.01 (1.49)	1.85 (3.28)	69.4	61.7
Dom.Female	62.3	221.7	1.60 (1.06)	1.58 (2.24)	70.5	63.0
Old Female	86.8	32.7	1.68 (0.91)	1.70 (0.77)	63.5	63.2
Subadlt 50	-	42.1	-	2.77 (2.90)	-	55.4

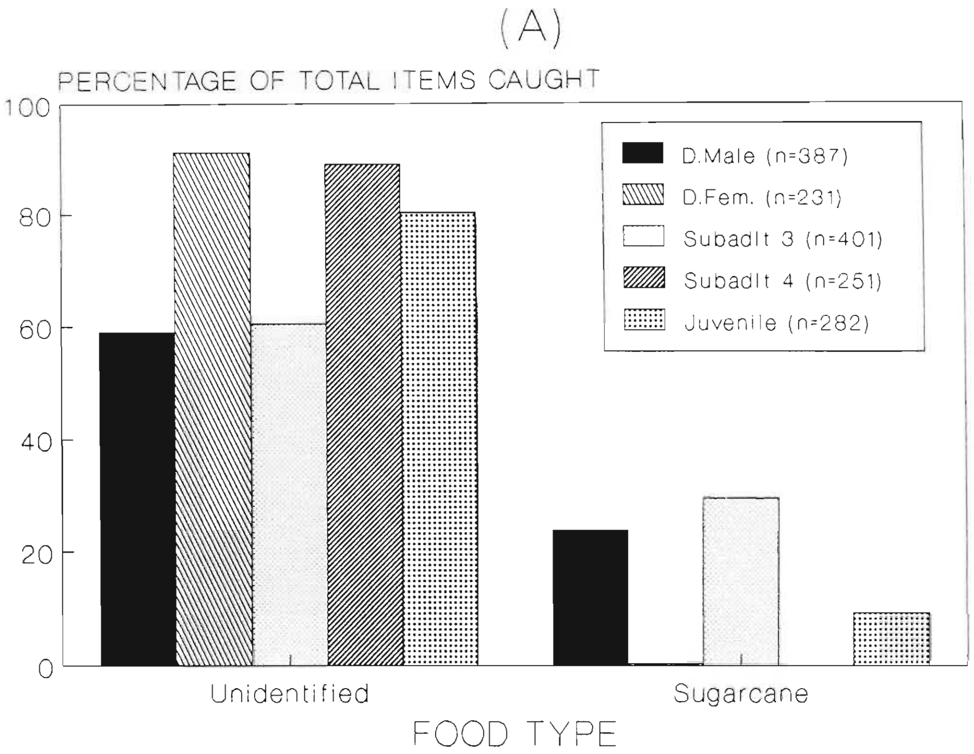
The percentage of total foraging attempts using each of the four major foraging techniques and the success rate of each method, are given for each individual in the Stainbank and Carlshaven groups in Tables 4:17 and 4:18. Each technique was utilised in approximately the same percentage of total foraging attempts by each individual in the Stainbank group (Table 4:17), with the exception of the juvenile who used digging to a lesser extent. While the juvenile was as successful as the other birds in picking, success rates for digging, scratching, and probing were 5.2-26.4% lower than the other birds in the group. The success rates of digging and probing increased with increasing bird age.

The dominant male of the Carlshaven group was 3.6-18.5% less successful than the dominant female for all techniques, particularly when probing or scratching (Table 4:18). Scratching and digging were utilised 11.8% and 4.3% more respectively, by the dominant female than the dominant male.

A comparison of the diet of individuals in the Stainbank group is shown in Figure 4:20. Frogs constituted 6.7% of the total number of food items caught by the dominant male. This was 3.2% higher than for the dominant female and 3% higher than for subadult 3. Frogs constituted only 2.4% and 1.4% of the diets of subadult 4 and the juvenile respectively. Orthopterans constituted 4% of the diet of subadult 4, which was greater than that for any of the other birds in the group. Caterpillars constituted 3.5% and 2.9% of the diets of the juvenile and dominant male respectively.

TABLE 4:17 The relative importance and success rates of the major foraging techniques for each individual in the Stainbank group.

FORAGING METHOD	BIRD IDENTITY	No. OF FORAGING ATTEMPTS	% OF ALL ATTEMPTS	SUCCESS (%)
PICKING	Dom. Male	363	53.5	82.6
	Dom. Female	216	37.5	75.9
	Subadult 3	386	48.0	81.9
	Subadult 4	288	44.5	66.3
	Juvenile	308	46.3	79.5
SCRATCHING	Dom. Male	179	26.4	10.6
	Dom. Female	251	43.6	12.0
	Subadult 3	279	34.7	13.3
	Subadult 4	235	36.3	11.5
	Juvenile	241	36.2	5.4
DIGGING	Dom. Male	99	14.6	28.6
	Dom. Female	82	14.2	22.0
	Subadult 3	114	14.2	17.4
	Subadult 4	85	13.1	18.8
	Juvenile	46	6.9	2.2
PROBING	Dom. Male	27	4.0	25.9
	Dom. Female	16	2.7	18.8
	Subadult 3	23	2.9	17.4
	Subadult 4	24	3.7	12.5
	Juvenile	29	4.4	1.7



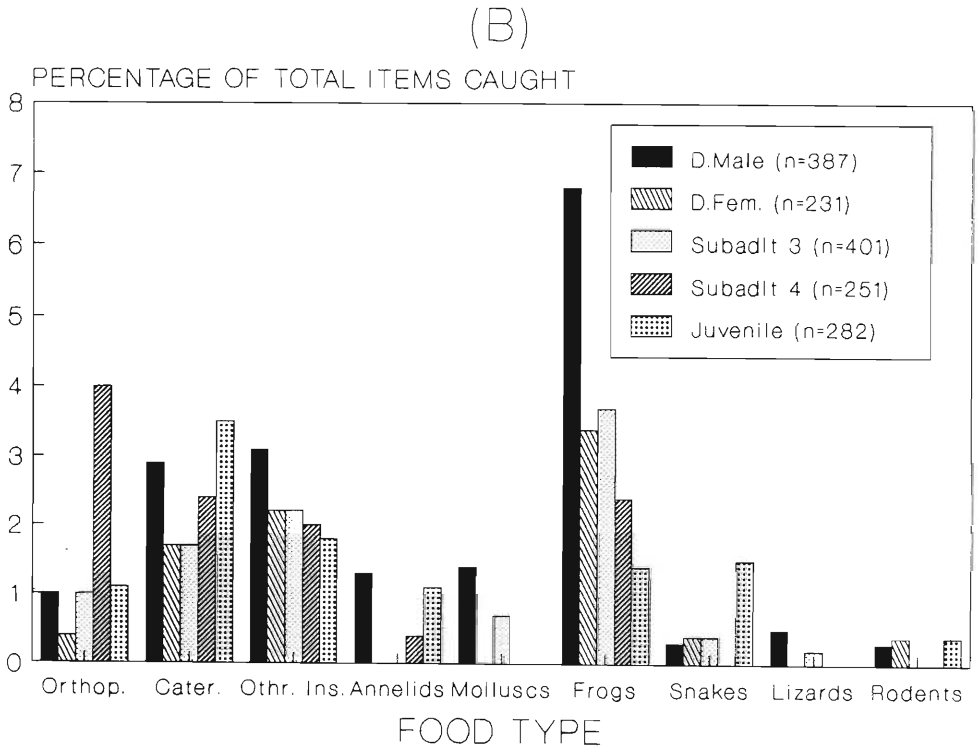


FIGURE 4:20 Dietary composition for each individual of the Stainbank group, based on field observations. ((A) Unidentified food items and sugarcane, (B) All identified animal food items).

TABLE 4:18 The relative importance and success rates of the major foraging techniques for each individual in the Carlshaven group.

FORAGING METHOD	BIRD IDENTITY	No. OF FORAGING ATTEMPTS	% OF ALL ATTEMPTS	SUCCESS (%)
PICKING	Dom. Male	796	65.1	82.8
	Dom. Female	258	48.7	86.4
	Old Female	140	70.7	78.6
	Subadult 50	58	51.3	77.6
SCRATCHING	Dom. Male	321	26.3	20.6
	Dom. Female	202	38.1	39.1
	Old Female	42	21.2	16.7
	Subadult 50	45	39.8	31.1
DIGGING	Dom. Male	56	4.6	32.1
	Dom. Female	47	8.9	36.2
	Old Female	6	3.0	33.3
	Subadult 50	8	7.1	25.0
PROBING	Dom. Male	17	1.4	29.4
	Dom. Female	10	1.9	40.0
	Old Female	5	2.5	40.0
	Subadult 50	-	-	-

More frogs were taken by the Carlshaven birds when compared with the Stainbank group (Table 4:9), but the proportion of frogs in the diet of each of the four birds in the Carlshaven group were similar and ranged from 6.5% for subadult 50 to 9.4% for the dominant female (Fig. 4:21). Orthopterans comprised 8.7% of the diet of the old female, which was two and a half times greater than in either member of the dominant pair. 22.6% of the diet of subadult 50 comprised annelids. This high percentage is, however, misleading since during the short period that foraging of this bird was monitored, it foraged in a patch of rotting bananas in which numerous small annelids were captured.

Since frogs were the most abundant identified food item in the diet of both groups, and constituted a critical food

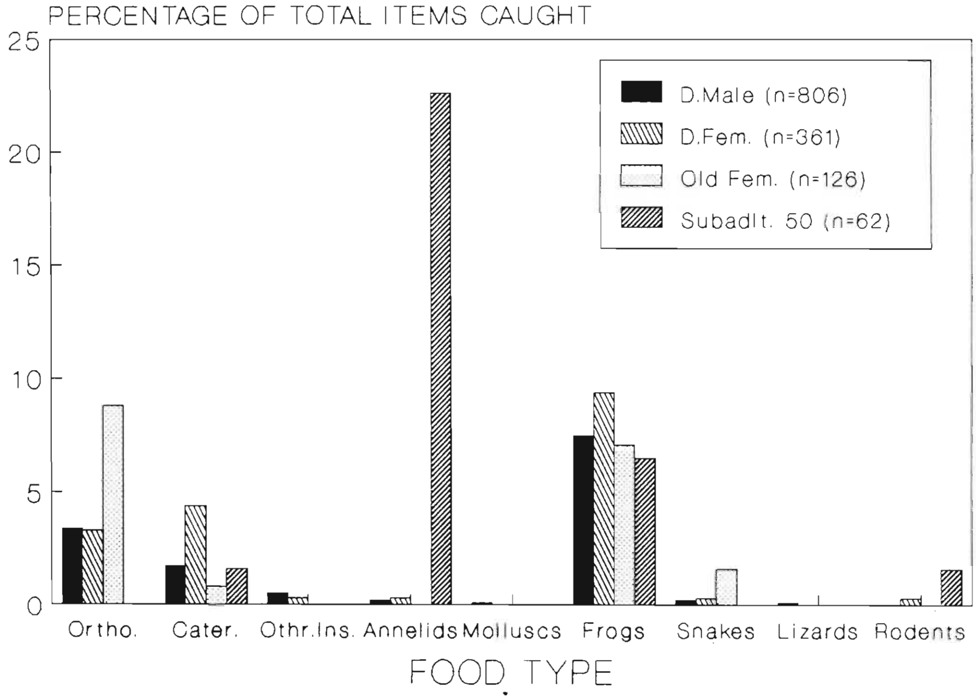


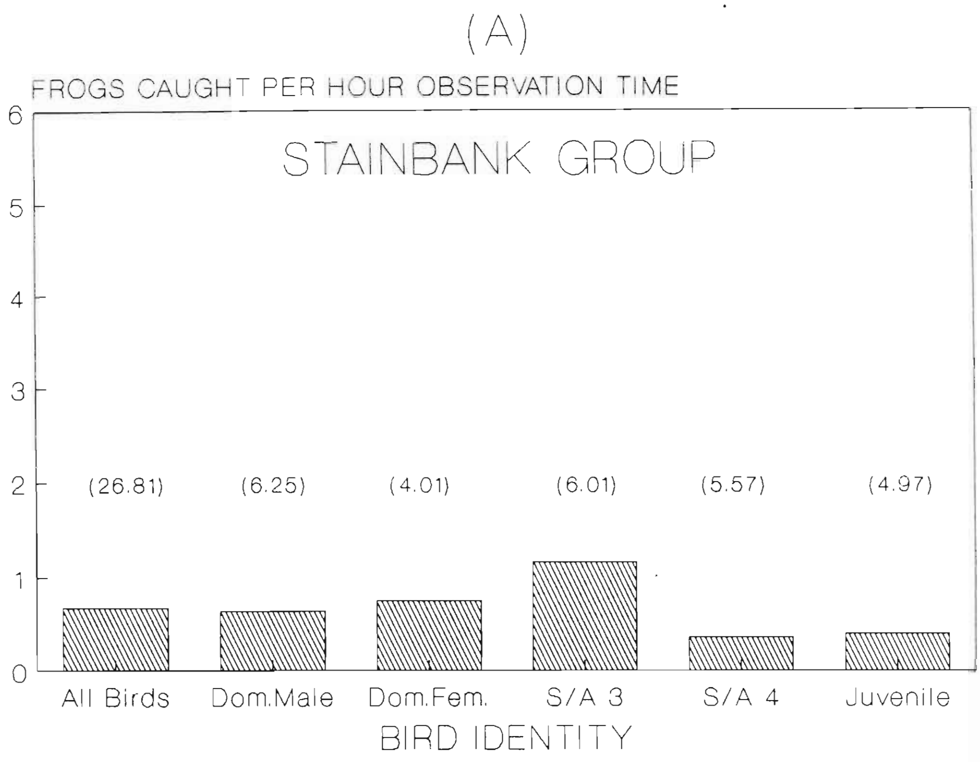
FIGURE 4:21 Dietary composition for each individual of the Carlshaven, based on field observations.

resource for nesting (section 4:3:6), a more detailed analysis of frogs in the diet of individuals was undertaken. Figures 4:22 (A) and (B) show the number of frogs caught per hour, during observation periods only, for each bird of the Stainbank and Carlshaven groups respectively. The birds of the Carlshaven group caught an average 2.51 frogs per hour more than birds of the Stainbank group. Subadult 3 exhibited the highest capture rate in the Stainbank group, of 1.16 per hour, compared with 0.64 by the dominant male and 0.75 by the dominant female (Fig. 4:22 (A)). Subadult 4 and the juvenile, exhibited the lowest capture rates of 0.36 and 0.4 per hour respectively. The dominant pair in the Carlshaven group exhibited capture rates of 2.61 and 3.81 per hour respectively. The old female and subadult 50 captured 4.02 and 5.71 frogs per hour respectively (Fig. 4:22 (B)).

Identified food items were recorded as eaten, lost, fed to another bird in the group, or carried back to the nest. In addition each food item was allocated to one of four size class (Table 4:4). The fate of all items caught by the Stainbank and Carlshaven groups, prior to and during nesting are given in Table 4:19.

TABLE 4:19 The fate of food items of different size classes captured by the birds of the Stainbank and Carlshaven group prior to and during nesting.

GROUP ID	PERIOD	SIZE CLASS + (sample size)	% OF FOOD ITEMS EATEN	LOST	GIVEN AWAY	CARR. TO NEST
STAIN.	Before Nesting	0-2cm (717)	99.4	0.1	0.4	-
		2-5cm (30)	66.7	6.7	26.7	-
		5-10cm (41)	73.2	2.4	24.4	-
		> 10cm (0)	-	-	-	-
CARLS.	Before Nesting	0-2cm (240)	99.6	-	0.4	-
		2-5cm (17)	94.2	5.9	-	-
		5-10cm (11)	81.8	-	18.2	-
		> 10cm (1)	100.0	-	-	-
STAIN.	During Nesting	0-2cm (611)	99.0	0.7	0.2	0.2
		2-5cm (84)	70.2	4.8	1.2	23.8
		5-10cm (49)	59.2	2.0	2.0	36.7
		> 10cm (10)	70.0	-	10.0	20.0
CARLS.	During Nesting	0-2cm (878)	98.4	1.1	0.3	0.1
		2-5cm (127)	55.2	1.6	5.5	37.8
		5-10cm (80)	50.0	2.5	3.8	43.8
		> 10cm (3)	33.3	-	-	66.7



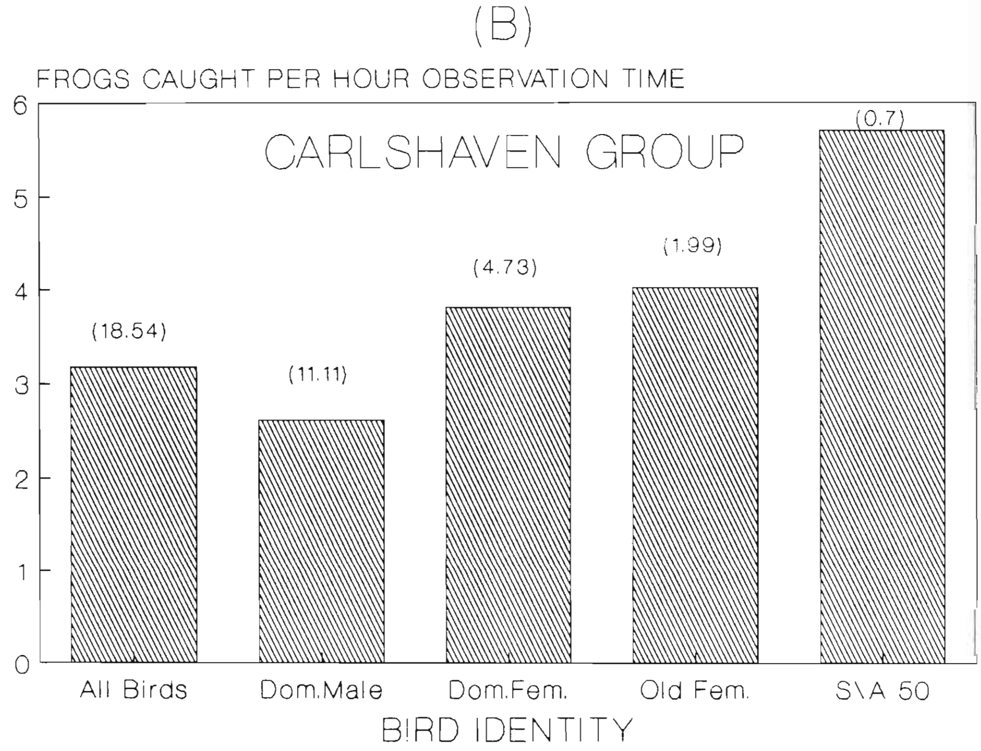


FIGURE 4:22 Rate at which frogs were caught during observation periods by each individual in the Stainbank (A) and Carlshaven (B) groups.

(Bracketed numbers represent total number of focus hours)

For both groups, over 98% of food items less than 2 cm in length were eaten, regardless of the time of year. 24.4-26.7% of items greater than 2 cm in length, captured by the Stainbank group were fed to other individuals in the group, of which 94.4% went to the juvenile. Only 2 items were fed to other individuals in the Carlshaven group. During nesting, 20-36.7% of food items greater than 2 cm in length, captured by the Stainbank group, were carried back to the nest, while 37.8-66.7% of items greater than 2 cm in length were carried back to the nest by the Carlshaven group.

Figures 4:23 to 4:26 show the fate of food items of different sizes captured by each individual in the Stainbank and Carlshaven groups prior to and during nesting. For these analyses, size classes 5-10 cm and > 10 cm were grouped together as the sample size for items >10 cm was insufficient for individuals. Table 4:20 shows the percentage of food items in each size class, that were fed to other individuals by each bird, prior to nesting. With the exception of one food item given away by subadult 3, only the dominant pair were involved in feeding the juvenile. The dominant male gave away just over half, and the dominant female between 14.3% and 33.3%, of food items greater than 2 cm in length. Although there was no juvenile in the Carlshaven group, the old female gave away 25% of food items greater than 5 cm in length to the young female.

Table 4:21 shows the percentage of food items, in each size class, carried to the nest by each individual during the nesting period. All five birds in the Stainbank group carried food to the nest, with the dominant pair carrying back a greater proportion of large food items. The juvenile carried back between 7.7% and 10% of items greater than 2 cm in length, but as will be shown in section 4:3:6, never actually returned to the nest with food during the observation period. Only the dominant pair in the Carlshaven group

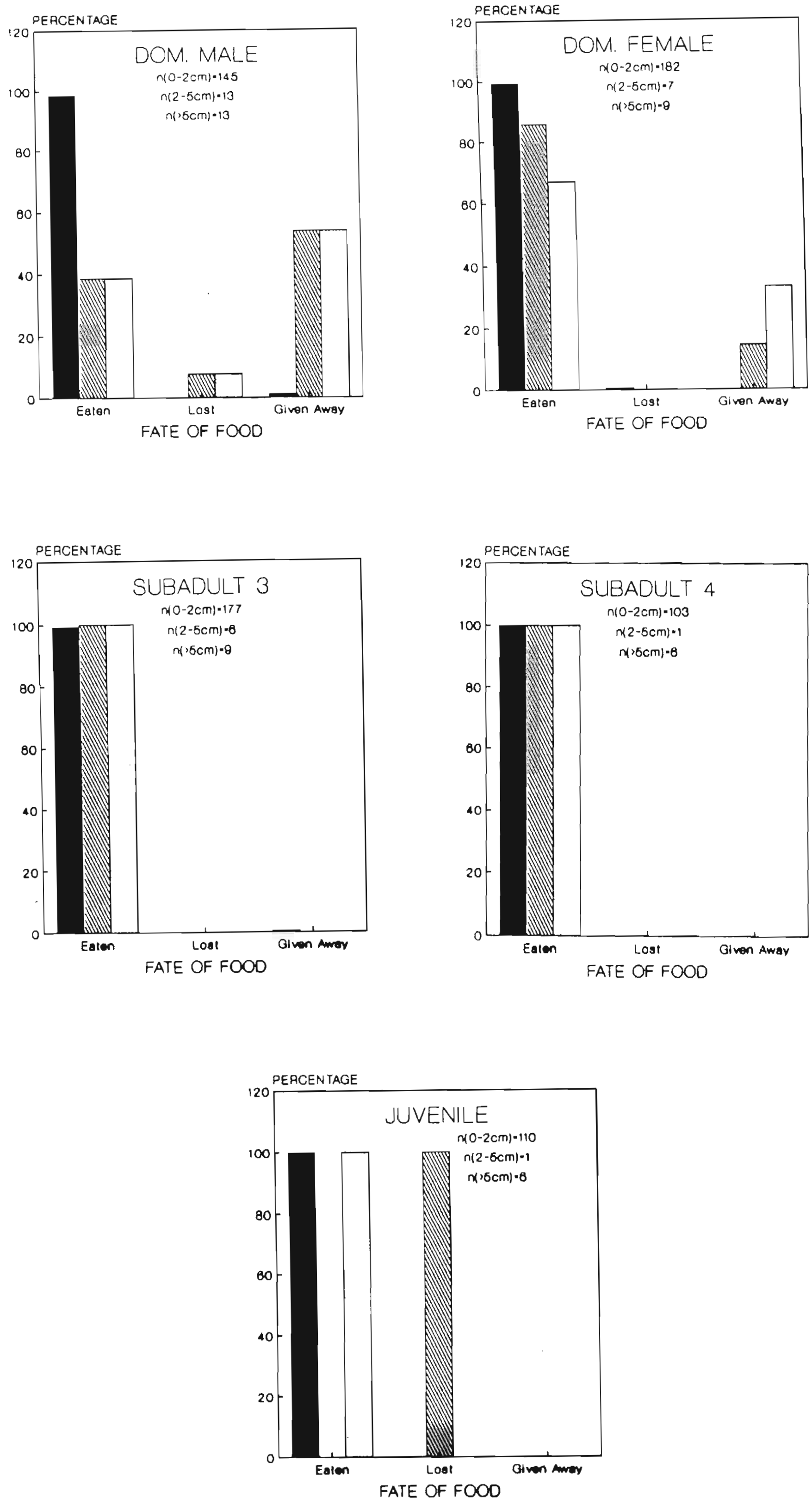


FIGURE 4:23 The fate of food items captured by individuals in the Stainbank group prior to nesting. (Size class index;)

■ 0-2cm ▨ 2-5cm ☐ >5cm

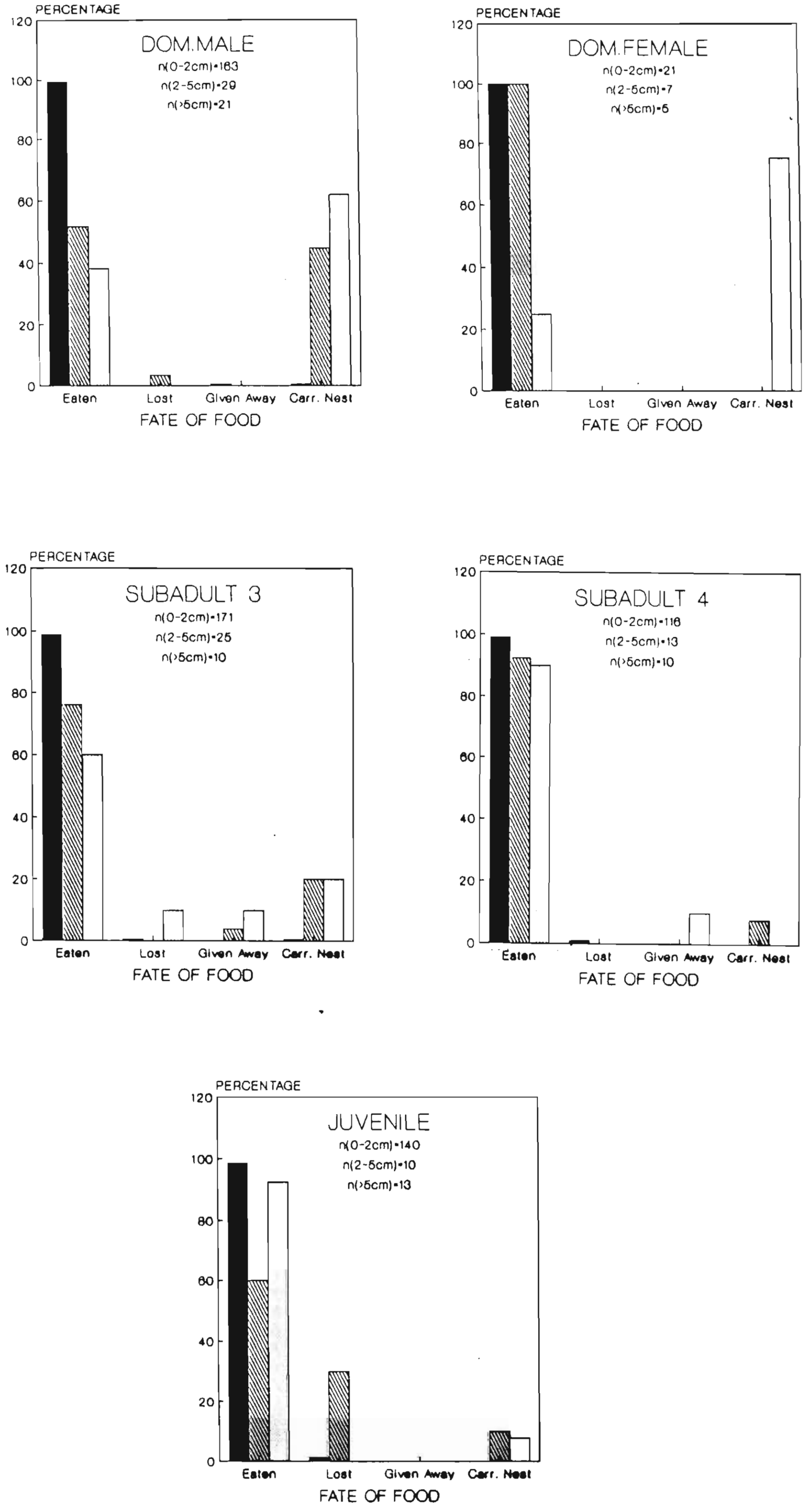


FIGURE 4:24 The fate of food items captured by individuals in the Stainbank group during nesting. (Size Class Index;)

■ 0-2cm ▨ 2-5cm ░ >5cm

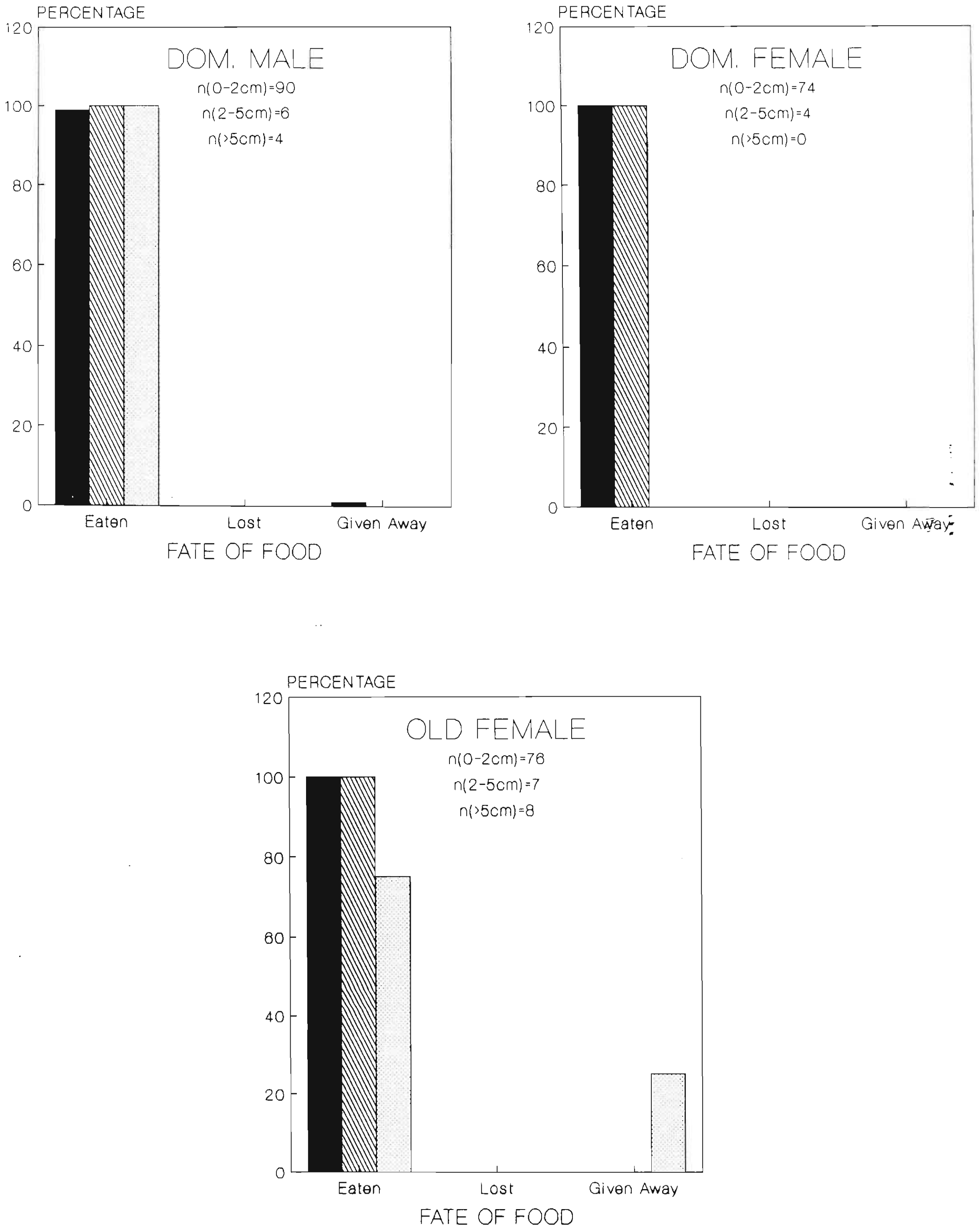


FIGURE 4:25 The fate of food items captured by individuals in the Carlshaven group prior to nesting. (Size Class Index;)

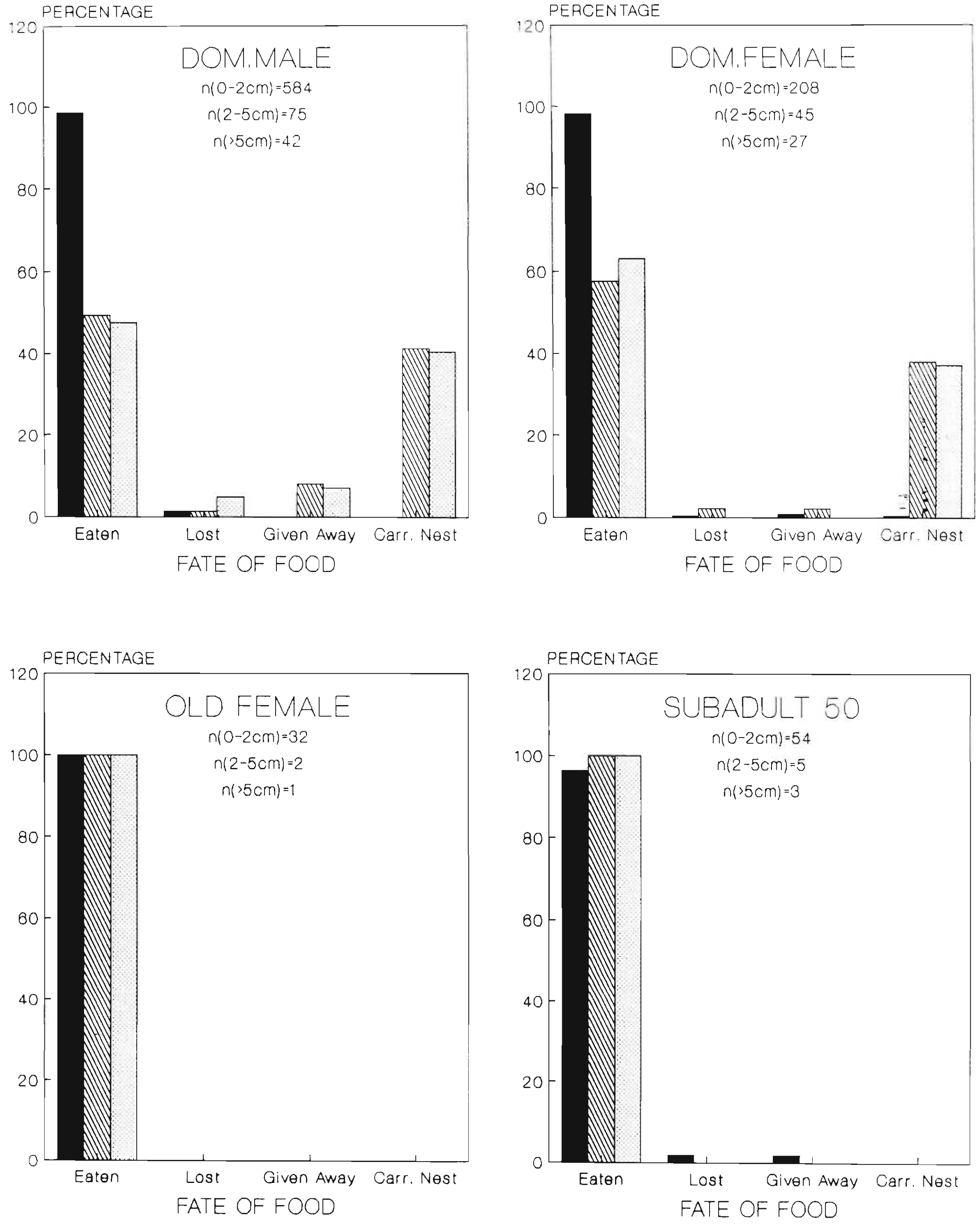


FIGURE 4:26 The fate of food items captured by individuals in the Carlshaven group during nesting. (Size Class Index;)

■ 0-2cm ▨ 2-5cm ☐ >5cm

TABLE 4:20 Percentage of food items of different sizes captured prior to nesting by each individual and fed to other birds.

BIRD IDENTITY	% GIVEN AWAY IN EACH SIZE CLASS + (n)		
	0-2 cm	2-5 cm	> 5 cm
STAINBANK G.			
Dom. Male	1.4% (145)	53.8% (13)	53.8% (13)
Dom. Female	0% (182)	14.3% (7)	33.3% (9)
Subadult 3	0.6% (177)	0% (6)	0% (9)
Subadult 4	0% (103)	0% (1)	0% (6)
Juvenile	0% (110)	0% (1)	0% (6)
CARLSHAVEN G.			
Dom. Male	1.1% (90)	0% (6)	0% (4)
Dom. Female	0% (74)	0% (4)	-
Old Female	0% (76)	0% (7)	25% (8)

TABLE 4:21 Percentage of food items of different sizes captured during nesting by each individual, that were carried to the nest.

BIRD IDENTITY	% CARRIED TO NEST IN EACH SIZE CLASS +(n)		
	0-2 cm	2-5 cm	> 5 cm
STAINBANK G.			
Dom. Male	0.6% (163)	44.8% (29)	61.9% (21)
Dom.Female	0% (21)	0% (7)	80.0% (5)
Subadult 3	0.6% (171)	20.0% (25)	20.0% (10)
Subadult 4	0% (116)	7.7% (13)	0% (10)
Juvenile	0% (140)	10.0% (10)	7.7% (13)
CARLSHAVEN G.			
Dom. Male	0% (584)	41.3% (75)	40.5% (42)
Dom. Female	0.4% (208)	37.8% (45)	37.0% (27)
Old Female	0% (32)	0% (2)	0% (1)
Subadult 50	0% (54)	0% (5)	0% (3)

carried larger food items back to the nest.

4:3:6: Nest activities

Table 4:22 timetables the nesting events in the Stainbank and Carlshaven nests. Approximate chick hatching dates were determined, based on estimated nestling age on the 28th November, as detailed in section 4:2:2.

The number of recorded nest visits and the number of bundles of food and nesting material delivered to the nest by each individual of both groups is shown in Table 4:23.

TABLE 4:22 Timetable of nesting events (S\G=Stainbank group
C\G=Carlshaven group)

NESTING EVENT	DATE (Day\Month)		NESTLING AGE (weeks)	
	S\G	C\G	S\G	C\G
Female stayed in nest for first time	±1\10	±25\09	N\A	N\A
Chick hatched	±14\11	±1\11	0	0
Female left the nest & foraged with the rest of the group	±14\12	±2\12	4	4
Fledgling left the nest	6\02	±25\01	12	12

The dominant male of the Stainbank group visited the nest on 88.1% of group visits, 50% more than subadult 3. Once the female left the nest, she visited the nestling as often as the dominant male. Subadult 4 and the juvenile only visited the nest on 14.3% and 4.8% of group visits respectively. The dominant male provided 55.4% of food returned to the nest over the entire observation period. The dominant female provided 35% of food bundles during the late nesting period (detailed later). Subadult 3 was the only non-breeding bird in the group to deliver food on more than 25% of group

TABLE 4:23 Number of recorded nest visits and the number of bundles of food and nesting material delivered to the nest by each individual. (* indicates the females contribution over the whole period, and ** her contribution once she left the nest.)

BIRD IDENTITY	No. NEST VISITS		No. BUNDLES WITH FOOD		No. BUNDLES WITH NEST MAT.	
	No.	% of tot.	No.	% of tot.	No.	% of tot.
STAINBANK G.						
Dom. Male	37	88.1%	31	55.4%	14	60.9%
Dom. Female *	12	28.6%	10	17.9%	4	17.4%
**	12	85.7	10	34.5	4	57.1%
Subadult 3	16	38.1%	12	21.4%	2	8.7%
Subadult 4	6	14.3%	2	3.6%	1	4.3%
Juvenile	2	4.8%	0	-	1	4.3%
CARLSHAVEN G.						
Dom. Male	31	79.5%	23	60.5%	11	61.1%
Dom. Female *	19	48.7%	15	39.5%	7	38.9%
**	14	100.0%	10	47.6%	5	71.4%
Old Female	0	-	0	-	0	-
Subadult 50	0	-	0	-	0	-

visits, while the juvenile never brought food to the nest. 78.3% of bundles containing nesting material were delivered by the breeding pair, with the male delivering 60.9%.

Only the dominant pair of the Carlshaven group returned to the nest with food. The dominant male provided 60.5% of the total number of food bundles delivered. Once the female left the nest, she provided 47.6% of food bundles. The old female and subadult 50 never visited the nest.

Identification of all food items brought to the nest was not always possible, since they were carried in tight bundles. Figure 4:27 shows the percentage of identified food items in each food class. Frogs were the most abundant food item returned to both nests, constituting 68% of the total number of identified food items for the Stainbank group and 80% for the Carlshaven group.

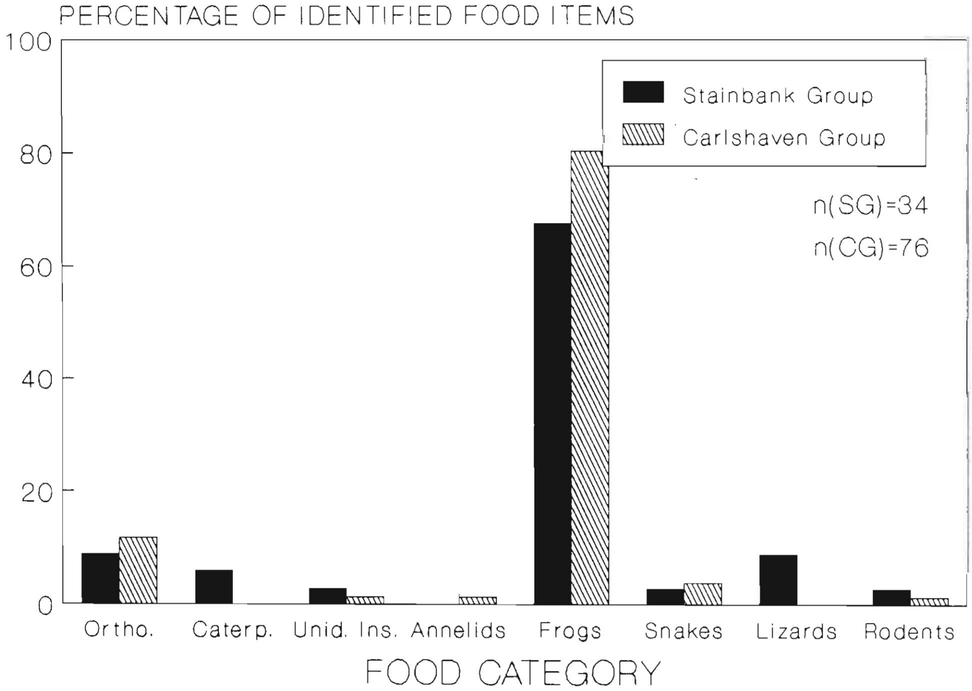


FIGURE 4:27 Composition of identified food items brought to the nests by each group.

The number of nest visits per hour of observation for each hour of the day, which included both contact time and time spent watching the nest, are shown for both groups in Figure 4:28. Both groups visited the nest throughout the day and no clear pattern could be identified.

In order to assess changes in nesting behaviour of individuals and of groups as a whole, with changes in nestling age, data were analysed for the following periods; (i) before hatching, referred to as the incubation period, (ii) when the nestling was 1-2 weeks old, 2-4 weeks old, 4-7 weeks old, and 7-10 weeks old. The periods when the nestling was 1-2 weeks and 2-4 weeks old are collectively referred to as the early nestling phase. During this period both the female and nestling were in the nest. The periods when the nestling was 4-7 weeks old and 7-10 weeks old are collectively referred to as the late nestling phase. During this period only the nestling was in the nest.

The size of food bundles brought to the nest by each group, during each nesting period, varied considerably. Not all bundles were visible long enough to allow an estimation of size. Table 4:24 shows the average bundle area for those brought to each nest during incubation, early nestling phase, and late nestling phase. These data serve as a crude basis for comparison between the two groups. Although the bundles brought to the Carlshaven nest were larger than those carried to the Stainbank nest in all three periods, these differences were not significant ($p>0.05$).

During incubation and early nestling phase, when the females were incubating eggs or attending nestlings, both females left the nest, on average, twice each day to forage and preen. The percentage of total contact time that the females

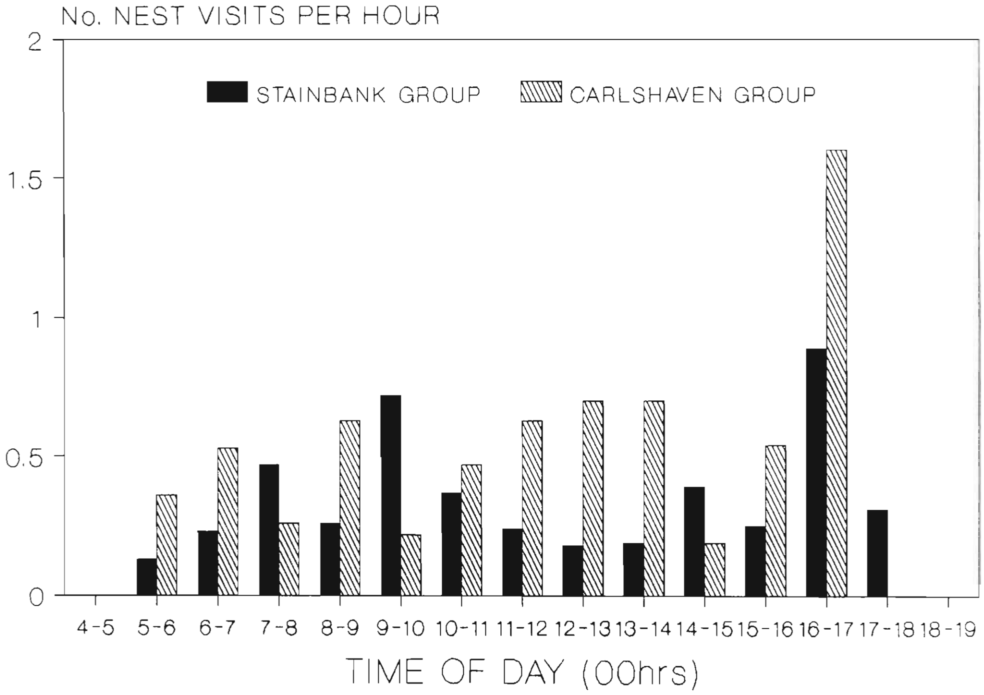


FIGURE 4:28 The relationships between the occurrence of nest visits and the time of day.

TABLE 4:24 Average bundle size delivered to each nest during the incubation period, early nestling phase, and late nestling phase.

NESTING PERIOD	GROUP IDENTITY	No.BUNDLES	AVE.BUNDLE AREA (mm^2)	STANDARD DEVIATION
Incubation	Stainbank	8	3150	3082
	Carlshaven	4	7250	2946
Early Nestling	Stainbank	11	3078	3483
	Carlshaven	15	6305	5271
Late Nestling	Stainbank	18	2037	1498
	Carlshaven	16	5625	5786

spent out of the nest during these periods are shown in Figure 4:29. The Carlshaven female spent 6.5-29.5% more contact time out of the nest than the Stainbank female, particularly prior to the chick hatching. Although the Carlshaven female spent an average of 76.9 minutes (± 137) out of the nest on each occasion, compared to 35.7 minutes (± 23) for the Stainbank female, this difference was not significant ($p>0.05$), largely due to the fact that the Carlshaven female spent 465 minutes out of the nest on one occasion. The Carlshaven female helped provision the nestling during early nestling phase, by bringing food bundles to the nest on 42% of the twelve recorded occasions that she left the nest. The Stainbank female did not bring food to the nest until the late nestling phase, when she ceased her nest attendance.

Changes in nest visiting rates, food delivery rates, and the individuals supplying the food bundles, with changes in nestling age were determined for both groups (Tables 4:25 and 4:26 and Fig. 4:30). The concentration of sampling in the middle of the day (Fig. 4:31), means that the data presented may not accurately represent the rates of nest visiting or food delivery for the entire day. However, as both groups were sampled in a similar way, and therefore subject to a similar error margin, these data were used to compare

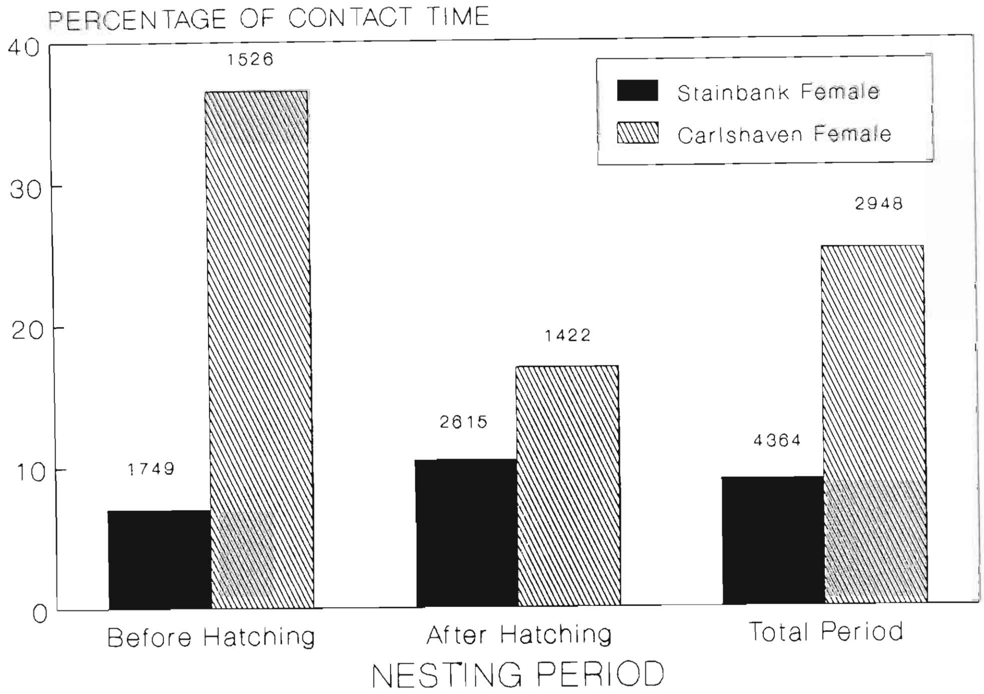


FIGURE 4:29 Percentage of total contact time spent out of the nest by the females during each nesting period.

(Numbers above each bar = total number of contact minutes)

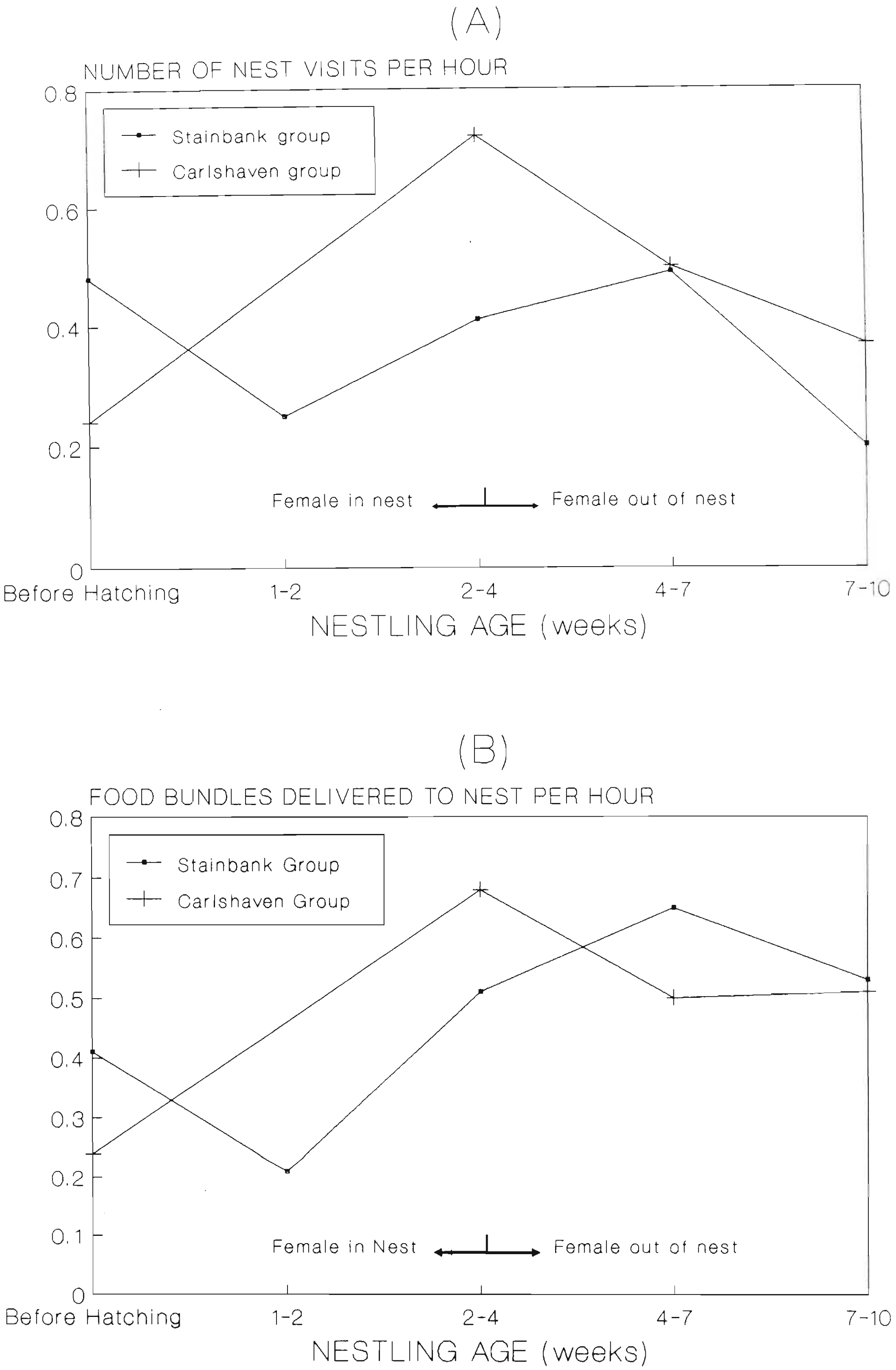
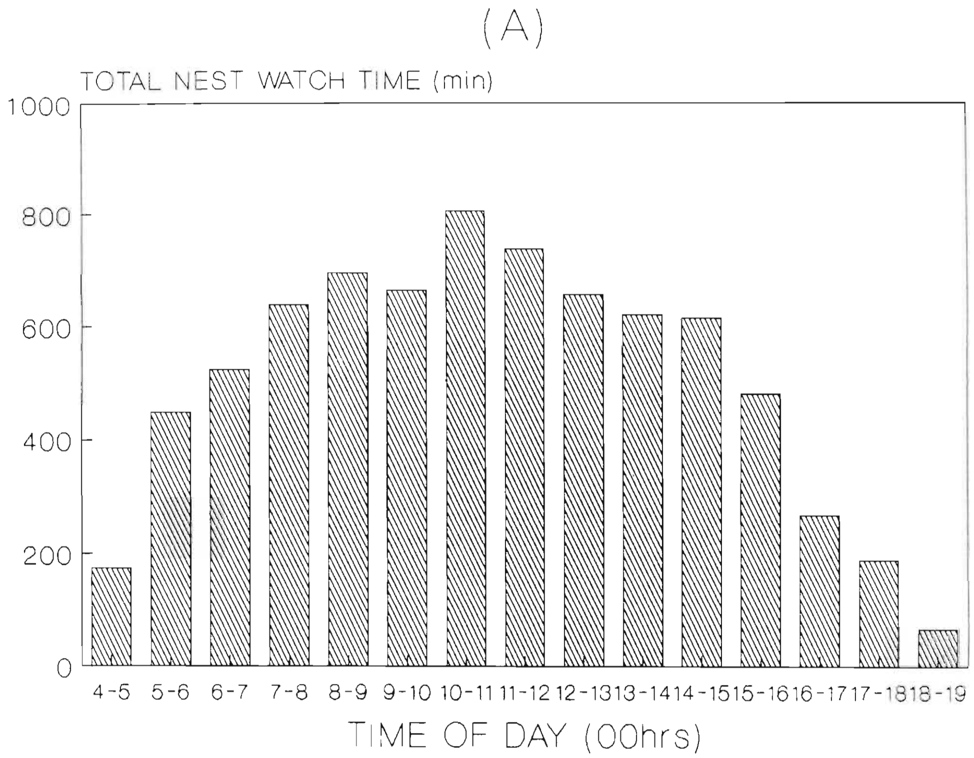


FIGURE 4:30 Changes in nest visiting rate (A), and food bundle delivery rate (B) with changing nestling age.



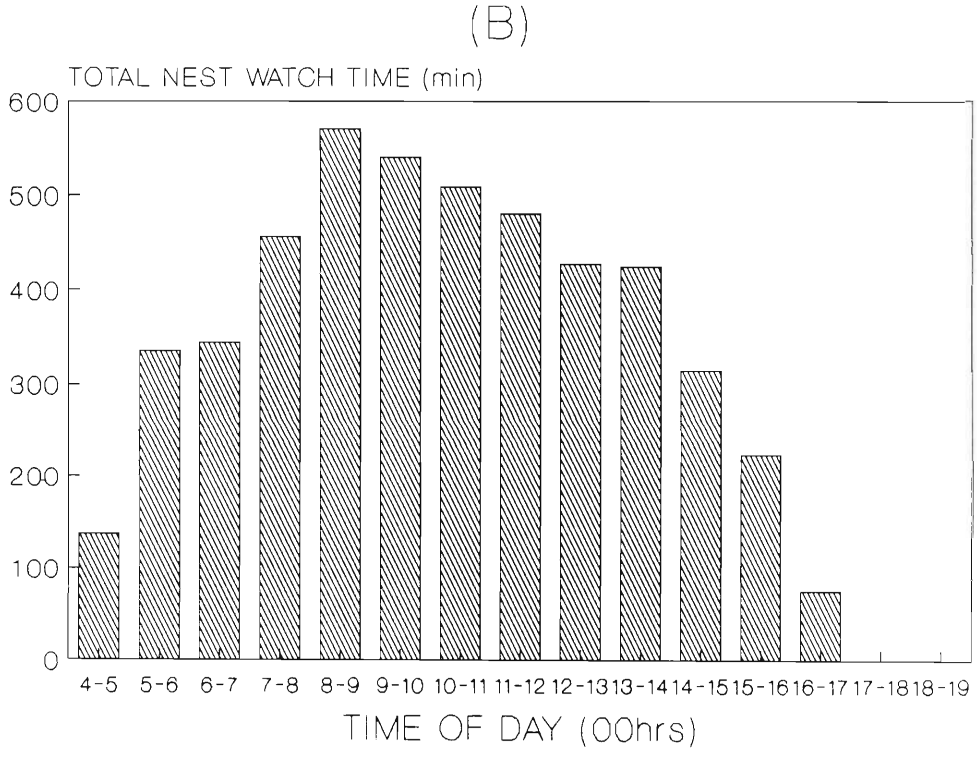


FIGURE 4:31 Duration of nest monitoring in each hour of the day for the Stainbank(A) and Carlshaven(B) groups.

the nest activities of the two groups.

TABLE 4:25 Changes in food demand and the individuals involved in meeting this demand with changes in nestling age: Stainbank group.

NESTLING AGE	DUR. NEST WATCH (hrs.)	VISIT PER HOUR	BUND. PER HOUR	BIRD ID.	No. NEST VIS.	BUND. DELIVERED		
						No.	% OF TOT.	RATE Bundle per hr
Before Hatching	29.2	0.48	0.41	**Dom.Male**	13	10	**83.3**	0.34
				S/A 3	5	2	16.7	0.07
				S/A 4	3	-		
				Juvenile	1	-		
1-2 weeks	23.9	0.25	0.21	Dom.Male	6	4	80.0	0.17
				S/A 3	2	1	10.0	0.04
2-4 weeks	19.7	0.41	0.51	**Dom.Male**	8	7	70.0	**0.35**
				S/A 3	2	2	20.0	0.10
				S/A 4	1	1	10.0	0.05
				Juvenile	1	-		
4-7 weeks	12.3	0.49	**0.65**	Dom.Male	3	3	37.5	0.24
				Dom.Fem.	6	5	62.5	**0.41**
7-10weeks	39.8	0.20	0.53	Dom.Male	7	7	33.3	0.18
				Dom.Fem.	5	5	23.8	0.13
				S/A 3	7	7	**33.3**	**0.18**
				S/A 4	2	1	4.8	0.03
				Unknown	1	1	4.8	

The visiting rate of 0.48 visits per hour for the Stainbank group prior to hatching was 95% greater than the rate in the first two weeks following hatching (Table 4:25). Visiting rate increased to 0.41 when the nestling was 2-4 weeks old and peaked at 0.49 at 4-7 weeks of age. During the final nesting period the rate decreased by 29% to 0.2 visits per hour. A similar pattern was exhibited by the Carlshaven group (Table 4:26), with an initial increase in visiting rate from 0.31 visits per hour prior to hatching, to a peak of 0.72 per hour when the nestling was 2-4 weeks old. Visiting rate then decreased to 0.5 and 0.37 visits per hour when the nestling was 4-7 weeks and 7-10 weeks old respectively. A comparison of visiting rates of the two groups during each nesting period, is shown in Figure 4:30 (A). The incubation period was the only time that the Carlshaven nest was visited at a rate less than the Stainbank nest. Unfortunately no data were collected for the Carlshaven group when the nestling was 1-2 weeks old, but when the nestlings of both nests were 2-4 weeks old, the Carlshaven group visited the nest 0.31 times an hour more than the Stainbank group. Although both groups visited the nest at approximately the same rate when the nestling was 4-7 weeks old, the Carlshaven group again visited at a greater rate during the period when the nestling was 7-10 weeks old.

TABLE 4:26 Changes in food demand and the individuals involved in meeting this demand, with changes in nestling age: Carlshaven group.

NESTLING AGE	DUR. NEST WATCH (hrs.)	VISIT PER HOUR	BUND. PER HOUR	BIRD ID.	No. NEST VIS.	BUND. DELIVERED		
						No.	% OF TOT.	RATE Bundle per hr
Before Hatching	25.4	0.31	0.24	**Dom.Male**	8	6	**100**	0.24
1-2 weeks	NO DATA							
2-4 weeks	23.7	0.72	**0.68**	**Dom.Male**	13	11	68.8	**0.46**
				Dom.Fem.	5	5	31.3	0.21
4-7 weeks	17.8	0.50	0.50	Dom.Male	7	3	33.3	0.17
				Dom.Fem.	9	6	**66.7**	**0.37**
7-10weeks	13.6	0.37	0.51	Dom.Male	3	3	42.9	0.22
				Dom.Fem.	5	4	57.1	0.29

The number of food bundles delivered to the Stainbank nest followed a similar pattern to nest visiting rate, with an initial decrease from 0.41 bundles per hour delivered to the female during incubation, to 0.25 per hour delivered to the female and nestling during the first two weeks following hatching. Delivery rate then increased by 145% to 0.51 per hour when the nestling was 2-4 weeks old and peaked at 0.65 per hour when the nestling was 4-7 weeks old. As with nest visiting rate, the number of food bundles delivered per hour in the final three week period decreased, to 0.53 bundles per hour. The Carlshaven female only received 0.24 bundles of food per hour during the incubation period. The highest food delivery rate of 0.68 bundles per hour occurred when the nestling was 2-4 weeks old. After the female left the nest, when the nestling was 4 weeks old, food delivery rate remained relatively constant at 0.5 bundles per hour. Assuming that the number of food bundles delivered per hour to be an indication of food demand by the individuals in the nest, the Stainbank group experienced the greatest demand for food delivery to the nest only after the female had left. In the Carlshaven group, however, the greatest food demand, in terms of food delivery to the nest, occurred when the nestling was 2-4 weeks old and the female was still in the nest.

A comparison of the food bundles delivered per hour by each group during each nesting period is shown in Figure 4:30 (B). Although visiting rate for the Carlshaven group was 75% greater than for the Stainbank group, during the period when the nestling was 2-4 weeks old, the number of food bundles delivered per hour by the Carlshaven group during this same period was only 33% more than the food delivery rate for the Stainbank group. During the period when the nestling was 4-7 weeks old, the Stainbank group delivered 0.15 more food bundles per hour than the Carlshaven group even though both groups visited the nest at approximately the same rate. In the final three week period, both nestlings received approximately the same number of food bundles per hour, even though the Carlshaven group visited the nest at a rate 85% greater than the Stainbank group.

A comparison of the mean number of food bundles delivered per visit by the birds of each group during each of the nesting periods (Table 4:27) offers an explanation for the differences in visiting rates and food delivery rate discussed above.

TABLE 4:27 Mean number of food bundles delivered per nest visit as the nestling aged.

NESTLING AGE	MEAN No. OF FOOD BUNDLES PER VISIT	
	STAINBANK GROUP Mean + (S.D.)	CARLSHAVEN GROUP Mean + (S.D.)
Before Hatching	0.9 (0.6)	0.8 (0.5)
1-2 weeks	0.8 (0.8)	No Data
2-4 weeks	1.3 (0.7)	0.9 (0.4)
4-7 weeks	1.3 (0.5)	1.0 (0.7)
7-10 weeks	2.6 (0.7)	1.4 (0.5)

The influence of helpers in the Stainbank group, particularly in the later stages of the nesting period, is evidenced by the fact that the mean number of food bundles delivered to the nest at each visit, steadily increased from 0.86 to 2.63 as the nestling grew older. The mean number of food bundles delivered per visit by the Carlshaven group, however, only reached an average of 1.0 after the female had left the nest, with a maximum of 1.4 bundles per visit during the last three week period.

When the Stainbank nestling was 4-7 weeks old and food delivery rate was highest, the female was foraging with the group and delivered 62.5% of food bundles to the nest (Table 4:25). In the two week period prior to this, the dominant male supplied 70% of bundles at a rate of 0.35 bundles per hour, which was twice as many bundles per hour than he delivered when the nestling was 1-2 weeks old. Once the female left the nest, the male only delivered 37.5% of bundles, at a rate of 0.24 bundles per hour. The greatest demand placed on an individual bird, in terms of the number of food bundles delivered per hour, was experienced by the dominant female, with a rate of 0.41 bundles per hour, when the nestling was 4-7 weeks old. Subadult 3 supplied 16% of food bundles prior to hatching, and 20% when the nestling was 2-4 weeks old. However, it did not help provision the nestling again, until it was 7-10 weeks old, at which stage it supplied a third of the food bundles. Subadult 4 brought food for the first time when the nestling was two to four weeks old although it returned to the nest three times during the incubation period. Although the second highest food delivery rate of 0.53 bundles per hour was exhibited when the nestling was 7-10 weeks old, this period showed the lowest delivery rates by the dominant pair, as 38.1% of food bundles were delivered by helpers.

During the period of greatest food demand at the Carlshaven nest (Table 4:26), when the nestling was 2-4 weeks old, the female was still attending the nest. As previously mentioned, however, she did provision the nestling on 42% of the occasions that she left the nest, delivering 31.3% of food bundles during this period. During this peak in food demand, the male delivered 68.8% of food bundles at a rate of 0.46 bundles an hour, a rate 92% higher than during any other period. Once the female left the nest, she supplied 66.7% of the food and the male reduced delivery rate to 0.17 bundles per hour. When the nestling was 7-10 weeks old, the dominant male and female delivered food at approximately the same rate, 0.22 and 0.29 bundles per hour respectively. The dominant female delivered 57.1% of food bundles and the male 42.9%, during this period.

In both groups, the dominant males experienced their greatest demand, in terms of the number of food bundles they delivered to the nest per hour, when the nestlings were 2-4 weeks old. The Carlshaven male delivered at a rate 0.11 bundles per hour greater than the Stainbank male during this period.

Foraging rates and foraging success rates of the dominant males of each group during each nesting period, is shown in Table 4:28. There were no significant differences (p>0.05) in foraging rates for either bird during any period. Although foraging rates of both males did not increase significantly during the period when the nestlings were 2-4 weeks old, they exhibited their greatest foraging success rates during this period (Table 4:28). Both birds exhibited their lowest success rates in the period immediately following the females emergence from the nest, when the nestling was 4-7 weeks old.

TABLE 4:28 Changes in the mean foraging rate and foraging success of the dominant males of both groups, relative to nestling age.

NESTLING AGE	BIRD IDENTITY	TOTAL OBSERV. TIME (Min)	MEAN FORAGING RATE (Attempts Per Min)±(SD)	FORAGING SUCCESS % +(No. For Attempts)
Before Hatching	Dom.Male (S/G)	58.5	1.58 ±(1.87)	58.6% (n=111)
	Dom.Male (C/G)	184.4	1.54 ±(1.15)	50.2% (n=277)
1-2 weeks	Dom.Male (S/G)	25.2	1.55 ±(0.83)	75.6% (n=41)
	Dom.Male (C/G)	NO DATA		
2-4 weeks	**Dom.Male (S/G)**	42.4	**1.27** ±(1.28)	**76.4%** (n=55)
	Dom.Male (C/G)	190.9	**1.36** ±(2.14)	**78.8%** (n=269)
4-7 weeks	Dom.Male (S/G)	16.9	0.77 ±(0.65)	26.3% (n=19)
	Dom.Male (C/G)	147.9	1.20 ±(1.17)	43.8% (n=208)
7-10weeks	Dom.Male (S/G)	53.5	1.48 ±(1.44)	54.7% (n=75)
	Dom.Male (C/G)	64.3	5.00 ±(7.38)	69.6% (n=299)

4:4 DISCUSSION

4:4:1 Activity patterns

B. cafer actively forage for most of the active day (Figs. 4:3 and 4:4). The two study groups spent approximately 97% and 75% of the active day foraging in the periods prior to and during nesting respectively (Fig.4:5). They foraged for approximately 100 minutes longer each day prior to nesting than during nesting, despite a longer day length in summer. A greater proportion of contact time was spent inactive or preening during the nesting period. Kemp and Kemp (1980) noted that *B. cafer* were susceptible to overheating and exhibited a number of behaviour sequences to increase heat loss as ambient temperatures rose above 26^{0}C. These included moving into the shade and reduced foraging activity. Although no comparison was made between ambient temperatures and bird activity, it seem likely that the increase in inactivity and preening, and the decrease in the proportion of time spent foraging during the nesting period, is partly due to increased ambient temperatures. Ambient temperature rose above 26^{0}C on 19% of the days from October to January. The results of Figures 4:5 and 4:6, however, show that the proportion of contact time spent foraging during the middle of the day, when the highest ambient temperatures occurred, was similar to that in the early morning and late afternoon, for the Carlshaven group during nesting. During nesting, the Stainbank group foraged actively for a greater proportion of contact time during the middle of the day. Time spent visiting the nest obviously reduces foraging time during the nesting period.

Based on the marginally higher foraging success rates (Table 4:12), and the greater number of frogs and snakes caught during the nesting period (Fig. 4:8), it is probable that the birds harvested a greater prey mass per hour during the nesting period than prior to nesting. Thus the decreased time spent foraging during nesting may be compensated by a greater prey and hence, energy return while foraging.

Because of the variability of the diet of B. cafer (Table 4:8), foraging is not restricted to a certain time of day by the activity of a prey species, as it is in many raptors (Thiollay and Clobert, 1990).

4:4:2 Diet

While B. cafer are reported to be entirely carnivorous (Kemp and Kemp 1980), this study showed that individuals from the Stainbank group ate 237 pieces of sugarcane pulp on three occasions (Table 4:9). In addition, seven different reports were received from five farms, where birds were observed eating pecan nuts. Birds were also reported to have eaten mielie-meal left by farm labourers, on two occasions. Both pecan nuts and sugarcane are exotic plants and their inclusion in the diet is clearly a learned behaviour. Eating sugarcane masticated by humans, also suggests that they could not utilise this energy and nutrient source unaided. There have been many records of non-animal food from captive birds (Kemp pers. comm.).

Of the identified food items, insects (particularly orthopteran and caterpillars) amphibia, annelids, and reptiles made up the bulk of the total number of food items in the diet (Table 4:9). This compares favourably with records from the Kruger National Park (Kemp and Kemp, 1978). Frogs formed an important constituent of the diet of both groups, comprising 3.8% and 7.9% of the total number of items caught, or 13.9% and 48.6% of the total number of identified prey items, of the Stainbank and Carlshaven groups respectively.

The dangers of interpreting foraging data such as those presented, is that the total energy return per prey item differs for each species caught, and with the size of each item. For example, the energy gained from eating one large frog is considerably greater than that from a single small grasshopper. It is therefore misleading to interpret foraging yield in terms of number of items caught, since the size and species of prey must be taken into consideration. Ideally the energy content per gram of food, and the relationship between body length and body weight for each species should have been calculated. Determination of energy yield would then have been possible and the importance of different prey items assessed. Since these data were not available in the present study, food items in each food category were divided into size classes. In this way a more meaningful interpretation of the foraging data was possible.

The proportion of frogs in each size class were very similar for both the Stainbank and Carlshaven groups (Fig. 4:7). The larger size and hence energy content of frogs, compared to that, for example, of insects, means that frogs comprise a far more important component of the diet than is indicated by the numerical treatment shown in Table 4:9.

The increase in the percentage of frogs in the diet of all individuals from both groups during November and December (Fig.4:8), was important to breeding success, since they formed the most abundant component of the food fed to the nestling and nest bound female (see section 4:4:6). During September and October, sugarcane constituted the most abundantly identified food item in the diet of the Stainbank group. The lack of sugarcane in the diet after October, was due to the fact that the harvesting season for sugarcane ended in mid-November, after which cane pulp, masticated by labourers, was not found.

4:4:3 Foraging behaviour

(i) GROUP FORAGING

Kemp and Kemp (1980) observed that B. cafer operate as close family units and forage by scanning the ground and surrounding vegetation while walking. The two most widely accepted benefits of group foraging are; (i) increased probability of locating or exploiting suitable food resources (Krebs, 1974; Petit and Bildstein, 1987; Valone, 1989), and (ii) decreased vulnerability to predators (Pulliam, 1973; Kenward, 1978; Caraco, 1979; Heinsohn, 1987; Petit and Bildstein 1987; Waite, 1987). Krebs (1974) stated that group foraging can increase the efficiency of capture through the transfer of information concerning the location of patchily distributed food resources. Valone (1989), however, points out that if food items are small and handled quickly, it is difficult for other individuals to be influenced by the foraging success of others in the group, and it is unlikely that group foraging will aid in determining patch quality.

As B. cafer prey are not usually in patches of numerous items in a small area, but are more uniformly spread throughout an area, it seems unlikely that individuals obtain information about food patches from other members of the group. However, on occasions when one of the study birds found patches of sugarcane (Stainbank group) or grasshopper hatchlings (Carlshaven group), other members of the group were attracted to such food patches. As shown for the White Ibis (Eudocimus albus) (Petit and Bildstein, 1987), it seems likely that, the advantages of group foraging vary according to prey type and particularly prey mobility. Advantages of group foraging may also vary from season to season, and with changing habitat type.

Younger individuals may gain the advantage of learning the location of good foraging areas from older birds in the group. As the group generally inhabit the same territory for many years, it seems likely that older individuals may, through experience, have learnt where the best foraging areas occur. In this study the movement patterns of the two study groups were clearly controlled by one of the dominant adults. When either left a given patch or foraging area, the rest of the group followed. Valone (1989) believes that this group behaviour may result in underutilisation of a patch. Charnov and Orians (1973) stated that "when the intake rate in any patch drops to the average rate for the habitat, the animal should move on to another patch". In B. cafer, patch residence times are determined by the dominant individuals in the group. It seems likely that through experience, the dominant birds in the group may be better able to assess optimal patch residence times for each habitat.

Individuals may also derive a benfit from group foraging by increased detection of potential dangers. Pulliam (1973) showed that the protection supplied by a group may allow each individual to spend less time in vigilance and more time foraging. It has been shown, however, that the less time spent in vigilance may not necessarily increase energy intake (Petit and Bildstein, 1987), or alter survival rates (Rabenold and Christensen, 1979). Although B. cafer have few predators in the Natal midlands, individuals often warned the rest of the group of approaching vehicles or people. Heinsohn (1987) noted that permanent groups, in White-winged Coughs (Corcorax melanorhamphus), provided protection for inexperienced juveniles and adolescents, which allowed them to devote more time for foraging. Waite (1987), however, stated that subordinates are more vigilant due to harrasment by older more dominant birds. The lack of aggressive behaviour between individuals in B. cafer groups, make this hypothesis unlikely for this species.

(ii) FORAGING TECHNIQUES

Picking was the major foraging technique utilised by both groups (Table 4:10). The relative use of each technique by the Carlshaven group, is similar to that recorded for birds in the Kruger National Park (Kemp and Kemp, 1978). The Carlshaven group utilised picking in 60.7% and digging, probing, and scratching in 36.8% of foraging attempts, compared to the 62% picking and 38% digging and scratching, recorded for birds in the Kruger National Park (Kemp and Kemp, 1978). The higher percentage of foraging attempts using digging scratching or probing (51.46%) by the Stainbank group was due to the increased utilisation of these methods while foraging in cane fields (Fig.4:15). Foraging success rates for attempts using picking were 50-68% higher than for any other foraging technique (Table 4:10). This is probably due to the fact that it is the only one of the four techniques in which the food item is visible prior to the foraging attempt.

The low success rates of digging, and the added investment in terms of time spent on each digging effort (Table 4:11), prompts the question as to why the birds use this foraging technique at all. The answer probably lies in the foraging returns, in terms of energy content gained per food item caught. 38% of items caught by digging were greater than 5cm in length. 50% of the frogs caught by the Stainbank group and 19.2% by the Carlshaven group, were obtained by digging (Fig. 4:9).

The greater percentage of frogs obtained by digging by the Stainbank group, suggests that there was a greater abundance of frogs on the ground surface in the territory of the Carlshaven group.

4:4:4 Territory and habitat utilisation

Prior to nesting, the birds utilised a greater percentage of their territories and were never observed to return to a roost site used the night before (Figs. 4:11 and 4:12). During this period the foraging behaviour of the group could best be described by a typical average rate maximisation model (see Stephens and Krebs (1986) for review). Average rate maximisation models are a combination of prey models (eg. Charnov and Orians, 1973) and patch models (eg. Charnov, 1976). In both models, the decisions made by the forager are evaluated on the basis of maximising the long-term rate of energy intake (Stephens and Krebs, 1986). Prey models ask what should be ignored and what should be eaten, given a fixed search method, place and pattern (Charnov and Orians, 1973). Charnov (1976) in his patch model, developed the marginal value theorem, which stated that a rate maximising forager will choose the residence time for each patch type so that the marginal rate of gain at the time of leaving the patch, equals the long term average rate of energy intake in the habitat. As previously mentioned, residence times in patches, are determined by the dominant individuals in a B. cafer group.

During nesting, foraging was restricted to within a radius of 4.5 kms and 1.5kms from the nest sites of the Stainbank and Carlshaven groups respectively. Both groups had two known roosts sites during this period, each within a 1 km radius of the nest (Figs. 4:11 and 4:12). They returned to the nest throughout the day with food bundles, and thus their foraging behaviour followed Central Place Foraging theory (Andersson, 1978; Orians and Pearson, 1979; Fagerstrom Moreno and Carlson, 1983; Stephans and Krebs, 1986), and more specifically Multiple Prey Loading (Orians and Pearson, 1979; Tinbergen, 1981; Fagerstrom et al., 1983). Central-place models deal with situations where a forager has to return to a fixed point to consume, store, or deliver prey items captured (Orians and Pearson, 1979; Schoener, 1979). Three central-place models have been proposed. The first model, known as the 'encounter at a distance' model (Schoener, 1979), deals with the case of a forager which hunts from a fixed point, such as a perch. The second and third models are those proposed by Orians and Pearson (1979), which deal with two different kinds of foragers, the single prey loader, and the multiple prey loader. During the nesting period, B. cafer return to the nest throughout the day, with food for the nestling and nest bound female. Food items carried to the nest are collected together in bundles, and thus B. cafer are considered multiple prey loaders. Provisioning the nestling, and the advantages of multiple prey loading, are dealt with in more detail in section 4:4:6.

In the Kruger National Park, B. cafer spend a considerable proportion of the active day foraging on well grazed savannas (Kemp and Kemp, 1980). Habitat requirements outside of the Kruger National Park, and especially in farming areas have, however, never been examined. In this study, habitat utilisation by the two study groups in the Natal midlands was assessed.

As expected for a large ground foraging bird, one of the major criteria influencing habitat selection appears to be short or sparse ground cover. Both study groups seldom utilised grasslands with grass above 0.4m in height, cane fields with cane higher than 0.5m, or Eucalyptus forests where the branches and undergrowth form dense mats, even though these vegetation types were present in the home range of each group (Fig.4:12 & Fig.4:13). The differences in habitat utilisation by the two groups (Tables 4:13 and 4:14) is probably not an indication of different habitat preferences, but rather a difference in available habitat types. For example, the Carlshaven territory had very little sugarcane, and no sugarcane within a 3 km radius of the nest site. In the Stainbank territory however, approximately 30-40% of the area within a 3 km radius of the nest site was under sugarcane. Approximately 20-30% of the area within a 3 km radius of the nest site in the Carlshaven group comprised short and medium height natural grassland. Fruit plantations occurred in the territory of the Carlshaven group, but were absent in the Stainbank territory.

32.75% of contact time with the Stainbank group was in short and medium height natural grasslands (Fig.4:12). Natural grasslands in the Stainbank territory, consisted of uncultivated areas which were either not utilised for farming or used as pastures for cattle. 53.25% of contact time with the Carlshaven group was in natural grasslands. The natural grasslands of the Carlshaven group consisted of both uncultivated areas which were not utilised for agriculture, and overgrazed grasslands. The grass roads between cane, maize and banana fields were also utilised by both groups and, in the case of those between sugarcane fields, offered not only a foraging area, but also a corridor which allowed access to harvested fields, without requiring the birds to fly.

Sugarcane fields were utilised extensively by the Stainbank group (38.85% of contact time), particularly prior to nesting (72.04%) (Table 4:13). Only fields with sugarcane less than 0.5 m tall were utilised (Fig. 4:12). Sugarcane in the study area is usually cut when it is 18-24 months old and takes approximately three to four months following harvesting, for the ratooned cane to grow to 0.5 m in height (Gibbs _pers. comm._[2]). Fields are planted in cycles so that cane is cut throughout the cutting season which is from mid-April to late November, or in a good season as late as mid-January (Gibbs _pers. comm._). These harvesting cycles make 30-40% of sugarcane fields in any one area suitable as foraging areas at any given time. _B. cafer_ therefore experience a dynamic patchwork of foraging areas, all connected by grassed roads which also offer suitable foraging. The increased utilisation of cane 0.3-0.5 m tall during the nesting period, was due to the cutting season ending in late November 1989, and thus the number of fields with cane below 0.3 m tall, decreased as the nesting period progressed.

Forests were utilised for foraging, provided branch growth below 0.5 m was minimal and ground cover short (<.3m) (Tables 4:13 and 4:14). Natural forests and Wattle plantations were utilised by both groups, but neither group foraged in Eucalyptus forests, where the lower branch growth and ground cover was denser than in Wattle plantations (Figs. 4:12 and 4:13). The reason why Pine plantations were not utilised is unknown but may be due to a low biomass of suitable food items. This was not substantiated in this study.

Insufficient data from other farming areas were available to draw any conclusions regarding which vegetation types, and

[2] Anthony Gibbs. P.O. Box 3. Eston. Natal.

particularly which agricultural lands, are suitable for foraging. From the limited data available for the Natal midlands, it is apparent that B. cafer are able to utilise a wide variety of farm lands. The major criteria for successful foraging is short or sparse vegetation cover. These observations are similar to observations that this species spends most of the foraging time in well grazed, short grassed savannas in the Kruger National Park (Kemp and Kemp, 1980).

With the exception of sugarcane pulp found on grassed roads between cane fields, no major food item occurred exclusively in one particular vegetation type (Fig. 4:14). Frogs were caught in all the major vegetation types, but in the Stainbank territory, they were most abundantly caught in forests, and in the Carlshaven territory they were most abundant in the diet when the birds foraged in savannas.

Foraging rates in different vegetation types were not significantly different ($p>0.05$), with the exception of the high foraging rate for the Carlshaven group in medium herbland (Table 4:15). Foraging success rates in grasslands were, however, 18-39% higher than the rate in sugarcane. The highest success rates were exhibited by the Carlshaven group foraging in short herbland (84.6%) and mature Banana plantations 80.6%. The lower foraging success rate in sugarcane fields is primarily due to an increase in scratching and digging. 58% of all foraging attempts in sugarcane employed scratching or digging, compared to only 28.6% and 37.3% for foraging attempts in grasslands by the Stainbank and Carlshaven groups respectively (Figs. 4:15 and 4:16). This difference in the relative use of each foraging technique, is probably the major reason for the difference in the over-all foraging success rates for each group. All individuals in the Carlshaven group had higher foraging success rates than the birds of the Stainbank group, not only for all foraging attempts (Table 4:16), but for each of the four major foraging methods (Table 4:17). These differences in success rates were probably due to differences in food availability and the different percentage of foraging efforts utilising picking, in the different vegetation types.

Digging and scratching were used in 51.3% and 65.2% of foraging attempts made in forests by the Stainbank and Carlshaven groups respectively (Figs. 4:15 and 4:16). The extensive use of scratching in sugarcane fields and forests is due to the amount of dead plant matter on the ground surface. In grasslands where there is less surface litter, prey items are more visible and therefore scratching is utilised to a lesser degree. The reason for the reduced utilisation of digging in fruit plantations (1.9%) is uncertain, but the small percentage of frogs in the diet while foraging in fruit plantations (Fig. 4:14) suggests that frogs are less abundant than elsewhere.

No clear pattern emerged as regards the changes in the relative use of each foraging technique, with changes in the height of the ground cover (Figs. 4:17 and 4:18).

4:4:5 Differences in foraging behaviour of individuals

In order to assess the role that different individuals play in provisioning for the nestling, it is essential to assess whether differences exist in the foraging behaviour and efficiency of individuals of different ages and social status. A comparison of the foraging data for individuals within each study group, revealed that foraging rates of individuals in the two groups were not significantly different ($p>0.05$), prior to or during nesting (Table 4:16). There were, however, differences in the foraging success rates for certain individuals (Tables 4:16-4:18).

The dominant male had the highest foraging success rates in the Stainbank group prior to and during nesting, followed by the oldest of the two subadults (subadult 3) and the dominant female (Table 4:16). Prior to nesting, the juvenile was fed throughout the day by the dominant pair (detailed in section 4:4:6). Although fed by other individuals, the juvenile foraged for itself, at approximately the same rate as the other birds. Foraging success, however, was only 7.2%, and thus markedly lower than that of the rest of the group. These findings are similar to those of Jansen (1990), who investigated the acquisition of foraging skills by Heron Island Silvereyes Zosterops lateralis chlorocephala. He determined that age had no significant effect on strike rate or movement, but did have a significant effect on success rate.

Rabenold and Christensen (1979) found that in the Stripe-backed Wren Campylorhynchus nuchalis, juveniles were the most inefficient foragers, but did not gain foraging experience by watching other birds within the group. Other studies, however, suggest that adult birds may teach juveniles how and where to forage (Alcock, 1969; Ligon, 1970; Woolfenden, 1975; Jansen, 1990). Alcock (1969) conducted experiments on four species of bird, to determine whether young birds learn how to procure hidden food by watching other birds. He noted that by watching an experienced feeder that it could not reach, a young bird learned that food was available in a certain place, but had not paid enough attention to the experienced foragers techniques to repeat it. When the young bird was allowed to approach the experienced feeder, and able to participate in the rewards of its skills, it did learn to uncover the food itself. On fifteen occasions during the pre-nesting period, one of the dominant pair of the Stainbank group was observed to commence digging or scratching and then allow the juvenile to continue the foraging attempt. Although these foraging attempts only resulted in three items being caught, a foraging success rate of 20%, this behaviour is seen as evidence of adult birds teaching foraging skills to young.

From the day the Stainbank female went into the nest for the first time, individuals in the group stopped feeding the juvenile, and it began to forage with approximately the same foraging success as the rest of the birds (51.2%). The increased success rate was almost immediate and throughout the nesting period, the success rates of the two youngest birds in each month were almost identical (Fig.4:19). This rapid transition in achieving high foraging success rate, poses the question of whether the juveniles ability to hunt actually improved dramatically over a short time, whether food availability increased, or whether the necessity for the juvenile to meet its own energy budget prompted a more concerted effort on the part of the juvenile to forage successfully? Farmers in the district reported that once the 1989/90 fledgling had left the nest, the juvenile again received food from the breeding pair, even though the group provisioned for the new fledgling as well.

Ashmole and Tovar (1968), showed that prolonged parental care should be especially common among birds that have small clutches and also use specialised feeding methods which can be perfected only by a prolonged learning process. Foraging success rates for each individual in the Stainbank group, for each of the four major foraging techniques (Table 4:17), showed that subadult 4, and particularly the juvenile, were as successful as older birds when picking, but were less successful when digging and probing. These two foraging methods probably required the most skill and experience, and although the sample size is small, it may be tentatively suggested that these foraging techniques may require time to learn and perfect. The juvenile also used digging less often the other birds.

In the Carlshaven group where all but one of the birds appeared to be fully mature, there were no marked differences between individual foraging success rates, for all foraging attempts (Table 4:16) or for each of the four major foraging techniques (Table 4:18).

A comparison of the composition of the diet of each individual in the Stainbank group, shows that frogs were more abundant in the diet of the dominant male, than any other bird (Fig.4:20). Frogs comprised 6.7% of the food items of the dominant male, compared to 3.5% and 3.7% for the dominant female and subadult 3 respectively. Frogs constituted only 2.4% and 1.4% of the food items of subadult 4 and the juvenile respectively. This correlates with the foraging success rates of digging for each individual (Table 4:17), since 50% of frogs were caught by digging (Fig. 4:9). Thus although foraging rates for each individual in the Stainbank group were not significantly different ($p>0.05$), the older more dominant birds had greater success rates when using more complex foraging methods, such as digging. This resulted in a greater proportion of frogs in the diet. This suggests that older birds harvest a greater total energy content per hour than younger birds. This is supported by the fact that subadult 3, the dominant male, and the dominant female captured 1.16, 0.64, and 0.75 frogs per observation hour respectively, compared to 0.36 and 0.4 frogs per hour captured by subadult 4 and the juvenile (Fig. 4:22).

In the Carlshaven group, the differences in dietary composition of individuals, were not as marked as in the Stainbank group (Fig.4:21). The only obvious differences were an abundance of orthopterans in the diet of the old female, and annelids in the diet of subadult 50. During the limited observation time accumulated with these two individuals, the old female found a patch with numerous orthopteran hatchlings and subadult 50 foraged in rotting bananas where many small annelids were found. These data therefore, may not be representative of the actual dietary composition of these individuals.

The proportion of frogs in the diet of the Carlshaven individuals were similar (Fig. 4:21). The Carlshaven group, however, caught an average 2.51 frogs per observation hour more than the birds of the Stainbank group (Fig. 4:22). The dominant pair of the Carlshaven group exhibited a lower frog capture rate than the old female and subadult 50, but still captured 1.97 and 3.06 frogs per hour more than the dominant male and female of the Stainbank group respectively. As will be discussed in section 4:4:6, this higher capture rate by Carlshaven individuals, played an important role in determining breeding success in this group.

4:4:6 Nesting activities

(i) REARING OF A CHICK TO FLEDGING

One of the major objectives of this study was to assess the role of different group members in provisioning for the nest bound female, nestling, and fledgling. As with all cooperative breeders, breeding in B. cafer is characterised by the presence of helpers at nests of a proportion of groups. The two study groups offer a good comparison of the breeding behaviour in a group with helpers to one without helpers. Here a helper is defined as an individual which "assists in the nesting of an individual other than its mate" (Skutch, 1961), and does not include individuals in the group which did not help directly in the rearing of the chick.

As previously mentioned, the foraging behaviour of B. cafer during the nesting period is described by Central Place Foraging theory (Andersson, 1978; Orians and Pearson, 1979; Fagerstrom et al., 1983; Stephans and Krebs, 1986), and more specifically Multiple Prey Loading (Orians and Pearson, 1979; Tinbergen, 1981; Fagerstrom et al., 1983). Optimization criteria have been used to predict the load that should be expected in different situations for multiple prey loaders (Orians and Pearson, 1979). Predictions of load size, are based on the idea that marginal time required for these animals to take an extra prey item increases with the number of items already loaded (Orians and Pearson, 1979). This decrease in marginal loading rate is not only due to prey depletion, in the case of patchily distributed prey (Cowie and Krebs, 1979), but also because the difficulty in capturing and handling an additional prey item increases with the number of items the predator is already holding (Kramer and Nowell, 1980).

The difficulty of handling a bundle with many small food items, makes it more practical and energetically more efficient to carry fewer larger food items. Not only does this enable a larger food bundle to be carried, and therefore maximises the energetic return with each bundle, but it also enables individuals to forage more efficiently for themselves at the same time. During the nesting period, a percentage of large food items caught by B. cafer individuals, were not eaten by the individual which caught them but carried to the nest (Tables 4:19 and 4:21). Individuals carrying food bundles continued to forage, and simply put the bundle down to capture other food items.

All five birds in the Stainbank group carried food items, although the juvenile never returned to the nest with food. 95% of food items carried to the nest were greater than 2 cm in length. The dominant male and female carried 44.8-75% of food items greater than 2 cm in length to the nest, while subadult 3 carried 20%. Only the dominant pair of the Carlshaven group carried food to the nest. 98.7% of food items carried to the nest were greater than 2 cm in length. The dominant pair of the Carlshaven group carried 37-41.3% of all food items greater than 2 cm in length to the nest (Table 4:21).

Frogs constituted the major component of food bundles carried to the nest in both groups, comprising 68% and 80% of identified food items returned to the Stainbank and Carlshaven nests respectively (Fig. 4:27). While frogs were obviously an important food species in the breeding process of the two study groups in 1989/90, I believe that it was the size of food item rather than the species that was important, and that if other species of comparable size were more abundant than frogs, they would have been more abundant in the food bundles. This argument is supported by a documentary film (Anglo Survival Series, U.K., on tape) on B. cafer in the Tsavo National Park, Kenya, where over 50% of the food brought to two nests were snakes.

It has been shown is some cases, that helpers reduce nestling feeding rate by parent birds (Brown, 1970; Ligon and Ligon, 1979; Wilkinson and Brown, 1984; Austad and Rabenold, 1985; Zack, 1986; Hunter, 1987). Brown (1970), observed that Mexican Jay (Aphelocoma ultramarina) helpers accounted for 47-74% of all feeding visits to the young, while Green Woodhoopoe (Phoeniculus purpureus) helpers supplied as much as 83% of food bundles returned to the nest (Ligon and Ligon, 1979).

During nest observations, the dominant male of the Stainbank group delivered 55.4% of all food bundles delivered to the nest (Table 4:23). Subadult 3 supplied 21.4% of all food bundles, but subadult 4 only supplied 3.6%. The juvenile never returned to the nest with carried food. Thus although the Stainbank group consisted of five individuals, only one of the non-breeding birds can confidently be considered a helper according to Skutch's (1961) definition. Stallcup and Woolfenden (1978) also found that older more dominant Florida Scrub Jay (Aphelocoma coerulescens) helpers contributed considerably more than younger helpers. Zack (1986), observed that the feeding rates of the breeding males in Grey-backed Fiscal Shrikes (Lanius excubitirius), were significantly higher than the feeding rate of all other individuals in the groups.

Neither subadult 50 nor the old female in the Carlshaven group returned to the nest with food, thus the group was without helpers (Table 4:23). The dominant male returned 60.5% of all food bundles during total contact time. The lack of help supplied by subadult 50 was expected as this individual was unrelated to the breeding pair and therefore would gain no inclusive fitness (Hamilton, 1963) from provisioning the nestling.

Before examining in more detail the role of individuals in provisioning the nestling and nest bound female, it is apparent from a comparison of the proportion of food bundles supplied by the dominant birds of both groups, that the presence of helpers reduced the amount of food delivered by the dominant breeding pair. The breeding pair of the Stainbank group, only supplied 75% of all food bundles returned to the nesting during observation periods, while the Carlshaven pair delivered all food bundles.

It has been found that in many cooperatively breeding avian species, help is supplied by all group members, including fledglings from the previous breeding attempt (Brown, 1970; Stallcup and Woolfenden, 1978; Ligon and Ligon, 1979; Austad and Rabenold, 1985; Hunter, 1987). Stallcup and Woolfenden (1978) observed, however, that although first year Florida Scrub Jay helpers made many nest visits, they delivered very little food. Kemp and Kemp (1980) observed two year old B. cafer individuals in the Kruger National Park helping provision a nestling, but note that they had no opportunity to determine the role of a one-year old immature. As previously mentioned, the juvenile of the Stainbank group was never observed to deliver food to the nestling or nest bound female. It is uncertain whether the minimal number of food bundles delivered by subadult 4 is the norm for an individual of that age, or whether the availability of larger food items in the Stainbank territory during the breeding period in 1989/90 was such that a bird of the foraging capabilities of subadult 4 had to consume all items caught in order to meet its own energy budget. The fact that the juvenile carried food items but never returned to the nest with a food bundle, suggests that a one year old bird learns how to provision for the nestling at this stage. This is emphasised by the fact that the juvenile returned to the nest on one occasion with nesting material. This contradicts the statements by Jamieson and Craig (1989), that feeding by helpers is only a "normal automatic response to feed a gaping and calling mouth". Ligon and Stacey (1989) also state that the feeding of nestlings by non-breeding helpers may be derived from a general stimulus response interaction, in which the birds respond to begging calls by nestlings. While, I have suggested that the juvenile learns not to eat all larger food items but rather carry them in a bundle, without the stimulus of a begging nestling, it is possible that the juvenile could hear the begging call without actually returning to the nest, and could therefore be responding to a begging stimulus.

During incubation, the Stainbank female received approximately twice the number of food bundles per hour as the Carlshaven female (Tables 4:25 and 4:26). Although the average size of bundles delivered by the Carlshaven male were larger than those of the Stainbank group, the difference was not significant (Table 4:24). Assuming that both females required a similar amount of food during this period, and assuming from delivery rates that the Stainbank female received a greater amount of food per hour, the question arises as to how the Carlshaven female reacted to a reduced food supply. Figure 4:29 shows that during this period, the Carlshaven female spent 36.5% of total contact time out of the nest foraging with the male, compared to 7% for the Stainbank female. This suggests that the reduced amount of food delivered to the Carlshaven female while she was in the nest, necessitated her foraging for herself for a greater period each day in order to meet her energy budget. Ligon and Ligon (1979), observed that female Green Woodhoopoe belonging to small groups, leave the nest more frequently than females belonging to larger groups. Austad and Rabenold (1985), working on Bicolored Wren (Campylorhynchus nuchalis), noted that greater nest failure in groups without helpers, was more accentuated during incubation than during feeding and post fledging dependency. It is uncertain whether breeding attempts by single pairs of B. cafer fail more often than attempts in groups with helpers. However, the possibility of greater nest failure in unaided pairs occurring as a result of reduced nest attendance by the female during incubation, rather than the inability of a pair to provide sufficient food for the nestling, must be considered.

During incubation, the Carlshaven male supplied 100% of the food bundles delivered to the incubating female, while the Stainbank male received help in provisioning for the female from subadult 3. This bird supplied 16.7% of the food bundles (Table 4:25), which is contrary to helping behaviour in the Mexican Jay (Brown, 1970), Red-cockaded Woodpeckers (Dendrocopos borealis) (Ligon, 1970) and the Florida Scrub Jay (Woolfenden, 1975; Stallcup and Woolfenden, 1978), where helping only occurs after the chick has hatched. Subadult 4 visited the nest on three occasions during nest observation time in this period, while the juvenile returned once. Neither bird, however, delivered food to the nest.

Growth rates of nestlings have been examined for numerous bird species and for most, if not all, the composite growth curve is of a basic "sigmoid" shape (Sumner, 1929; Brody, 1945; Ricklefs, 1968; Ricklefs, 1974; O'Connor, 1984; Komen, 1986). O'Connor (1984) states that in species rearing a single chick only, growth of the nestling is linked with the environmental constraint of food, as dictated by the ability of the parent to supply food for growth. Komen (1986) notes that the intrinsic rate of growth may be effected, and even distorted, by fluctuations in food supply. Few studies have attempted to estimate the daily food consumption of altricial nestlings under natural conditions (Royama, 1966; Westerterp, 1973; Ricklefs and White, 1981; Tinbergen, 1981; Komen, 1986). Westerterp (1973), stated that feeding frequency alone cannot give an accurate representation of food consumption by nestlings. Energy intake of nestlings has been shown to initially increase with nestling age, reaching a plateau or peak, in the latter case decreasing slightly at the end of the nestling period (Royama, 1966; Westerterp, 1973; Ricklefs, 1974; Ricklefs and White, 1981; Tinbergen, 1981; Komen, 1986). Komen (1986), indicated that rise and peak in energy intake by nestlings, coincides with the peak in energy required for growth, and the increase in existence metabolism with increase in body weight.

The question that arises in this study is, what role do different individuals in the group play in provisioning the nestling and nest bound female, and how do these roles change with changes in the energy and nutrient demands of the nestling? Although the energetic demands of nestlings have not been determined, the amount of food delivered to the nest at different stages of development, provides an insight into the periods when the greatest demand for food by the nestling and nest bound female occurs.

The Stainbank group was the only group for which data for the first two weeks following hatching were collected. During this period food bundles were delivered at a rate 0.23 bundles an hour less than during the incubation period (Table 4:25). This indicates that the energetic demands of the nestling and nest bound female were less than that of the incubating female alone. During this period the dominant male supplied 80% of the food items delivered to the nest.

Food delivery rate increased by 143% to 0.51 bundles per hour during the period that the nestling was 2-4 weeks old. Although food delivery rate increased by 143%, visiting rate only increased by 64%. The difference in rates was due an increased amount of food delivered by helpers in the group. During this period, 30% of food bundles were delivered by subadult 3 and subadult 4. Subadult 3 increased delivery rate by 100% during this period. Even with the help of the two subadults, the dominant male experienced his greatest demand during this period, in terms of the number of food bundles delivered to the nest per unit time. During the period when the nestling was 2-4 weeks old, the female was still nest bound, and did not help provision the nestling. Stallcup and Woolfenden (1978) observed that the amount of food delivered to the nest of Florida Scrub Jays, increased with nestling age and that helpers only commenced delivering once the nestling was 1-2 days old. It seems likely that the commencement of food delivery by helpers, coincides with increased energy demands of the nestling.

Although no data were collected for the activities at the Carlshaven nest during the first two weeks following hatching, a similar marked increase in the number of food bundles delivered to the nest when the nestling was 2-4 weeks old was also observed (Table 4:26). Food delivery rate during this period was 180% higher than the rate during incubation, and nest visiting rate increased by 132%. Unlike the Stainbank group, the Carlshaven pair had no helpers to aid in meeting this increased food demand. During this period the dominant female, unlike the Stainbank female, returned to the nest with food after 42% of her short foraging visits away from the nest. Although the female supplied 31.3% of the food bundles during this period, the dominant male still experienced his greatest demand, in terms of the number of food bundles delivered to the nest. He delivered 0.46 bundles per hour which was a delivery rate 31% higher than the maximum delivery rate of the dominant male of the Stainbank group. Unlike the Stainbank group, delivery rate to the Carlshaven nest during this period, was higher than during any subsequent period. As the female was still in the nest, it is uncertain whether the energetic demand of the nestling peaked during this period or during the subsequent three weeks.

When the nestlings from both groups were 2-4 weeks old, both dominant males delivered food bundles at a rate higher than at any other stage of the nestling period (Tables 4:25 and 4:26). Although they delivered more food bundles per hour, foraging rates during this period were not significantly greater ($p>0.05$) than during other periods (Table 4:28). This suggests that the dominant males probably provisioned to capacity throughout the nesting period. Higher success rates were exhibited by both individuals during this period (Table 4:28). The reason for these increased success rates is not clear. These results suggest that the timing of breeding is important, so that foraging yield peaks at a time when the greatest demand is placed on the provisioning birds. The question of the timing of breeding will be dealt with in more detail later.

In the three week period after the Stainbank female left the nest, food delivery rate increased, to 0.65 bundles per hour (Table 4:25). This was the maximum delivery rate observed during nesting. As only the nestling was provisioned during this time, it is clear that the energetic demands of the nestling were maximal during this period. Although delivery rate peaked during this period, neither of the subadult birds brought food to the nest. The dominant female delivered 62.5% of the food bundles at a rate of 0.41 bundles per hour. The delivery rate by the dominant male decreased from 0.65 to 0.24 bundles per hour, 69% fewer bundles per hour than prior to the female leaving the nest. It is possible that prior to the female leaving the nest, the dominant male experienced a work load that was greater than the 'maximum sustained work load' (Drent and Daan, 1980). The females emergence from the nest, allowed the male to reduce his delivery rate. This reduced work load of the male, may have been essential in order for him to maintain his own condition. The dominant female, being an older bird and an experienced breeder, was able to supply the majority of food bundles given to the nestling during this period. The reason for the lack of help supplied by the subadults is uncertain. It is possible that the subadults did help during this period, but were not observed to do so as the activities at the nest were only monitored for 12.3 hours. The females emergence from the nest (Table 4:22), may have been necessitated by the peak in food demand of the nestling, since the group may not have been capable of provisioning for a female as well as the nestling during this period.

As previously mentioned, the peak in food delivery rate to the Carlshaven nest occurred when the female was still nest bound, and decreased from 0.68 bundles per hour when the nestling was 2-4 weeks old to 0.5 when it was 4-7 weeks old (Table 4:26). It is therefore unclear during which period the energy demands of the nestling were greatest. As with the Stainbank group, the dominant female of the Carlshaven group brought the majority of food bundles to the nest immediately after she left the nest to assist with feeding. She supplied 66.7% of food bundles at a rate of 0.37 bundles per hour. During this time, the dominant male decreased delivery rate from 0.46 bundles per hour to 0.17.

Although the nest visiting rate of both groups during this period was similar, and only the dominant pairs provisioned the nestling, the Stainbank nestling received 0.15 bundles of food per hour more (30%) than the Carlshaven nestling (Fig. 4:30). This was due to a higher delivery rate by the dominant male and female of the Stainbank group (Table 4:27).

When the nestling was 7-10 weeks old, food delivery rate by the Stainbank group decreased while that to the Carlshaven nest remained relatively constant (Fig. 4:30 (B)). This correlates with the predicted decrease or leveling out of energetic demand of nestling in the latter stages of nesting (Royama, 1966; Westerterp, 1973; Ricklefs, 1974; Ricklefs and White, 1981; Tinbergen, 1981; Komen, 1986). Although both nestlings received approximately the same number of food bundles per hour during this period, the Carlshaven group visited the nest at a rate of 0.37 visits an hour compared to 0.2 by the Stainbank group (Fig. 4:30). The Stainbank group were able to deliver a comparable amount of food in fewer visits than the Carlshaven group, due to the efforts of subadult 3 and to a lesser extent subadult 4 (Table 4:25). An average 2.6 bundles were delivered per visit to the Stainbank nestling, compared with 1.4 per visit to the Carlshaven nestling (Table 4:17). During this period, 38.1% of food bundles delivered to the Stainbank nest were supplied by helpers, of which 88% were supplied by subadult 3 (Table 4:25). The number of food bundles delivered per hour by the dominant birds of both groups was less than during the previous period. Although the Carlshaven nestling received food bundles at approximately the same rate during the entire late nestling phase, the task of provisioning was more evenly shared by the dominant pair during the later period when the nestling was 7-10 weeks old. The female supplied 57.1% of the bundles and the male 42.9% (Table 4:26).

In all of the above discussion, it has been assumed that the chicks of both groups were of the same size and condition at the similar ages. A comparison between the two groups, has shown that the presence of helpers reduced the provisioning rate of the dominant male, particularly in the two week period prior to the female leaving the nest. Subadult 3 was the only non-breeding bird in the Stainbank group which supplied a significant amount of food to the nestling. The help supplied by this individual, and the limited help supplied by subadult 4 occurred predominantly in the periods when the nestling was 2-4 weeks old, and again at the end of the nesting period. When the nestling was 2-4 weeks old, the female was still in the nest, and the dominant male experienced the greatest demand. It seems likely that the help of subadults during this period would be more essential than when both of the dominant pair were provisioning the nestling. Fagerstrom _et al_. (1983) hypothesized that during brood development there is a shift from an initial stage in which the energetic needs and digestive capabilities of the young is limiting, to a final stage in which the foraging capacity of the parents is limiting. In _B. cafer_ it seems possible that the increased help supplied by subadults when the nestling was 2-4 weeks old, may coincide with the start of the latter stage in which the foraging capacity of the parents is limiting. The reason for the increased help supplied during the later part of nesting is unclear.

In order to provision adequately for the nestling and nest bound female, the dominant male of the Carlshaven group visited the nest more often with food than the Stainbank group (Fig. 4:30). If the birds do experience a 'maximal sustained work load' (Drent and Daan, 1980), the question is, how did a pair without helpers manage to provision adequately to allow successful breeding? The greater nest visiting rate by the Carlshaven male, the larger bundles of food delivered to the nest (Table 4:24), and the smaller foraging area (Fig.4:10 & Fig.4:11), suggest that the Carlshaven group, and particularly the dominant male, were able to capture a greater number of large food items, particularly frogs, closer to the nest, and in a shorter time period than the birds of the Stainbank group. This is supported by the data on the number of frogs caught per hour of observation time for each individual (Fig. 4:22). The greater percentage of frogs that were caught by picking rather than digging (Fig. 4:9), may be the critical factor influencing the greater frog capture rates by the Carlshaven group. Thus it appears that the crucial factor in the comparison of the foraging ecology of the two groups, particularly as it relates to breeding success, is the availability of frogs in the immediate vacinity of the nest site. This may well have allowed the Carlshaven breeding pair to adequately provision the nestling and nest bound female without requiring assistance. It may be suggested too, that in a season where frogs are less abundant, the dominant male may need to forage further from the nest in order to collect sufficient food for the nestling. This would inevitably result in an increase in energetic costs of rearing the nestling and perhaps reduce breeding success. The chances of a group with helpers breeding successfully in a year in which large food items are less abundant, or in a poor territory, are therefore greater than for a single pair.

The fact that the Carlshaven group consisted of only two birds at the beginning of the 1989/90 breeding season, does not indicate that this group had not bred successfully in recent attempts. As indicated in Chapter Two, the Carlshaven group had consisted of four birds at the beginning of 1989, and unconfirmed reports suggest that group size had fluctuated between four and six individuals in recent years. The breeding success of the group in recent years, suggest that the Carlshaven group inhabited a high quality territory. This is confirmed by the results of this study. There is still a need therefore, for a similar study to be conducted on a two bird group, which has not bred successfully in recent years, and which inhabits a territory of lower quality than the Carlshaven group.

As with most birds studied, the timing of breeding is critical. From work on the timing of breeding in birds (Perrins, 1970; Jones and Ward, 1976; O'Connor, 1980; Mendelsohn, 1984), it has been shown that body condition of the breeding female and availability of food reserves, are controlling factors in the timing of egg laying. Perrins (1970) showed that laying date in some species is determined by the condition of the female. Jones and Ward (1976), stated that the controlling factor in the timing of breeding is the condition of parent bird and particularly the state of its protein reserves. Mendelsohn (1984) noted that breeding in Blackshouldered Kites (<u>Elanus caeruleus</u>) depends on a good food supply, and that breeding usually starts before prey abundance reaches a peak. He suggested that kites respond to some measure of rodent breeding activity, and that this may be the best predictor of future prey abundance. Drent and Daan (1980), suggested that the answer to the timing of breeding, and the number of eggs produced, depends on some combination of local environmental conditions and the state of the parent.

In order for a <u>B. cafer</u> group to invest in a chick, it is important to reduce the risks of nest failure. As shown above, the abundance of frogs in the two study areas appears to be a crucial factor which influences breeding success. In order for breeding to succeed, laying should be timed so that frogs are abundant at the time when the energy demands of the nestling are highest. In <u>B. cafer</u>, where the nesting period is long, the condition of the female at the start of the breeding season, can not offer any indication of the food abundance mid-way through the nesting period, thus it is likely that some other factor must influence the timing of breeding. Kemp and Kemp (in press) observed that laying date is influenced by the occurrence of the first spring rains. While there is a correlation between laying date and rainfall, Kemp an Kemp (in press) states that it is unlikely that rainfall per se influences laying date, but rather that rainfall effects the availability of food and nutrients for the laying female.

Having examined the provisioning of the nestling and nest bound female in B. cafer, it seems unlikely that a group could rear more than one chick per year. The long nesting period, the size of the bird, and the mode of foraging, restrict the amount of food that can be provided for the developing nestling. Energetic demands of the parent birds and helpers, limit the size of the brood (Drent and Daan, 1980). Although B. cafer lays two eggs, only a single nestling ever fledges. Obligate siblicide has been predicted to occur where competition for breeding vacancies is intense (Simmons, 1988). Although unlikely, it is not impossible that in a season where there is an 'over-abundance' of larger food items, that a large group with many helpers may be capable of successfully rearing two chicks in one season.

The above arguments support the view that in many cooperative breeders, reproductive success per group is not just correlated with the number of helpers, but in some cases habitat quality, size of home range, and parental age and experience (Woolfenden, 1975; Brown, 1978; Trail, 1980; Zack, 1986; Lennartz Hooper and Harlow, 1987; Stacey and Ligon, 1987; Leonard Horn and Eden, 1989).

(ii) FEEDING OF THE FLEDGLING

Neither the role of group individuals in feeding fledglings, nor the acquisition of foraging skills by fledglings, in their first few months of life, was investigated in this study. The juvenile in the Stainbank group, however, was followed and foraging data recorded. The acquisition of foraging skills have already been discussed for this individual (section 4:4:5). As previously mentioned, with the exception of one food item fed to the juvenile by subadult 3, only the dominant male and female fed the juvenile during contact hours in August and September. The dominant male was observed to feed the juvenile on fourteen occasions, and the dominant female on four occasions. All food items fed to the juvenile, with the exception of one, were greater than 2 cm in length, 50% of which were 5-10 cm in length (Fig. 4:19). The dominant male fed the juvenile 53.8% of food items caught that were greater than 2 cm in length, while the dominant female fed the juvenile 14.3% of food items 2-5 cm in length, and 33.3% of items 5-10 cm in length (Table 4:20). The juvenile followed close to one of the dominant pair throughout the day. As mentioned previously, the adult birds not only fed the juvenile, but also appeared to teach it where and how to forage (as detailed in section 4:4:5). Although non-breeding birds did not feed the juvenile during the observation period, they may have done so earlier in the year. Helpers have been observed to feed fledglings in Green Woodhoopoe (Ligon and Ligon, 1979). Florida Scrub Jay helpers have been observed to assist in teaching the young to forage and avoid predators (Woolfenden, 1975). The dominant pair fed the juvenile until the female first went into the nest, at the start of the next breeding season.

The long nesting period, together with the extended period that the fledgling is dependent on the parent birds for food, means that a breeding pair invest, at least, an entire year to the rearing of a single chick to adulthood.

4:5 SUMMARY

(i) B. cafer actively forage for most of the active day.

(ii) They are predominantly carnivorous, with frogs forming an important constituent in the diet of the two study groups.

(iii) Picking was the most abundantly utilised foraging technique.

(iv) Although the foraging success rate of digging was low, and the time invested in digging high, the energetic yield justifies the use of this method.

(v) B. cafer are able to utilise lands used for a wide variety of agricultural practices. The major criteria, in terms of habitat selection, being a short or sparse ground cover.

(vi) Younger birds were less successful in foraging attempts using digging and probing.

(vii) The acquisition of foraging skills, particularly digging and probing, takes time and experience. The juveniles foraging success rate increased from 7.2% prior to nesting, to 51.2% during nesting.

(viii) Frogs were the major food item fed to the chick and nest bound female.

(ix) The presence of helpers reduced the feeding and nest visiting rates of parent birds.

(x) The juvenile did not act as a helper. The eldest of the two subadults helped the most. The subadults helped most during the periods when the demand for food delivery to the nest was highest, and at the end of the nesting period.

(xi) Helpers reduced the amount of time that the female spent away from the nest during incubation and early nestling phase.

(xii) An abundance of frogs close to the nest, enabled the Carlshaven pair to adequately provision the nestling, without helpers.

(xiii) The fledgling is provisioned by the parent birds until the following breeding attempt.

CHAPTER FIVE

GENERAL CONCLUSION

Based on data presented in Chapters Three and Four, it is evident that B. cafer are able to utilise lands used for a wide variety of agricultural practices. Their ability to adapt to these habitats for foraging is essential for the long-term survival of the species in Natal. The diversity of habitats which are utilised, together with the variety of prey items eaten, suggest that B. cafer may be less affected than most large bird species, by the increased utilisation of land for farming. The data in Chapter Four, suggest that two of the major foraging requirements of B. cafer are; (i) short or sparse ground cover, and (ii) an adequate supply of food items, such as frogs, larger than 2 cm in length and available close to the nest site during the nesting period. Although birds were observed to forage in Wattle plantations in the Natal midlands, they never utilised Eucalyptus or Pine plantations. This suggests that increased planting of these forest types, particularly in the Natal midlands, could pose a threat to the survival of the species.

The role that helpers play in breeding is an important aspect of the biology of B. cafer. It is evident that they may substantially reduce the provisioning requirements of parent birds, especially during periods when the demand for food delivery to the nest is highest. Although the Carlshaven group managed to successfully rear a chick during the 1989/90 season without the aid of helpers, the retention of helpers in a group may be important at times where food is limiting, or in groups in low quality territories. Group investment in a nesting, is clearly a long term one, with the fledgling being dependent on the rest of the group for food for its entire first year, and even into its second year (Kemp and Kemp, 1980).

The low density of B. cafer in Natal (Chapter Two), the fact that a maximum of one chick is produced per group per year, together with the vital role that each individual plays in the breeding process, particularly in years of food shortage, mean that the survival of each individual is important. It is possible that the loss of one group member in a year in which food supply is reduced, could directly influence the breeding success of the group in that year, and subsequent years. In the development of a conservation policy for this species, it is essential to recognise the importance of each individual.

B. cafer have few known predators in the farming regions of Natal. Because of their foraging habits and dietary diversity, however, they are extremely susceptible to food poisoning. During the duration of this project, four birds were reported to have died from suspected food poisoning, in the Natal midlands and Drakensberg regions. The consumption of poison bait, as well insects and amphibians killed by pesticides, could pose a major threat to the survival of B. cafer.

Probably the most important limiting factor, is the availability of suitable nest sites. Since a group may use the same nesting site every year, the conservation of these sites is essential. Although farming practices do not necessarily mean a reduced availability of suitable foraging habitat, if they destoy nest sites, the survival of the species in these areas could be seriously threatened.

Education can play a major role in the conservation of this species. Its size and habits, make it easily identified by the layman, and subsequently a knowledge of the behaviour and intricate family structure of this species can induce interest in the conservation of the species.

This study has only addressed a few questions as regards the foraging ecology and breeding biology of B. cafer in Natal. Future studies should focus on the following aspects of B. cafer biology:

(i) A more detailed examination of the habitat requirements of B. cafer throughout the Natal region.
(ii) The foraging ecology and breeding biology of two bird groups which have not bred successfully for a number of years.
(iii) The energy and nutrient requirements of, (a) nestlings during development and (b) adults.
(iv) The long term structure and dynamics of groups, and the factors influencing delayed breeding.

The distribution data presented in Chapter Three, should be constantly updated, and an added effort should be made to assess the status and distribution of B. cafer in KwaZulu regions. A long-term study should be initiated to assess the distribution of groups, and the changes in group structure. These data are essential if the status of B. cafer in Natal is to be closely monitored.

In summary therefore, I believe that any conservation policy introduced to protect this species should take cognisance of the following points; (i) the conservation of the nest site, (ii) the control of poisoning and pesticide use, and (iii) education of the public. The increase in Eucalyptus and Pine plantations should also be considered.

The ability of B. cafer to survive in areas which are used extensively for agriculture, together with the fact that they are protected by Zulu folk law, suggest that as long as nest sites are protected, and the use of poisons and pesticides is controlled, this species should not become threatened in Natal. The complex breeding biology and social structure of this species, suggests that the unnatural death of one or two individuals in a group could have a profound effect on the breeding success of groups for some years.

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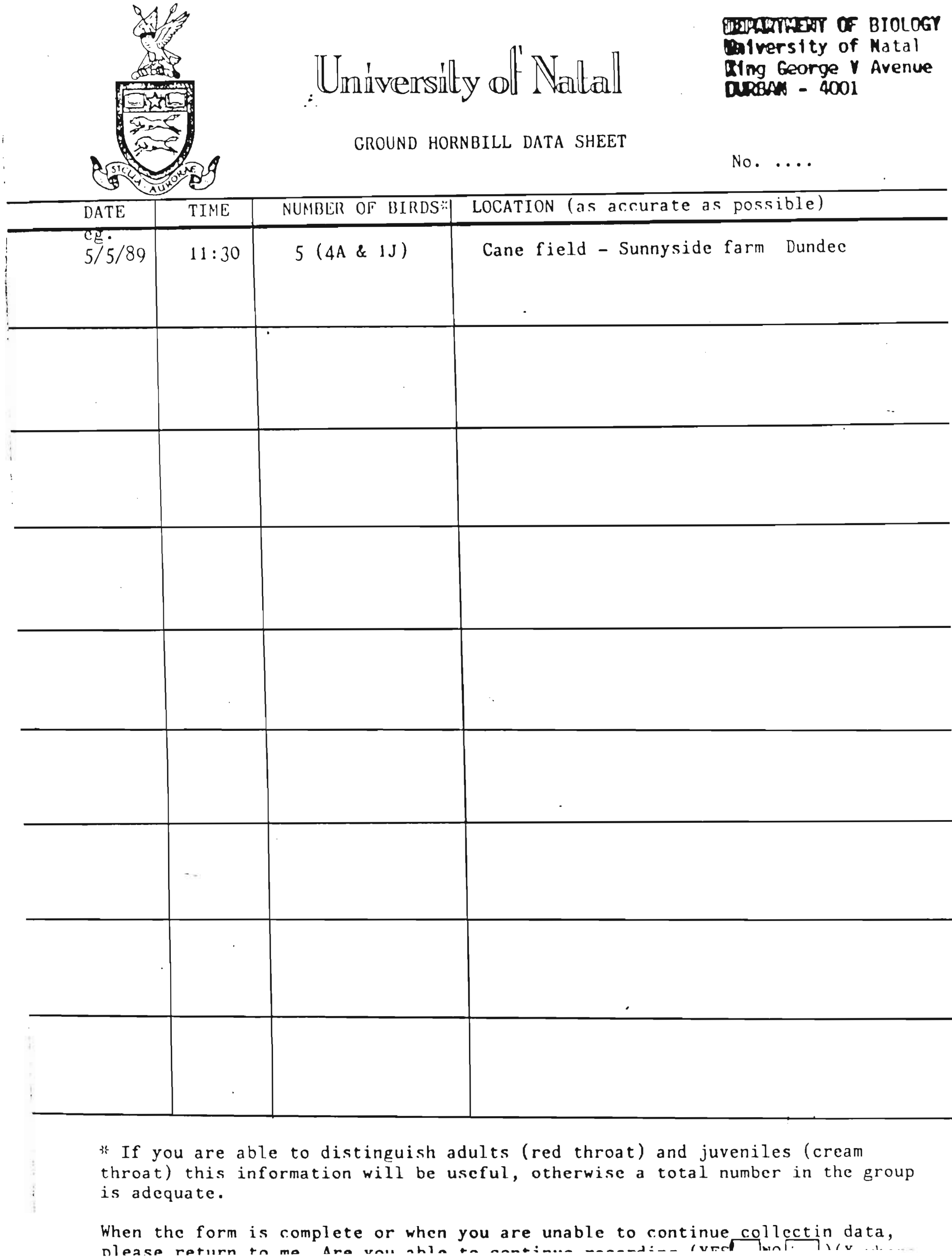
APPENDIX 1

Articles published in the popular press which appealed for sightings of B. cafer in Natal.

DATE OF PUBLICATION:	PUBLICATION
19 February 1989	Sunday Tribune (Today Supplement)
March 1989	Natal Section Mountain Club S.A. mag.
6 March 1989	Natal Witness
13 March 1989	Natal Witness
April 1989	Natal Wildlife Magazine
8 April 1989	Star Newspaper
15 May 1989	Natal Witness
19 May 1989	Farmers Weekly
5 March 1990	Natal Witness
19 March 1990	Natal Witness
May 1990	Natal Conservancy Magazine

APPENDIX 2

An example of the data sheets sent to Natal farmers



University of Natal

DEPARTMENT OF BIOLOGY
University of Natal
King George V Avenue
DURBAN - 4001

GROUND HORNBILL DATA SHEET

No. ....

DATE	TIME	NUMBER OF BIRDS*	LOCATION (as accurate as possible)
eg. 5/5/89	11:30	5 (4A & 1J)	Cane field - Sunnyside farm Dundee

* If you are able to distinguish adults (red throat) and juveniles (cream throat) this information will be useful, otherwise a total number in the group is adequate.

When the form is complete or when you are unable to continue collectin data, please return to me. Are you able to continue recording (YES ☐ NO ☐)(X

APPENDIX 3

Details of reported sightings.

GRID REF.	REF.No.	LOCATION	DATE	No.Birds	GRP SIZE
$27^{0}30'$ $31^{0}0'$		3km from Itala	08/90	2	2
$27^{0}30'$ $31^{0}15'$		2.5km form Itala	08/90	2	2
$27^{0}45'$ $31^{0}0'$	A1	Swart Mfolosi	02/89	4	4
$27^{0}45'$ $31^{0}15'$	102	Ngome Forest	Early 89	N/K	N/K
$28^{0}0'$ $31^{0}0'$	X5	2kms S of Nhlazatshe	12/10/89	3A+1J	4
$28^{0}0'$ $31^{0}15'$	B1	2kms E of Warmbad	8/07/89	3A+2J	5
$28^{0}0'$ $31^{0}45'$	x16	Sontuli/Mfolosi G.R.	/89	4A+2J	6
$28^{0}0'$ $32^{0}0'$	74	Hluhluwe G.R.	15/04/89	2A+1J	3
$28^{0}15'$ $30^{0}30'$	120	Leksand	04/89	4	4
	33	Roodeklip	23/12/88	2	2
$28^{0}15'$ $31^{0}15'$	41	Overloed	/89	3	3
	x6	Ondini	08/12/89	5	
			26/12/89	2A	
			28/12/89	2A+1J	5
	116	Manzini Estate	04/89	2	
			06/06/89	2A	
			09/06/89	2A	
			11/06/89	2A	
			12/06/89	2A	
			21/06/89	4A	2
	117	Nooitgedag	05/89	4	4
	2	Ntonjaneni Pass	/88	5	5
$28^{0}15'$ $31^{0}45'$	3	Mfolosi G.R.Trail	/88	3	3
	x21	Mfolosi G.R.	06/90	2A	2
$28^{0}30'$ $29^{0}0'$	x3	1km N Mont Aux Sources Hotel	06/02/90	2A	2
$28^{0}30'$ $29^{0}15'$	42	Geluksburg	05/03/89	10	10
$28^{0}30'$ $30^{0}0'$	1	Enlameni Mission	01/88	3	
			04/89	3	3
	B11	2km E Enlameni	/89	3	3
	36	Mashunka Falls	02/89	7	7
$28^{0}30'$ $31^{0}0'$	B9	Langefontein	12/11/89	2	2

		101	Nkandla Forest	09/05/89	5	5
28°30'	31°15'	4	Golf C. Melmoth	/89	3	
				20/06/89	3A	
				02/02/90	1A	3
		132	Edge Town Melmoth	/89	3	3
28°45'	29°15'	65	Driefontein	02/89	3	3
		67	Paisley	12/88	3	3
28°45'	29°45'	97	Rondedraai	04/89	5	
				12/07/89	1A	
				18/08/89	5A	
				20/08/89	5A	
				30/10/89	3A	
				10/01/90	5A	
				02/02/90	4A	
				17/03/90	2A+1J	6
		x1	Mielietuin	01/06/89	5A	5
28°45'	30°15'	40	Nchosa	02/03/89	3	
				06/07/89	1A+2J	
				23/07/89	3A	
				24/07/89	3A	
				01/08/89	3A+2J	
				11/08/89	3A+2J	
				12/08/89	3A	
				18/08/89	3A	5
		68	Geluk Stade	03/89	7	
				09/08/90	6A	6
		99	Winterhoek	03/89	3A+2J	5
		99b	Nelsrust	03/89	3A+2J	5
28°45'	31°15'	78	Ntumeni	18/04/89	3A	
				19/04/89	3A	
				22/04/89	3A	
				26/04/89	3A	
				27/04/89	3A	
				28/04/89	3A	
				04/05/89	3A	
				10/05/89	3A	
				09/06/89	3A	3
		B3	1km SE Ntumeni	/89	6	6
		5	Muhlatuzi R./ Mvusane R. conf.	/89	5-6	5-6
		6	Congella Rd.E'we.	/89	3	3
		61	2km from Eshowe Melmoth road	26/03/89	2A+1SA	3
		x21	Greenhill	27/07/89	6A	6
		x22	100m N/W Ntumeni mill turnoff	01/08/89	3A	
				11/04/90	2A	3?
28°45'	31°30'	115	Obenjeni Estate	03/05/89	2SA	2
		70	Ngoya Forest	01/89	4-5	4-5
		53	1km before Ngoya	03/88	3	3
28°45'	31°45'	x20	Umhlatuzana River	12/07/89	4A	4

			3km fm. Varsity			
29°0'	29°15'	12	Cathkin Park	/89	3	3
		x13	Nkosana Lodge	08/07/89	5	5
29°0'	29°30'	127	Ntabamhlope	12/05/89	3	3
		62	Between White M. & Draycott	29/03/89	4	4
		125	Longwood Estate	25/05/89	6	6
		49	The Heights	13/03/89	4A+1J	
				03/09/89	4A+1J	
				05/09/89	4A+1J	
				23/09/89	4A+1J	
				13/10/89	4A+1J	
				21/10/89	4A+1J	
				27/11/89	1	
				28/11/89	1	
				30/11/89	1	
				15/12/89	1	
				25/12/89	3	
				28/12/89	2	
				04/02/90	3A	
				05/02/90	3A	
				24/02/90	3A	3
29°0'	30°15'	51	Waterfall	03/89	4	4
		126	18km fm. Greytown om Mooiriver Road	01/89	2	2
		96	Roseta Avacardo	15/05/89	5	5
29°0'	30°30'	107	10km N Greytown on Muden Road	08/05/89	2	2
		100	Chipperfield	09/04/89	1	1
29°15'	29°30'	x4	Mount Erskine	28/12/89	1A	1
29°15'	30°0'	113	Lidgeton	01/88	5	
				04/89	2	2
		103	Blairmore	16/05/89	2	2
		80	Old Cranford	/89	5	5
		64	Hansberensky	11/88	3	3
		91	Spitzkop	11/05/89	2	
				13/10/89	1A	
				05/11/89	2A	
				31/01/90	1A	
				10/04/90	2A	
				11/07/90	2A	2
		B7	Brooklands	89	2	
				08/90	2A	2
		x7	Saddle	23/06/89	1A	
				25/06/89	1A	
				27/07/89	2A	
				15/08/89	2A	
				06/09/89	2A	
				07/09/89	2A	
				12/09/89	2A	
				20/09/89	2A	

				31/10/89	2A	2
		x8	Triandra	10/08/89	1A	
				01/12/89	2A	
				19/01/90	2A	
				31/01/90	2A	
				31/05/90	2A	2
		x9	Shannon	21/11/89	2A	
				24/11/89	2A	
				16/06/90	2A	
				11/08/90	2A	
				28/08/90	2A	2
		x10	Martenburg	27/06/90	2A	
				17/08/90	2A	2
29°15'	30°15'	110	Gartmore	10/05/89	4-5	4-5
		48	Summerhill	30/05/89	5	
				02/06/89	5	
				16/06/89	5	
				22/06/89	5	
				23/06/89	5	
				24/06/89	5	
				28/06/89	5	
				29/06/89	5	
				30/06/89	5	
				04/07/89	5	
				08/07/89	5	
				14/07/89	5	
				22/07/89	5	
				31/07/89	5	
				02/08/89	5	
				16/09/89	5	
				17/09/89	5	
				04/10/89	5	
				06/10/89	5	
				14/11/89	5	
				11/12/89	4	
				05/01/89	4	
				29/03/90	4A+1J	5
29°15'	30°45'	50	Glenaire	04/03/89	2	2
29°15'	31°0'	94	Confluence Suze & Pambela Rivers	31/08/88	3	3
29°15'	31°15'	7	7km W Stanger	19/02/89	4	4
29°30'	29°30'	B4	Brookland	12/04/89	3	
				15/09/89	7	7
		37	Hillside	01/89	4	
				30/04/89	4	
				08/05/89	2	
				30/07/89	4	
				01/08/89	4	
				19/08/89	4	
				24/08/89	3	
				03/09/89	4	
				08/09/89	4	

				24/09/89	3	
				02/10/89	4	
				08/10/89	4	
				23/10/89	4	
				24/10/89	4	4
		13	Farm W Hillside	09/04/89	5	5
		x14	Saddle Tree	/88	4-5	
				/89	4-5	4-5
29^{0}30'	29^{0}45'	44	Malmani	/89	3	3
		81	Between Hillside & Sunnyside	04/89	4	4
		123	Sunnyside	/88	2	
				24/04/89	4	
				25/08/89	2	4
29^{0}30'	30^{0}15'	92	Ottos Bluff	05/89	2	2
29^{0}30'	30^{0}30'	130	Nagle Dam	11/07/89	3	3
		x19	Nagle Dam/fishery	19/08/89	3	
				20/11/89	2	3
		47	Harrison Flats	/89	5	5
		55	Montesseal	10/88	2	2
		95	Mqueku River	09/88	5-6	5-6
		8	Umgeni Valley	06/88	3A+1J	4
29^{0}30'	30^{0}45'	96	Umgeni-Inanda Dam	88	1	1
29^{0}45'	29^{0}30'	B2	Brooklands	06/90	3	3
		x2	2kms Bulwer on Underberg Road	26/11/89	3A	3
		60	Hlabeni	11/88	2	
				15/06/89	2	
				23/06/89	6	
				24/06/89	3	
				06/08/89	2	2
		x15	Menin	03/09/89	2A	
				12/09/89	2A	
				17/09/89	2A	
				19/10/89	2A	2
29^{0}45'	29^{0}45'	124	3km from Bulwer on Underberg Road	30/05/89	N/K	N/K
		82	Sun Valley	04/89	4	4
		34	Ashtonvale G.F.	12/88	3	3
		14	Ashtonvale	/89	4	
				22/01/89	3	
				27/01/89	3	
				07/12/89	4	
				13/02/90	4	4
		76	Epson Forest	17/04/89	2	2
		83	Meadow	25/04/89	5A+1J	6
		58	Inglenook	13/03/89	8	8
		77	Comrie Plantation	17/04/89	2	2
		x18	Emeralddale	01/08/89	3	3
29^{0}45'	30^{0}0'	98	Red Acres	15/05/89	2	2

		57	Ottos Kop	04/89	3	3
		56	Roselands	01/89	2	2
		111	Heath	24/03/89	2A+1J	
				11/06/89	1A	
				22/08/89	2A	
				01/10/89	2A	2

$29^{0}45'$	$30^{0}15'$	108	1km Fm. Richmond	13/05/89	2	2
		121	Hillingdon	23/05/89	3	
				02/06/89	1	
				10/06/89	1	
				12/06/89	1	
				16/06/89	1	
				21/06/89	1	
				25/06/89	1	
				04/07/89	1	
				11/07/89	1	
				13/07/89	1	
				21/07/89	1	
				25/07/89	1	
				26/07/89	1	
				27/07/89	1	
				30/07/89	2	
				20/06/90	2A	
				24/06/90	2A	
				03/07/90	2A	
				04/07/90	2A	
				07/07/90	2A	
				12/07/90	2A	
				13/08/90	2A	
				14/08/90	2A	2
		129	7km fm. Richmond on Ixopo Road	06/07/89	3	3
		112	Eagles Gorge	/88	4	
				04/09/89	3	
				25/11/89	3	3
		118	Thurlow	/88	2	
				01/89	1	
				06/89	5	
				30/09/89	3A	3
		104	Garden of Eden	04/89	3	3
		10	Phoenix	/88	6	
				03/89	4	
				21/06/89	3	
				30/06/89	3	
				07/89	3A	
				26/09/89	3A	
				02/10/89	2	
				01/10/89	3A	
				15/05/90	2	
				27/05/90	2	
				06/08/90	2	2
		p1	Millstones	03/09/89	3	
				04/09/89	3	3
		p2	Rosebank	29/11/89	3	
				12/89	3A	
				12/12/89	3A	3

	p3	Lincoln	11/07/89	3A	
			13/07/89	3A	
			30/07/89	3A	
			07/08/89	3A	
			09/09/89	3A	
			10/10/89	3A	3
	p4	Rosewood	12/89	3A	3
	p5	Strathfieldsaye	10/89	3A	
			25/06/89	3	
			17/12/89	2A	
			19/12/89	1A	
			12/89	3A	3
	p6	Lasquiti	17/07/89	4A	
			17/07/89	3A	
			24/07/89	4A	
			25/07/89	4A	
			10/08/89	4A	
			21/09/89	1A	
			21/09/89	3A	
			03/11/89	2A	
			03/11/89	1A	
			08/11/89	2A	3
	p7	Winshaw	12/89	3A	3
	p19	Newton	13/07/89	4A	
			17/07/89	4A	
			25/07/89	4A	
			26/07/89	4A	
			08/08/89	4A	4
	p8	Curraghmore	10/89	4A	4
	p9	Tanfield	16/07/89	3A	3
	p10	St Jude	12/89	3A	3
	p11	Diepe Kloof	10/89	3A	3
	p12	Glen Echo	04/10/89	3A	3
	119	Stathven	12/88	5-6	5-6
29°45' 30°30'	32	Milford Estate	23/02/89	3	
			05/12/89	3	3
	133	Broadacres	07/89	2A+2J	4
	n2	Bredasfontein	07/90	4	4
	p13	Desdale	10/07/89	5	5
	p14	Belgium	11/07/89	4A+1J	
			12/89	5	5
	p15	Max Wilton	11/07/89	4A+1J	
			25/07/89	5	
			08/89	5	5
	p16	Dering	19/12/89	4	4
	p17	Hope Valley	10/89	5	5
	p18	Gumtree	09/07/89	4A+1J	
			28/07/89	4A+1J	
			29/07/89	4A+1J	
			05/10/89	4A+1J	5
	114	Giggleswick	19/05/89	5	5
	35	Virginia	02/89	4	4
	x21	Pricilla Vale	06/89	5	
			10/10/89	5	
			11/89	5	
			03/90	5A+1J	6

		x20	Stony Hill	13/09/89	5		
				14/09/89	5		
				15/09/89	5		
				09/11/89	3	5	
		117	Polo Ground	/89	5	5	
		9	Shongweni Dam 3km from N2	/88	2	2	
		131	Shongweni Dam	04/89	2	2	
		71	2km fm. Shongweni Dam	06/01/89	2	2	
30^{0}0'	29^{0}0'	27	Ashton	05/02/89	1	1	
30^{0}0'	29^{0}45'	15	Braecroft	02/89	2		
				27/06/89	2		
				30/06/89	2		
				01/07/89	2		
				09/07/89	2		
				24/07/89	2		
				25/07/89	2		
				26/07/89	2		
				27/07/89	2	2	
		84	1km S Braecroft	29/04/89	2	2	
		122	Mount Herma	/89	3	3	
		85	Mayfields	04/89	3		
				28/06/89	2A+1J		
				11/07/89	2A+1J		
				14/07/89	2A+1J		
				22/07/89	2A+1J		
				12/08/89	2A+1J		
				14/08/89	2A+1J		
				12/08/89	2A+1J		
				14/08/89	2A+1J		
				20/05/90	2A		
				02/07/90	2A	2	
		x40	Burnside	25/09/89	2A+1J	3	
		x41	Rivermead	09/09/89	2A+1J	3	
		x17	Summerford	30/08/89	2A+1J	3	
30^{0}0'	30^{0}0'	59	Carisbrooke	03/89	4	4	
		90	Myhill	03/89	2	2	
		43	Langefontein East	04/89	4		
				12/07/89	2	2	
		89	Langefontein West	01/05/89	3		
				25/08/90	2A+1J	3	
30^{0}0'	30^{0}15'	79	Mkomaas V. Game F	04/89	2	2	
		46	Karlshaven	/89	3		
				05/10/89	2		
				03/90	3A+1J	4	*
		1	Inhlazuka Ridge	12/89	2		
				02/90	3A	3	
30^{0}15'	29^{0}15'	86	Fishermans Bend	06/88	5	5	
30^{0}15'	29^{0}45'	B5	Ebuta Umzimkulu	07/89	4		
				3/09/89	4		

				10/09/89	4	
				13/09/89	3	
				06/90	3	
				20/08/90	3	3
		x12	Umzimkulu bridge	24/07/89	3	3
30^{0}15'	30^{0}0'	109	Highrhones	14/05/89	5	
				05/89	5	
				05/06/89	2	
				06/06/89	2	
				08/06/89	2	
				23/07/89	5	
				24/07/89	5	
				02/08/89	5	5
		x11	Ravenswycke	18/07/89	5A	
				22/08/89	5A	5
		B6	Kununata	/89	3	3
30^{0}15'	30^{0}15'	17	Hlutankunga	/89	N/K	N/K
		18	Cambelton	02/89	3	3
		19	Kynassa	12/88	1	1
		20	Mgayi Sugar Et.	/88	2	2
30^{0}30'	29^{0}15'	87	10km N Ft.Donald	03/89	4	4
30^{0}30'	29^{0}30'	B8	2kms W.Willowdale	09/89	4	4
30^{0}30'	29^{0}45'	75	Sutherland	/89	2	2
30^{0}30'	30^{0}0'	39	Retredt	01/03/89	2	
				27/06/89	2	
				30/06/89	2	
				22/07/89	2	
				01/08/89	2	
				15/08/89	2	
				22/08/89	4	
				28/08/89	4	
				31/08/89	4	4
		x20	Ravenhill	05/02/90	2A	
				27/02/90	2A	2
		72	Horseshoe	08/04/89	3	
				08/04/89	3A+1J	4
		73	Opp. Church Oribi	07/04/89	3A+1J	4
		26	Fountain Hills	/89	4	4
30^{0}30'	30^{0}15'	22	Sipofu	88	5	5
		23	Criden	08/88	4	4
		24	Balarat	02/89	4	4
		x12	10km fm. coast towards Paddock	16/06/89	2A+1J	3
30^{0}45'	30^{0}0'	B10	Falls Bergsma	01/04/90	2	2
		x23	Newlands	20/06/90	2A+2SA+1J	5
		x24	Scedmore	22/05/90	2A+2SA+1J	5
		x25	Etheldale	12/10/89	2A+2SA+1J	
				15/05/90	2A+2SA+1J	5

30°45'	30°15'	25	Renkin	/89	2	2
		B12	2kms W.Izotcha	05/90	1	1
31°0'	30°0'	38	Misty Falls	/89	4	4
		29	Transkei Border	/88	2	2