CHAPTER 6

ANIMAL DISTRIBUTION, ABUNDANCE AND ASSOCIATIONS WITH ENVIRONMENTAL FACTORS

6.1 INTRODUCTION

This chapter investigates the large animal distributions and abundance in Western Central Kalahari during parts of 1983 and 1984, and the associations between these animals and selected environmental factors including land uses. The data acquisition methods were described in Chapter 3.

The data base obtained in this study is broad. It could have been used for investigating more biological and ecological topics. These include animal movement patterns and their relatiopnship to landscapes and the altitudinal gradient within the study area; species by species' response to the rate of production and change of the herbaceous layer standing crop and condition; inter-specific animal associations for purposes of identifying competition or otherwise for the resources; productivity by soil types and location, and indeed the interrelationships of the independent variables themselves, for example soils and vegetation types; harvester termite, soil types and herbaceous layer cover; distribution of tree and bush species by altitudinal gradient and/or landscapes; and several other topics. These investigations could not be pursued, because of time constraints. The need to investigate the above topics in some greater detail is appreciated.

This chapter intends to satisfy the second objective of this study (see Chapter 1) and validate or otherwise the hypotheses stated thereunder, as well as satisfy the second requirement of the first objective.

6.2 ANIMAL DISTRIBUTION AND ABUNDANCE

6.2.1 Introduction.

The second objective of this study was to document distribution and abundance of selected wild and domestic animals in Western Central Kalahari (see Chapter 1). The importance of understanding the distribution and knowledge of the selected animals' abundance was discussed in that chapter. The data for mapping distribution and computing abundance values were collected by systematic sampling in seven different surveys (see sections 3.1, 3.2 and 3.3). This part gives the animal distribution maps and abundance results.

Distribution maps were produced using several methods. The animal distribution maps in three dimensional diagrams were produced using the SYMAP and ASPEX computer packages developed by the Laboratory for Computer Graphics and Spatial Analysis of Harvard University (Dougenik and Sheehan 1976, Hanson 1980). SYMAP is used to create the map outline as well as a programme for interpretation and plotting by ASPEX in three dimensions. The plots show animal mean densities. The higher the peak the greater the density. However, the peak scales are different for each survey and for each species i.e. while each map's horizontal scale is the same for each survey and species, the density (vertical) scales differ between surveys because the ranges of density differed between surveys.

Animal abundance has been estimated for the ten animal species using the now conventional formulae for determining densities and population estimates.

6.2.2 Animal Distribution.

6.2.21 General: This section reviews only the general distribution of the animal species studied. The quantitative association of the animal distributions with other environmental factors or independent variables is given in section 6.3.

Ten animal species observed were eland, gemsbok, hartebeest, wildebeest, springbok, kudu, ostrich, cattle, horse and donkey. Although the distribution maps will be given for all the ten animal species, only six, the eland, gemsbok, hartebeest, wildebeest, springbok and cattle will be discussed. These six animal species were chosen for several reasons:

(i) the five wild animal species are the more numerous and thus much sought after by local residents for meat and hides; understanding the species' seasonal distribution may be used in management to help in reducing hunting effort and increasing hunter success and thus enhance the objectives of the country's policy of wildlife utilisation;

(ii) understanding the seasonal distribution patterns of these wild animal species will help identify the most important areas which require specific management action such as protection under an appropriate land use category;

(iii) understanding the distribution patterns of cattle and the five wild animal species will help identify areas of conflict between the two groups of animals.

While the other two wild animal species are also important and require consideration, the politics of their local utilisation is less heated. Donkey and horse distributions are to a large extent, dictated by human presence because they are largely used as transport. Therefore a demand for understanding their distribution is not as acute as for other animals. However, it would be of interest to investigate the possibility of consistent distributions in a certain pattern, away from settlements, communal cells and farms, and over a period of time, to see if there could be any association between such distributions and poaching.

6.2.22 Distributions: Figs. 6.1 to 6.10 show, for each animal species, a set of seven maps, each corresponding to a specific survey.

<u>(a) **Eland distribution** (Fig. 6.1):</u> The eland seem to be generally restricted to the southwestern part of the study area. Animals were found in this part in 6 out of the 7 surveys. A few eland were noted in the central (1 survey) and east (4 surveys) of the study area.

The area in the southwest of the study area that seems to be most favoured is approximately south of 24° 00'S latitude between 20° 30'E and 21° 00'E longitudes, while in the east it is the area approximately south of 24° 00'S approximately between 22° 00'E and 22° 30'E longitudes. In the November 1983 and January 1984 surveys, the distribution was wider, going as far north as approximately 23° 30'S latitude and into the central part of the study area around 21° 30'E longitude (November 1983).

The general nature (see Chapter 5) of the western and eastern parts of the study area where the occurrences were observed is as follows:

(1) Vegetation types: Scattered tree, scrubland, clumped woodland, grassland, and open woodland;

(2) Landforms: In flatland, undulating and rolling to small sand-hills and low sand-dune area;

(3) Drainage system: In the west the two main parallel fossil drainage systems and in the east the fossil delta drainage area;

(4) Soil types: Types 2 and 3 which have moderate to high pan soil cover (see section 5.2.4); and

(5) Land uses: In the west only conservation areas, both national park and wildlife management area, while in the east are the TGLP farms, conservation areas (only wildlife management area) and mineral prospecting areas.

(b) **Gemsbok distribution** (Fig. 6.2): The areas in which the gemsbok consistently occurred, with only a few minor deviations for the duration of the study period were:

(i) the northern: mainly north of 23° 30'S latitude east of 21° 15'E longitude;

(ii) the eastern: mainly south of 24° 00'S latitude between 22° 00'E and 22° 45'E longitudes;

(iii) the southern: mainly south of 24° 21'S latitude, west of 22° 45'E longitude;

(iv) the western: mainly south of 23° 30'S latitude west of 21° 15'E longitude.

There were areas the animals were persistently not found in. These are around the Matsheng Villages enclosed by 23° 45'S, 22° 00'E, 24° 15'S, 21° 45'E south latitudes and east longitudes; the area west of 21° 00'E longitude north of 23° 30'S latitude occupied by Kule and Ncojane villages and the Ncojane farms; the area east of 23° 00'E longitude occupied by Kokong and Morwamosu Villages and the area around Kang Village.

The areas with the highest concentrations and most frequent usage were mainly the south and western parts of the study area with the east and north having lesser concentrations in that respective descending order. Overall the animals were well dispersed in almost the same pattern for the duration of the study.

While the distribution maps suggest animals avoided the Ncojane farms in the north, in the east they were found near the southern parts of Phuduhudu ranch and also over the present location of TGLP ranches east of Tshane. It is to be noted that the Ncojane farms are occupied by farmers while the TGLP ranches east of Tshane were, except for one, unoccupied. The southwestern parts of Phuduhudu ranch were relatively undisturbed in terms of human presence.

The general nature of the areas with gemsbok occurrences is:

(1) <u>Vegetation types:</u> Grassland, scrubland, scattered trees, open woodland, clumped woodland, park woodland;

(2) <u>Landforms:</u> Flatland, landforms 2a and $2b_2$ of undulating land region low sand-dune fields, rolling land to small sand-hills of the sand-hills and sand-ridges land region;

(3) <u>Drainage systems:</u> In the east the fossil delta are and in the west the parallel fossil river systems;

(4) <u>Soil types:</u> Types 1, 2 and 3 which are red and grey soils with little or no pan soil cover to the mixed soils with moderate to high pan soil cover.

(5) <u>Land uses:</u> Conservation areas both wildlife management area and national park in the west, wildlife management areas in all other parts, TGLP farms east of Tshane and mineral prospecting areas.

<u>(c) **Hartebeest distribution** (Fig. 6.3):</u> Two general observations on hartebeest distribution can be made. One is that, except for September 1983, September 1984 and to some extent April 1984 surveys, the distribution consistently shows two main divisions that are separated by a band of little occupancy. The divisions are generally aligned diagonally in a northwest/southeast direction. The eastern band remains generally close to the eastern boundary approximately east of 22° 15′E longitude in the study area, and is more consolidated with higher densities, while the western band shows more

loose consolidation and higher variability both spatially and in density. While the eastern band does not seem to move west of 22° 00'E longitude, the western band does not seem to move east of 21° 30'E longitude either.

The second observation is that generally the southern part of the study area between 21° 00'E and 22° 30'E longitudes south of 24° 15'S latitude seem to be used less i.e. it generally had fewer animals throughout the study period than other areas. This is almost a reverse of the gemsbok situation. This area is mainly low sand-dunes and sand-rises.

Other parts of the study area were also avoided. The area around Matsheng Villages was again consistently less occupied by this species, as was the Kule-Ncojane Village area and the Ncojane farms. The TGLP farms area east of Tshane was occupied by hartebeest.

The general nature of the areas occupied is:

(1) <u>Vegetation types:</u> Grassland, scattered trees, scrubland, open woodland, clumped woodland, park woodland;

(2) <u>Landforms:</u> Flatland, land form $2b_2$ of undulating land region and landforms 4a, 4b, 4c and 4d of sand-hills and sand-ridge region;

(3) <u>Drainage Systems:</u> The fossil delta river system in the east and the western fossil river system of the study area. In the east hartebeest occurrences were mainly to the north and northeast of the fossil delta river system.

(4) <u>Soil types:</u> Types 1, 2 and 3.

(5) <u>Land uses:</u> Conservation areas mainly wildlife management areas; private farm northwest of Kang, Phuduhudu ranch and TGLP farms east of Tshane; mineral prospecting areas.

<u>(d) **Wildebeest distribution** (Fig. 6.4):</u> The wildebeest distribution shows a general similarity to that of the hartebeest except the local densities and concentrations are reversed and also the southern part of the study area seems to be used more by wildebeest than by hartebeest. However, the striking similarity is the division of occurrences into two main bands one in the east, the other

west of the study area. The two divisions are generally aligned diagonally in a northwest/southeast direction. In between them is a band of apparent least occupation. The eastern group occurs generally east of 22° 00'E longitude while the western occurs generally west of 21° 30'E longitude. The eastern group is mostly in low comparative densities with more scattered sub-groups while the western shows more consolidation with high comparative densities. The west was more consistently occupied by higher densities than other parts of the study area. The west is therefore preferred more.

The animals were more dispersed in the study area in November 1983, April 1984, June 1984 and to some extent August 1984. The highest densities were between November 1983 and June 1984.

The wildebeest like the preceding three species show no occupation of the Matsheng Villages area and other permanent settlements. Their occurrence has been noted on the TGLP ranches east of Tshane. The habitat characteristics of the areas occupied by wildebeest are similar to those already determined for hartebeest, except the low sand-dune area and the national park were also occupied more frequently by wildebeest.

(e) **Springbok distribution** (Fig. 6.5): The springbok favours mostly the western part of the study area particularly west of 21° 30'E longitude south of 23° 30'S latitude. Within this area, there appears to be a specific preference for a strip between 21° 00'E and 21° 30'E longitude south of 23° 15'S in which the animals were always found, invariably in highest densities, although north of approximately 23° 45'S the comparative densities were generally lower. In the eastern part of the study area, the area most favoured appears to be between approximately 22° 30'E and 23° 00'E longitude south of 24° 00'S latitude where densities were generally moderate.

Overall the animals were wide spread with relatively lower comparative densities in November 1983, August 1984 and September 1984. Although the mean densities were relatively high in April and June 1984, the distributions were less spread out.

No occupation of Matsheng Villages area and other permanent settlements as well as the farms areas except the Ncojane farms was detected. Some minor occurrences were detected in Ncojane farms.

The general nature of the areas occupied are:

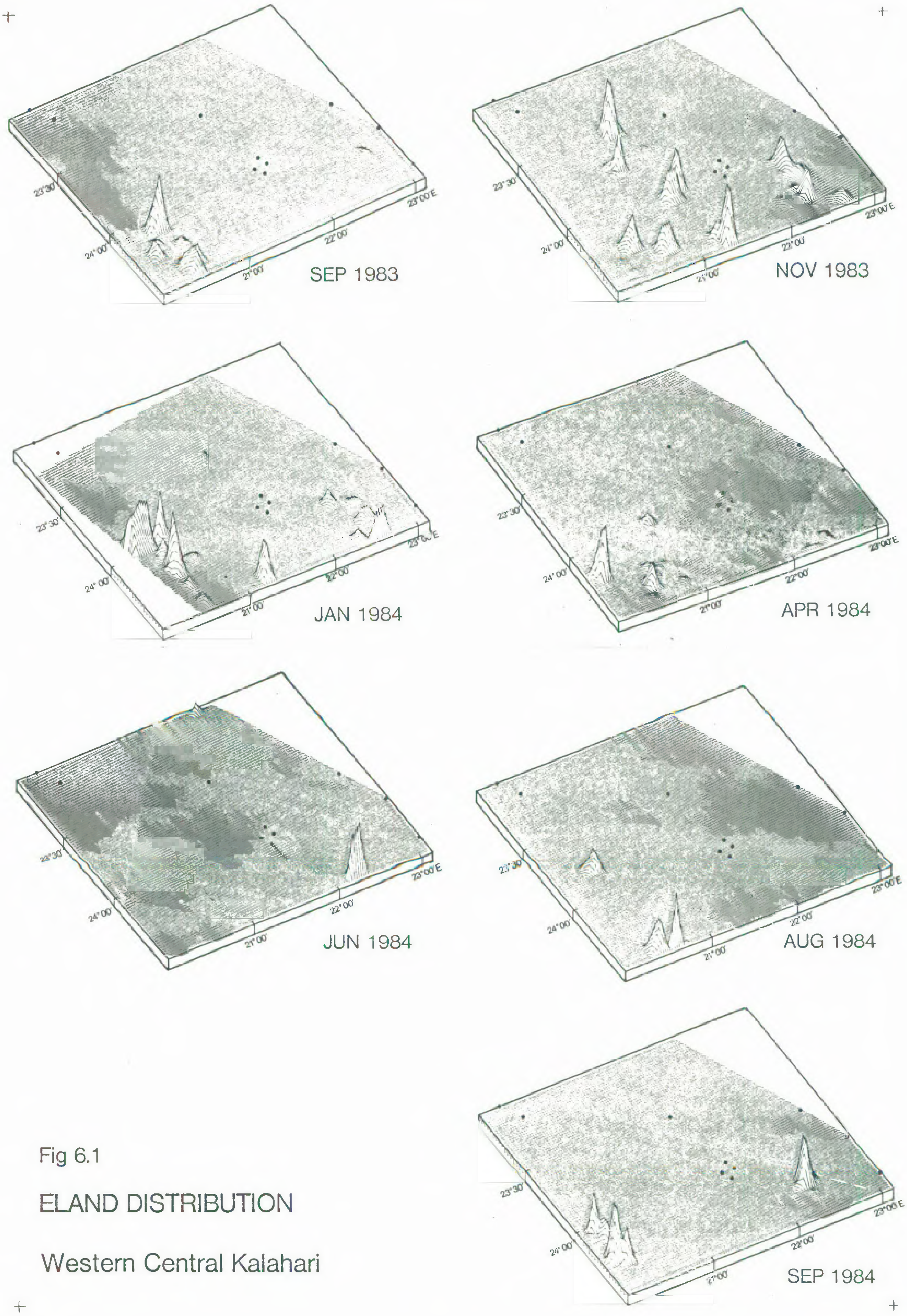

Fig 6.1

ELAND DISTRIBUTION

Western Central Kalahari

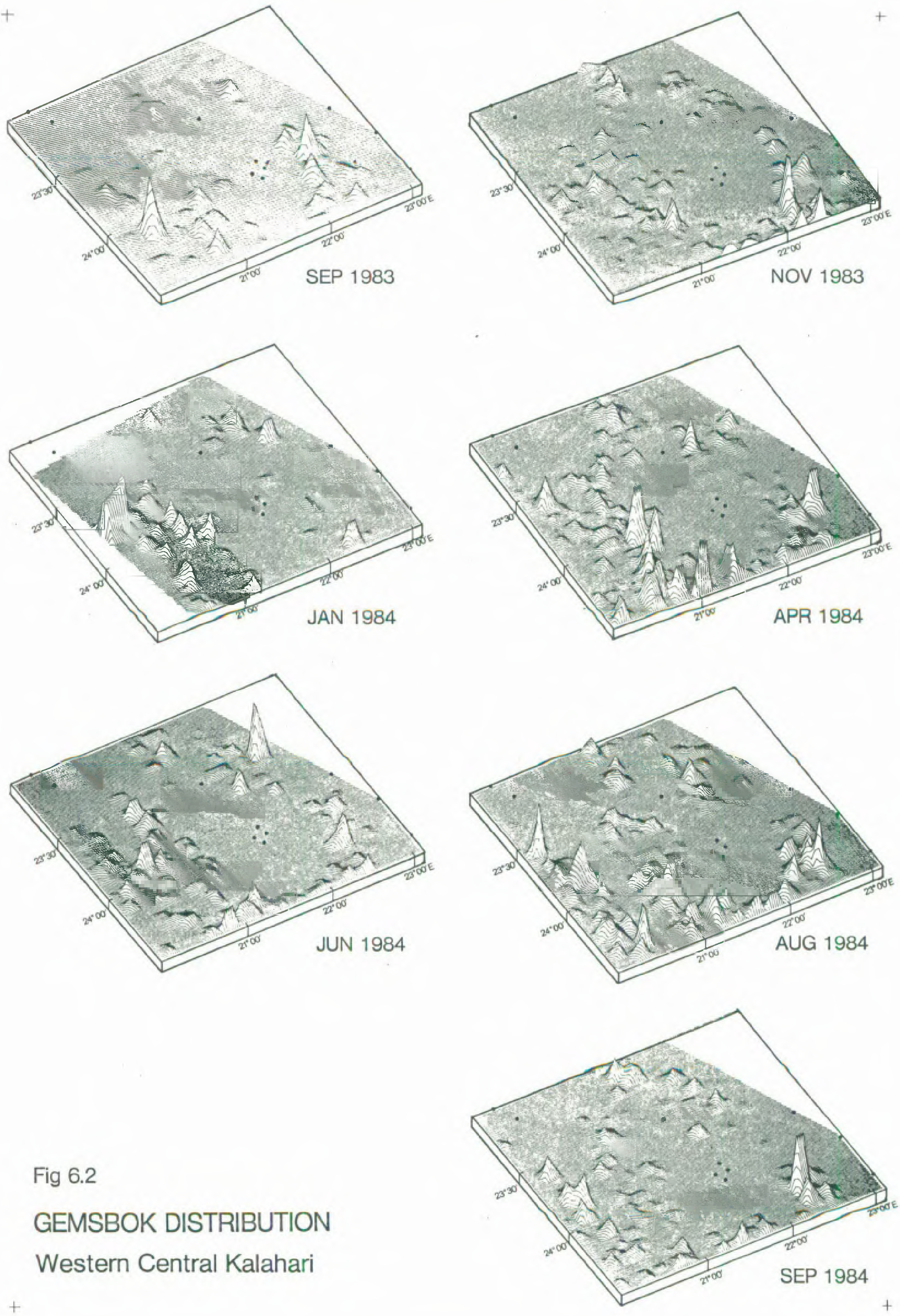

Fig 6.2

GEMSBOK DISTRIBUTION

Western Central Kalahari

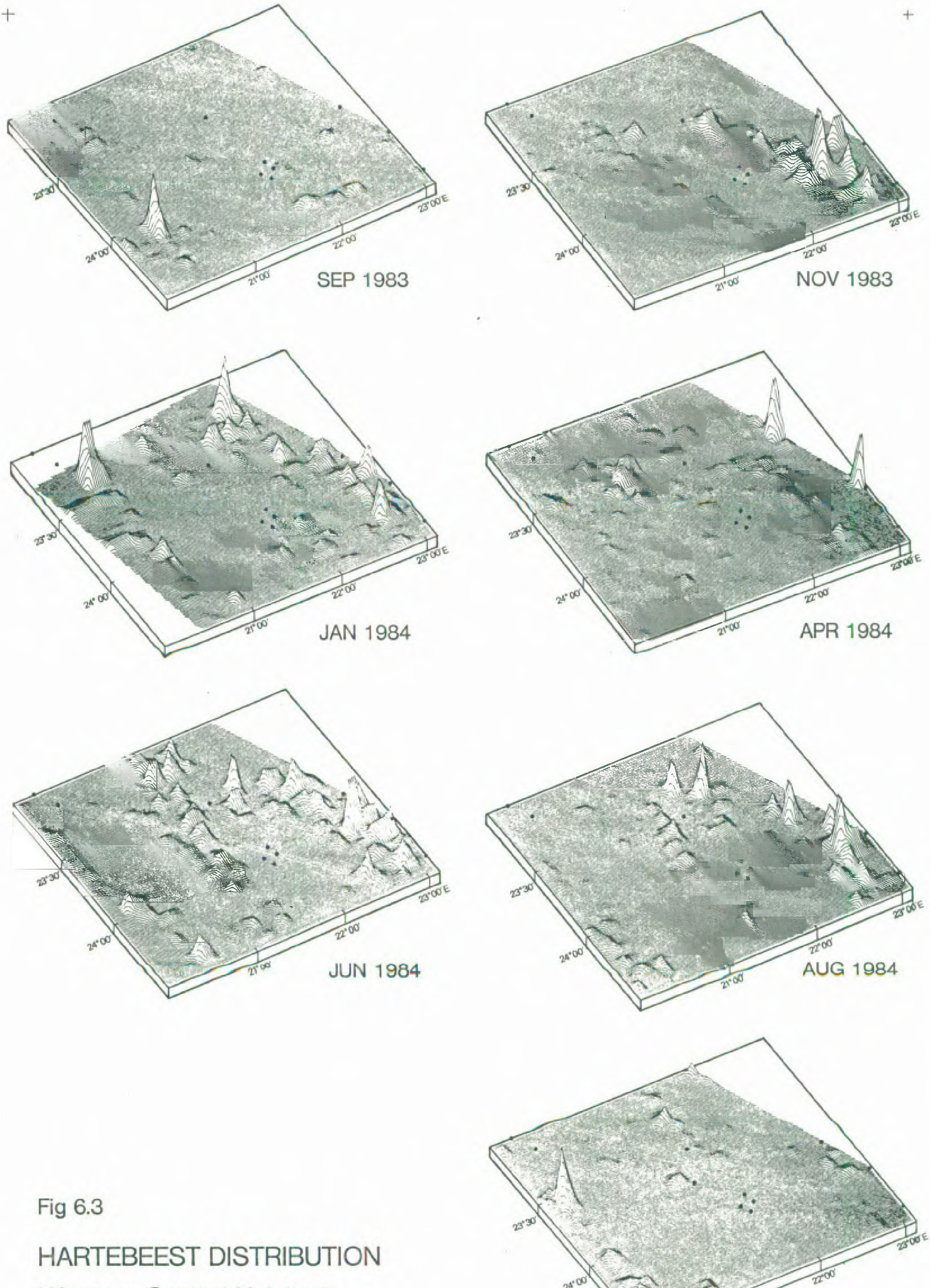

Fig 6.3

HARTEBEEST DISTRIBUTION
Western Central Kalahari

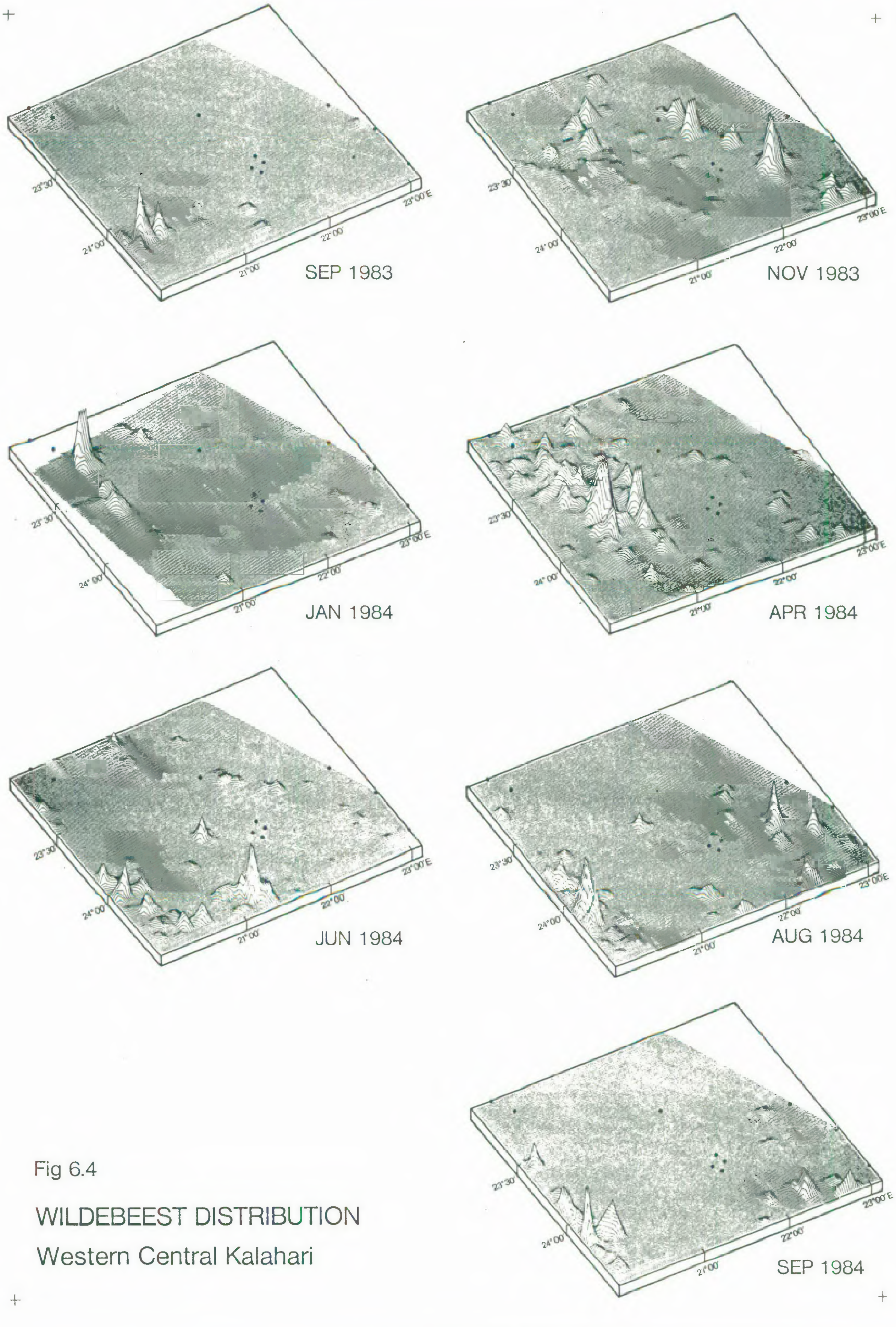

Fig 6.4

WILDEBEEST DISTRIBUTION
Western Central Kalahari

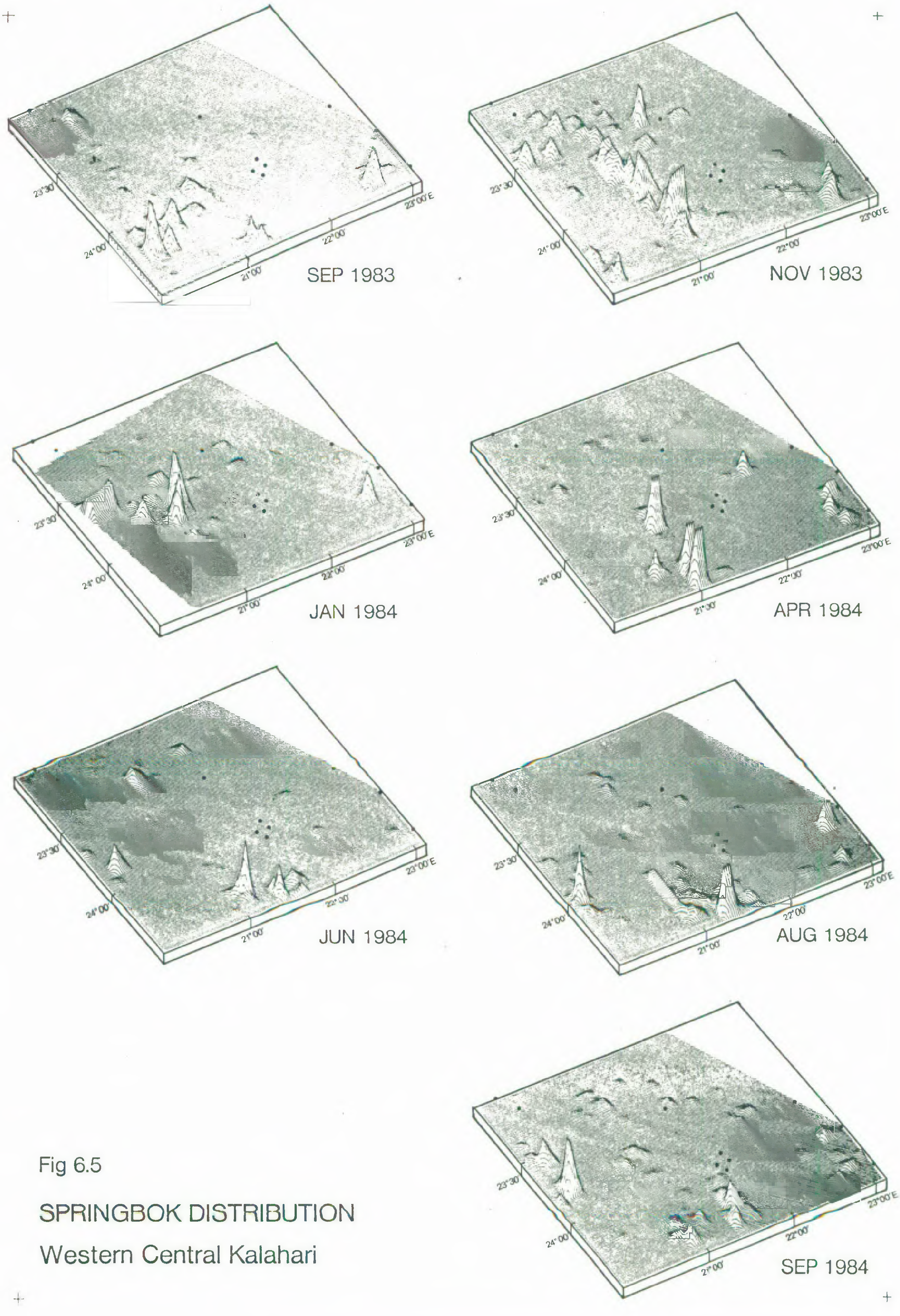

Fig 6.5

SPRINGBOK DISTRIBUTION
Western Central Kalahari

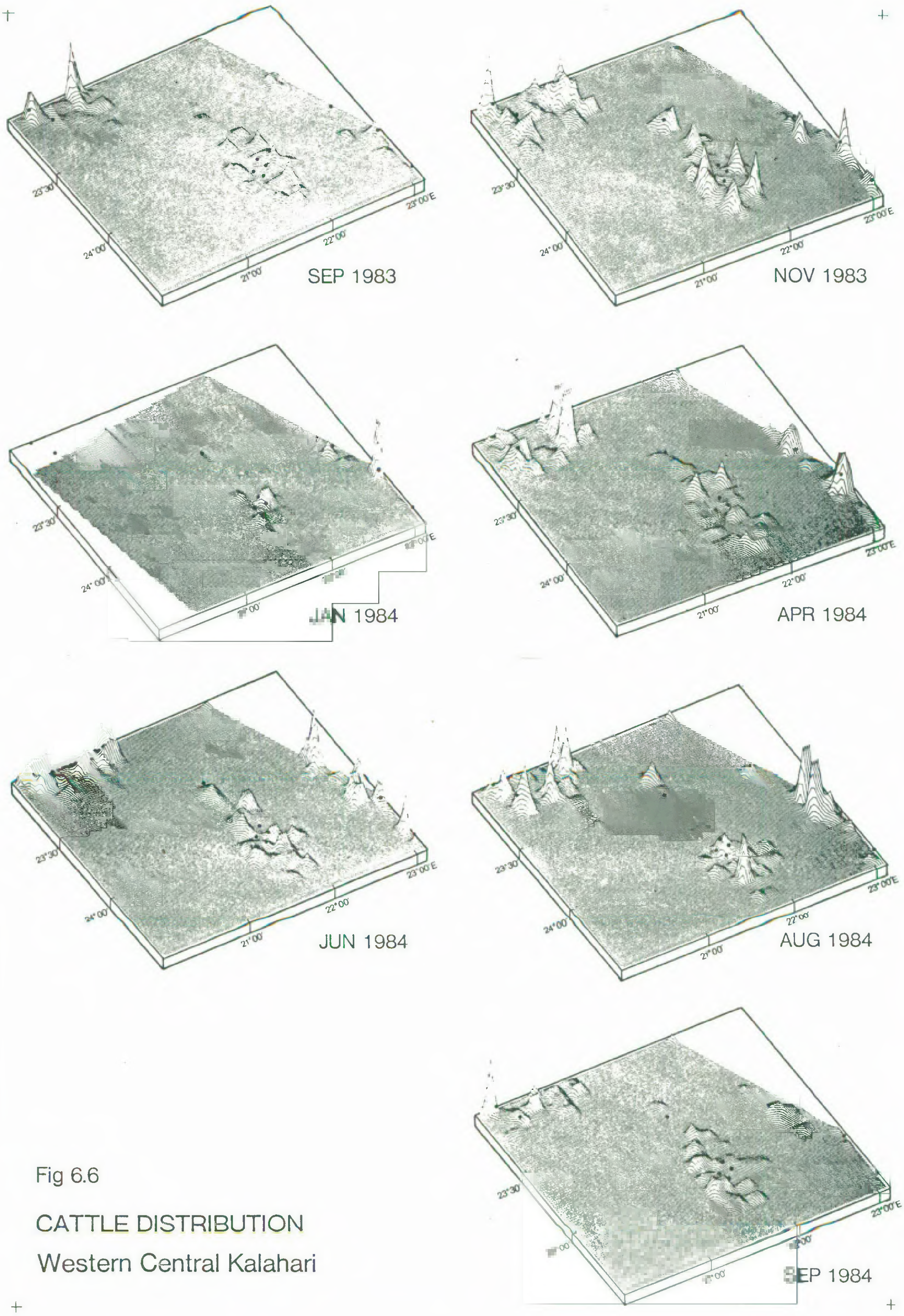

Fig 6.6

CATTLE DISTRIBUTION

Western Central Kalahari

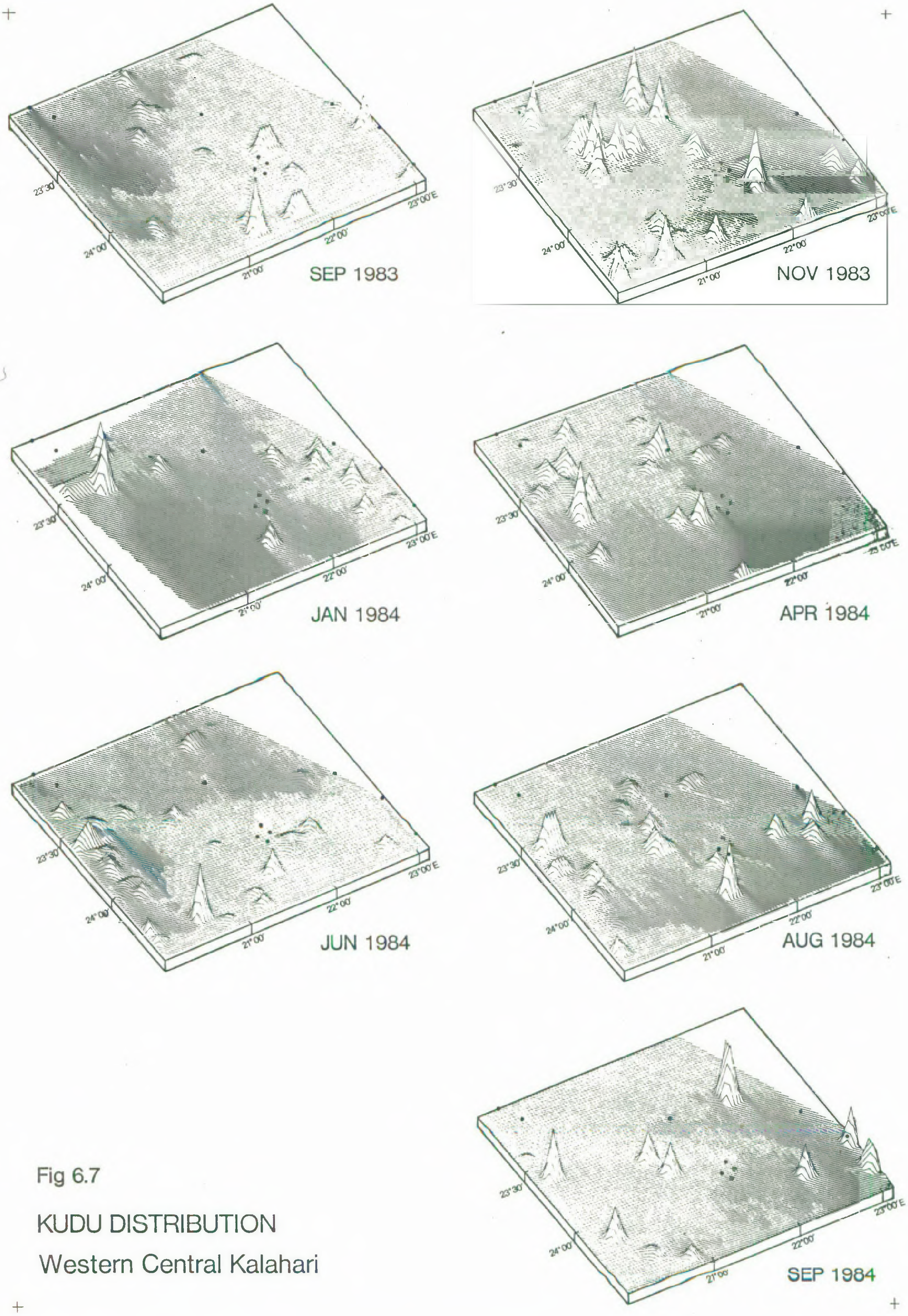

Fig 6.7

KUDU DISTRIBUTION

Western Central Kalahari

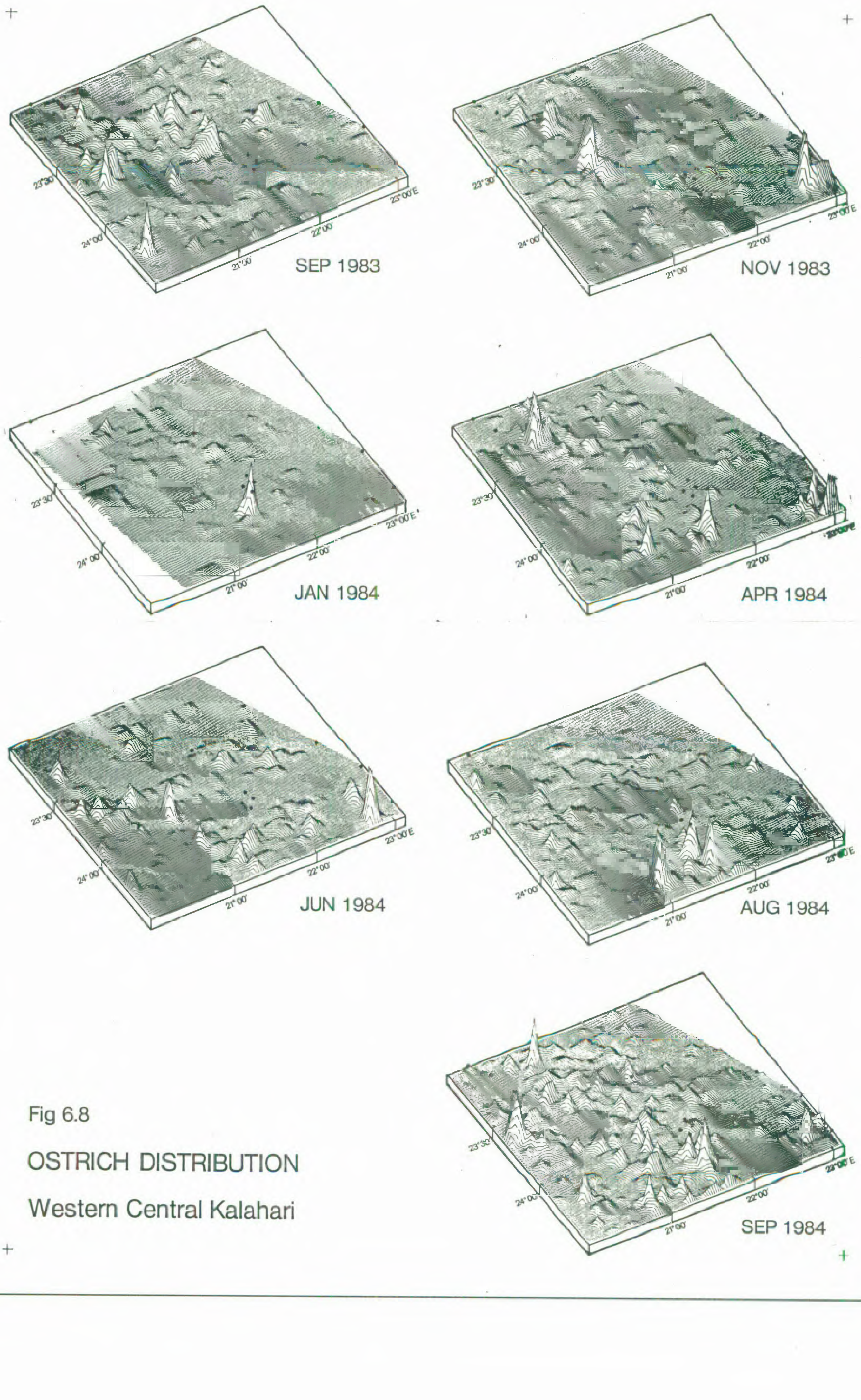

Fig 6.8

OSTRICH DISTRIBUTION

Western Central Kalahari

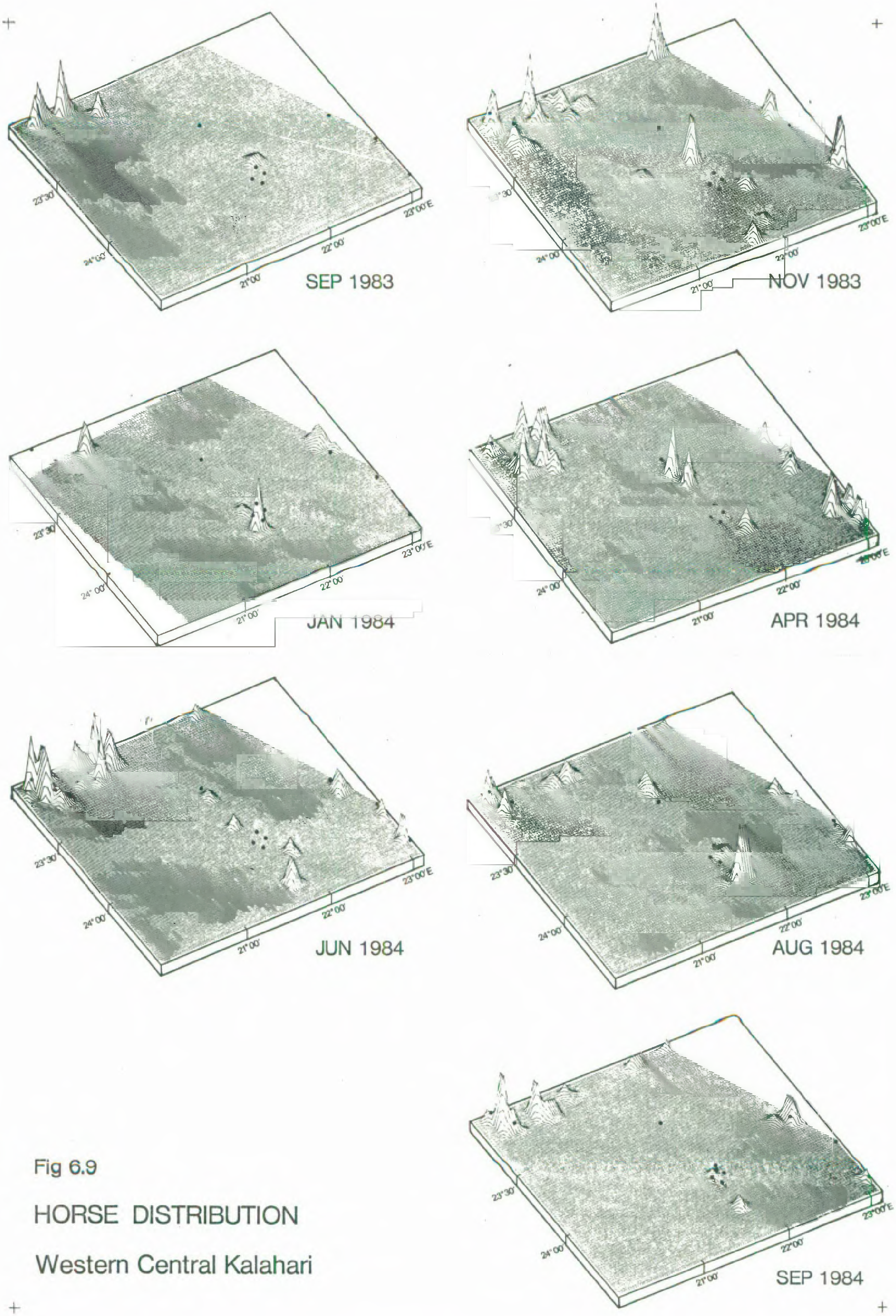

Fig 6.9

HORSE DISTRIBUTION

Western Central Kalahari

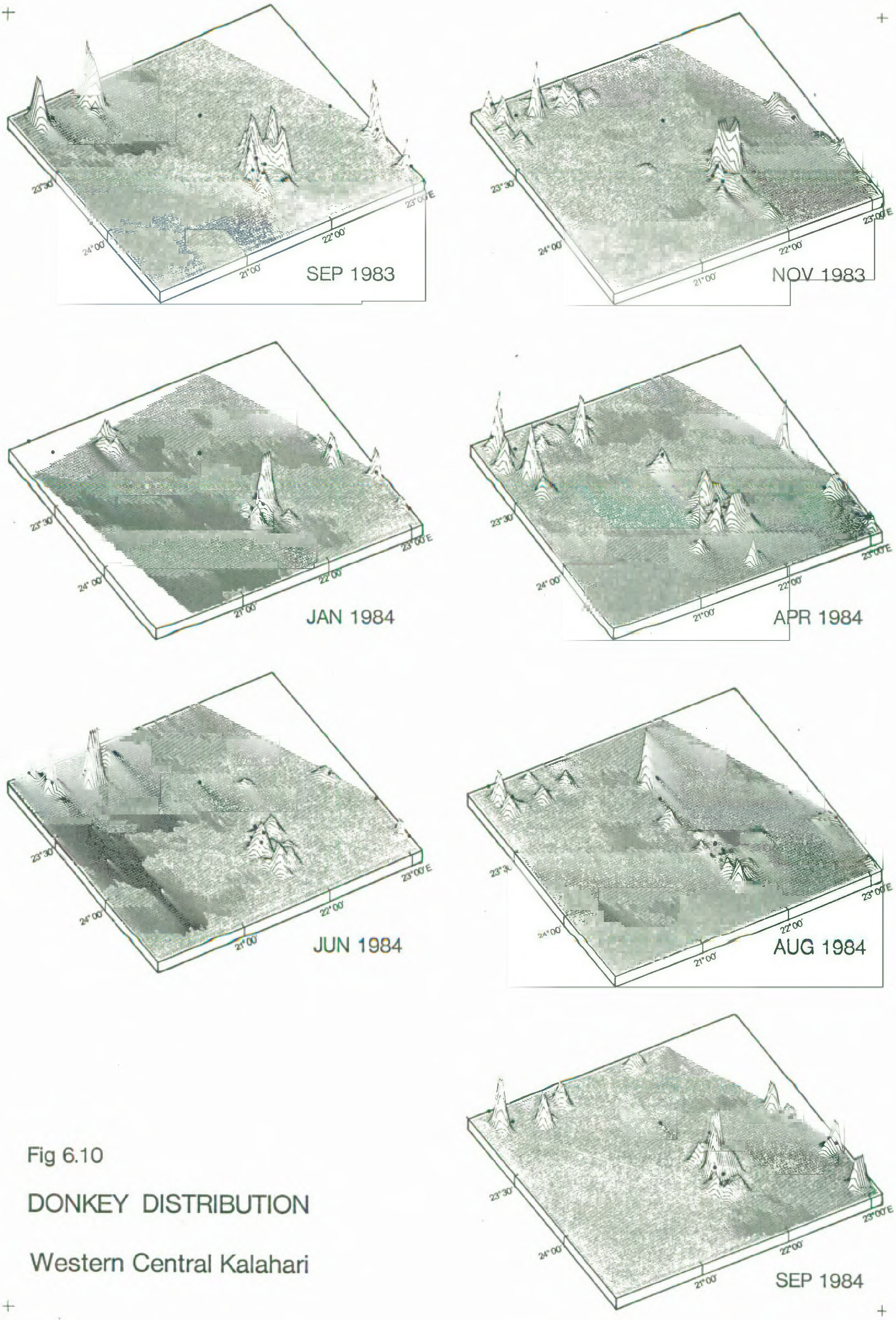

Fig 6.10

DONKEY DISTRIBUTION

Western Central Kalahari

(1) <u>Vegetation types:</u> Park woodland, scrubland, scattered trees, grassland and clumped woodland;

(2) <u>Landforms:</u> Flatland, undulating (2a, $2b_2$) low sand-dune area;

(3) <u>Drainage systems:</u> The fossil river systems around 21° 00'E longitude and the eastern edge of the fossil delta system around 22° 30'E longitude south of 24° 00'S latitude;

(4) <u>Soil types:</u> Types 1, 2 and 3.

(5) <u>Land uses:</u> Conservation areas mainly wildlife management area, mineral prospecting areas.

<u>(f) **Cattle distribution** (Fig. 6.6):</u> The cattle distributions are along the eastern boundary of the study area approximately east of 23° 00'E longitude, the area occupied by Kokong Village near southeast corner, Morwamosu Village on the eastern corner, Phuduhudu ranch, Kang Village, the private farm northwest of Kang, Lonetree borehole in the northeast corner, Ncojane farms, Kule-Ncojane Villages, Ohe Village and the Matsheng Villages of Lehututu, Hukuntsi, Tshane, Lokgwabe. The land use map, Fig. 5.13 (Section 5.5) shows the specific locations of the above respective land uses.

It may be noted in especially the June 1984, August 1984 and September 1984 distribution maps that to the east of Tshane Village there is a protrusion of cattle occurrence eastwards to just beyond 22° 15'E longitude. This is the site of the Tshane east TGLP ranch which was occupied during the course of the study. An inspection of the wild animal distribution maps shows this area to be also occupied frequently primarily by hartebeest, wildebeest, gemsbok and ostrich with infrequent occupation by springbok. Ground reconnaisance in this area encountered the above species and kudu in this locality as well as cattle.

6.2.23 Summary and Conclusion on Animal Distributions: The gemsbok distributions show a more or less fixed seasonal distribution pattern. The pattern is in two big areas with the centre around the Matsheng Villages, one arc concave eastwards and the other westwards meeting both north and south of the centre. The centre of the arcs is itself unoccupied as well as areas around other settlements and farms. The dispersion of animals remained more or less the same throughout the study.

The eland are restricted to mainly the southwestern part of the study area.

The hartebeest and wildebeest have closely related distribution patterns with only slight differences between the two. The major difference is only in actual distribution of numbers or local densities. The hartebeest have highest local densities in the east while the wildebeest have those in the west.

Springbok shows a relatively defined distribution pattern. This species seems to favour most the area between 21° 00′E and 21° 30′E longitudes south of 23° 15′S latitude. They also occur elsewhere in the study area with lesser frequencies.

Cattle are confined to settled areas, communal cells and farms.

Overall, the distribution maps show the whole study area is utilised by wild animals throughout the year. Although the specific densities fluctuate with seasons, the general pattern of fluctuation for all species is that of high densities from November to June and lower densities outside this period. The settled areas, communal cells and fenced farms have little wild animal presence but high cattle presence in them. However, the occurrence of wild animals outside these areas suggests such animals actually go through these areas or around them depending on whether the areas are fenced or not. This observation from distribution maps is confirmed by presence of animal spoors which were frequently seen on the ground going through the Matsheng Villages quadrangle of Lehututu, Tshane, Lokgwabe and Hukuntsi during this study. Unpublished data held by the author, on observation of animal trail patterns outside settled areas, also collected in this study, indicate that as long as the settled areas or farms are not fenced, animals will use them in transit although the animals are actually not found over such areas.

The combined animal distributions, embracing the respective animal species distribution maps over the study period can be summarised as in Fig. 6.11. The main areas heavily occupied by wildlife species are basically west of 21° 30′E longitude south of 23° 15′S latitude in the western part of the study area; the area between 22° 15′E and 23° 00′E longitudes south of 24° 00′S latitude in the southeast of the study area; the area south of 24° 15′S latitude

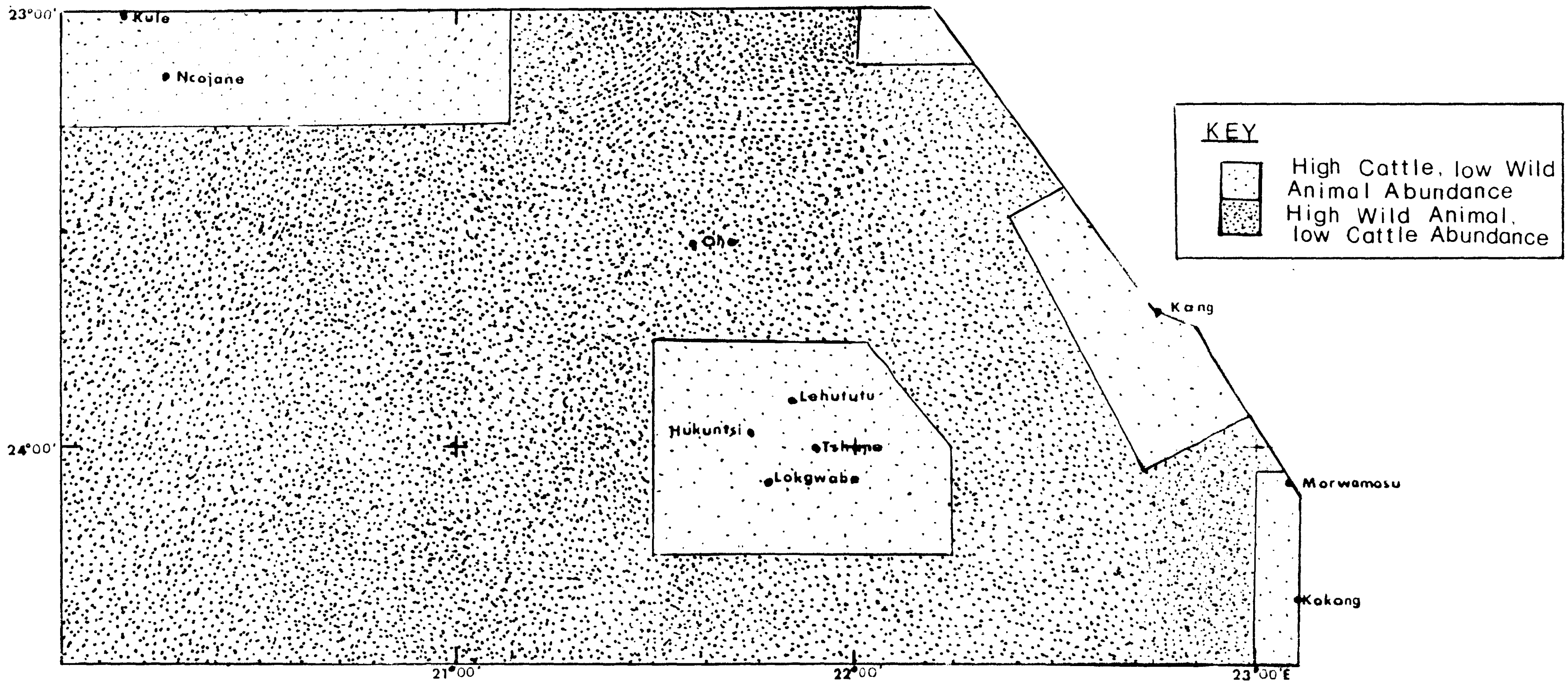

Fig. 6.11 Animal Utilisation of Western Central Kalahari

in the south of the study area; the area between 23° 15'S and 23° 45'S latitude; a diagonal band aligned in a northwesterly/southeasterly direction approximately 15 kilometres southwest of Kang to about 20 kilometres northeast of Lehututu, and a band between Morwamosu and Kang Villages.

6.2.3 Animal Abundance.

6.2.31 General: This section aims at determining densities and population estimates for the ten animal species studied. The determinations are made survey-by-survey to investigate whether there were density changes between surveys.

During the study, the main unit of aerial sampling was the transect. The transects were of unequal sizes. The data were however, recorded on a grid-cell sub-unit basis (see Chapter 3). The grid-cell sub-units were of equal sizes. Two methods have been described by Jolly (1969a) for determining density and population estimates using unequal-sized and equal-sized sampling units. Jolly's Method 1 which uses equal-sized sampling units was preferred over his more complex Method 2 which relates to unequal-sized sampling units. It was therefore decided the grid-cell sub-units would be used in the analysis as equal-sized sampling units.

6.2.32 Analysis: The first step was to estimate the mean overall density of animals within the sample zone using formula (1) below (see Jolly 1969a, Norton-Griffiths 1978, Caughley and Grigg 1981, Seber 1982). This then allowed the alternative estimations of population total by formula (2). Variance and standard error were estimated using formulae (4) to (7). Only variance of Y is tabulated in the results.

The following notations and formulae were used in the calculations:

Let y = Animals counted (corrected for counting bias) within a grid-cell sub-unit

$\sum_n y$ = Sum of animal counts over n sub-units

a = Area of a grid-cell sub-unit (Km^2) (= $2km^2$ for each sub-unit)

A = Area of the survey zone (km^2) (= $42200km^2$)

n = Number of grid-cell sub-units sampled (= 844)

N = Total number of grid-cell sub-units that could be fitted in the whole survey zone (= 21100)

$\hat{D}$ = Mean overall density within the sample zone

$\hat{Y}$ = Population estimate in the survey zone

S^2 = Sample variance i.e. variance of corrected counts among sub-units within the sample zone

$SE(\hat{D})$ = Standard error of estimated mean overall density

$SE(\hat{Y})$ = Standard error of population estimate

$Var(\hat{D})$ = Density variance

$Var(\hat{Y})$ = Population variance

then $$\hat{D} = \frac{\sum_n y}{a.n} \qquad \text{------(1)}$$

$$\hat{Y} = \hat{D}.A = \frac{N.\sum_n y}{n} \qquad \text{------(2)}$$

$$S^2 = \frac{1}{n-1}\left[\sum y^2 - \frac{(\sum y)^2}{n}\right] \qquad \text{------(3)}$$

$$SE(\hat{D}) = \sqrt{\frac{(N-n)S^2}{Aan}} \qquad \text{------(4)}$$

$$SE(\hat{Y}) = \sqrt{\frac{N(N-n)S^2}{n}} \qquad \text{------(5)}$$

$$Var(\hat{D}) = [SE(\hat{D})]^2 = \frac{(N-n)S^2}{Aan} \qquad \text{------(6)}$$

$$Var(\hat{Y}) = [SE(\hat{Y})]^2 = \frac{N(N-n)S^2}{n} \qquad \text{------(7)}$$

The next step in the analytical procedure was to determine if the computed population estimates differed significantly between surveys. This was estimated using the formula:

$$d = \pm \frac{(\hat{Y}_a - \hat{Y}_b)}{\sqrt{Var(\hat{Y}_a) + Var(\hat{Y}_b)}}$$

where d is a test of difference factor

$\hat{Y}_a$ and $\hat{Y}_b$ are the two survey population estimates compared

$Var(\hat{Y}_a)$ is the population variance of population estimate in survey a

and $Var(\hat{Y}_b)$ is the population variance of population estimate in survey b.

The subscripts a and b represent any two of the six surveys compared.

The two estimates are considered significantly different at the 5% level when the absolute value of d exceeds 1.96 since n > 30 in all the surveys compared. The January 1984 survey has been excluded because four transects were not observed during its conduct and it will be left out of any investigations of seasonal abundance trends.

6.2.33 Results: Table 6.1 gives the density and population estimates with their respective standard errors and variances for the seven surveys conducted. Table 6.2 gives the difference factor d values for the population estimates of the respective surveys compared. From Table 6.2 it is observed that for some animal species the population estimates between surveys were not significantly different while in others the population estimates were significantly different.

The species-by-species information derived from Table 6.2, is summarised below.

(i) Eland: The population estimates for September 1983, June 1984, August 1984 and September 1984 are similar, as well as those for November 1983 and April 1984.

(ii) Gemsbok: Three sets of similar population estimates have been deduced. They are September 1983, April 1984, August 1984; September 1983, September 1984; and November 1983, June 1984.

(iii) Hartebeest: The population estimates for September 1983 and September 1984, and for April 1984 and August 1984 are similar. November 1983 and June 1984 are significantly different from each other as well as from other population estimates.

(iv) Wildebeest: The population estimate for September 1983 is not similar to any other. However, the population estimates for November 1983, April 1984 and June 1984 are similar as well as those for August 1984 and September 1984.

(v) Ostrich: Two sets of similar population estimates deduced are August 1984 and September 1984 in one set, and September 1983, November 1983, April 1984 and June 1984 in the second set.

(vi) Kudu: The population estimate for June 1984 is not similar to any other. The population estimates for September 1983 and September 1984 are similar. The population estimates for November 1983, April 1984 and August 1984 are also similar.

TABLE 6.1 MEAN DENSITY AND POPULATION ESTIMATES OF TEN ANIMAL SPECIES IN WESTERN CENTRAL KALAHARI

Date	Factor	ANIMAL SPECIES									
		Eland	Gemsbok	Hartebeest	Wildebeest	Springbok	Ostrich	Kudu	Cattle	Horse	Donkey
Sept 1983	Σy	72	978	503	825	1739	924	30	1670	23	82
	$\hat{D}$	0.043	0.586	0.302	0.495	1.043	0.565	0.018	1.001	0.014	0.049
	$\hat{Y}$	1822	24743	12726	20872	43996	23832	759	42251	582	2075
	SE($\hat{D}$)	± 0.02	± 0.08	± 0.10	± 0.24	± 0.24	± 0.05	± 0.01	± 0.19	± 0.01	± 0.01
	SE($\hat{Y}$)	± 847	± 3462	± 4130	± 10162	± 10292	± 2236	± 253	± 8020	± 249	± 508
	Var($\hat{Y}$)	7.18×10^5	1.20×10^7	1.71×10^7	1.03×10^8	1.06×10^8	5.00×10^6	6.40×10^4	6.43×10^7	6.22×10^4	2.58×10^5
Nov. 1983	Σy	908	1542	9748	3990	2903	949	138	3425	128	150
	$\hat{D}$	0.542	0.919	5.809	2.378	1.730	0.566	0.082	2.048	0.076	0.089
	$\hat{Y}$	22863	38780	245152	100344	73008	23895	3475	86444	3219	3777
	SE($\hat{D}$)	± 0.15	± 0.13	± 0.92	± 0.42	± 0.29	± 0.05	± 0.02	± 0.30	± 0.02	± 0.02
	SE($\hat{Y}$)	± 6285	± 5275	± 38615	± 17512	± 12154	± 2195	± 720	± 12452	± 889	± 806
	Var($\hat{Y}$)	3.95×10^7	2.78×10^7	1.49×10^9	3.07×10^8	1.48×10^8	4.82×10^6	5.19×10^5	1.55×10^8	7.91×10^5	6.50×10^5
Jan. 1984	Σy	162	707	2962	2228	2755	933	66	1688	54	55
	$\hat{D}$	0.112	0.488	2.046	1.538	1.903	0.644	0.046	1.166	0.037	0.038
	$\hat{Y}$	4721	20594	86323	64932	80291	27191	1932	49194	1574	1603
	SE($\hat{D}$)	± 0.04	± 0.09	± 0.30	± 0.48	± 0.60	± 0.11	± 0.01	± 0.43	± 0.02	± 0.01
	SE($\hat{Y}$)	± 1517	± 3798	± 12742	± 20307	± 25273	± 4433	± 585	± 17931	± 720	± 548
	Var($\hat{Y}$)	2.30×10^6	1.44×10^7	1.62×10^8	4.12×10^8	6.39×10^8	1.96×10^7	3.43×10^5	3.22×10^8	5.18×10^5	3.07×10^4
Apl. 1984	Σy	857	1207	2889	3679	11721	1055	79	3586	55	104
	$\hat{D}$	0.508	0.715	1.712	2.180	6.944	0.625	0.047	2.124	0.033	0.062
	$\hat{Y}$	21425	30175	72225	91975	293025	26375	1975	89650	1375	2600
	SE($\hat{D}$)	± 0.26	± 0.08	± 0.31	± 0.29	± 2.13	± 0.07	± 0.01	± 0.33	± 0.0±	± 0.01
	SE($\hat{Y}$)	± 10966	± 3545	± 13205	± 12151	± 89967	± 2954	± 504	± 14098	± 333	± 587
	Var($\hat{Y}$)	1.20×10^5	1.26×10^7	1.74×10^8	1.48×10^8	8.09×10^9	8.73×10^6	2.54×10^5	1.99×10^8	1.11×10^5	3.45×10^5
June 1984	Σy	390	1471	6423	4411	6739	887	296	3332	77	116
	$\hat{D}$	0.231	0.871	3.805	2.613	3.992	0.526	0.175	1.974	0.046	0.069
	$\hat{Y}$	9750	36775	160575	110275	168475	22175	7400	83300	1925	2900
	SE($\hat{D}$)	± 0.19	± 0.11	± 0.43	± 0.53	± 1.22	± 0.06	± 0.04	± 0.29	± 0.01	± 0.02
	SE($\hat{Y}$)	± 8019	± 4433	± 18104	± 11494	± 51277	± 2656	± 1522	± 12069	± 460	± 714
	Var($\hat{Y}$)	6.43×10^7	1.97×10^7	3.28×10^8	5.06×10^8	2.63×10^9	7.05×10^6	2.32×10^6	1.46×10^8	2.12×10^5	5.11×10^5
Aug. 1984	Σy	16	1075	3215	2294	3586	673	101	3146	85	138
	$\hat{D}$	0.010	0.637	1.904	1.359	2.124	0.499	0.060	1.864	0.050	0.082
	$\hat{Y}$	400	26875	80375	57350	89650	16825	2525	78650	2125	3450
	SE($\hat{D}$)	± 0.19	± 0.11	± 0.43	± 0.53	± ±.11	± 0.06	± 0.04	± 0.29	± 0.01	± 0.02
	SE($\hat{Y}$)	± 8019	± 4433	± 18104	± 22494	± 51277	± 2656	± 1522	± 12069	± 460	± 714
	Var($\hat{Y}$)	9.68×10^4	9.23×10^6	1.65×10^8	1.25×10^8	3.45×10^8	2.57×10^6	5.12×10^5	1.89×10^8	4.16×10^5	9.36×10^5
Sept 1984	Σy	108	772	680	2040	972	603	52	1984	57	87
	$\hat{D}$	0.064	0.457	0.403	1.209	0.576	0.357	0.031	1.175	0.034	0.052
	$\hat{Y}$	2700	19300	17000	51000	24300	15075	1300	49600	1425	2175
	SE($\hat{D}$)	± 0.03	± 0.06	± 0.09	± 0.29	± 0.11	± 0.03	± 0.01	± 0.21	± 0.01	± 0.01
	SE($\hat{Y}$)	± 1223	± 2661	± 3839	± 12318	± 4683	± 1225	± 419	± 8907	± 377	± 502
	Var($\hat{Y}$)	1.50×10^6	7.08×10^6	1.47×10^7	1.52×10^5	2.19×10^7	1.50×10^6	1.76×10^5	7.93×10^7	1.42×10^5	2.52×10^5

TABLE 6.2 THE DIFFERENCE FACTOR d BETWEEN THE VARIOUS POPULATION ESTIMATES COMPARED

Dates of Estimates Compared / SPECIES	d														
	1/2	1/4	1/5	1/6	1/7	2/4	2/5	2/6	2/7	4/5	4/6	4/7	5/6	5/7	6/7
Eland	3.32	21.41	0.98	1.58	0.59	0.23	1.29	3.57	3.14	1.45	45.13	14.73	1.17	0.87	1.82
Gemsbok	2.22	1.10	2.14	0.46	1.24	1.35	0.29	1.96	3.30	1.16	0.71	2.45	1.84	3.37	1.88
Hartebeest	5.99	4.30	7.96	5.02	0.76	4.24	1.98	4.05	5.88	3.94	0.44	4.02	3.61	7.76	4.73
Wildebeest	3.93	4.49	3.62	2.41	2.96	0.39	0.35	2.07	2.82	0.72	2.10	3.37	2.11	2.63	0.57
Springbok	1.82	2.75	2.38	2.15	1.74	2.42	1.81	0.75	3.74	1.20	2.21	2.98	1.45	2.80	3.41
Ostrich	0.02	0.68	0.47	2.55	3.43	0.67	0.50	2.60	3.51	1.06	2.84	3.53	1.72	2.43	0.87
Kudu	3.56	2.16	4.30	2.33	1.10	1.71	2.33	0.94	2.61	3.38	0.63	1.03	2.90	3.86	1.48
Cattle	2.98	2.92	2.83	2.29	0.61	0.17	0.18	0.42	2.41	0.34	0.56	2.40	0.25	2.25	1.78
Horse	2.85	1.90	2.56	2.25	1.86	1.94	1.29	1.00	1.86	0.97	1.04	0.10	0.25	0.84	0.95
Donkey	1.79	0.68	0.94	1.26	0.14	1.18	0.81	0.26	1.69	0.32	0.75	0.55	0.46	0.83	1.17

1 = September 1983; 2 = November 1983; 4 = April 1984; 5 = June 1984; 6 = August 1984; 7 = September 1984.

(vii) Springbok: The similar population estimates deduced are September 1983, September 1984; November 1983, August 1983; and April 1984, June 1984.

(viii) Cattle: The population estimates for September 1983 and September 1984 are similar and so are those for November 1983, April 1984, June 1984 and August 1984.

(ix) Horse: The population estimates for this species are almost all similar. The November 1983, April 1984, June 1984, August 1984 and September 1984 estimates are similar. However September 1983 and September 1984 are also similar.

(x) Donkey: The population estimates of all the six surveys are not significantly different.

6.2.34 Discussion and Conclusion: In general, except for the eland and springbok, the results show that most species were in higher numbers in the study area between November 1983 and June 1984 than in September 1983, August 1984 and September 1984.

The domestic animals, except the donkey also showed some population fluctuation with time. There was no significant difference between the various **donkey** estimates. **Cattle** had highest numbers from November 1983 to August 1984 and lowest in September 1983 and September 1984. **Horse** showed almost a similar pattern as cattle except the September 1984 estimates showed no significant difference from the September 1983 estimates as well as from the November 1983 to August 1984 estimates. The September 1983 estimates were however, significantly different from the November 1983 to August 1984 ones.

It would be expected that cattle and horse, like the donkey, should show no population changes with time because they should be sedentary. This is to a large extent true and partly confirmed by the results. The September 1983 and September 1984 estimates which differ from the rest may be traceable to several factors. The horse in the area is used for hunting but predominantly as transport in managing cattle. Its population-fluctuation similarity with cattle can therefore be explained in terms of cattle population fluctuations. The cattle population change is probably related to their movement between places inside the study area and those outside (personal knowledge). This movement is especially practised at Kang and Ncojane ranches.

The combined cattle population in these two areas is estimated at between 60 and 70% of study area cattle population. At Kang the onset of the dry season (May) concentrates cattle near the village. There is high demand for water and grazing in and around this village at this time. Watering of animals at the single borehole in the village may involve spending from one night to a series of nights in the queue and many cattle die during this period. It has become a habit now to move the cattle from this village around July to the Quushe and Morgan boreholes near the northeast corner of and outside the study area. During the rainy season (November to April/May) as water becomes available in pans nearer to the village, the cattle are brought back.

At Ncojane ranches, because there is high overstocking the dry season grazing is not able to support the large cattle numbers. Many cattle are moved during the dry season out of these leased ranches back to villages like Makunda, Karakobis and Kalkfontein north and outside the study area where many owners reside. Most of these cattle-owners have boreholes located in areas with moderate grazing usually on the periphery of communal areas. It is the opinion of the author that it is these movements that largely accounted for the cattle population drop in the study area during the dry period especially around September, the month with the worst grazing conditions. It is also possible that if the sampling procedure changed between surveys this could induce apparent population changes. However, the sampling procedures were standardised in this study and each survey was conducted the same way as every other.

In the wild animal species, a more or less similar pattern of population changes as cattle is noticed. The months September 1983, August 1984 and September 1984 generally had lower populations of **eland, springbok, gemsbok, hartebeest, wildebeest, ostrich** and **kudu,** than November 1983, April 1984 and June 1984. A few cases showed insignificant variations within this general pattern.

Overall, eland, gemsbok, hartebeest, wildebeest, springbok, ostrich, kudu, cattle and horse showed with a few minor variations two general population divisions, high abundance in the period November 1983 to June 1984 and low abundance in September 1983, August 1984 and September 1984. The donkey showed no change.

The population changes of all wild species appear to be connected with seasonal, climatic and vegetation condition changes. Section 5.3 showed the seasonal patterns of the study area and the climatic factors prevailing in each season while Section 5.4.3 examined the vegetation condition. The period November 1983 to May 1984 had higher rainfall, moderate relative humidity and was warm to hot as compared to the September 1983 and July 1984 to September 1984 period. Trees, bushes and herbaceous plant layer were also green during this period. As already shown (see Section 5.4.34) the higher the degree of greenness the higher the nutritive value of the foliage. There is evidence showing that the African animal movements and utilisation of habitats are resource based (see Jarman 1972, Western 1976, Bothma and Mills 1977). This topic has recently been reviewed more broadly by Dingle (1980) and Baker (1982). Evidence given by these sources shows that animals will move into and utilise habitats that are more favourable than others. This is examined below in relation to areas adjoining the study area and the study area itself.

In the Southern Kalahari, Bothma and Mills (1977) found that gemsbok, hartebeest and springbok had peak abundance in the Nosop Valley where they fed on sprouting grass after the first highest monthly rainfall during the wet season (March to May). By late dry season (October to December) the animals moved north and east, out of the area. Wildebeest, however, had peak abundance in the Nosop Valley, where they concentrated around water pumped from boreholes, in August to October, but by January their abundance was again low. Bothma and Mills (1977) indicated springbok and hartebeest moved out of the Nosop Valley as the grass matured. These findings have been confirmed by Mills and Retief (in press). This means since by late dry season (October to December) the food quality in the Nosop Valley was low, the animals moved north and east in search of better quality forage. A comparison with the Western Central Kalahari shows that from the 1983 to 1984 study period, this movement would coincide with the early rains, sprouting green herbaceous layer and green trees in November (see section 5.4.3). Thus because the late dry season in Southern Kalahari coincides with early wet season in Western Central Kalahari further north, gemsbok, hartebeest and springbok moved out of the late dry season in the south (Southern Kalahari) into early wet season in the north (study area).

The Southern Kalahari receives higher winter rainfall than the Western Central Kalahari because of the Atlantic Ocean Anticyclone influence (see section 2.4.22). It would be expected that although the rainfall is minimal overall, it would generally encourage better forage production in the south (Southern Kalahari) in winter than in the north (the study area). Animals would then tend to move south out of the study area in winter to feed on better forage in Southern Kalahari.

Indirect evidence seems to indicate that hartebeest and wildebeest also move between the study area and the areas to the north and the east. The wildebeest favours northerly movements while hartebeest favours the easterly movements. Farmers at Ncojane Ranches all point out the wildebeest come from the north and northeast through their farms in November. During this time the northern farms fences are damaged most.

Williamson and Ngwamotsoko (in preparation) argue that wildebeest come into the study area after leaving Lake Xau further northeast of the study area, where heavy mortalities occur almost annually during the dry season (mainly July to September) concentrations of animals there. Lake Xau provides water but nograzing. Towards the end of the dry season (September/October) wildebeest move into the Central Kalahari Game Reserve. This movement has been observed by Williamson (pers. comm.). Wildebeest do not stay in the Central Kalahari Game Reserve though, but move further south. Although no direct observation has been made on this movement between the Central Kalahari Game Reserve (CKGR) and the Western Central Kalahari, wildebeest have been seen on the Okwa Valley apparently moving south in October (pers. obs.). Williamson and Ngwamotsoko (in preparation) have hypothesised that wildebeest move into the Western Central Kalahari because of mineral salts obtained from salt-licks on pans. The CKGR lacks these. Considerable use is made of these mineral licks by animals (Parris 1976, pers. obs.)

Hartebeest, are seen every year in big herds between Motokwe and Tshwaane east of the study area in September and October with apparent movement to the southwest (pers. obs.). The area between Motokwe and Tshwaane is popular for hartebeest hunting at this time.

From the foregoing review it would appear the study area provides optimum habitat conditions for the wildebeest, hartebeest, gemsbok and springbok during the wet season (November to April) than the neighbouring areas. It also appears the hartebest and wildebeest population from the north, east and south converge here at this time and move out at the onset of the dry season. However, there is no direct evidence for the actual pattern of movement. There is a need to study this further.

The **eland** population abundance fluctuated in a similar manner as the other five species. It is presumed those fluctuations were influenced by the same factors which affected the abundance of other species discussed above.

Many species considered have peak breeding during the November to June period (see section 2.6.2) and indeed many calves of many species were observed during this period, in this study. The habitats are apparently more suitable here even for breeding, than elsewhere. It is however, necessary to investigate this aspect further and more directly.

From the foregoing it may be concluded that the animals increase in abundance in the study area during the November to June period because of breeding and immigration to feed on good quality food resulting from increased rainfall, and there are many pans providing essential mineral supplements. The animals move out as the food quality deteriorates during the dry period July to October.

6.3 EVALUATION OF ASSOCIATIONS

6.3.1 Introduction.

This section investigates quantitatively the relationships between animals and some selected environmental factors. It is hoped such quantified relationships will identify those environmental factors which had greater influence in directing animal distributions in the study area during the study period. This information is especially important for management for it identifies the basic requirements for the animal species presence in a particular habitat.

The results of this section will satisfy the second requirement of the first objective (Chapter 1). The environmental factors (independent variables) chosen for investigation of association with the eland, gemsbok, hartebeest, wildebeest, springbok, ostrich, kudu, cattle, horse and donkey, and documented in Chapter 5 are altitudinal variations, landscapes, drainage systems, soil types, big pan occurrences, surface water occurrences, vegetation community types, herbaceous plant cover and condition, bushfire occurrences, harvester termite infestation, settlements, communal cells, farms, conservation areas, and mineral prospecting areas. These independent variables may be grouped as physiography, habitat status and land features. However, in the evaluation, they have been treated separately.

6.3.2 Evaluation Procedure.

Multivariate analysis was adopted because of the large number of the variables involved. It was decided canonical correlation analysis backed up by discriminant analysis would be used for investigating associations.

Canonical correlation analysis is a technique which is employed in analysing the structure of a matrix consisting of independent and dependent variables, and undertaking pairwise correlations of the two sets of variables. Here the interest is in finding linear relationships between the two sets of variables which are most closely associated i.e. the correlation between the two linear relationships is maximum (Bofinger 1975, Warwich 1970) and it is hoped the coefficients in the canonical variate will show two distinctly defined groups falling either in the high or low weights correlation coefficients (both either positive or negative) i.e. correlation or no correlation. It is also hoped that the variables which fall in the high weight group form a plausible association which is acceptable when interpreted biologically. In practice it is unlikely that such two distinctly defined groups of high and low weight will occur. Indeed, as found in canonical correlation analysis of data in this study, there are mixed weights with very wide ranges. In this case a subjective cut-off point in weights of 0.3 was adopted. According to Bofinger (1975) this is the generally accepted cut-off point in literature. Those variables that had a weight of -0.3 and below, or 0.3 and above, were taken as highly correlated, while those between 0.26 and 0.3 (or between -0.26 and -0.3) were taken as showing a slight trend towards association and anything with weights between

0.26 and -0.26 was treated as showing insignificant association.

Animal communities were created when all the animal species were collectively compared with all the environmental variables in the canonical correlation analysis. There were then two steps involved in the analysis. The first was to identify those animal species which had high correlations with each other (i.e. individually had canonical correlation coefficient > 0.3 or < -0.3 at $p < 0.05$). These animals then constituted a community. The values indicated in the results for each member of the community are therefore canonical correlation coefficients showing the level at which that species relates to others in the community. Thus these values may be called inter-specific canonical correlation coefficients. The second step of the analysis is then to compare the derived animal community with the environmental variable and obtain the appropriate canonical correlation coefficient between the community and that variable. The cut-off points were then decided as discussed in the preceding paragraph.

Correlation analysis has recently been used by Crowe, Schijf and Gubb (1981) in studying the effects of rainfall variation, fire, vegetation etc. on some animal communities in the northern Cape in South Africa.

Discriminant Analysis is a multivariate analysis technique which identifies variables which may be used in discriminating i.e. maximally separating out the groups. It is capable, like correlation analysis of producing correlation statistics. The latter quality makes it useful as a supporting technique to the canonical correlations analysis technique, while the former quality gives it the added advantage of being able to select, for example, species preferences by maximising the differences (discriminating) between the closely related variable groups. The related groups put together may constitute one environmental attribute or variable, for example soils of types 1, 2, 3 and 4 may be considered as groups within an environmental or independent variable "soil type". Bofinger (1975) and Strahler (1978) have discussed the theoretical and practical applications of discriminant analysis.

Discriminant analysis may be applied to data presented in two forms, either as present and absent or in actual counts, densities or measures. Strahler (1978) calls the absent/present form binary discriminant analysis. In this study, the real values (densities) of animals were used instead of the absent/present form.

Discriminant analysis can be invoked in two modes (Strahler 1978). Both modes, the Q- and R-modes, described by Strahler (1978) for binary discriminant analysis, were adopted in this study, although the usual multivariate discriminant analysis stepwise procedure (and not binary) was used, to which they are equally applicable.

The Q-mode was used as back-up to CANCORR for confirmation of canonical correlations analysis results. The R-mode was used for analysis of associations to a variable-group level. The basic difference between the two modes is that, while according to Strahler (1978) in the Q-mode the object is to define the best orthogonal trends which separate the environmental or independent variable groups, in this study by using animal species as "grouping" variable, in the R-mode the objective may be considered as the reverse of the Q-mode. That is, it is the animal species groups that are separated using the other independent environmental variables as "grouping" variables.

The analysis was undertaken using CANCORR sub-programme (Warwich 1970) of SPSS package (Nie, Hull, Jenkins, Bent, Steinbrenner 1970) for canonical correlation analysis, and the BMDP7M sub-program (Jennrich and Sampson 1983) of the University of California, Los Angeles BMDP package (Dixon, Brown, Frane, Engelmann, Hill, Jennrich and Toporek 1983) for stepwise discriminant analysis. These packages were considered robust enough to handle the multivariate analysis of the data collected.

CANCORR produces canonical correlation coefficients for the two sets of variables. By matching variables in the first set (animals) with variables in the second set (independent variables) each of which should have a weight of -0.3 and below, or 0.3 and above for close association, then the canonical correlation interpretations may be made provided the significance level is high ($p < 0.05$). The other statistics printed include Chi-square values and eigenvalues. High Chi-square and high eigenvalues generally correspond with high significance level. The inspection of the three will immediately alert one to expectations of either high or low correlations in the canonical variates (sets of variables). BMDP7M prints, among other results, matrices of means, standard deviations and coefficients of variation of input data as the first stage of analysis. These matrices, especially the means, are useful in themselves for interpretation of associations even before the results of the discrimination process are examined. The means matrix shows at a glance the "distribution pattern" of the densities of each animal species by independent variable group. This further enables one to form an opinion about species/variable-group associations in the event that the discriminant process found no variable (animal species) with a factor loading high enough for entry or found some group had no count of any species in it and thus had zero input value. This was found commonly in the case of independent variables like wild-fires, herbaceous plant cover and condition, surface water etc. i.e. those variables whose scores changed with seasons.

The second stage of analysis shown in the print-out is the determination of the F-value for factor loadings. The factor loadings then show how each animal species is likely to be selected for evaluation with the various variable groups. The higher the F-value the more likely is the animal species corresponding to that value to be selected. In fact it would appear in this study's results, only animal species with the factor loading of F $\geq$ 4 were selected, with those left out implied as having little or no preference for any particular environmental variable group. Where no further analysis is made beyond F-value and factor loading sequence, an examination of the F-values and means matrix will show the relative importance of the species' preferences, albeit without confirmation from the discriminant function coefficients. The final stage is the presentation of computed canonical correlation scores (cf canonical correlation analysis), canonical discriminant function coefficients and canonical variables evaluated at group means.

6.3.3 Results and Discussion.

6.3.31 Results: (a) General: Both the canonical correlation analysis and discriminant analysis gave several association results between various animal species and various environmental independent variables. These results are summarised in Tables 6.3 to Table 6.17. in Appendix 4.

<u>(b) Interpretation Guidelines for Tables 6.3 to Table 6.17:</u>

Tables 6.3 to 6.17 show the following information:

(i) the animal species or community of several animal species members (column 1) which have shown significant correlation ($p < 0.05$) (column 4) with the respective group or category (column 5) of the independent variable (see Section 6.3.2 about animal communities).

(ii) the canonical correlation coefficients (column 3) show the various weights at specific probabilities p (column 4) corresponding to the specific animal species or communities in relation to the specific independent variable group (column 5). The positive and negative signs associated with these values indicate the "higher" or "lower" status of the independent variable. That is, before the independent variable is sub-divided into various groups (see Chapters 3 and 5), for R-mode *discriminant* analysis, the *canonical correlation* analysis treats it in terms of higher status (+) or lower status (-), basically akin to presence and absence, which is how the coded input data are first presented. Thus the CANCORR sub-programme identifies higher status by positive sign and lower by negative. Once the independent variables are subdivided and coded into groups for BMDP7M discriminant analysis, the status ceases to be in terms of high or low but takes on the specific name of the group, which once analysed is identified as a specific group in column 5. Thus the nature of the sign in column 3 should agree with the relevant placing of the group in column 5 on the scale of groups of the particular variable with $p < 0.05$. As an example, if there are seven groups of a variable, the positive sign corresponding to the higher status of that variable should correspond to any group above 4 and the negative below 4. What specific group above or below 4 is mainly responsible for the association or separation is a matter for BMDP7M to show and this is identified as a group under column 5.

It will be noted that the same signs occur in the animal species interspecific associations coefficients in the community (column 1). The general interpretation is the same. The positive sign indicates **high abundance** i.e. many animals, while the negative sign indicates **low abundance** or few animals, of that species in the community.

The relationship between especially the signs in the animal community species inter-specific correlation coefficients (column 1), and the canonical correlation coefficient (column 3) sign may basically then take the following simplified forms:

Form	Column 1	Column 3
1	+	-
2	-	+
3	+	+
4	-	-

In interpreting the results in Tables 6.3 to 6.17 these forms become important as will be seen in the interpretation example below.

(iii) Column 4 shows the probability p at which the correlations occurred. The probability at which correlations were considered to have not occurred by chance was taken as 0.05. Any p values lower than 0.05 show an even smaller probability of chance occurrence.

(iv) Column 5 shows the group of the independent variable identified as mainly responsible for the correlation found. The determination of this group is obvious where individual animal species are concerned. However, in the case of a community the group determination was somewhat more complicated.

No easy reconciliation to group level could be made between CANCORR canonical correlation analysis results and BMDP7M discriminant analysis results at a community level. The community membership also tended to differ between the two procedures for the same variable for the same survey. CANCORR tended to give communities with more members than BMDP7M although there would be what could be termed a constituent core membership in both. Since it is the view of the author that it is more desirable to manage the habitat to the benefit of more community members, a subjective choice was made of the CANCORR-produced communities instead of BMDP7M's. The corresponding canonical correlation coefficient (column 3) for the chosen community was also taken. By comparing and contrasting the variable groups (column 5) corresponding to individual members of the community (especially the core members) as given by both CANCORR and BMDP7M, a more generalised subjective group of either "High", "Low", "Hard", "Soft" etc. as will be encountered in column 5 of various tables, was deduced. In all cases the deduction came out consistent with the sign attached to the respective canonical correlation coefficient in column 3. (See (ii) above for discussion of relationship between the signs and the groups). This increased the confidence placed on this grouping. Some independent variables were treated (recorded and coded) in terms of absent or present. These appear in the tables of the respective variables.

(v) Column 6 is the author's subjective and qualitative opinion of the implications of the quantified associations. Three words are used for convenience, in expressing the opinion - preference, tolerance and avoidance. Their use is not meant to express an ecological certainty but to convey the general meaning in qualitative terms, of the signs and figures appearing in columns 1, 3, 4 and 5. The final opinion is expressed in terms of how the largest number of animals can be said to be correlated in qualitative terms, with the independent variable proper (if it is a case of absent or present) or with the independent variable group (in the case of those independent variables with many groups). Tolerance is used to describe a situation where it becomes less meaningful to express the relationship in terms of preference, for example if high positive and significant correlation were found between hartebeest and settlements, it becomes less meaningful to say hartebeest prefer settlements, whereas tolerance would be more meaningful.

To illustrate the various interpretation guidelines given above, parts of Tables 6.3, 6.4 and 6.7 are interpreted below:

(a) From Table 6.3: Herbaceous layer cover and condition has ten groups (see also Table 5.9). (i) Gemsbok, in April 1984 preferred areas of sparse and fawn herbaceous layer ($p < 0.01$) while hartebeest preferred areas of moderate cover with fawnish-green herbaceous layer ($p < 0.001$). The above relate only to single species. (ii) Animal communities with low numbers of gemsbok, low number of wildebeest, low numbers of springbok and low numbers of donkey tended to be found in areas with high grouping of herbaceous layer's cover and condition status in January 1984 ($p < 0.001$). However, animal communities with few eland, few gemsbok and many wildebeest were found in areas with low grouping of herbaceous layer's cover and condition status for the same month, ($p < 0.005$).

(b) From Table 6.4: Bushfire occurrences has three categories or groups - no fire, old fire scar and burning fire. (i) Many hartebeests in June 1984 preferred old fire scar sites ($p < 0.001$). (ii) Communities with many hartebeests and donkeys, and few springboks preferred areas with high grouping of bushfire occurrences in November 1983 ($p < 0.001$).

(c) From Table 6.7: Communal cells have absent/present groups. (i) Many elands showed a tendency towards tolerating communal cells in September 1983 i.e. they were relatively near communal cells that month ($p < 0.001$). (ii) Communities with many cattle and many donkeys preferred communal cells in September 1983 ($p < 0.001$) (see other associations of same community for other periods for the same independent variable).

(vi) Summary of results: The information in Tables 6.3 to 6.17 (Appendix 4) is summarised below in Table 6.18. Only independent variables with canonical correlation coefficients of 0.3 and above or -0.3 and below, at $p < 0.05$ are listed in Table 6.18 in relation to the six animal species chosen and the date. The harvester termite has been included because it appears to be an urgent element to investigate. This is meant to show the independent environmental variables which showed significant correlations with the specific animal species at the specific time. Communities are not included.

Table 6.18 gives the following stories for the six animals species and the harvester termite.

Eland were most abundant in the Gemsbok National Park in September 1983. This means of all the environmental factors including land use, correlation with the national park was the only significant one that month.

For the rest of the study period no futher significant correlations occurred with the national park nor with any other environmental factor. Animals were distributed without any preference for or influence from any specific environmental factors compared.

Gemsbok were most abundant near farms in the wildlife management area in November 1983. They were most abundant in the Gemsbok National Park in January 1984 and April 1984. However, they were most abundant away from (i.e. avoided) farms in January 1984. They were away from both farms and communal areas from April 1984 to September 1984. They were mostly found in fossil drainage valleys (*mekgatsha*) in the areas below 1120 metres above sea level which is the southern part of the study area, in November 1983. They were also found mostly in fossil drainage valleys in January 1984 and in June 1984. In January 1984 the fossil drainage valleys gemsbok were found in were in the Gemsbok National Park.

Gemsbok were most abundant in park woodland in the Gemsbok National Park in January 1984. In April 1984, they were mostly found in the Gemsbok National Park on sites with sparse and fawn herbaceous plant layer.

Gemsbok were found in large numbers away from big pans in June 1984.

In summary, gemsbok generally avoided farms and communal areas during the study period. They preferred the Gemsbok National Park and the fossil drainage valleys. However, wildlife management areas and park woodland were also important during part of the study period.

Hartebeest were most abundant in areas below 1120 metres above sea level in November 1983, June 1984 and August 1984. They were abundant in mineral prospecting areas in November 1983 and August 1984. In June 1984 and August 1984, they were found away from fossil drainage valleys. They were found mostly on old bushfire scars and on areas with moderate cover and fawnish-green herbaceous plant layer in June 1984. In August 1984, they were found in the sand-hill and sand-ridge land region in areas with light harvester termite infestation.

Hartebeest in general therefore occurred in great abundance, during parts of the study period in areas below 1120 metres above sea level which also had mineral prospecting sites, but away from fossil drainage valleys. Bushfire scars, moderately covered areas with fawnish-green herbaceous plant layer and areas lightly infested with harvester termites were important. The sand-hill and sand-ridge land region below 1120 metres above sea level with mineral prospecting areas was also highly utilised during part of the study period.

Wildebeest were most abundant in fossil drainage valleys in areas above 1200 metres above sea level (northern study area) in April 1984. In June 1984 and August 1984 they were more abundant in the low sand-dune fields (southern study area) with soil type 3 (soils with moderately high percentage of white pan soil) in June 1984 and August 1984. Wildebeest, in general therefore occurred in great abundance in low sand-dune areas with soil type 3 during the latter part of the study period. Fossil drainage valleys in the areas above 1200 metres above sea level were important in April 1984.

Springbok were most abundant in areas with park woodland in November 1983. In June 1984 and August 1984 they were most abundant in wildlife management areas. The wildlife management area preferred in August 1984 was in the low sand-dune fields (southern study area), where there was sparse cover both green herbaceous plant layer. They occurred in areas with soil type 3 in September 1984.

The springbok, therefore occurred mostly in wildlife management areas towards the end of the study period. Park woodland, low sand-dune areas, sparsely covered areas with green herbaceous layer and soil type 3 were also very important during parts of the study period.

Cattle as expected, were most abundant in communal areas and farms during all the months of the survey except November 1983 and January 1984. In April 1984, they were abundant around areas with surface water i.e. surface water held by pans after rain. In September 1984 they were concentrated in permanent settlements. Cattle therefore, as could be expected, were concentrated in farms and communal areas for most of the study period, and in September 1984 were concentrated in permanent settlements. Areas with surface water were also important.

Harvester termite infestation was concentrated in wildlife management areas on sites with sparse cover and fawn herbaceous plant layer in Ausut 1984 and September 1984. The infestation was also present in farms in September 1984.

6.3.32 Discussion and Conclusions: The results in Tables 6.18 (see also Tables 6.3 to 6.17, Appendix 4) show that various species of animals have varying degrees of requirements of the various environmental factors. These requirements, and utilization of the various areas with such factors by the various species and communities of animals also vary with time. Some species utilise or occur in some areas simultaneously and call for the need to manage such areas for community survival.

These results have shown that no single environmental factor can be isolated as the only important factor to be considered when any particular species of animals are under consideration. Only the highest degrees of preference or otherwise are shown above, because an examination of the distribution maps, evaluation of the means matrix and factor loadings (F values) of the BMDP7M discriminant analysis results show that there was a much wider distribution and interaction with a greater number of environmental factors by animals than shown in the final analysis. It is therefore important when the management of the whole area is considered to bear this in mind. Those factors identified as highly preferred or avoided serve to indicate what core or basic requirements must be available, and are to be included or excluded from whatever area is considered for management. Thus since it is a combination of factors that create favourable or unfavourable conditions at various times of the year, for animal presence, management should be on the basis of sustained use of the area by animals year round.

The results have also identified that the wild animal species may be said to avoid or show little tolerance of the communal cells and settled areas as well as farms. Gemsbok showed a clear avoidance. Again a comparison with the distribution maps, evaluation of F values and means in the discriminant procedure analysis shows that it was the fenced farms and the communal cells around permanent settlements that were mainly avoided. The unfenced farms and temporary settlements are still used by animals to varying degrees. In Section 6.2.23 it was, however, shown that however, even the permanent settlements and the communal cells around them are used by most wild animals species in transit. Only occupation of these areas is thus avoided. Cattle and other domestic animals, as can be expected, use these areas almost exclusively.

Another environmental factor that requires further study is the

TABLE 6.18 Independent Variables Showing High Correlations with Animal Species Western Central Kalahari 1983/1984

Species	Date	Correlation - Independent variable or group
Eland	Sept. 1983	National Park.
Gemsbok	Nov. 1983	Wildlife Management area, drainage valleys, farms, low altitude (< 1120m a.s.l.).
	Jan. 1984	National Park, park woodland, drainage valleys away from farms.
	April 1984	National Park, sparse and fawn herbaceous layer, away from farms, away from communal cells.
	June 1984	Drainage valleys, away from big pans, away from farms, away from communal cells.
	August 1984	Away from farms, away from communal cells.
	Sept. 1984	Away from farms, away from communal cells.
Hartebeest	Nov. 1983	Mineral prospecting areas, low altitude (< 1120m a.s.l.).
	June 1984	Low altitude areas (< 1120m a.s.l.), away from drainage valleys, old bush-fire scars, moderate and fawnish-green herbaceous plant layer.
	August 1984	Mineral prospecting areas, away from drainage valleys, sand-hill and sand-ridge land region, low altitude (< 1120m a.s.l.), light harvester termite infestation areas.
Wildebeest	April 1984	Drainage valleys, high altitude (>1200m a.s.l)
	June 1984	Low sand-dune area, soil type 3 (11% to 20% white pan soil).
	August 1984	Low sand-dune area, soil type 3 (11% to 20% white pan soil).
Springbok	Nov. 1983	Park woodland.
	June 1984	Wildlife management areas.
	August 1984	Wildlife management areas, sparse and green herbaceous layer, low sand-dune area.
	Sept. 1984	Soil type 3 (11% to 20% white pan soil)
Cattle	Sept. 1983	Communal cells, farms.
	April 1984	Communal cells, farms, areas with surface water.
	June 1984	Communal cells, farms.
	August 1984	Farms.
	Sept. 1984	Permanent settlements, farms, communal cells.
Harvester Termite	August 1984	Wildlife management areas, sparse and fawn herbaceous layer.
	Sept. 1984	Mineral prospecting areas, wildlife management areas, farms, sparse and fawn herbaceous layer.

harvester termite. The results from the two aerial observations of this habitat factor show that, other than being wide-spread, there was a consistent high correlation with sparsely covered and fawn herbaceous plant layer. Heavy harvester termite infestation was found in these sparsely covered areas with fawn grass. From the ground observations reported in Chapter 5 about harvester termite activities of harvesting dead debris and cutting the fawn grass stalks, the sparseness of cover can only be accountable to such activities. Since their activities seem also to become intensive when the grass or herbaceous layer is dry and fawn, the author considers such high availability of food determines their pattern of distribution. However, the heavy intensity distribution was confined mainly to the southern parts of the study area yet there was also more herbaceous plant layer cover in the northern parts of the study area where only light infestation occurred. It is speculated that possibly the grass stalks in this relatively higher rainfall area remained green and made harvesting somewhat difficult, whereas in the south the stalks were observed to be dry to the base and thus easy to harvest from the base. However, there is need to investigate this field further.

That harvester termites and other termites can cause considerable reduction of herbaceous plant layer cover has been mentioned by Lee and Wood (1971). Quoting other sources, these authors say in Zululand, South Africa, harvester termites reduced the carrying capacity by 25% annually, in Central Asia another hodotermitid accounted for up to 20% loss of grass, and in south west Queensland yet another hodotermitid had been identified with causing complete denudation in areas never grazed by stock. Coaton (1958, 1963) has suggested that over-grazing creates favourable conditions for successful establishment of new colonies of the harvester termite, and has linked the heavy infestations in areas utilised by wild animal life as being a result of overgrazing by wildlife. The relationship between overgrazing by either domestic or wild animals and harvester termite has not been investigated in Botswana. However, it was observed in the field in this study that gemsbok and springbok seemed to prefer the areas of heavy harvester termite infestation. It was also observed that in these areas lush grass shoots appeared on remnant grass stubble earlier than in grass stands with dry standing hay. The lush green grass would undoubtedly attract grazers.

However, these interrelationships require immediate investigation, for if overgrazing by animals, is the key to heavy infestation by harvester termite, then there is a real threat to the whole of Western Kalahari since it is so sensitive to grazing. The uncontrolled livestock grazing system common in the permanent villages and Ncojane farms and shortly to be so in the TGLP present and planned ranches, will open up the rest of the area to harvester termite invasion. By grazing the heavily infested area with livestock, the areas will be rendered bare, with the subsequent problem of soil erosion through the action of wind.

An examination of the Landsat imagery of the study area for the study period shows that more than 40% of the area displays overgrazing characteristics. About 15% is in communal cells and farms and may thus be primarily accountable to livestock grazing while the other 25% away from communal cells and farms may be accountable to harvester termite infestation, wild animal grazing and bushfires. Since bushfires do not seem to be a major problem in the study area and the wild animal numbers obtained for the study area do not only fluctuate seasonally but are also not confined distributionally to the areas identified as overgrazed, it may reasonably be concluded that the harvester termites must account for most of the destruction in the rest of the areas showing overgrazing.

The results in this chapter further emphasize the need to adopt a careful and integrated land utilisation plan that recognises the interrelationships of the land resources both biotic and abiotic, of the area.