ECOLOGY AND MANAGEMENT OF CHITAL AND BLACKBUCK IN GUINDY NATIONAL PARK, MADRAS[1]

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(With three text-figures)

Key Words: Guindy National Park, *Axis axis*, *Antilope cervicapra*, population ecology, habitat use, feeding, wildlife management

We studied population size, density, and structure, seasonal habitat use, and feeding habits of chital and blackbuck in the 2.7 km² Guindy National Park, in Madras, Tamil Nadu, using line-transect sampling during 1991-92, and compared these with observations made during 1975-82 in the park. The chital population (density of 212.3/km² during 1991-92) has been stable or even increased between 1975 and 1992. Artificial feeding may be responsible for low fawn and adult mortality and thus for maintaining very high chital density. On the other hand, the blackbuck population has declined sharply from about 250 animals in 1979 to about 85 (density of 17.5/km²) today. Demographic changes include a lower fertility and a lower recruitment into the young male age classes. The likely causes for the decline are habitat changes in blackbuck territorial areas and competition with chital. There was much overlap in space use and food items of the two ungulates. Management measures such as habitat manipulation, cessation of artificial feeding, control of exotics, and introduction of blackbuck from other areas may be needed for saving the blackbuck in this insular park, once considered a stronghold of this endangered species.

Introduction

Guindy National Park (GNP), in Madras city (Tamil Nadu, southern India), harbours a diversity of animal and plant life (Selvakumar 1979, Selvakumar *et al.* 1981, Menon 1986a, Santharam 1986). It is an important remnant of the tropical dry evergreen forest of the Coromandel coast (Champion and Seth 1968). A substantial population of introduced chital (*Axis axis* Erxleben) and a smaller native population of blackbuck (*Antilope cervicapra* L.) inhabit GNP (Krishnan 1972). In the past, GNP has been regarded as one of the southern strongholds of blackbuck (Ranjitsinh 1989, Rahmani 1991), an antelope now given endangered status and placed in Schedule I of the Wildlife (Protection) Act of 1972 (Anon. 1992).

We (RS and RKGM) along with R. Selvakumar have been making ecological observations in GNP since 1974. By the early 1990s we had noticed a drastic decline in the blackbuck population. We then began a more systematic monitoring of the ecology of GNP particularly to understand the dynamics of chital and blackbuck and explore the causes of the latter's decline. In this paper, we present results (for 1991 and 1992) on population densities, demography, and seasonal habitat utilisation of chital and blackbuck, including a qualitative account of their feeding habits. These results, we believe, will be of value in formulating scientific management strategies.

Study Area

Location and Area: GNP is a 2.7 km² park located in the southwest corner of Madras city (13° N, 80° E). Arterial roads to the city, and densely populated areas fringe GNP on the northern and western sides. A wall of 9.5 km perimeter surrounds the park, which also has an extensive network of roads (14 km) and trails. GNP has two large tanks (Kathan Kollai or KK Tank and Appalam Kolam or AK Tank) and two ponds, which have little or no water during the dry months (Fig. 1).

History: Before 1821, Raj Bhavan (then called the Guindy Lodge) was in private hands. In

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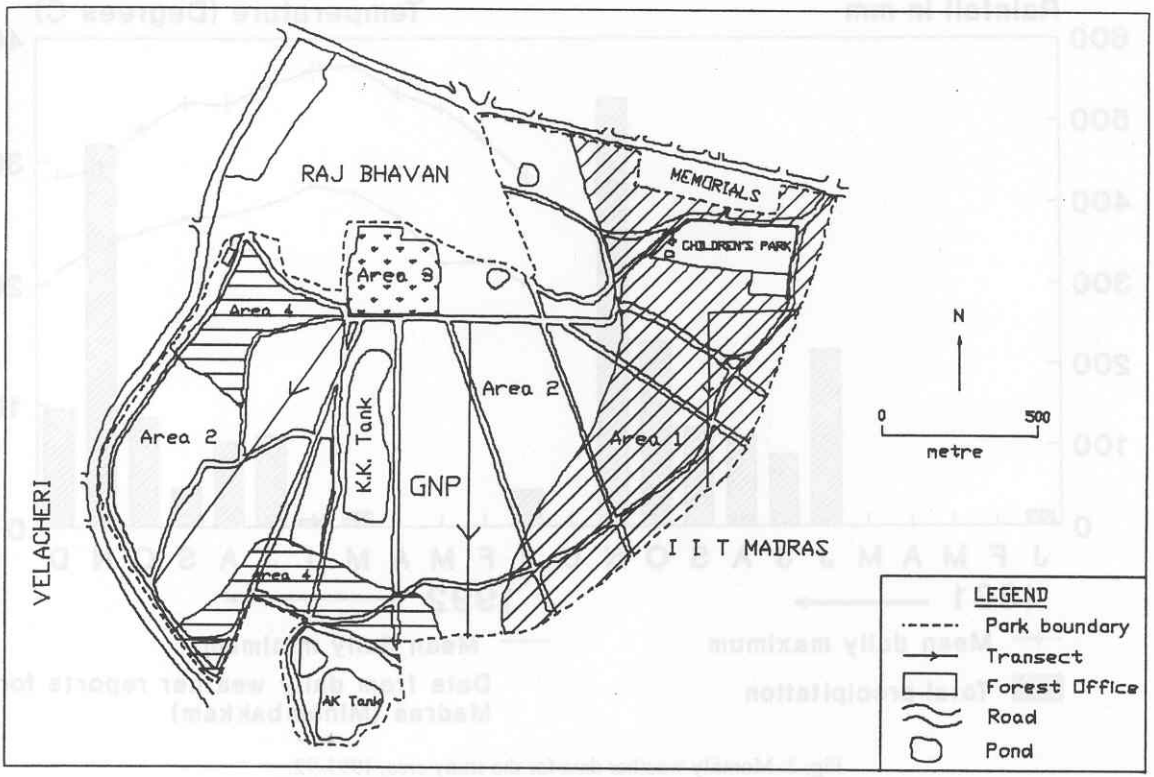

Fig. 1. Map of GNP showing habitat types, transects and surrounding areas.

1821, it was bought by the government and made the official country residence of the state Governors. The original area of about 505 ha. was declared a Reserved Forest in 1910. However, between 1961 and 1977, 172 ha. were set aside for various educational institutions and memorials. The remaining area popular as the Guindy Deer Park was, under suggestions from local naturalists, declared a National Park in 1978. More details about the history of the park are given by Menon (1986a).

While blackbuck are a native faunal element of GNP, chital were introduced into the park from the Government House on Mount Road when Raj Bhavan was developed (Krishnan 1972). The exact year of introduction is not given. However, Raj Bhavan became the only official residence of the Governor of Madras in 1946 (Chaudhuri 1990). Thus, the present chital population is probably derived from individuals introduced in the late 1940s. Some albino male blackbuck were also introduced by the Maharaja of Bhavnagar.

Climate: This region has a tropical dissymmetric climate (Meher-Homji 1974). The mean annual maximum and minimum temperatures are 32.9°C and 24.3°C. The mean annual rainfall is 1,215 mm (range 522 to 2,135 mm) (Climatological Table, India Meteorological Dept., Madras - Minambakkam 1931-60). The total rainfall in 1991 was 1,313 mm, while in 1992 it was 1,091 mm (Fig. 2). Based on rainfall pattern and water availability in the environment, we defined three broad seasons for this study.

(a) *Dry Season (January - March):* January, February, and March are the months of least mean rainfall - 25.8 mm, 6.3 mm, and 15.1 mm, respectively. Dew is an important source of moisture

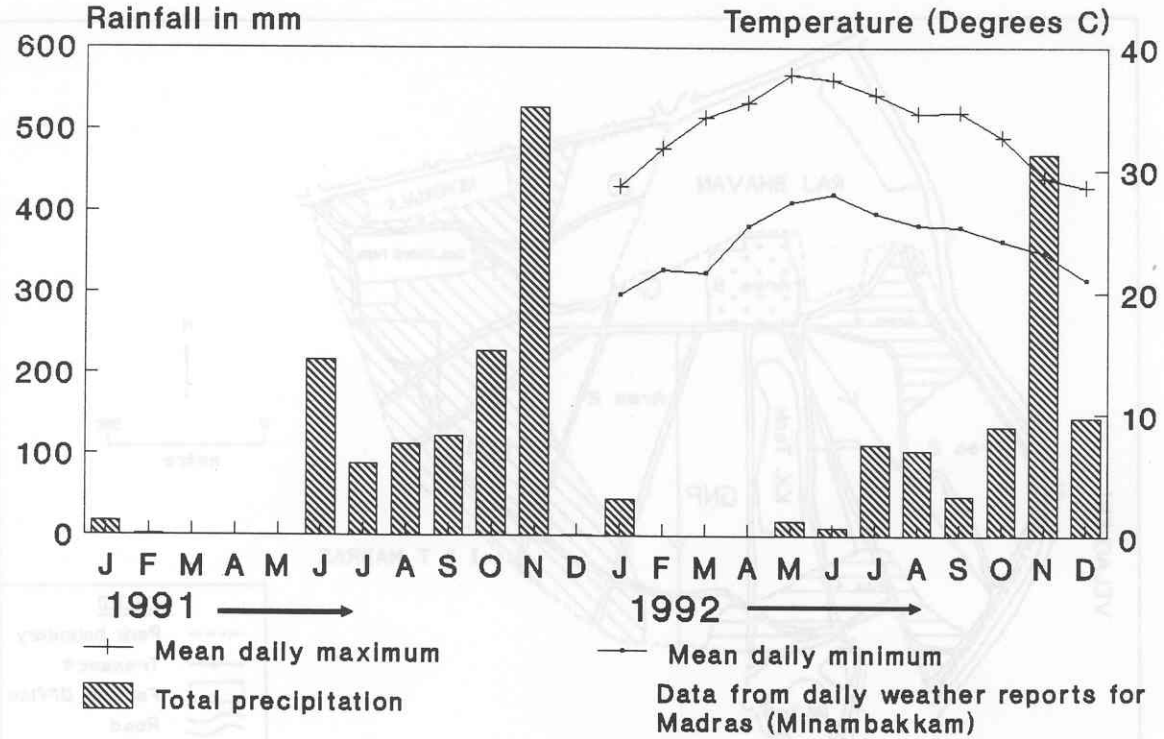

Fig. 2. Monthly weather data for the study area, 1991-92.

during this season.

(b) *Summer or Pre-Monsoon Season (April - May):* This season is characterised by high temperatures, and erratic rainfall. This regime is believed to determine the peculiar vegetation of the Coromandel-Circar coast (Meher-Homji 1974, Puri *et al.* 1989).

(c) *Monsoon or Wet Season (June - December):* During this season, Madras receives rain from the south-west (SW) monsoon (June-September) and the north-east (NE) monsoon (October-December). Maximum precipitation occurs during October-November from NE monsoon depressions in the Bay of Bengal. In June 1991, there was 217 mm of rain, but poor rainfall in June 1992 necessitated inclusion of that month's data in the pre-monsoon season as hot, dry conditions prevailed.

Vegetation: GNP is an isolated remnant of the tropical dry evergreen forest (Champion and Seth 1968) once spread over the Coromandel-Circar coastal plains. This vegetation has been reclassified as the '*Albizia amara* Boiv. community' (Puri *et al.* 1989). Over 350 species of plants, both native and exotic have been recorded (Dr. C. Livingstone, pers. comm.). Physiognomically, it occurs as discontinuous or dense scrub-woodlands and thickets (see Meher-Homji 1973, 1974, Puri *et al.* 1989, for floristic aspects). Plant nomenclature in this paper follows Mayurnathan (1929) as updated by Matthew (1983).

The park can be divided into four broad habitats based on canopy and dominant plant species (see Fig. 1, Selvakumar 1979):

Area 1: This area has nearly closed canopy dominated by introduced *Acacia planifrons*. There is a dense undergrowth dominated by *Clausena dentata* shrubs.

Area 2: This area has semi-open scrub and

thickets. The dominant tree is the palmyrah palm (*Borassus flabellifer*). *Randia dumetorum*, *R. malabarica*, and *Carissa spinarum* are very common.

Area 3: This is an open, cleared meadow called Polo Field which measures about 230 x 160 m. A total of 67 species of herbs, grasses, and sedges were collected from this area.

Area 4: This is probably a true remnant of the original vegetation of the region. Physiognomically similar to Area 1, it is characterized by presence of *Acacia chundra*, the exotic cactus *Cereus peruviana*, and predominance of *Glycosmis mauritiana* in the understory.

Fauna: Besides chital and blackbuck, other mammals such as bonnet macaque (*Macaca radiata*), jackal (*Canis aureus*), common mongoose (*Herpestes edwardsi*), small Indian civet (*Viverricula indica*), common palm civet (*Paradoxurus hermaphroditus*), blacknaped hare (*Lepus nigricollis*), threestriped palm squirrel (*Funambulus palmarum*), several species of bats and rodents are present. Nearly 150 species of birds have been seen in the park (Selvakumar *et al.* 1981, V. Santharam, unpubl.). Reptiles such as the saw-scaled viper (*Echis carinatus*) and the fan-throated lizard (*Sitana ponticeriana*) are typical. Nine species of amphibians and several fishes are known (R. J. R. Daniels, unpubl.) from the area.

Methods

Density estimation: We collected systematic data on a monthly basis from January 1991 to December 1992. Three broad habitat types were identified for sampling:

(a) woodland (Area 1 & 4) occupying about 34% of GNP
(b) scrubland (Area 2) occupying about 59%, and
(c) grassland or Polo Field (Area 3) covering < 3% of the area.

Water bodies covered about 3% of the park area.

The line transect method was used to estimate animal density (Burnham *et al.* 1980). Three transects, each about 1 km long, were laid randomly and marked with paint. Two were placed in the scrubland, and one in the woodland to sample the habitats in rough proportion to their availability. Each transect was walked twice every month by one of us (TRSR). Sampling was uniform between the two time blocks of the day when animals were active (0600 - 0900 h and 1600 - 1900 h). A transect length of 6 km per month, or 144 km over the two years, was covered. For each sighting, the species, group size, age-sex data, and perpendicular distance from the transect line to the centre of the group (using a rangefinder) were noted. Total counts were made in the grassland every month. Data on age, sex, and group size were also collected along roads and trails. The mean group size (Y), and its standard error (SeY), were estimated by habitat type and season for the entire study area. All observations were made on foot.

The computer program TRANSECT (White 1987) was used to estimate density of groups (Dg, number of groups/km^2), and its standard error (SeDg), using the Fourier Series estimator (Burnham *et al.* 1980, Karanth and Sunquist 1992). The mean ecological density (D, number of individuals/km^2), and its standard error (SeD), were derived using standard equations (Drummer 1987 as used by Karanth and Sunquist 1992):

$$D = Dg \times Y$$

$$SeD^2 = SeDg^2 \times SeY^2/n + SeDg^2 \times Y^2 + SeY^2/n \times Dg^2$$

where: n - number of groups.

Population size was calculated by extrapolating density estimates to the park area excluding the area under water bodies (= 2.6 km^2). Blackbuck density was extrapolated to the park area excluding the grassland. The mean number in the grassland (derived from the systematic total counts) was added to the above estimate to derive the population size of blackbuck. A total count was carried out in GNP and Raj Bhavan to cross-check the results of the TRANSECT analysis. This was done mid-way through the study on 29 December 1991, when blackbuck were confined to the high-visibility open scrubland and grassland areas.

Demography: Chital were assigned to age-sex classes after Schaller (1967) and based on observations on known-aged animals in the adjacent Children's Park Zoo. Chital fawns were classified as small (< 2 months old) and big fawns (2-10 months old). Fertility rate of females was estimated by the method in Sinclair (1977). After the birth-peak and hiding period in January-February, changes in the proportion of fawns (per 100 females) could be followed easily between March and October. A regression equation of log proportion of fawns against time was calculated over this period. Assuming that all births occurred on January 1, projecting the above equation backwards gave the log proportion of pregnant females on January 1. Fertility would be underestimated in this method if mortality is higher in the first two months. However, converting to logarithms reverses this trend and the residual bias is low (Sinclair 1977: 171-3). The mean monthly mortality rate of chital fawns born in the early part of the year was also calculated over March-October in the following way: the instantaneous monthly mortality rate (z) was calculated as: $z = \log_e N_t - \log_e N_{t-1}$; where N_t = number of fawns/100 females in month t, and e is the base of natural logarithms (after Caughley 1977). This was translated into the finite monthly mortality rate as $1 - e^{-z}$. The mean monthly mortality rate was averaged over the months March to October and expressed as a percentage. Adult mortality was based on carcasses found; this being only a minimum measure of mortality.

Blackbuck were classified by horn, coat-colour, and body-size characteristics (after Schaller 1967, Mungall 1978, Selvakumar 1979) as adult males (age > 3 years), subadult males (age < 3 years), adolescent males (age < about 14 months), females, and fawns. Fawns were classified as small (age < about 1.5 months old) and big fawns.

RESULTS

CHITAL

Crude density of chital: The crude density of chital in GNP during 1991 and 1992 was 185.4/ km² (± 29.3/ km² - 95% confidence interval) and 239.2/km² (± 37.2/km²), respectively. The mean population total shows a statistically significant increase from 482 in 1991 to 622 in 1992 ($z = 2.22$, $p < 0.05$; Table 1). However, it is emphasized that this trend needs to be monitored further before definite conclusions, can be drawn.

TABLE 1

CHITAL POPULATION DENSITY AND SIZE IN GUINDY NATIONAL PARK

Year	n	Density D/km²	Standard error of density SeD	CiD /km²	Total Population Mean P	CiP
1991	288	185.4	15.0	156.1-214.7	482	406-558
1992	379	239.2	19.0	202.0-276.4	622	525-719

CiD - 95% confidence interval of density.
CiP - 95% confidence interval of population.
n - Number of groups (sample size).

Seasonal habitat utilization of chital: The seasonal density of chital in a habitat type was often higher than the high crude densities reported above (see Table 2). The mean chital density in GNP over the two years was 212.3/km². A seasonal density in the considered habitat type greater or lesser than this, can be taken to indicate greater or lesser utilization, respectively. Data analysis showed a similar pattern of seasonal habitat utilization in both years. Hence, the two years' data were pooled (Fig. 3).

Dry Season: The woodland is now highly preferred by chital (Table 2). In January, many chital still used the scrubland and grassland. But as the season progressed, the use of these habitats decreased. Overall, the scrubland was underutilized and very few chital used the grassland (mean number on Polo Field = 4.3, range = 0-14, n = 37 total counts).

Summer or Pre-Monsoon: Chital continued to occur at a higher density in woodland than in scrubland or grassland. The grassland still had very few chital (mean number on Polo Field = 1.94, range = 0-8, n = 34 total counts). Seen relative to the

TABLE 2
SEASONAL HABITAT UTILISATION OF CHITAL IN GUINDY NATIONAL PARK, 1991-92

Season	Habitat	n	Density D/km²	Standard error of density SeD	CiD /km²
Dry	Woodland[a]	59	317.1	47.0	225.1-409.2
	Scrubland[a]	111	109.2	12.8	84.0-134.3
	Grassland[b]	37	107.4	16.5	75.1-139.7
Summer	Woodland	45	353.3	57.6	240.5-466.1
	Scrubland	86	119.9	14.4	91.7-148.2
	Grassland	34	48.5	12.8	23.4-73.6
Wet	Woodland	40	97.0	19.5	58.7-135.3
	Scrubland	318	279.0	18.7	242.5-315.6
	Grassland	85	632.3	62.3	510.2-754.4

CiD - 95% confidence interval of density.
a - Densities based on transect estimates; n - number of groups (sample size).
b - Mean density and its standard error (SeD) were calculated from systematic total counts for the grassland. The 95% CiD was calculated as mean ± 1.96 SeD; n - number of total counts.

available area, the woodland was overutilised, and the scrubland and grassland underutilised as in the Dry Season (Fig. 3).

Monsoon or Wet Season: The situation was reversed after the rains with chital density increasing in the scrubland and grassland, and decreasing in the woodland. Considerable numbers of chital aggregated in the grassland (mean number on Polo Field = 25.3, range 1-83, n = 85 total counts). The scrubland and grassland were clearly overutilised relative to the available area (Fig. 3).

General feeding habits of chital: During the dry season, chital frequently ate fallen fruits (e.g. *Ficus benghalensis, Albizia lebbeck, Limonia acidissima*) in the woodland. Much browsing occurred, mainly on *Randia dumetorum, R. malabarica,* and *Carissa spinarum*. Leaves of *Maytenus emarginata, Cassia roxburghii*, and *Syzygium cumini*, fruits of *Phoenix loureirii*, and the inflorescence of *P. farinifera* were eaten. From March

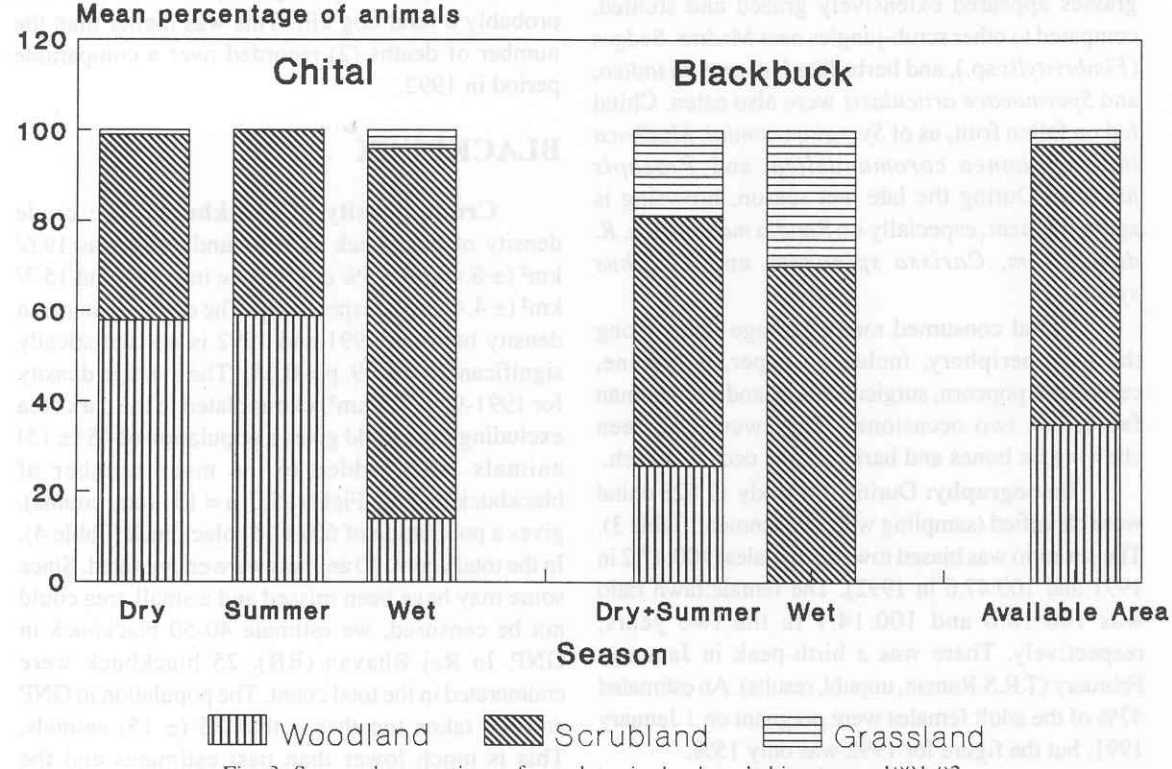

Fig. 3. Seasonal proportions of ungulates in the three habitat types, 1991-92.

onwards, chital also consumed the paragrass (*Brachiaria mutica*) provided by the Forest Department at ten feeding sites.

During summer, chital often fed on the pods of *Tamarindus indica* dropped by foraging bonnet macaques. Fallen fruits of *Acacia planifrons*, *Albizia lebbeck*, *Ficus benghalensis*, *Borassus flabellifer*, and *Phoenix sylvestris* were also eaten. One rumen examined, had seeds of *Polyalthia longifolia*. Browsing occurred on both *Randia* species, *Capparis sepiaria*, and *Canthium parviflorum*. Chital commonly grazed near the edges of ponds and fed on garbage along the park periphery. Aggregations of 20-50 chital fed at the artificial feeding sites in the evenings.

During the early wet season, chital were most frequently seen grazing. They ate many common grass species: *Heteropogon contortus*, *Cynodon dactylon*, *Cymbopogon flexuosus*, *Eragrostis* sp., *Vetiveria zizanioides*, and *Aristida setacea*. Many grasses appeared extensively grazed and stunted, compared to other scrub-jungles near Madras. Sedges (*Fimbristylis* sp.), and herbs like *Limnophila indica*, and *Spermococe articularis* were also eaten. Chital fed on fallen fruit, as of *Syzygium cumini*, *Madhuca indica*, *Lannea coromandelica*, and *Prosopis juliflora*. During the late wet season, browsing is again frequent, especially on *Randia malabarica*, *R. dumetorum*, *Carissa spinarum*, and *Ziziphus xylopyrus*.

Chital consumed many garbage items along the park periphery, including paper, polythene, cardboard, popcorn, surgical cotton, and even human faeces (on two occasions). They were also seen chewing on bones and bark, on one occasion each.

Demography: During this study 11,828 chital were classified (sampling with replacement, Table 3). The sex ratio was biased towards females (100:47.2 in 1991 and 100:47.6 in 1992). The female:fawn ratio was 100:18.0 and 100:14.1 in the two years, respectively. There was a birth-peak in January-February (T.R.S.Raman, unpubl. results). An estimated 47% of the adult females were pregnant on 1 January 1991, but the figure for 1992 was only 15%.

TABLE 3

POPULATION STRUCTURE OF CHITAL IN GUINDY NATIONAL PARK

Age/sex Class	1991 %	1992 %
Females	49.2	53.4
Yearling Females	9.9	7.0
Fawns	8.8	7.5
Yearling Males	8.8	6.6
Juvenile Males		7.2
Adult Males	23.2	18.2
Number of animals classified, N	4981	6847

The mean monthly mortality rate of fawns was 9.7% between March and October 1991, but in 1992 mortality was negligible (0%). Data on adult deaths in 1991 were not collected. In 1993, eight adult chital carcasses were found during the dry season, from late February to early May, only one of which was probably a feral dog kill. This was higher than the number of deaths (2) recorded over a comparable period in 1992.

BLACKBUCK

Crude density of blackbuck: The crude density of blackbuck in 1991 and 1992 was 19.6/km² (± 6.4/km²; 95% confidence interval) and 15.3/km² (± 4.4/km²), respectively. The decrease in mean density between 1991 and 1992 is not statistically significant ($z = 1.09$, $p > 0.05$). The average density for 1991-92 (17.5/km²) extrapolated to the park area excluding Polo Field gives a population of 45 (± 15) animals. This, added to the mean number of blackbuck on Polo Field (15.0, n = 151 total counts), gives a population of 60 (± 15) blackbuck (Table 4). In the total count, 40 animals were enumerated. Since some may have been missed and a small area could not be censused, we estimate 40-50 blackbuck in GNP. In Raj Bhavan (RB), 25 blackbuck were enumerated in the total count. The population in GNP and RB taken together is thus 85 (± 15) animals. This is much lower than past estimates and the

TABLE 4

BLACKBUCK POPULATION DENSITY AND SIZE IN GUINDY NATIONAL PARK

Year	n	Density D/ km²	Standard error of density SeD	CiD D/km²	Mean Population (excl. Polo Field)	Mean no. in Polo Field	Total Population	CiP
1991	50	19.6	3.3	13.2-26.0	51	16.5	68	51-85
1992	48	15.3	2.2	11.0-19.7	40	14.0	54	43-65

CiD - 95% confidence interval of density.
CiP - 95% confidence interval of total population.
n - Number of groups (sample size).

possible reasons for this decline form the major focus of this paper (see Discussion).

Seasonal habitat utilisation of blackbuck: The data for the dry season and summer were pooled to obtain sufficient sample size for TRANSECT analysis. Blackbuck used the woodland only during the dry months (Fig. 3). Density estimates for the scrubland and the grassland are given in Table 5.

Dry season and Summer: The mean density of blackbuck in the scrubland during this period was 18.2/km². To obtain a relative estimate of blackbuck use of the woodland we compared the number of blackbuck groups seen within 10 m from the transect line (visibility bias thus being small) in the scrubland and woodland. In 22 km of transect, 7 groups were seen in the woodland, and 8 in the scrubland, indicating almost equal usage. On the grassland (Polo Field), an average of 14.6 and 6.5 blackbuck were seen during the dry season and summer, respectively (n = 35 and 33 total counts, respectively). Fewer blackbuck were seen on Polo Field in the mornings than in the evenings. While the scrubland and grassland were used more or less in proportion to availability, the grassland was highly preferred by blackbuck (Fig. 3).

Wet season: The blackbuck avoided use of the woodland and concentrated in the scrubland and grassland areas after the green flush of vegetation following the rains. The mean density in the scrubland increased slightly, and the Polo Field grassland became the primary centre of blackbuck activity. The mean number of blackbuck on Polo Field was 17.9 (n = 83 total counts) during this season. Both the scrubland and grassland were overutilized when seen relative to available area (Fig. 3).

TABLE 5

SEASONAL HABITAT UTILISATION OF BLACKBUCK IN GUINDY NATIONAL PARK, 1991-92.

Habitat	Season	n	Density D/km²	Standard error of density SeD	CiD /km²
Grassland	Dry	35	365.0	35.5	295.4-434.6
(Polo Field[a])	Summer	33	162.0	25.5	112.0-212.0
	Wet	83	448.3	20.8	407.6-488.9
Scrubland[b]	Dry+Sum	36	18.2	3.8	10.7-25.7
	Wet	49	25.9	3.7	18.6-33.1

CiD - 95% confidence interval of density.
a - Mean density and its standard error (SeD) were calculated from systematic total counts. The 95% CiD was calculated as mean ± 1.96 SeD; n - number of total counts.
b - Densities based on transect estimates; n - number of groups (sample size).

General feeding habits of blackbuck: During the dry season, blackbuck in the woodland foraged in small clearings, or along road edges. They browsed extensively on *Carissa spinarum, Randia dumetorum*, and *R. malabarica*. Fallen fruits of *Pithecellobium dulce* and leaves of *Aegle marmelos* were also eaten. Only twice, in the late dry season a male was seen feeding at the artificial feeding site on Polo Field, when no other animals were present.

Many blackbuck feed on dry, coarse grasses in Polo Field and near KK Tank, especially in the evenings.

In the wet season, blackbuck mostly grazed on grasses such as *Aristida setacea, Cynodon barberi, Heteropogon contortus, Cymbopogon flexuosus, Chrysopogon fulvus, Vetiveria zizanioides,* sedges such as *Fimbristylis ovata*, and herbs such as *Justicia prostrata* and *Indigofera linnaei*. These plants were common in Polo Field and nearby open areas.

Demography: During the study, 3,108 blackbuck were classified (sampling with replacement, Table 6). The adult sex ratio was 100:21.0 (females : males) in 1991, and 100:18.8 in 1992. The proportion of sub-adults and young declined from 13.2% in 1991 to only 6.3% in 1992.

TABLE 6

POPULATION STRUCTURE OF BLACKBUCK IN GUINDY NATIONAL PARK

Age/sex class	1991	1992	1979[a]	
	%	%	%	Number
Female (Ad+Yrl)	71.6	78.8	58.4	152
Adult Male	15.0	14.8	8.9	35
Sub-adult Male	4.2	3.8	23.5	49
Adolescent Male	4.4	0.0	5.0	13
Fawns	4.6	2.5	4.2	11
Number of animals classified	1484	1624		260

a - From Selvakumar (1979), (total count).

The female: fawn ratios were 100:6.4 and 100:3.1, respectively. In 1991, most births occurred in September-October, while in 1992, most births were in November-December (T.R.S.Raman, unpubl. results). Thus in 1991, the fawn: female ratio peaked at 27.8:100 in October, while in 1992, it was highest at just 10.5:100 in December. Fawn mortality was difficult to estimate. Out of five fawns regularly seen with the blackbuck herd on Polo Field in November-December 1992, only two were seen with the herd in January 1993.

Predation: In GNP, the only natural predators are a few (about 6-12) jackals and some feral dogs. Both jackals and dogs chased chital and blackbuck on several occasions. The albino blackbuck male suffered a large wound on its thigh after being attacked by two jackals in 1993, but managed to survive.

DISCUSSION

POPULATION TRENDS IN CHITAL AND BLACKBUCK

The average population size of chital and blackbuck in GNP in 1991-92 was 550 and 60, respectively. Comparison with past data suggests that while chital have either remained stable or increased slightly in numbers, the blackbuck have declined drastically.

Selvakumar (1979) reports a population of 360 chital for 1979. This is probably an underestimate and should be taken as the minimum number, as the total count method used (in which RS and RKGM participated) would have missed animals in dense vegetation. Menon (1982) used line transects and estimated an average population of 520 chital in 1981-82. The current trend (1991-92, this study) appears to be one of increase.

In contrast, blackbuck were far more numerous in the past. An average of six censuses (Forest Dept. records, total counts and transects) in 1975-80 gives a total of 295 blackbuck. Selvakumar (1979) likewise estimated 260 blackbuck in 1979. The average of four line-transect estimates in 1981-82 was 333 blackbuck (Menon 1986a, unpubl. data). These estimates and other observations (by RS and RKGM) clearly showed that at least 250 blackbuck inhabited the combined GNP and Raj Bhavan areas till 1981. The current trend (1991-92, this study) appears to be one of decline, with a population of only 85 animals.

BLACKBUCK DECLINE: ROLE OF HABITAT CHANGES

Provided that obvious requirements such as

food, space, and water are available, a major requirement for free-ranging blackbuck is the opportunity for the males to express territorial behaviour. Non-territorial males rarely reproduce (Walther *et al.* 1983). Blackbuck are well known to prefer open areas for their territorial activities and feeding. The availability of such habitats is thus likely to be a decisive factor in blackbuck population dynamics. For instance, in this study, Polo Field, the main territorial ground, occupying less than 3% of GNP's area held about 25% of the blackbuck population through the year (Fig. 3). Loss of this small area can disproportionately lower the population that can be retained in GNP.

While no quantitative data exist regarding habitat changes in GNP over the last 15 years, certain striking aspects are evident. Based on comparative notes kept on the vegetation of the Park in the 1970s by one of us (RS), we find that the major changes are:

i) *Vegetation change and deterioration of territorial areas:* Polo Field, in 1979 was an open meadow occupied by five to six territorial males (Selvakumar 1979, RKGM, unpubl. data). During the current study, it was found overrun by numerous weeds (*Cassia tora, Cassia occidentalis, Croton bonplandianus, Sida cordifolia,* and *Prosopis juliflora*) and tree saplings (*Cassia fistula, Borassus flabellifer*), until cleared by the Forest Department in April 1992. The number of territorial males on Polo Field during the current study was never more than 2 until the rut of April 1992. After the weeds on Polo Field were removed, 3 males were regularly seen there. A fence now separates this area from Raj Bhavan.

Two other open areas used by blackbuck in the past have been lost. The first is an area classified by Selvakumar (1979) under AREA 3. In 1984-85, this 2.5 ha. area west of KK Tank, was fenced off to grow grass for the animals in Children's Park zoo. The area is almost wholly unused now. While many chital easily get across the partially collapsed fence, only two blackbuck males were seen inside in 1992. Female blackbuck shy away from entering this area. When under our suggestions, a portion of the fence was removed, female blackbuck were seen using the area (A. T. F. Vanak, pers. comm.) and males were observed initiating territorial activity (RKGM, pers. obs.). The second grassland area that has been lost, along the eastern bank of the KK Tank, is now overrun by dense clumps of *Acacia auriculiformis* trees and saplings.

Other vegetation changes may not have been evident. *Dodonaea viscosa*, once a common plant in the Park, is now rare. The fate of many other species is not known.

ii) *Increase in plant biomass:* The vegetation in many areas is clearly much denser today. The undergrowth of *Clausena dentata* in AREA 1 is now almost 1 - 2 m taller (and denser) than it was in the 1970s. As mentioned earlier, Polo Field too has been overrun with shrubs and weeds. Some areas included by Selvakumar (1979) in AREA 3, are indistinguishable from AREA 2 now. These areas were also grazing grounds for cattle in the past. The exclusion of livestock may have contributed to the growth in the vegetation.

There is also a large influx of biomass into the Park every year in the form of artificial fodder. One ton fresh weight (or an estimated 350 kg dry weight) of grass, provided for about 100 days each year for the last 15 years, totals 525 tons dry weight of biomass (nearly 200 tons/km^2). This large influx of biomass may have upset the nutrient cycles in GNP leading to an increase in woody and herbaceous vegetation. The curtailment of wood-poaching by the Forest department in recent times could also have led to an increase in woody vegetation. This may have shaded-out the growth of grass in some areas, forcing chital to forage in other places such as Polo Field.

iii) *Fragmentation:* GNP has lost considerable area in the past to memorials and educational institutions, and has been isolated from the adjacent Raj Bhavan and the Indian Institute of Technology (IIT) campuses by physical barriers. It is not known when the Raj Bhavan fence was built, but the wall separating IIT and GNP was built in the late 80's and completed by about 1989. It is unlikely that the observed blackbuck decline is a simple result of the

sub-division of a once-contiguous population, with the blackbuck lost by GNP being gained by other areas. Our observations suggest that there has been a parallel decline in blackbuck numbers in IIT also (RKGM and TRSR, unpubl. data). In GNP, the fragmentation is likely to have mainly affected the spatial distribution of blackbuck territories (especially between GNP and Raj Bhavan) and seasonal movements of the ungulates.

BLACKBUCK DECLINE: COMPETITION WITH CHITAL

While habitat changes are likely to be the primary cause for the blackbuck decline, competition with the high-density chital population may be another important factor. Chital are a highly adaptable species (Krishnan 1972) and may be exerting considerable competitive pressure on blackbuck for food and space. The density of chital in GNP was higher than in other areas for which information is available (Table 7). Competition is possible as chital and blackbuck share many food items in common (see Feeding Habits). Also, during the wet season, chital are found in large numbers in the scrubland and grassland areas which are prime blackbuck habitats. Polo Field may be occupied by as many as 100 chital in October-November in the evenings, physically disrupting the blackbuck herd, and the territorial behaviour of males, as has been noticed on a few occasions.

TABLE 7

ECOLOGICAL DENSITIES OF CHITAL IN OTHER NATURAL AREAS

Place	Chital density D/km²	Source
Bandipur, Karnataka	36-85	Sharatchandra & Gadgil 1975
	43-45 (up to 120)	Johnsingh 1983
Chitawan, Nepal	15.4-17.3	Seidensticker 1976
Corbett, U.P.	45.5-49.3	De & Spillett 1966
Gir, Gujarat	42.3-53.9	Khan *et al.* 1990
Kanha, M.P.	23.2	Schaller 1967
Karnali Bardia, Nepal	90.4-114.2	Dinerstein 1980
Nagarahole, Karnataka	50.6	Karanth & Sunquist 1992
Powderhorn, Texas	18.9	Ables 1974
Wilpattu, Sri Lanka	12.1	Eisenberg & Lockhart 1972

How are chital maintained at such high densities in GNP? A natural factor may be that the vegetational diversity and edge-to-forest ratio in GNP is high (Eisenberg and Seidensticker 1976). However, the other contributing factors are artificial feeding of chital and low mortality from predation.

i) *Artificial feeding:* In temperate Parks, artificial feeding during winter is known to maintain populations of deer at higher densities, with lower mortality, higher body weight, and better reproduction (Putman and Langbein 1993). In GNP, when no feed was provided, fawn mortality (in 1991) and adult mortality (in 1993) were high. In contrast, mortality was much lower in 1992, when artificial feed was provided. Artificial feed may also help chital attain higher fertility due to improved nutritional status during the dry months, which coincides with the peak rut of chital in GNP (Miura 1981, T. R. S. Raman, unpubl. results). The absence of artificial feeding in 1991 would then explain the lower fertility observed in 1992.

Blackbuck do not seem to prefer the artificial feed provided. Possibly, the milling aggregations of 20-50 chital at these feeding sites physically deter blackbuck. Aggressive interactions between chital and blackbuck have been recorded at feeding sites in Texas (Walther *et al.* 1983: 216). Thus only chital benefit from the artificial feed provided.

ii) *Low mortality from predation:* Many large mammal populations are limited by predation, and increase when predators are removed (see Sinclair 1989, for a review). Menon (1987) gleaning data from Forest Department records reported that, in 1979, a total of 107 deer (about 17% of the total population) were killed by feral dogs. While few kills may have been due to jackals, dogs are the most important predators of chital in GNP. Blackbuck mortality to dogs was not high in GNP and IIT compared to chital (Menon 1986b). No data are available regarding the total number of kills during the current study. However, in 1992, the Forest

Department sanctioned the shooting down of dogs in GNP, thus removing this source of mortality of chital.

TRENDS IN HABITAT UTILISATION

Understanding the seasonal distribution and movements of the ungulates in GNP is important in considerations of the dynamics of the two species. The seasonal movements of chital and blackbuck were clearly governed by the availability of food in the three habitat types. Between January and May, drying up of grass forage in the scrubland and grassland led to frequent browsing and increasing use of woodland. In summer, most trees set fruit (Rajasekhar 1992) and shed their leaves, and these are then consumed. After the first monsoon showers, the grass flush in the scrubland and grassland induce high utilisation of these areas. This is not surprising as both species are predominantly grazers (Mungall 1978, Mishra 1982). Late in the season, as the grasses mature, there is a return to frequent browsing presumably because deeper-rooted browse species produce fresh growth even after the rains cease.

While this pattern is similar to the one described by Selvakumar (1979), two notable differences exist. In the past, considerable movement, especially of chital, used to occur between GNP and the surrounding areas (Menon 1982). Today, with the walling-up of GNP it has become a small, closed system. Secondly, systematic total counts of chital and blackbuck on Polo Field during 1977-78 by one of us (RKGM) showed few chital (up to 12 or so individuals) and many more blackbuck on Polo Field (Table 8). Currently, the reverse situation, with more chital on Polo Field during the wet season, prevails. The maximum number of blackbuck seen on Polo Field during the current study was 29, and chital was 102. Poor availability of grass forage in other areas due to dense growth of woody vegetation may be responsible for the present shift to the grassland.

TABLE 8

SOME PAST TOTAL COUNTS OF BLACKBUCK ON THE POLO FIELD GRASSLAND

Date	Males	Females	Total
06.08.1977	3	14	17
06.11.1977	19	45	64
16.11.1977	10	43	53
11.12.1977	5	29	34
15.01.1978	5	31	36
10.031978	—	—	53
30.05.1978	19	31	50

VIABILITY OF THE BLACKBUCK POPULATION

Small, isolated populations of wild animals are vulnerable to extinction through demographic, environmental, and genetic stochasticity, and catastrophes such as disease epidemics (Shaffer 1981). In this light, several aspects of blackbuck demography require attention.

Currently, the proportion of fawns and young males in the population is much lower than in 1979 (Table 6). Fewer fawns are seen per female than in other blackbuck populations in places like Mudmal (Prasad 1983), Point Calimere (Natarajan 1989), areas reported by Schaller (1967), Velavadar and Tal Chapar (Ranjitsinh 1989). The percentage of fawns in the GNP population declined from 4.6% in 1991 to 2.5% in 1992. Also, in 1992, no adolescent males were seen at all in GNP, indicating total lack of recruitment into that age class. At present, there are just 8 adult blackbuck males in GNP and 2-3 younger males. In terms of behaviour, the presence of younger males may play a beneficial role in influencing territorial behaviour and reproduction of adult males (Walther *et al.* 1983). Currently, large mortality of adult males in any year may spell disaster for the blackbuck in GNP at prevailing recruitment rates.

The sex ratio of blackbuck in GNP is more biased towards females than in the other natural areas mentioned above and even when compared to the population in 1979. If only some of the eight adult males in the population are doing most of the breeding, it would decrease the effective population size and accentuate inbreeding (Frankel and Soulé 1981).

Selvakumar (1979) found that the August-October rut of blackbuck contributed the major proportion of the annual fawn crop the following January-April. During this study, the March-April rut contributed most of the fawn crop, with births occurring almost entirely during September-December. The reasons for this reversal are not evident. Increased interference by large chital aggregations on the territorial activities of blackbuck on Polo Field during the October rut may be a reason.

PRACTICAL CONSIDERATIONS AND MANAGEMENT

What are the conservation objectives that define feasible management options for GNP? We suggest that GNP can serve as a useful reserve for maintaining a viable population of blackbuck, preserving the remnants of the natural vegetation, and addressing social and educational functions of the park in Madras city. The following management suggestions are made in the light of this study:

1. *Habitat manipulation* can be used to improve and increase the territorial grounds of blackbuck in GNP. This can be targeted at two particular areas without disturbing the natural vegetation of the Park:

(a) the defunct 2.5 ha. grass plot west of KK tank - where the entire fence surrounding the plot must be removed to allow free access to blackbuck males and females, and (b) the area east of KK tank - where the profusely growing clumps of *Acacia auriculiformis* can be removed.

As these areas are close to Polo Field and represent past territorial grounds, they are likely to be used by blackbuck when these changes are made. Close monitoring will yield valuable information on the results of such management measures. Periodic control of weeds and woody plants on Polo Field will also be beneficial.

2. *Reduction in chital numbers* can be achieved by allowing natural mortality factors to operate. Artificial feeding of chital during the dry season and the shooting of dogs should stop. Stopping artificial feeding is also important to stop the inflow of large quantities of biomass into the Park.

Stopping artificial feeding may have slightly deleterious effects on the blackbuck in the short term, as chital may eat a greater amount of food during the dry season, which may otherwise be available for the blackbuck. However, in 1991 and 1993, when artificial feeding was either not carried out or minimal, the blackbuck population did not seem to be affected by increased competition with chital. This is probably because, during the dry season, many blackbuck feed on dry and coarse grasses in areas like Polo Field and near KK Tank, where few chital feed.

3. *Control of exotic plants*, specifically *Acacia auriculiformis, Prosopis juliflora, Antigonon leptopus*, and *Cereus peruviana* is suggested. The vegetation in AREA 4 can be targeted for intensive protection from invasion by exotics, wood-removal, and disturbance, as a 'remnant' patch of the tropical dry evergreen forest.

4. *Introduction of a few blackbuck* from other areas, including some sub-adult males from IIT, is recommended to counter inbreeding depression and loss of demographic vigour, and modify the distorted population structure. Standard guidelines suggested for such introductions can be followed (Sale 1986).

5. *Regular, long-term monitoring* of the ecology of the Park will be valuable in assisting management. Monitoring population trends, mortality, and results of management actions such as habitat manipulation, will be useful.

CONCLUSIONS

The decline of blackbuck in GNP illustrates that mere protection of a National Park may not be enough to ensure its viability. Prudent and interactive management is called for, especially in parks like GNP. GNP represents the plight of many such small, isolated nature reserves. Maintaining a viable population of blackbuck in GNP is however a feasible and challenging task. The experience so gained will be useful in management of other sanctuaries in the country. GNP harbours a remnant of tropical dry evergreen forest vegetation which

today occupies only 1% of the potential area along the Coromandel coast (Meher-Homji 1986). In Chingleput District, near Madras, satellite data show that over 99.9% of the area under scrub-jungle vegetation has been lost (P. Dayanandan, pers. comm.). Conservation of GNP is also important for tapping its valuable potential as a field laboratory to train students in the field of ecology and to educate tourists about conservation.

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