A STUDY OF THE MAJOR COMPONENTS OF THE KALAHARI PAN ECOSYSTEM

by

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ABSTRACT

The soil, climate, vegetation and wildlife of a cross-section of pans in the Central Kalahari were examined and the interrelationships of the major components of the pan ecosystem were investigated. It was established that the pan ecosystem is actively maintained by the combined actions of its biotic and abiotic components, thus confirming the need to conserve and understand natural ecosystems rather than individual species or groups of species.

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CHAPTER 1

INTRODUCTION

In September 1967, I was appointed as the first Game Warden in Southern Botswana, the greater part of which is sparsely populated Kalahari sandveld and which still supports large wildlife populations. While carrying out a preliminary game survey of the Kweneng District during 1967 it became clear that throughout the Kalahari sandveld areas pans were a focal point for many wildlife species. These pans are a fascinating feature of the Kalahari and evoke comment from all research workers.

A more intensive study of pans and their role in the Kalahari habitat commenced in 1968 as part of the overall research program of the Department of Wildlife and National Parks (Botswana) and soon confirmed the earlier observation that many wildlife species utilize pans. It also underlined the extent to which man and his live-stock were adversely affecting the pan habitat (Parris and Child 1973). As pans should not be studied in isolation, attempts were made to gain an understanding of the Kalahari environment as a whole, particularly of such aspects as wildlife move-ments, availability of moisture, and interactions between man and wildlife. These as-pects were briefly discussed in a paper read at the Conference on Sustained Pro-duction from semi-arid areas with special reference to the Kalahari (Parris 1972).

The large wildlife populations in Southern Botswana play an important part in the economy of the region and a basic understanding of the wildlife and its habitats is essential for the sound management of these resources. As pans were shown to be important to wildlife I continued with a more detailed longterm study of these pans and pan-like areas in the Kalahari.

In this treatise the major components of the pan ecosystem are examined and dis-cussed and it is hoped that these findings will lead to a better understanding of the Kalahari and so assist in its conservation.

CHAPTER 2

STUDY AREA

Location

As pointed out by several authors (Wellington 1955, Leistner 1967 and Parris and Child 1973) the term 'Kalahari System' in its broadest sense refers to the huge sandveld area of Southern Africa including nearly all of Botswana, the north-eastern part of South-West Africa, a large portion of Angola and Zambia, and smaller parts of Rhodesia and the north-western areas of the Cape Province of South Africa.

Leistner (*op cit.*) points out that geographically the Kalahari is usually taken to be that portion of the sand-covered Kalahari System which lies between the Orange and Zambezi Rivers, and describes how earlier authors have often used the Bakalahari Rise or 'Schwelle' which extends roughly from Kanye in the south-east through the Kuli-Nojane area of Botswana to the watershed between the Nossob and Epikuro Rivers in the north-west to divide the Kalahari into northern and southern sections.

The present study was conducted in Botswana in that portion of the Kalahari lying between the Okwa River in the north and the Molopo River in the south (Fig. 1). The eastern boundary of the study area follows the boundary of the heavier soils of eastern Botswana while the western boundary follows the international boundary between Botswana, South-West Africa and South Africa.

The northern, eastern and southern boundaries of the study area coincide with the major vegetation boundaries of Weare and Yalala (1971). The south-western portion of the study area overlaps slightly into the duneveld of the Southern Kalahari defined by Leistner (1967) and described as the dune-covered, southern-most and most arid part of the Kalahari System.

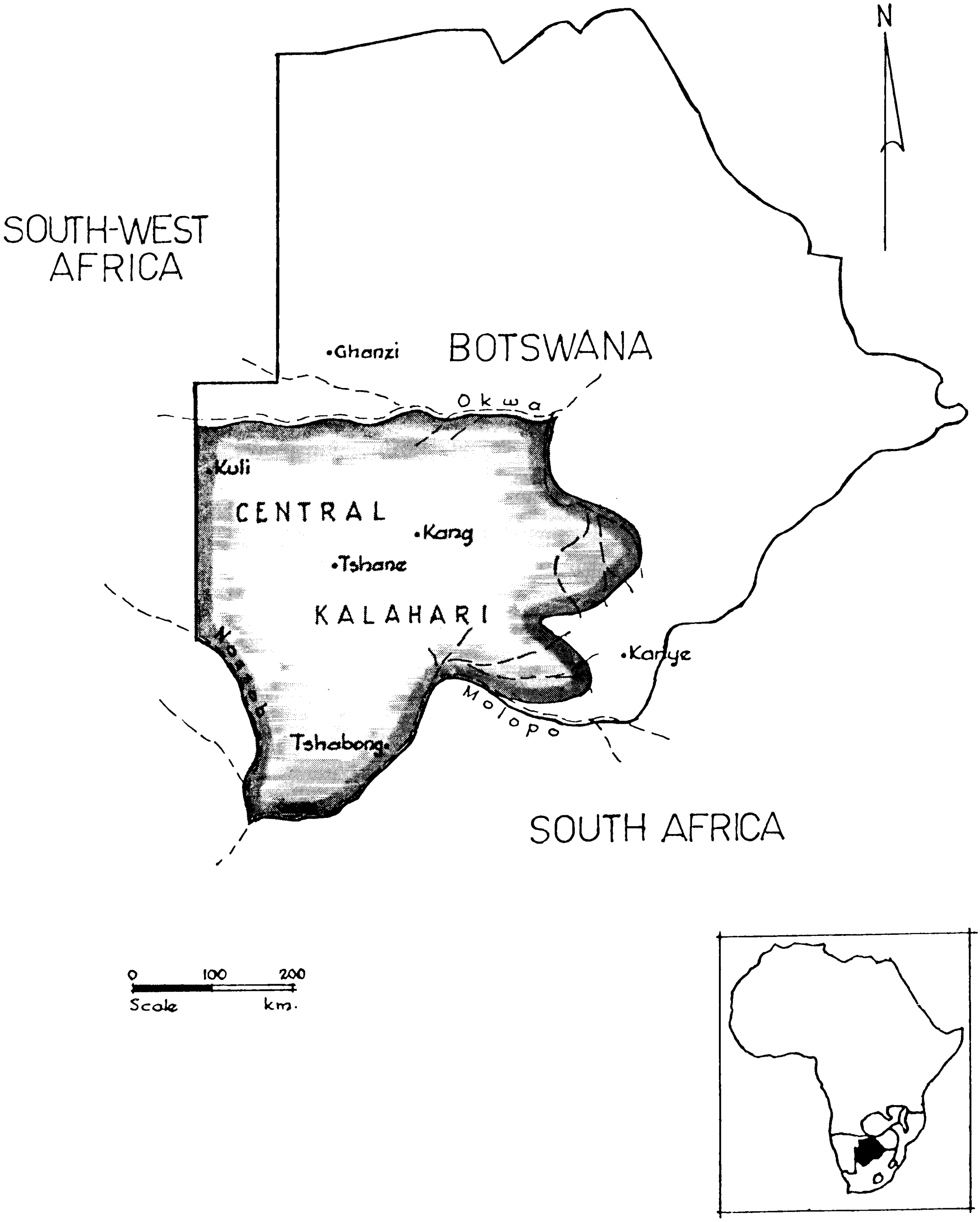


Figure 1 : The study area in Botswana is defined as the Central Kalahari and its location is indicated by the shaded outline

That part of the Kalahari in Botswana covered by the present study and illustrated in Fig. 1 adjoins the Southern Kalahari and is therefore conveniently defined as the 'Central Kalahari'.

Physiography

The Central Kalahari is a vast sand-covered plain with no marked variations in relief. Only a few isolated low rock outcrops occur, the most extensive being around Tshabong, and from low-flying aircraft the Central Kalahari appears perfectly flat.

The Bakalahari rise which extends in a north-westerly direction across the Central Kalahari between Kanye and Kuli has an elevation of between 1100 m and 1270 m, (Blair-Rains and Yalala 1972). The land dips gradually north-eastwards from this rise towards the Makgadikgadi depression at 880 m and south-westwards from the rise it dips towards the Molopo-Nossob confluence at 790 m above sea level.

The sandveld in the central and eastern parts is almost flat or gently rolling while towards the south-west irregular rises and dunes are more apparent. In the extreme south-western parts regular linear dunes typical of the dunes of the Southern Kalahari and described by Leistner (1967) occur.

Drainage during moister times was by means of the river systems shown in Fig. 1 but at present these riverbeds are mainly wide dry valleys in the sandveld, only sections of which flow a little during excessively wet seasons.

Scattered throughout the Central Kalahari, and providing small-scale local relief, are hundreds of pans varying from small depressions to those lying some 15 m or more below the surrounding sandy plain.

Geology

The most striking aspect of the geology of the Central Kalahari is the almost uninterupted mantle of sand covering the area.

Boocock and Van Straaten (1962) describe the geology of the region in considerable detail and give a generalized stratigraphical succession for the region. The Kalahari beds are the most recent and uppermost geological deposits with an average depth of 100 m. The lowest layer of the Kalahari beds comprises Kalahari marls of which there are no natural exposures. Overlying the Kalahari marls are calcareous and silicified sand and sandstone, grit and minor conglomerates which form a tableland of varying thickness below the sand mantle.

The uppermost layer of the Kalahari beds consists of reddish-brown and greyish-white Kalahari sands. This sand layer is between 3,5 m and 35 m thick and is unbroken except for a few isolated rocky outcrops, old drainage lines, known as fossil valleys, and pans. The presence of artifacts underneath this sand mantle indicate its age as lower or middle Pleistocene.

Boocock and Van Straaten (*op. cit.*) describe the most recent components of the Kalahari beds as the pan sediments, recent calcretes and silcretes. These relatively thin layers of calcrete are frequently diatomaceous and are noticeable around pans and along fossil river valleys. The pan sediments are found on the larger pan floors and are distinctive dark clayey sands or alkaline calcareous clays.

Climate

General

The Kalahari is a virtually flat tableland situated in the centre of the Southern African Region, with an average elevation of 1 000 – 1 300 m above sea level and its climate is therefore controlled by the regional climate of Southern Africa as a whole (Pike 1972). In general the weather over the Central Kalahari comes under the influence of three air masses. During the winter months warm and exceedingly dry air dominates the climate and gives rise to warm dry sunny days with temperatures rising over 20°C by midday followed by cold clear nights during which terrestrial radiation is active and night temperatures often fall below freezing. This weather is prevalent throughout the dry-season months from April to September although during the early winter this dry air may be broken up by the attenuated effects of cold air masses of Polar origin penetrating from the south which can result in short periods of light rain particularly in the south.

During the summer, incursions of tropical continental air from the east coast or equatorial air from the north give rise to conditions conducive to the development of thunderstorms.

Rainfall

The geographical position of the Kalahari is such that it receives the attenuated effects of these various air masses and this results in a high degree of variability particularly in the annual amounts and distribution of the rainfall, with long intervening dry spells. Pike (1972) gives the annual coefficient of variation for rainfall as 50–80 per cent as an illustration of its extreme variability.

Since the two important moist air currents enter the area from the north and the east one would expect the annual rainfall to be higher in the northern and eastern areas and progressively lower towards the south west. This is true as is shown in the rainfall isohyets in Fig. 2 which are based on the Botswana Weather Bureau Rainfall Map (Blair-Rains and Yalala 1972). The paucity of weather stations in the area results in rainfall data in the literature varying slightly between different authors (Leistner 1967, Blair-Rains and Yalala 1972, and Pike 1972). However because of the high coefficient of variation this difference in published annual totals is not particularly significant. Longterm monthly rainfall figures are given in Table 1.

Air temperature

Air temperatures in the Central Kalahari are marked by high summer maxima, and midday temperatures exceeding 37,8°C (100°F) are not unusual during December and January. During the summer months temperatures have the least diurnal variation while during the winter months a diurnal variation of 25°C is common. The more arid areas in the south-west have greater extremes of temperature in summer and winter. Ground frosts are common during the winter months, and are more frequent in the south-west. The air temperatures at two weather stations are given in Table 2.

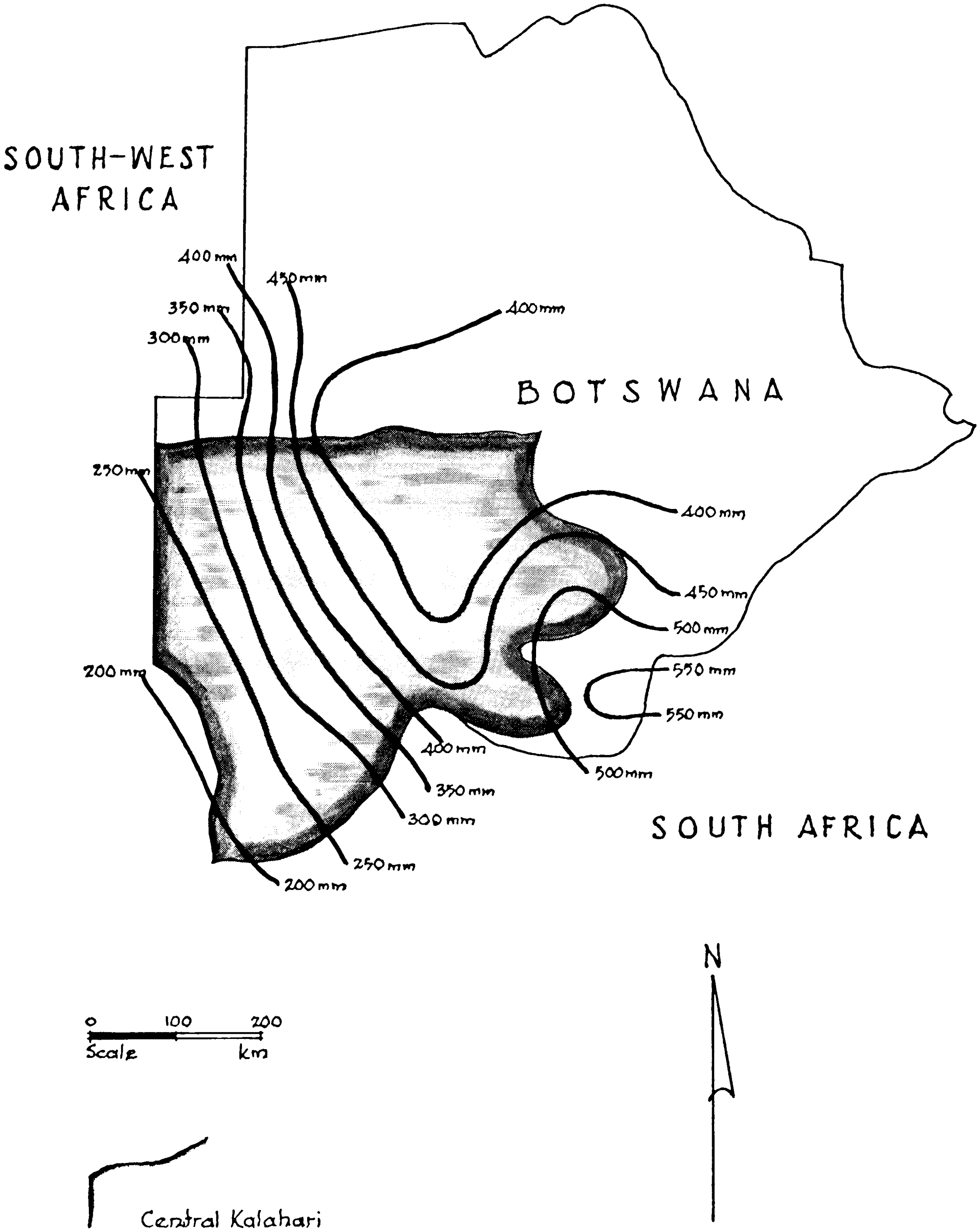


Figure 2 : The annual rainfall in mm in the Central Kalahari, Botswana, as indicated by the rainfall isohyets

Table 1 : Means of monthly and annual rainfall in mm at three stations in the Central Kalahari, Botswana

Month	Tshabong	Tshane	Ghanzi
January	41,0	65,7	97,5
February	50,1	49,3	93,4
March	45,4	61,4	78,7
April	32,0	26,4	38,3
May	11,6	7,9	7,8
June	9,9	5,8	1,3
July	2,0	5,1	0,3
August	1,0	0,5	0,3
September	8,9	0,5	1,5
October	13,2	10,1	21,0
November	22,0	53,0	45,6
December	41,4	24,8	66,3
ANNUAL MEAN	278,5	310,5	452,0

The means are for 24 years at Tshabong, six years at Tshane and 34 years at Ghanzi (after Blair-Rains and Yalala 1972)

Table 2 : Means of monthly air temperatures in ^{o}C at two stations in the Central Kalahari, Botswana

Month	Tshabong		Ghanzi	
	maximum	minimum	maximum	minimum
January	38,9	13,4	36,9	13,6
February	37,1	13,1	35,8	12,9
March	35,4	10,2	34,2	11,2
April	33,5	1,1	32,8	5,5
May	29,8	– 1,8	30,3	0,3
June	27,2	– 5,9	27,5	– 2,2
July	27,1	– 4,7	27,9	– 2,2
August	30,5	– 4,4	31,5	– 0,1
September	34,1	– 1,8	35,3	2,7
October	36,6	4,6	37,3	8,5
November	38,5	7,6	37,7	10,2
December	38,9	9,1	36,9	11,8

The means of maximum and minimum air temperatures are for 10 years at Tshabong and 20 years at Ghanzi (after Blair-Rains and Yalala 1972)

Relative humidity and evaporation

The relative humidity of the air is generally low except during the short periods of summer rainfall. The combination of high temperatures and low humidity results in a high annual evaporation rate. Blair-Rains and Yalala (1972) give the annual evaporation at Ghanzi as 3 000 mm and point out that rainfall is unlikely to exceed evaporation in the Central Kalahari for any month of the year.

Wind

Andersson (1969) describes the surface winds in the Central Kalahari as mainly light north-easterly. Leistner (1967) referring to the winds of the Southern Kalahari says that the dominant winds are north-westerly and that they are the most frequent and violent in August and September at the time when the vegetation is driest and most subject to wind erosion.

Vegetation

Weare and Yalala (1971) in their vegetation map of Botswana describe the vegetation of the Central Kalahari area as Shrub Savanna, while the vegetation to the east and north of the study area is described as Tree Savanna. The boundary between the Shrub Savanna and Tree Savanna coincides with the eastern and northern boundary of the study area defined in this treatise as the Central Kalahari.

The Shrub Savanna is subdivided into three vegetation types. The Arid Shrub Savanna which is found in the extreme south-west and is associated with the lowest annual rainfall and regular sand dunes. This vegetation type is not typical of the Central Kalahari and falls within the north-eastern limit of the Southern Kalahari, as defined by Leistner (1967) who describes the vegetation of the Southern Kalahari in detail. Weare and Yalala (*op cit.*) give two further subdivisions of the Shrub Savanna namely the Southern Kalahari Bush Savanna and the Central Kalahari Bush Savanna.

The Southern Kalahari Bush Savanna adjoins the Arid Shrub Savanna along its north-eastern boundary and covers the southern half of the study area. It is rolling sandy country with flat dunes, wide plains, depressions and pans. The main tree species are *Acacia erioloba, A. mellifera* and *Boscia albitrunca,* while the perennial grasses include *Stipagrostis uniplumis, Eragrostis lehmanniana, Schmidtia pappophoroides, Antephora pubescens, Panicum kalahariense* and *Aristida meridionalis.* Pans are common in the area and a number of grasses, trees and shrubs are associated with pans. These species include *Acacia mellifera, A. newbrownii, Catophractes alexandri* as low shrubs while the most common grasses are *Cenchrus ciliaris, Cynodon dactylon* and *Setaria* spp. with *Sporobolus* spp., *Eragrostis truncata* and *Panicum coloratum* associated with the pan floors.

The Central Kalahari Bush Savanna vegetation type covers the northern half of the study area and its northern and eastern boundaries coincide roughly with the boundaries of the study area. The physiography is similar to the Southern Kalahari Shrub Savanna and in general the same species of woody plants and grasses are found, with the addition of *Lonchocarpus nelsii* trees and shrubs, with *Terminalia sericea* becoming more frequent and other trees such as *Acacia fleckii* entering the community. The grass species are the same as in Southern Kalahari Shrub Savanna. Blair-Rains and Yalala (1972) prepared a vegetation map of the Southern and Central State Lands of Botswana using physiognomic units and noted that a relatively small number of woody and herbaceous plants occur in a variety of combinations which intermingle in mosaic patterns of Shrub Savanna, thicket or stunted woodland and grassland, and in their physiognomic habitat map of the Kalahari Gemsbok National Park, Bothma and De Graaff (1973) recognize six major habitat types i.e. riverbeds, pans, tree savanna, flat open grassy plains and two types of dune habitat.

Human and livestock populations

Using the 1964 National census figures for Botswana, Fosbrook (1972) gives the total human population for the Central Kalahari (including the farms around Ghanzi) as in the region of 42 000.

These people are not spread evenly throughout the area but are mainly concentrated in fairly large permanent villages. The people do, however, move considerable distances from their villages during hunting trips or while searching for fresh attractive grazing for their stock.

In the central, western and southern parts of the Central Kalahari a human population of about 30 000 is centred around Kuli, Tshane, Kang, Tshabong and along the Molopo River with the areas inbetween virtually uninhabited. In the eastern parts of the Central Kalahari a population of about 10 000 is more evenly spread throughout the area because of the greater number of boreholes. Many of these people move regularly between the Kalahari and the adjoining areas further to the east and are therefore not permanent residents of the Central Kalahari.

The total number of livestock in the Central Kalahari is given by Thomson (1972) as 237 000 cattle 59 000 sheep and 167 000 goats and these animals are concentrated in the same areas as the human populations described above.

The Central Kalahari therefore has a low overall human and livestock population but certain localized areas have a fairly high human concentration and suffer from overpopulations of cattle and small stock.

Important features of the study area

The following aspects of the study area make it particularly valuable as an area in which to study the interactions between wildlife and pans in the Kalahari:

(1) It is an extensive area ($\pm$ 200 000 km^2) with few roads and virtually no fences.

(2) There are numerous pans throughout the area, the majority of which are not permanently settled.

(3) It still contains large natural wildlife populations and because of the factors mentioned in (1) and (2) above these large wildlife populations are still able to utilize the pans relatively undisturbed as they have done for many thousands of years.

It has therefore been possible to observe and measure the pan ecosystem under natural conditions in the Central Kalahari of Botswana.

Intensive study sites

Regular measurements and observations were concentrated at two study sites within the Central Kalahari. The first intensive study site included the pans in the Mabua Sehube Game Reserve, and is situated in the southern part of the Central Kalahari (Figs. 3 and 4). The second study site included the pans in the north-eastern section of the Khutse Game Reserve which lies in the north-eastern part of the Central Kalahari (Figs. 3 and 5). Both these Game Reserves were proclaimed during the study period and their declaration was in part a result of the findings of this study on pans.

The two intensive study sites were selected for the following reasons:

(1) They are situated well away from permanent human settlements and livestock populations. In the case of Mabua Sehube the nearest permanent human settlement is more than 100 km from the pans and in the case of Khutse the nearest permanent human settlement to the east is more than 20 km from the pans, while the area to the north and west has no permanent settlements for hundreds of kilometers

(2) Large wildlife populations were common in the vicinity of the pans

(3) Permanent Game Scout Camps were established in the two Game Reserves which ensured that the wildlife populations were protected from excessive poaching.

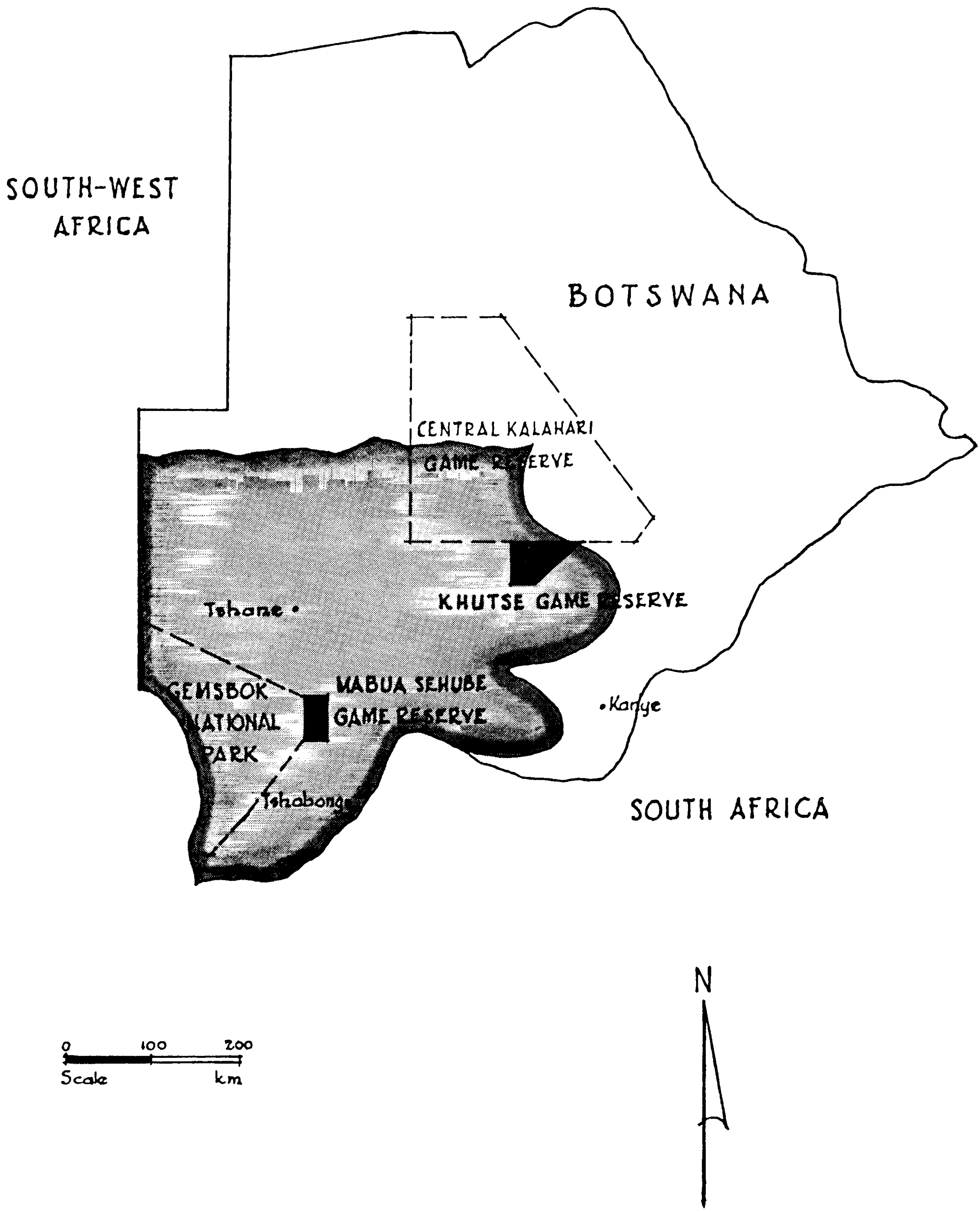


Figure 3 : Game Reserves and National Parks in the Central Kalahari, Botswana. Mabua Sehube Game Reserve and Khutse Game Reserve are shaded black and the boundaries of the Central Kalahari Game Reserve and the Gemsbok National Park are indicated by broken lines

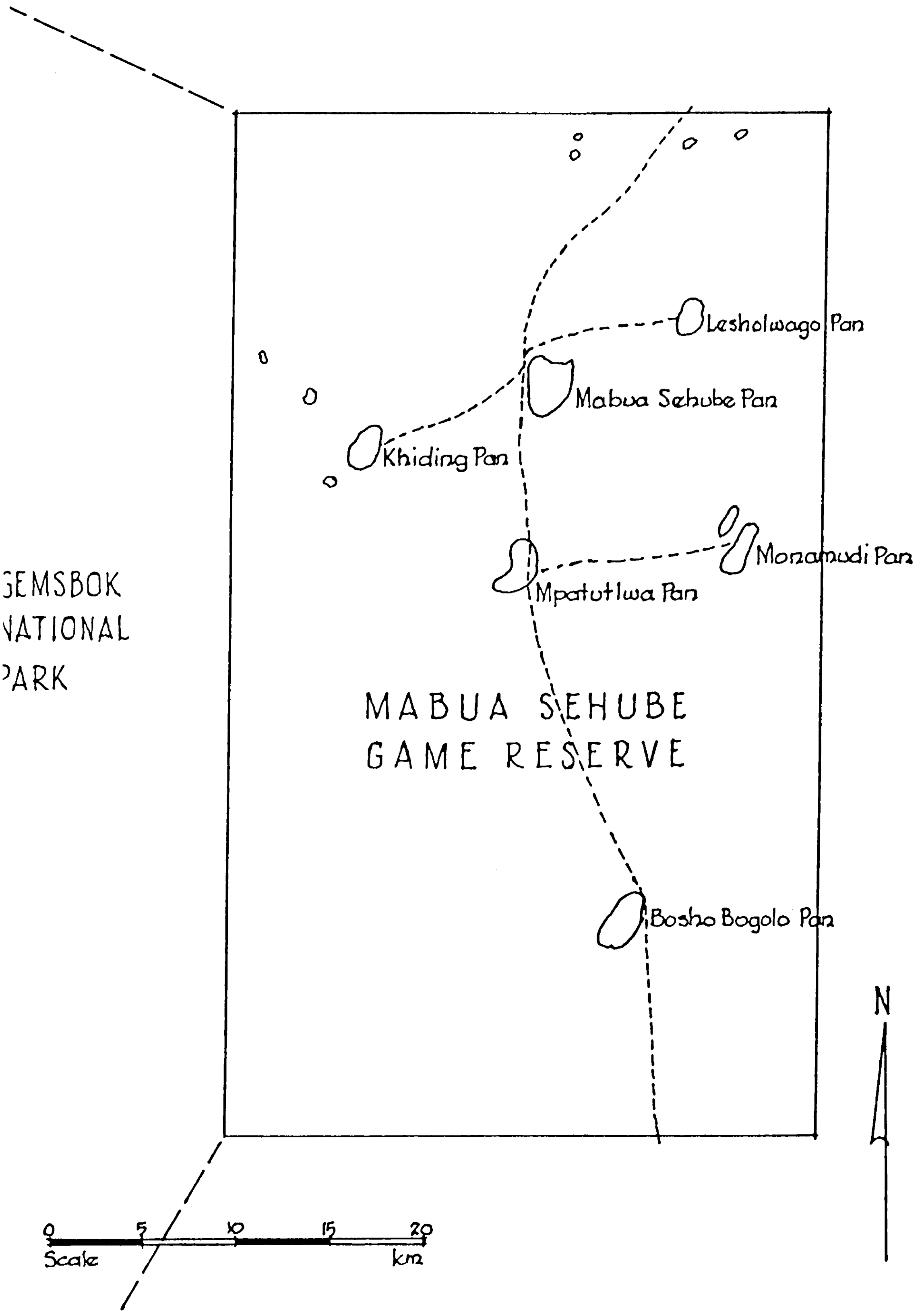


Figure 4 : Mabua Sehube Game Reserve in the Central Kalahari, Botswana, showing the location of the major pans in the Game Reserve

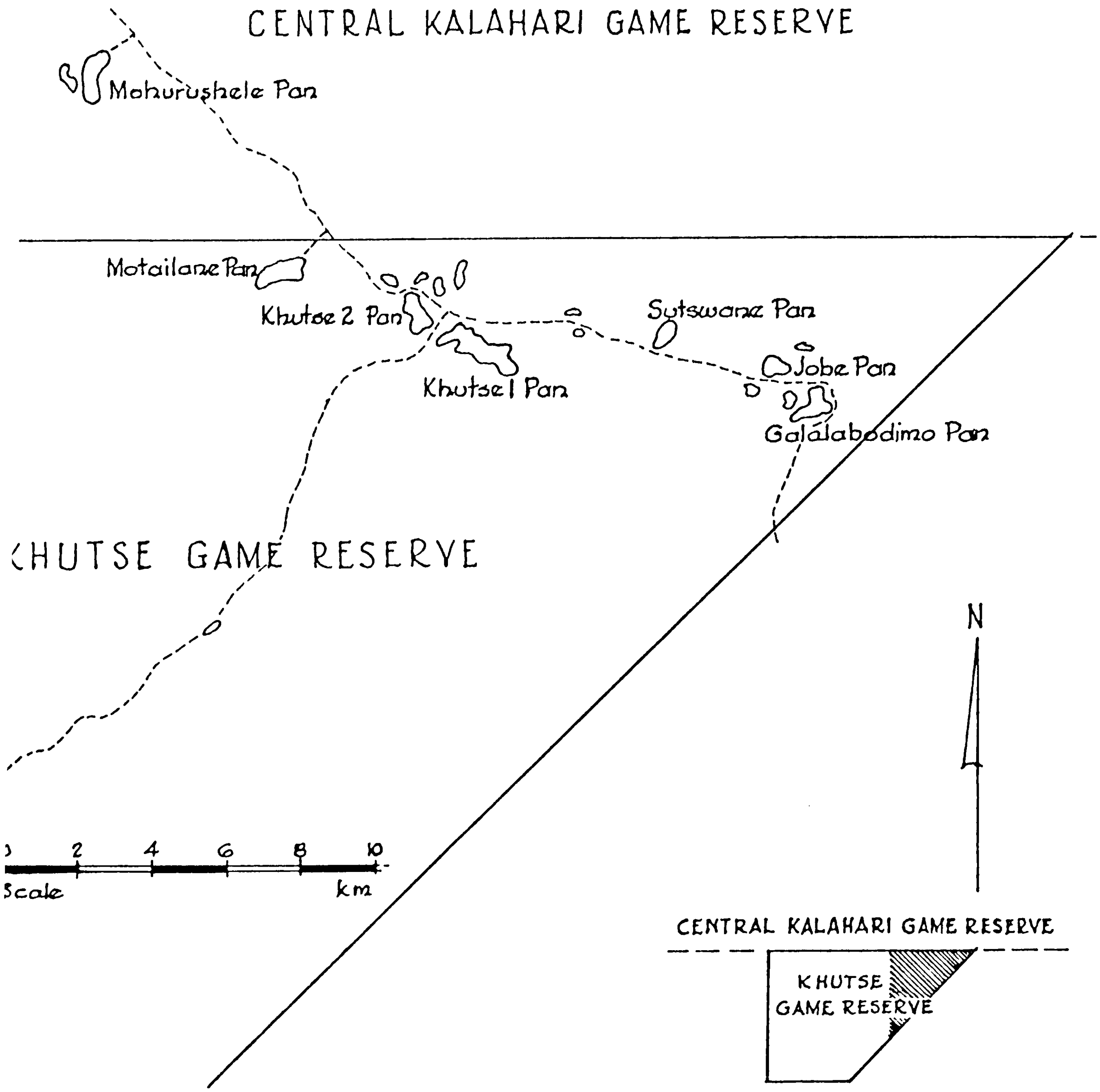


Figure 5 : The north-eastern section of Khutse Game Reserve in the Central Kalahari, Botswana, showing the location of the major pans in the area

CHAPTER 3

METHODS

Use of fixed points in selected habitats

A cross section of habitat types in the intensive study sites were selected, and at each of these sites a fixed marker usually consisting of a pile of calcrete rocks was erected. By using these fixed markers as reference points it was possible to sample the same sites on each pan each year. In the Mabua Sehube Game Reserve the markers were erected in 1968, and in 1969 in the Khutse Game Reserve. These markers, an example of which appears in Fig. 12, were used throughout the study period.

Fixed point and general photographs

At the fixed point markers referred to above, black-and-white photographs were taken in a standard way each year in each habitat type. The camera was held at the same height and angle each time so that the photographs can be used for direct habitat comparisons. Different habitat types at different sites can also be compared thus or the habitat at the same site can be compared between years. The fixed point photographs were taken between August and October during the dry season, when the shortterm fluctuations in the vegetation due to rainfall are at their lowest and when the impact of the fauna on the vegetation is most conspicuous.

Fixed point photographs were also taken to illustrate differences in vegetation inside, and adjacent to the bush exclosures mentioned later.

General photographs, both black-and-white and colour, were taken throughout the study area to illustrate particular features.

Pellet group counts

Pellet group counts were done in each habitat type using the method described by Parris and Child (1973). With antelope each distinguishable pellet group falling within a sample plot was counted. When a pellet group lay partly in and partly out of the plot it was counted if more than half the group fell within the plot.

At each sample site the pellet groups in a total of twenty plots were counted. The twenty plots were laid out as follows:- From the fixed point marker described above, twenty paces were taken and on the twentieth pace a circular plot with an area of 3,8 m^2 was laid out and the pellet groups counted within the plot. Another twenty paces were then paced out in the same direction and a second plot measured and counted. In this way a total of ten plots was laid out over a distance of approximately 200 m. A second line of ten plots parallel to the first and approximately 10 m to the side were then measured, giving a total of 20 plots at each site.

The size of the plot was determined by earlier workers to form a convenient fraction of an acre. The size of the plot was retained so that meaningful comparisons can be made with previous pellet surveys.

The total number of pellet groups of each antelope species in the 20 plots was added and this figure was used for comparing habitats. Springhare pellets were recorded as either present or absent in each plot as their pellets do not occur in distinguishable groups. The number of plots out of 20 in which springhare pellets were recorded is used for comparing habitats. Hare pellets were recorded in the same way as springhare pellets.

Pellet group counts were done during the dry season at the same time as the vegetation measurements and give a measure of habitat use by a particular species or a group of species. The results of the pellet group counts in this study are used to illustrate relative habitat use and are not used as an absolute measure of habitat use by different species.

Bush exclosures

Earlier research (Parris and Child 1973) showed that the vegetation on unsettled pans is subjected to heavy use by wildlife. A series of bush exclosures were erected in the intensive study sites to determine what effect the exclusion of large herbivores would have on the vegetation. The bush exclosures consisted of a dense thorn branch barrier 1,5 m high laid out to form a square with 10 m sides. Additional thorn branches were added to the hedge as required. Each of the exclosures was placed in a specific habitat type and with similar vegetation inside and adjacent to the bush kraal. Each year the vegetation inside the exclosure and that adjacent to the exclosure was compared using black-and-white photographs taken from a standard position, and recording differences in the herbaceous plants.

Measurements of vegetation

Measurements of the vegetation on pans were done during the dry season and at the same sites each year using fixed point markers. As discussed in the section on photographs it is during the dry season that the impact of the fauna on the vegetation is most conspicuous.

Percentage ground cover

Ground cover refers to that part of the soil surface that is covered by either plant canopy or rooted plants. The ground cover of the vegetation was measured by means of a step-point transect consisting of 100 points at 2 m intervals. At each point, plant litter, rooted plants and plant canopy was recorded. The total number of strikes per 100 points was used as a measure of per cent ground cover. A greater number of points at each site would give a more reliable measure of ground cover for that particular season but annual fluctuations in the rainfall are so great that the ground cover varies considerably from year to year and is as much a reflection of the previous rainy season as a reflection of normal vegetative cover.

As in the case of the pellet group counts the measurements of per cent ground cover are used to compare the relative ground cover in different habitats and not as an absolute measure of ground cover.

Height

When a sample point fell under the canopy of a plant the height of that plant was recorded. The plants at each transect site were grouped into woody plants i.e. trees and shrubs, perennial grasses, annual grasses, and forbs, and the measurements in each group were combined to give the average height of plants in the group.

General

A black-and-white photograph of the vegetation was taken at each sample site from a standard position and additional general notes were made.

Animal counts

General

Each time a pan in the intensive study areas (Figs. 4 and 5) was visited the number of animals seen on the pan, the date and time was recorded.

Regular counts

At Mabua Sehube Pan the number of animals seen on the pan each morning were recorded during the period April 1968 to March 1969 by the Game Scouts stationed at the pan. At Lesholwago, Khiding and Mpatutlwa the animals were recorded weekly. At Khutse 2 Pan the number of animals seen on the pan each morning were recorded during the period January 1970 to December 1971 by the Game Scouts stationed near the pan.

The presence of open water in the water-holes was also recorded during the regular game counts on Khutse 2 pan.

Soil analyses

Standard soil samples were taken on and around a cross-section of pans in the study area. The samples were collected and placed in plastic bags or paper packets and taken to the laboratory in Gaborone for analysis. In the laboratory both the physical and chemical properties of each sample were analysed and all samples were analysed using standard and therefore comparable techniques.

Use of aerial photographs

Aerial photographs and 'print-lay-downs' of the study area were examined to determine the number, size and distribution of pans in the Central Kalahari. Distortion along the edges of the photographs results in a slight overlap but it was nevertheless possible to plot the size and distribution of the pans accurately. The field maps prepared from these aerial photographs are at present the most reliable maps of this little known area.

General notes and observations

The study on pans was not a full-time research project but between September 1967 and January 1972 I visited numerous pans at all times of the year in the course of my normal duties as a Game Warden. During these visits general observations were made which assisted me in gaining a broad-based overall appreciation of pans and their position in the Kalahari habitat.

CHAPTER 4

RESULTS AND DISCUSSION

Distribution of pans in the Central Kalahari

Pans of varying size are found throughout the Kalahari and as described by Smithers (1971) a feature of the Kalahari in Botswana is the great number of pans which characterise it. Leistner (1967) reports that pans in the Southern Kalahari duneveld are usually found associated with flat ground that has little or no overall surface gradient, and that the main concentration is found in the south-western sector between Aroab, the confluence of the Nossob and Molopo Rivers and Upington.

An examination of aerial photographs of the Central Kalahari showed no consistent pattern in the distribution and arrangement of pans but there are noticeably more pans in the central area roughly co-inciding with the Bakalahari Schwelle or Rise, and fewer pans to the south-west and north-east of this central area (Fig. 6). In some areas particularly near dry river beds pans are arranged in lines and are the remains of old tributaries of the dry rivers. Good examples of these pans are found in the Khutse Game Reserve and along parts of the Okwa. However in most cases the pans are scattered and show no particular pattern of distribution.

Description and dimensions of pans

Leistner (1967) describes pans in the Southern Kalahari as generally flat-bottomed depressions periodically containing water and classifies them into various groups, the most common type of pan being the kalkpan or calc-pan and which is apparently peculiar to the Kalahari (Wellington 1955). A less common type of pan in the Southern Kalahari has a high concentration of minerals mainly Na and Cl on its floor and is referred to as a salt pan, and Leistner (*op cit.)* refers to one of the largest of these salt-pans near Abiquas Puts as being 4,8 km long. Rarest in the Southern Kalahari are rock-pans which occupy depressions in seemingly solid bedrock, while shallow depressions lined with compact calcareous sand and situated on sandy flats or between ridges are known as sand- or dune-pans. These

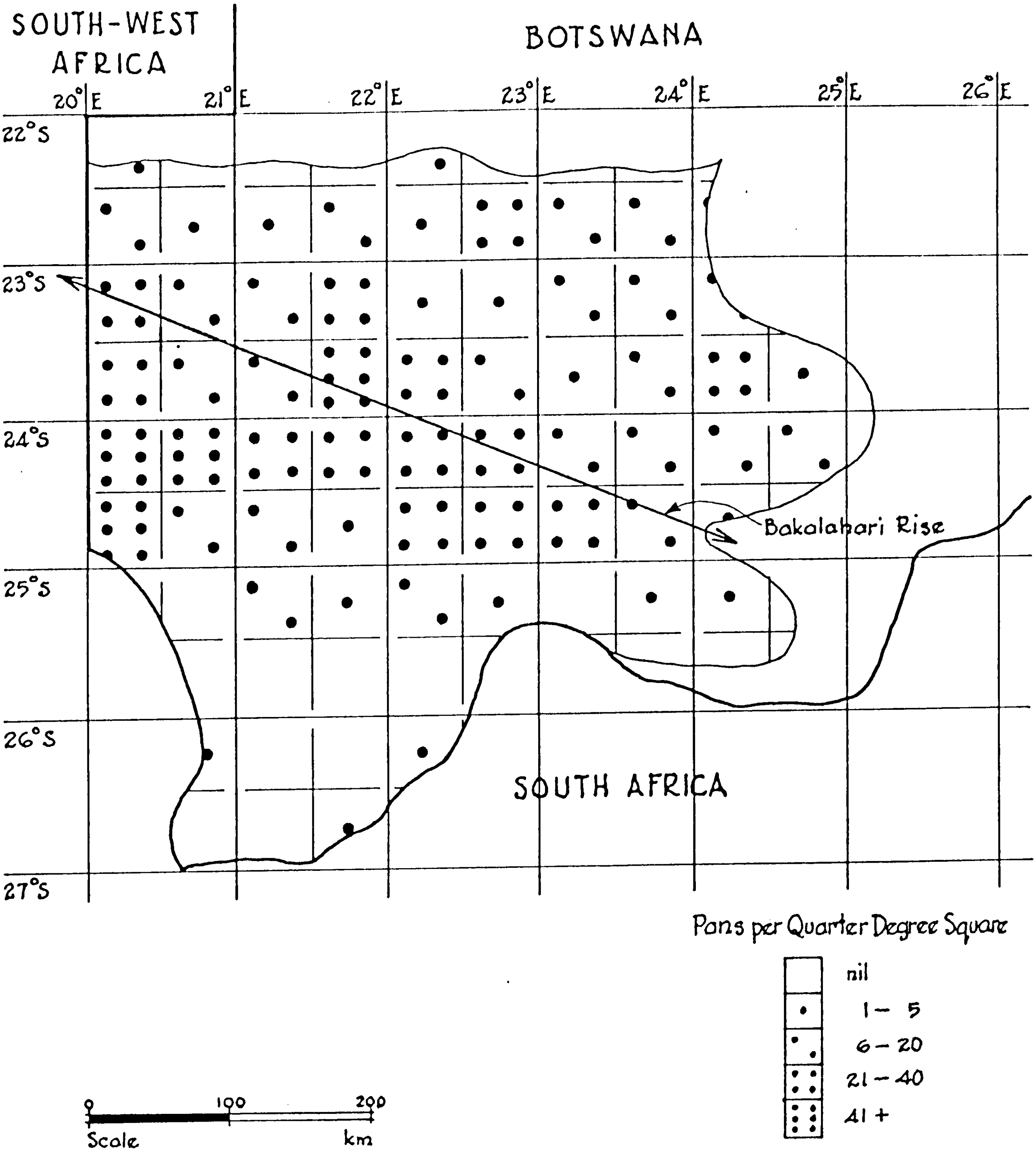


Figure 6 : Density and distribution of pans in the Central Kalahari, Botswana. The number of pans per quarter degree square were determined from aerial photographs and each quarter degree square classified into one of five pan density classes as indicated. The approximate position of the Bakalahari Rise is indicated by the diagonal line across the Central Kalahari

are regarded as either incipient pans or as pans about to be smothered by encroaching sand.

Leistner (1967) notes that one feature which is characteristic of virtually all large pans in the Southern Kalahari is an accumulation of sand on the lee side (which is almost invariably the south-east) of the pan. These dunes are commonly called koppe or heads, being normally higher and always lighter in colour than others in the vicinity. From high vantage points they are usually visible for several kilometres and as they often have distinctive shapes they make useful landmarks for travellers.

Blair-Rains and Yalala (1972) describe pans in the Central Kalahari as flat-floored depressions of variable size lying 15 m or more below the surrounding surface and which frequently have a pronounced tree- or shrub-covered ridge (lunate dune) along their south or south-western edge. The Central Kalahari is virtually flat and for this reason pans are conspicuous as they have a floor which lies below the level of the surrounding sandveld and a dune on the lee edge often noticeably higher than the surrounding sandveld (Figs. 7 and 8).

It is important to stress, however, that both the absolute dimensions of the pan floor and pan dune and their dimensions relative to each other vary considerably between pans. On some pans the pan dune is scarcely noticeable while on others such as Mabua Sehube it forms an impressive sandy hill. Similarly the pan floor may be less than 30 m in diameter in the case of small shallow pans, while the diameter of the pan floor on many of the larger pans exceeds a kilometre. In the Central Kalahari only a few of the largest pans have a pan floor exceeding 5 km in diameter, and they do not have the vast dimensions of pans such as the Makarikari in north-eastern Botswana or Etosha in South-West Africa. In spite of the tremendous variation in the dimensions of pans they have certain features in common which clearly distinguish them from the surrounding relatively homogenous sandveld. These features are:-

(1) Endoeric drainage, i.e. the ground slopes inwards towards a central low point, the pan floor, which lies below the level of the surrounding sandveld.

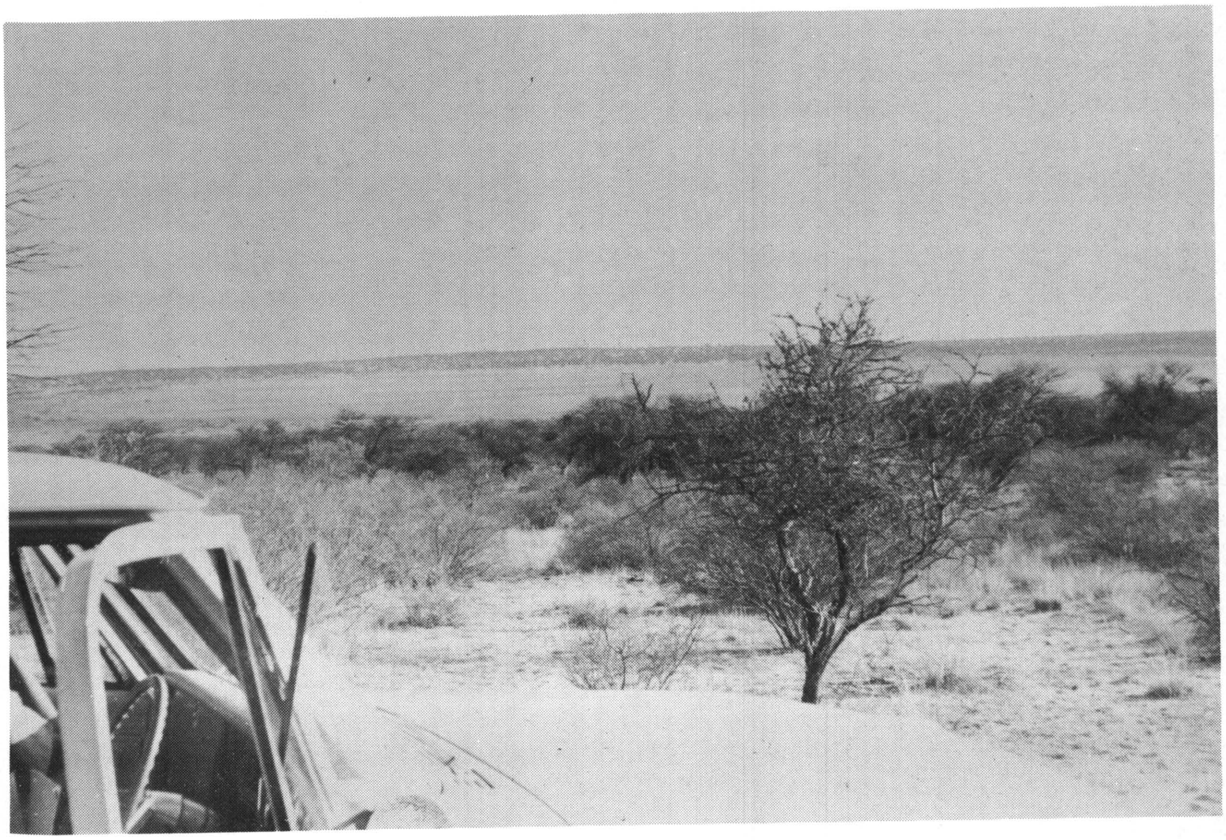


Figure 7 : Mabua Sehube Pan in the Central Kalahari, Botswana. The vehicle is on the northern side of the pan and the photograph illustrates the sunken pan floor and the high dune on the southern side of the pan

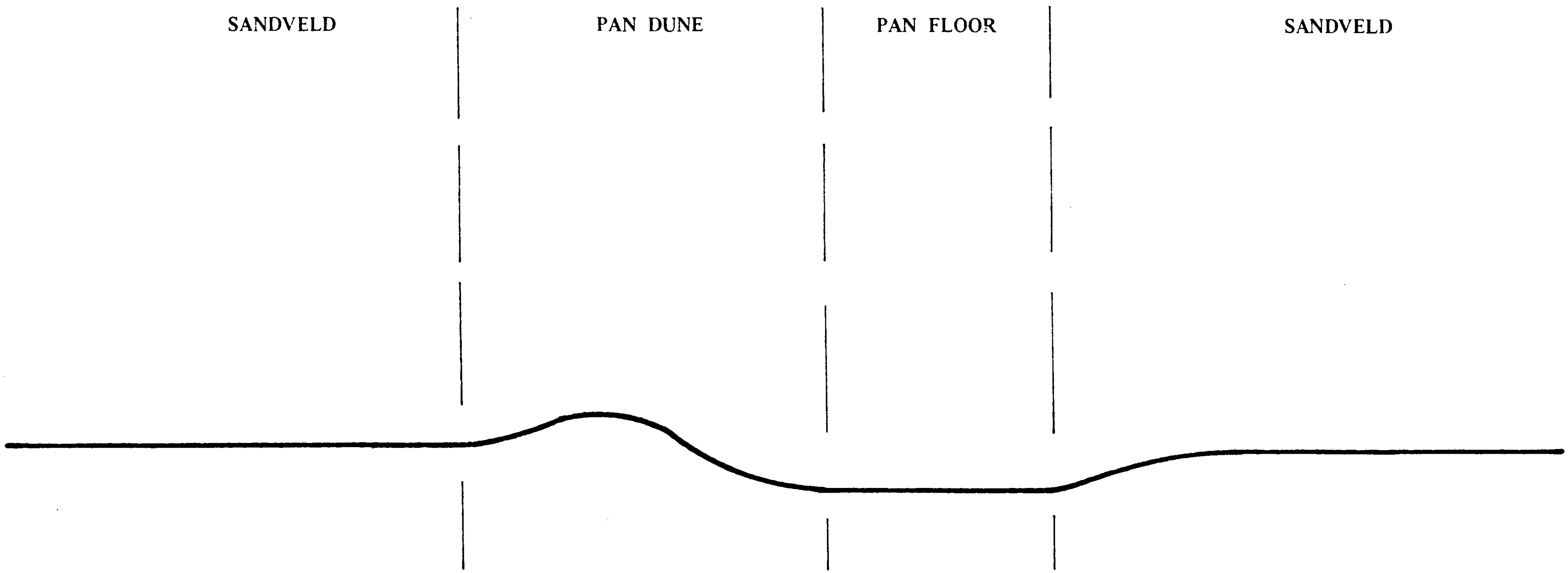


Figure 8 : Diagrammatic cross-section through a typical pan in the Central Kalahari, Botswana. The outline indicates the relative elevations of the pan dune, pan floor and surrounding sandveld

(2) The presence of compact soil on the pan floor.

(3) One or more seasonal water-holes.

(4) One or more salt-licks.

A diagrammatic cross-section through a typical pan in the Central Kalahari is given in Fig. 9. The relative proportions of the difference sections of the pan vary between pans and not all pans have all the sections that are shown in Fig. 9. Some pans for example have no calcrete cliff, while others have no conspicuous dune, etc.

The aerial photograph of Mabua Sehube pan (Fig. 10) illustrates the appearance of a large pan from above, and examples of the various sections of a typical pan are illustrated in Figs. 11–15. An example of the typical sandveld surrounding pans is given in Fig. 16.

Pan soils

General

Before discussing the physical and chemical properties of the soils found on pans in the Central Kalahari, it is important to first consider the properties of soils in the Kalahari as a whole. Leistner (1967) describes the properties and variations in soils of the Southern Kalahari in detail and as the soils of the Central Kalahari are similar to those in the Southern Kalahari his description of soils provides a useful base-line.

The soils of the Southern Kalahari are divided into two main groups i.e. fine soils and sandy soils. The division is done on the percentage sand (i.e. particles from 0,02 mm – 2,0 mm in diameter) in the soil. Fine soils are those with a sand content of 40–85 per cent and sandy soils are those with a sand content of 86–99 per cent. Conversely, fine soils have a relatively high silt and clay fraction, while sandy soils have a relatively low silt and clay fraction. The fine soils are further divided into river soils and pan soils, and the sandy soils are further divided into white sand, pink sand and red sand based largely on the colour and calcium content. The main physical and chemical properties of these soil groups are given in Table 3.

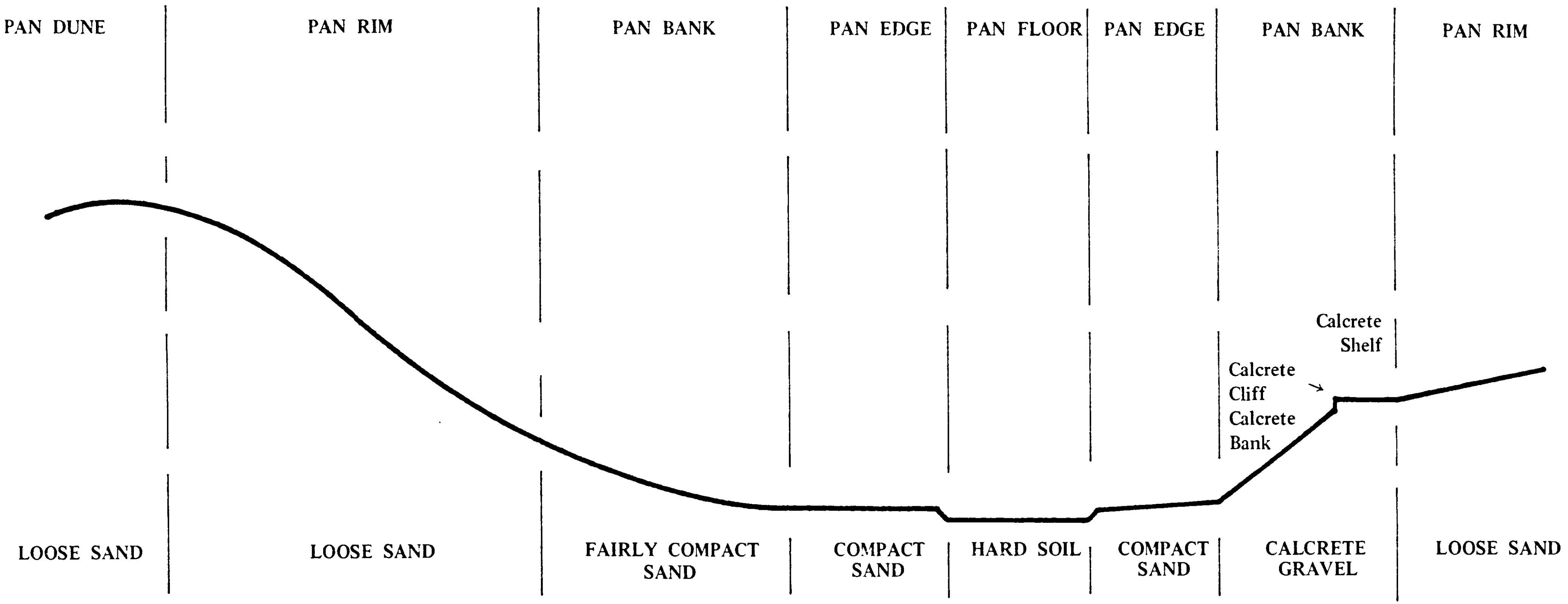


Figure 9 : Diagrammatic cross-section through a typical pan in the Central Kalahari, Botswana. The position of the various sections of the pan are indicated above the outline of the pan, with their corresponding soil types indicated below the outline

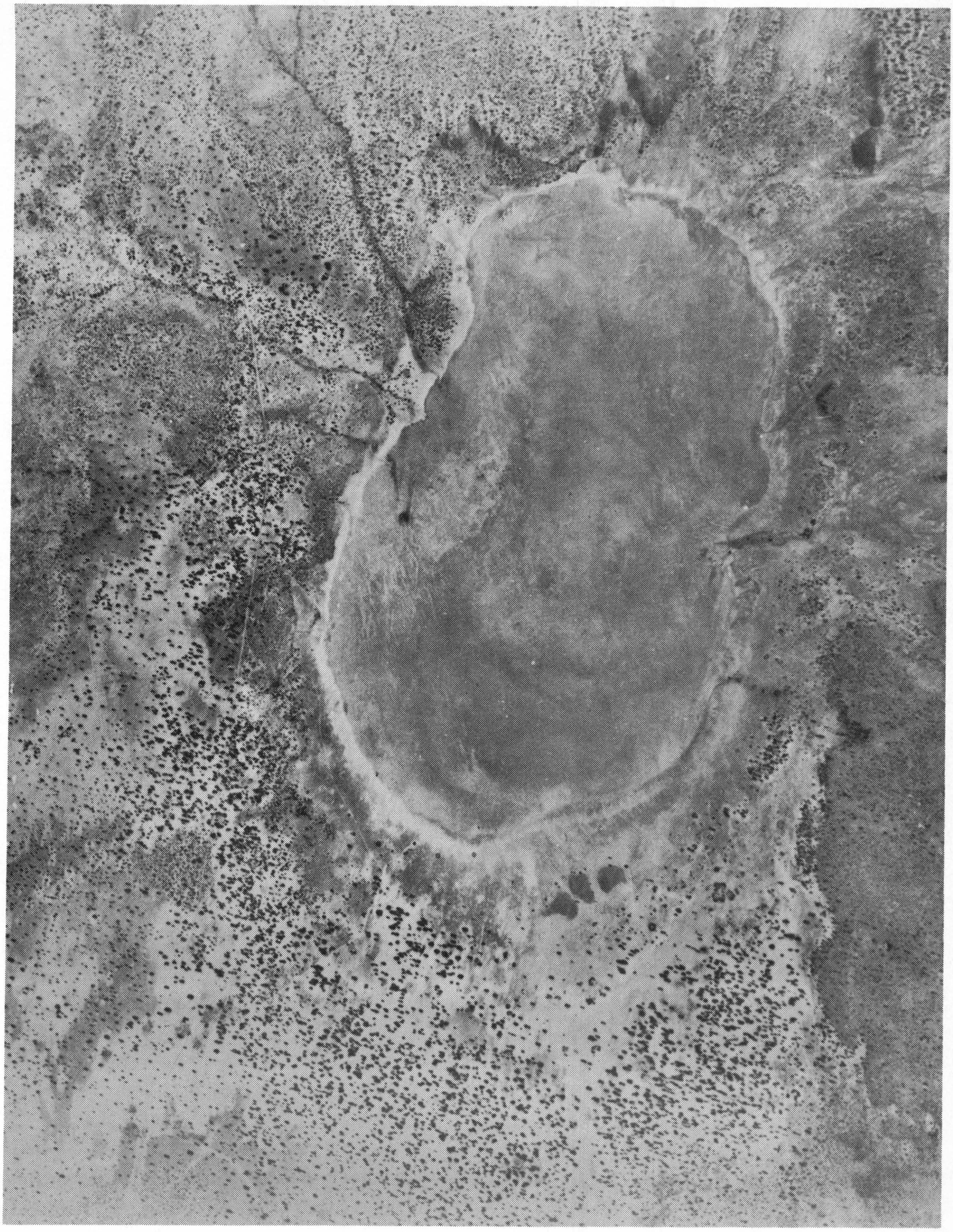


Figure 10 : Aerial photograph of Mabua Sehube, one of the larger pans in the Central Kalahari, Botswana. The pan lies with its northern side at the top of the page and the high tree covered dune is at the bottom of the page. The uniform grey area in the centre of the photograph is the pan floor and the dark lines leading to the edge of the floor are drainage lines. The pan floor is approximately 2 km long and 1 km wide

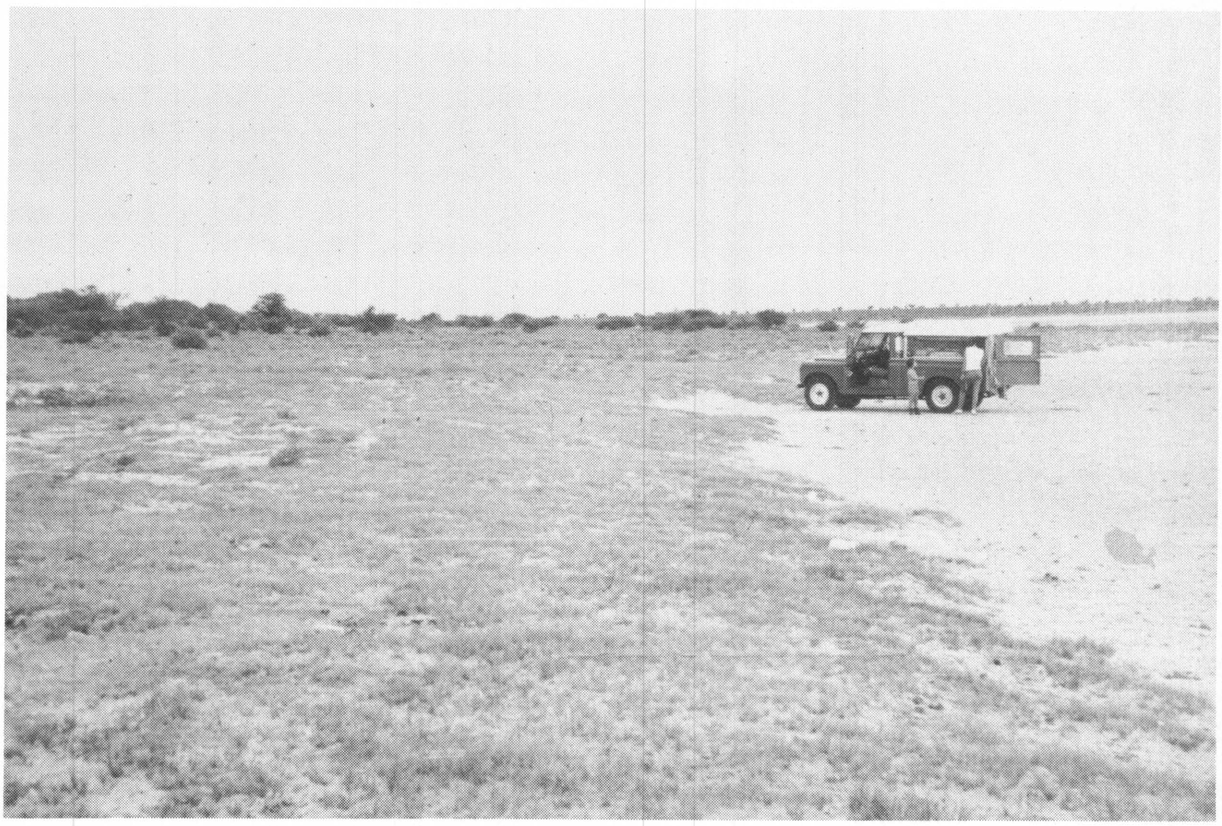


Figure 11 : Kakia Pan, Central Kalahari, Botswana, showing a typical pan edge covered with short grass and shrubs. The bare pan floor is on the right

Figure 12 : **Bosho Bogolo Pan, Central Kalahari, Botswana, showing typical pan bank vegetation comprising mainly of the shrub *Rhigozum trichotomum* and the perennial grass *Stipagrostis obtusa*. The pile of calcrete stones in the foreground is one of the fixed point markers used during the study**

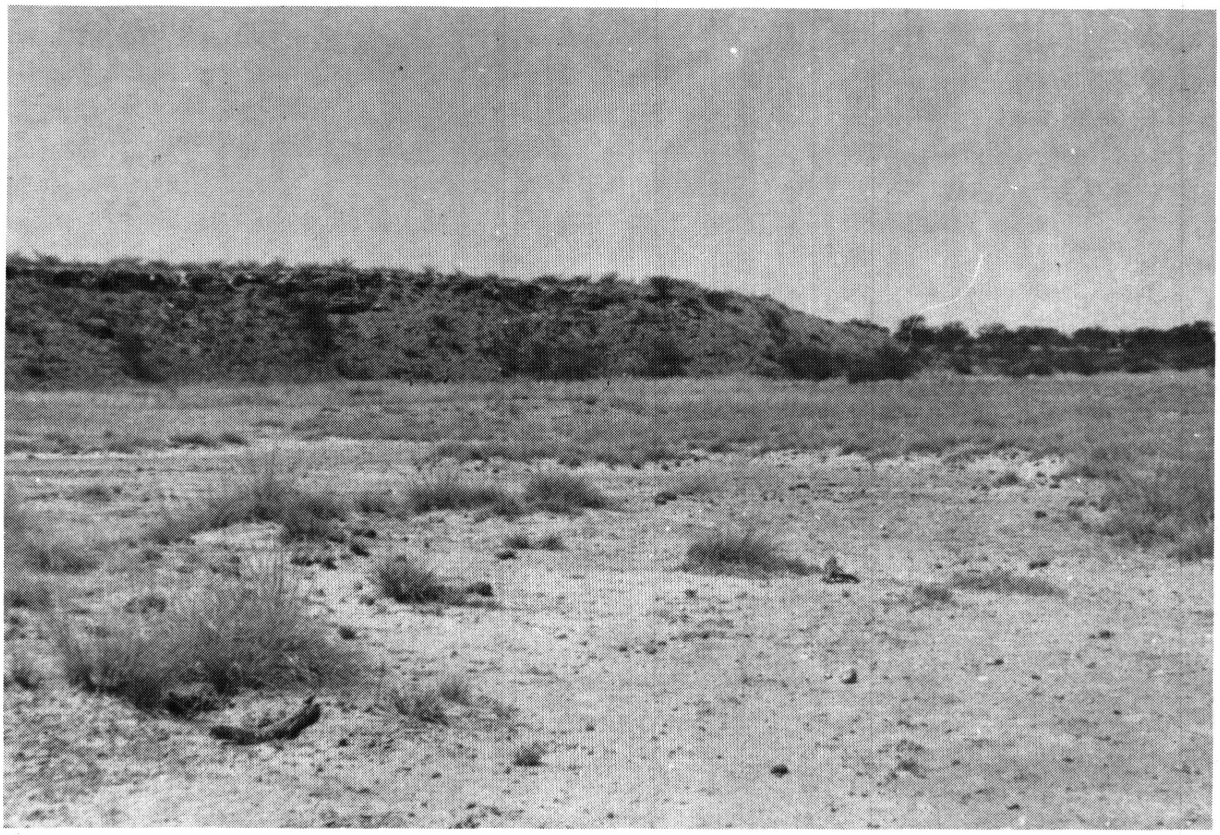


Figure 13 : Mabua Sehube Pan, Central Kalahari, Botswana, showing a typical calcrete bank and calcrete cliff. The vertical calcrete cliff at the top of the bank is approximately 2 m high

Figure 14 : Khiding Pan, Central Kalahari, Botswana, showing a section of a typical calcrete shelf. Loose calcrete pebbles on the surface and Karroid shrubs less than 300 mm high are a feature of these calcrete shelves

Figure 15 : Mabua Sehube Pan, Central Kalahari, Botswana, showing typical pan rim vegetation where shrubs such as *Acacia mellifera,* and trees such as *A. erioloba* and *Boscia albitrunca* are common

Figure 16 : Typical sandveld vegetation photographed north of Mabua Sehube Pan, Central Kalahari, Botswana. The perennial grass in the foreground is *Stipagrostis uniplumis*, the shrubs are *Rhigozum trichotomum* and *Grewia* spp. and the trees are *Boscia albitrunca*

Table 3 : Physical and chemical properties of the main soil types in the Southern Kalahari duneveld (after Leistner 1967)

SOIL PROPERTY	SOIL TYPE				
	Red sand	Pink sand	White sand	River soil	Pan soil
Consistency	loose	fairly compact	fairly compact	compact	compact
Percentage sand (2,0ˉ – 0,02 mm)	98,0	95,6	89,7	67,6	42,7
Percentage silt (0,02ˉ – 0,002 mm)	0,4	0,0	0,6	5,9	9,7
Percentage clay (<0,002 mm)	2,4	5,7	8,6	20,5	22,6
Total percentage silt and clay	2,8	5,7	9,2	26,4	32,3
pH	6,8	8,5	8,6	8,7	9,5
Resistance	4 300	2 600	2 100	600	96
Loss on ignition	0,5	0,8	1,9	6,1	10,1
Soluble in 1% citric acid: K	0,003	0,010	0,01	0,03	0,08
Soluble in 1% citric acid: Ca	0,010	0,050	0,59	1,67	0,63
Soluble in 1% citric acid: Mg	0,010	0,010	0,04	0,38	0,43
Soluble in 1% citric acid: P	0,001	0,002	0,01	0,03	0,03

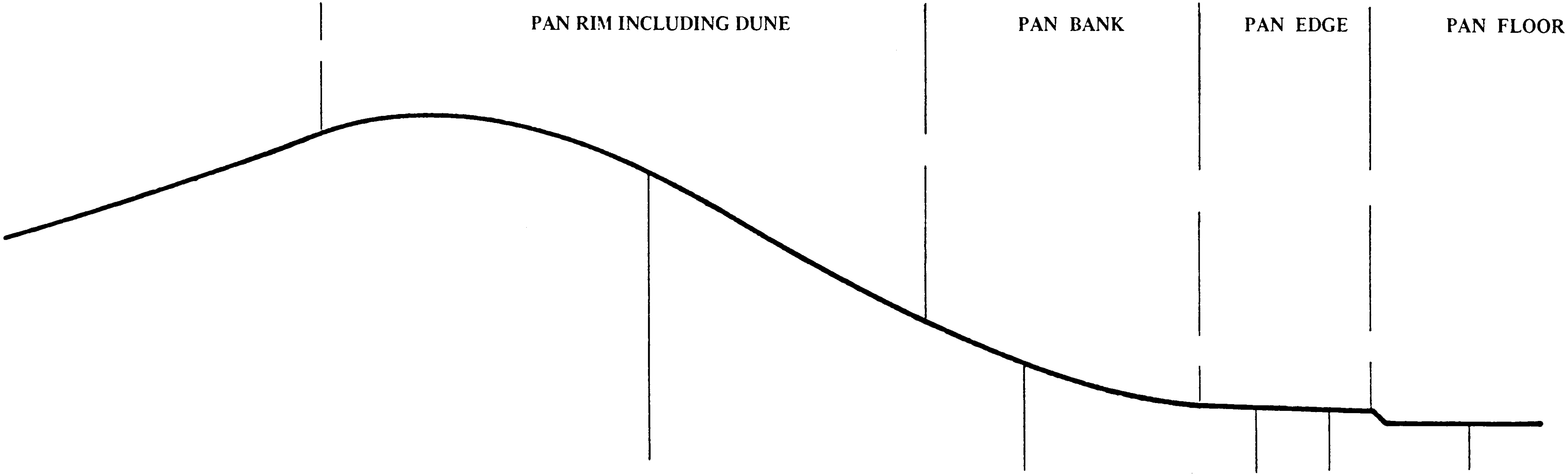
When the five columns in Table 3 i.e. red sand, pink sand, white sand, river soil and pan soil are compared a gradient is evident in almost all soil properties. For example the per cent sand decreases progressively from red sand to pan soil and the pH increases progressively from red sand to pan soil. Weare and Yalala (1971) describe the soils of the Central Kalahari as brown to reddish brown or grey to white sands which are usually structureless, mildly acidic and with a low fertility. According to Blair-Rains and Yalala (1972) the pinkish to brownish ochre appearance of the red sands is almost entirely due to a coating of ferrix oxide, typical of regions with a dry climate. This ferric oxide is easily reduced when the grains come into contact with moisture or organic material as well as by mechanical abrasion, changing the colour of the sand to a whitish grey.

Calcrete outcrops as illustrated in Figs. 13 and 14 occur as either a level shelf or as a sloping bank and the soil consists of calcrete gravel covered with varying thicknesses of sand.

A typical pan includes a variety of soil types (Fig. 9). The pan dune and upper pan banks have a loose sandy soil while the pan floor has a hard, fine soil. On the calcrete banks the soil consists chiefly of a mixture of calcrete pebbles and loose sand.

Physical properties

A series of soil samples was taken on Mabua Sehube Pan starting on the bare pan floor, sampling each main vegetation zone outwards from the floor to the dune (Appendix 1); the main physical properties of these soils are illustrated in Fig. 17. The soil sample taken on the pan floor had the highest total silt and clay content i.e. 77 per cent and the lowest total sand content i.e. 22 per cent. The pan edge sample nearest to the bare floor had the next highest total silt and clay content i.e. 16 per cent and the next lowest total sand content i.e. 87 per cent. This trend of decreasing silt and clay content outwards from the pan centre continued up onto the pan dune which had the lowest total silt and clay content i.e. only 7 per cent.



Per cent Fine Earth		100	100	99	99	96
Per cent Coarse Sand	(0,5 – 2,0¯ mm)	5	11	13	13	2
Per cent Medium Sand	(0,25 – 0,5¯ mm)	36	31	26	27	5
Per cent Fine Sand	(0,10 – 0,25¯ mm)	45	42	40	37	11
Per cent Very Fine Sand	(0,05 – 0,10¯ mm)	7	7	9	10	4
Total per cent Sand		93	91	88	87	22
Per cent Silt	(0,002 – 0,05¯ mm)	3	5	6	7	30
Per cent Clay	(< 0,002 mm)	4	5	7	9	47
Total per cent Silt and Clay		7	10	13	16	77

Figure 17 : Physical properties of the soils on Mabua Sehube Pan, Central Kalahari, Botswana. Surface soil samples were taken at the sites indicated on the pan profile, and the figures are the results of routine laboratory analyses

A similar series of soil samples was taken on Khutse 2 Pan with a sample in each vegetation type from the floor outwards into the sandveld (Appendix 1); the main physical properties of the soils are given in Fig. 18.

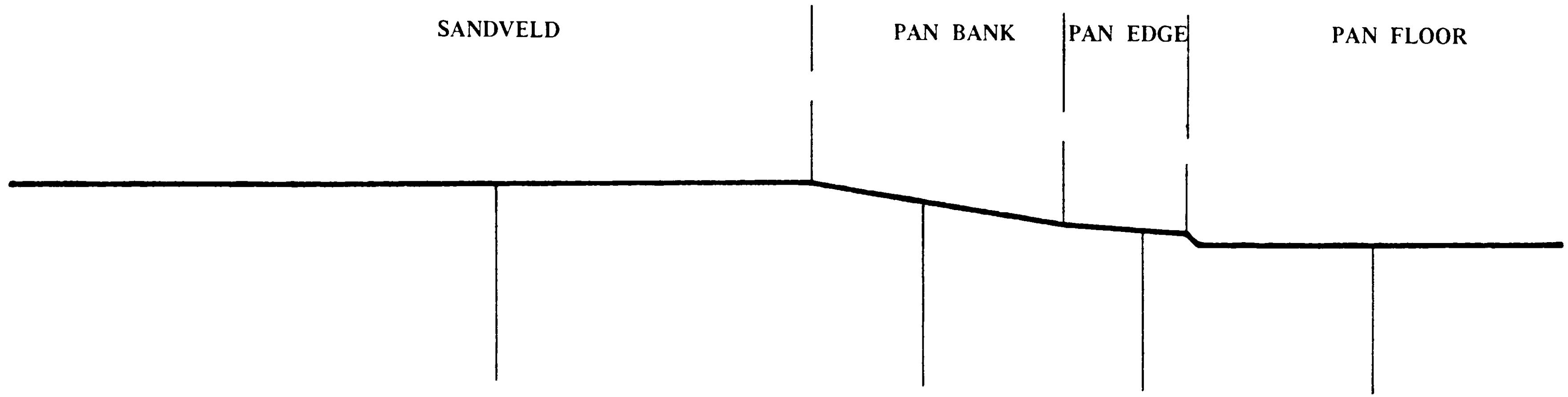
Khutse 2 Pan which lies more than 300 km to the north-east of Mabua Sehube Pan does not have the deep highly saline floor which is a feature of Mabua Sehube Pan, its bank is less steep than the bank on Mabua Sehube Pan and it supports many different plant species. Yet, in spite of these differences between the two pans the physical properties of the soils on the two pans are remarkably similar. There is a decreasing proportion of silt and clay in the soil outwards from the pan floor corresponding with an increasing sand content. Although the silt and clay content on the pan floor of Mabua Sehube Pan is considerably higher than the silt and clay content on the pan floor on Khutse 2 Pan, the silt and clay content of the pan edge and pan bank soil samples are very similar.

Chemical properties

As in the case of the physical properties, the chemical properties of the series of soil samples taken on Mabua Sehube Pan and Khutse 2 Pan are arranged according to their position on the pan profile (Figs. 19 and 20).

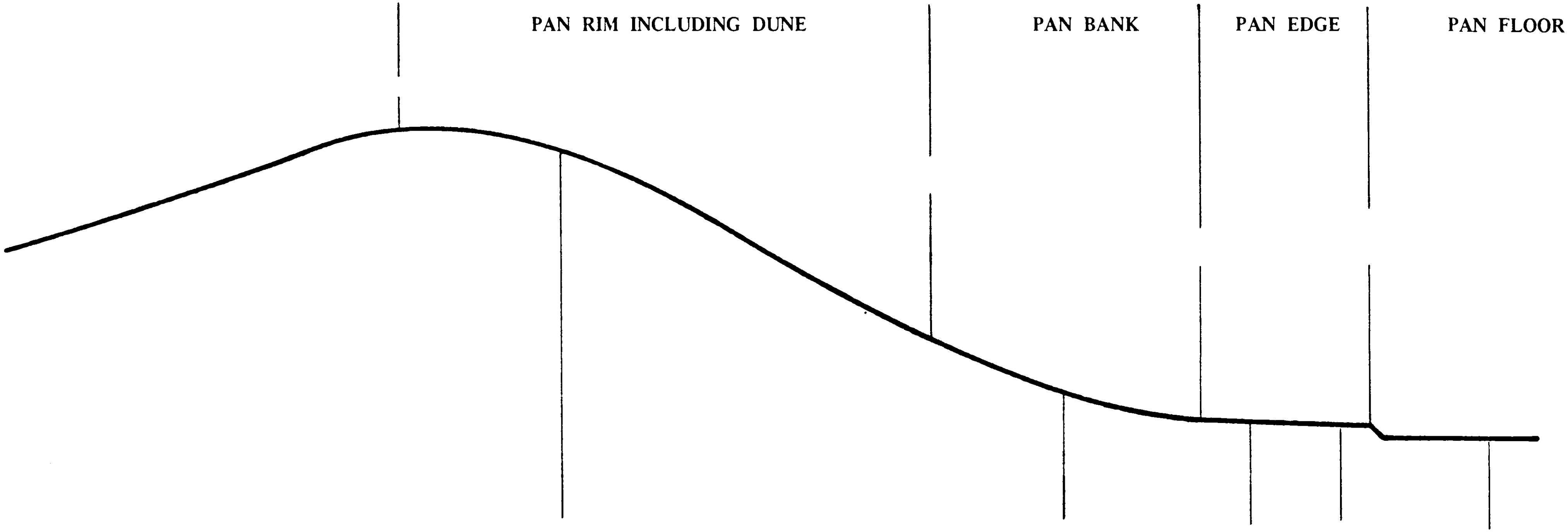
The chemical properties of the soils both on Mabua Sehube and Khutse 2 pans exhibit a gradient outwards from the pan floor and on both pans the highest concentration of minerals was found on the pan floor. This high mineral content is also reflected in the high pH values and electrical conductivity readings.

A sample of the soil on the pan floor of a selection of pans in the Central Kalahari was analysed for comparative purposes (Appendix 2) and the main chemical properties of these soil samples are shown together with the chemical properties of two sandveld soils near pans in Table 4. The variation in the conductivity of the pan floor soils reflects differences in their mineral content but they all have a higher mineral content than the sandveld samples. These results agree with results from the Southern Kalahari (Table 3) which showed that the soils on pan floors are the most highly mineralized.



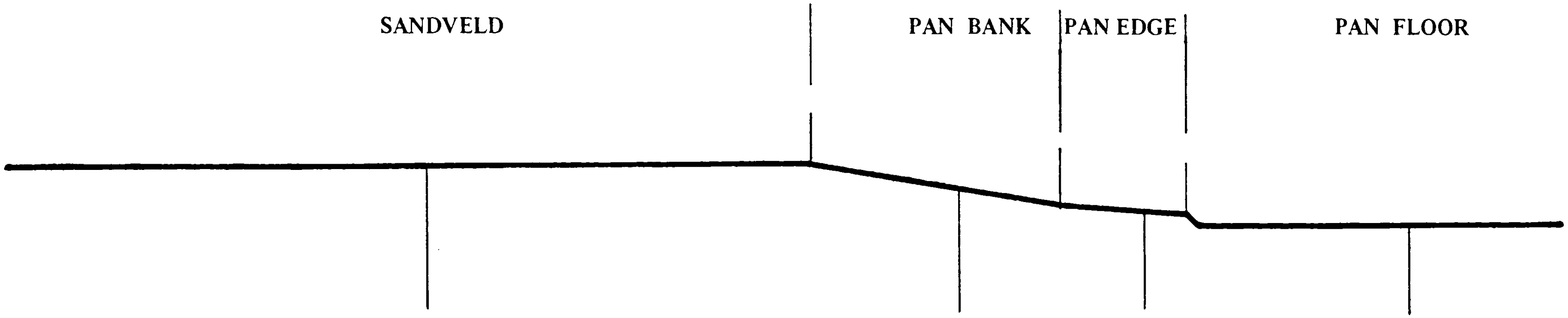
		Sandveld	Pan Bank	Pan Edge	Pan Floor
Per cent Fine Earth		100	100	100	100
Per cent Coarse Sand	(0,5 – 2,0 mm)	0,3	0,2	1	1
Per cent Medium Sand	(0,25 – 0,5 mm)	10	12	10	7
Per cent Fine Sand	(0,10 – 0,25 mm)	64	65	64	45
Per cent Very Fine Sand	(0,05 – 0,10 mm)	18	13	13	12
Total Per cent Sand		92,3	90,2	88	65
Per cent Silt	(0,002 – 0,05 mm)	3	4	3	17
Per cent Clay	(< 0,002 mm)	4	5	8	19
Total Per cent Silt and Clay		7	9	11	36

Figure 18 : Physical properties of the soils on Khutse 2 Pan, Central Kalahari, Botswana. Surface soil samples were taken at the sites indicated on the pan profile, and the figures are the results of routine laboratory analyses



pH	8,8	9,1	9,0	9,0	9,9
Electrical conductivity (1:5 suspension U mhos)	40	70	85	100	15 000
Gross extractable cations					
Na (Meg. 100 g)	0,02	0,11	0,87	1,4	16,9
K (Meg. 100 g)	0,16	0, 30	0,68	1,3	8,5
Ca (Meg. 100 g)	2,0	15,6	18,1	16,8	20,0
Mg (Meg. 100 g)	0,7	0,9	1,7	2,1	1,3

Figure 19 : Chemical properties of the soils on Mahua Sehube Pan, Central Kalahari, Botswana. Surface soil samples were taken at the sites indicated on the pan profile, and the figures are the results of routine laboratory analyses



	Sandveld	Pan Bank	Pan Edge	Pan Floor
pH	7,7	8,2	8,2	9,0
Electrical Conductivity (1:5 suspension in U mhos)	20	20	50	60
Gross extractable cations				
Na (Meg. 100 g)	0,01	0,02	0,05	0,10
K (Meg. 100 g)	0,15	0,10	0,18	0,48
Ca (Meg. 100 g)	1,2	1,5	9,6	18,0
Mg (Meg. 100 g)	1,0	0,6	0,6	1,6

Figure 20 : Chemical properties of the soils on Khutse 2 Pan, Central Kalahari, Botswana. Surface soil samples were taken at the sites indicated on the pan profile, and the figures are the results of routine laboratory analyses

Table 4 : Chemical properties of various pan floor soils and sandveld soils in the Central Kalahari, Botswana. The analyses are of surface soil samples

Area	Site	Chemical Properties													
		pH	Electrical conductivity in U mhos	Per cent Ca CO_3	Gross extractable cations (Meg 100 g)				Saturated paste Soluble cations Me/100 g			Saturated paste Soluble anions Me/100 g			Per cent Carbon
					Na	K	Ca	Mg	Na	K	Ca+Mg	HCO_3	Cl	SO_4	
Mabua Sehube Game Reserve	Khiding pan floor	8,5	1 100	47	4,3	2,3	18,7	6,8	3,5	0,05	3,4	0,1	4,2	1,9	1,06
	Lesholwago pan floor	9,5	5 200	48	32	0,44	13,8	0,8	28	3,1	0,4	0,7	25,2	5,0	0,76
Kuli-Nojane Area	Kuli pan floor	8,2	100	26	0,15	0,95	17,8	0,5	0,08	0,05	0,4	0,3	0,5	0,1	0,81
	Ukwi pan floor	8,8	5 050	36	36	2,6	17,0	4,3	25	0,73	2,0	0,2	28	0,6	0,33
Khutse Game Reserve	Khutse pan floor	8,8	50	6	0,06	0,29	11,5	0,9	0,007	0,01	0,3	0,1	0,07	0,02	0,46
	Muhurushele pan floor	8,3	100	22	0,14	0,62	16,9	1,6	0,01	0,01	0,5	0,2	0,4	0,04	0,84
Khutse Game Reserve	Sandveld 100 m from Khutse 2 pan	7,7	20	0,5	0,01	0,15	1,2	1,0	0,005	0,01	0,1	0,01	0,04	0,03	0,21
Mabua Sehube Game Reserve	Sandveld Mabua Sehube Dune	8,8	40	0,5	0,02	0,16	2,0	0,7	0,02	0,02	0,09	0,07	0,03	0,02	0,12

The important properties of pan soils can therefore be summarised as follows:-

(1) The pan comprises a wide range of soil types and there is a gradient of both chemical and physical properties of the soils from the centre of the pan outwards towards the rim.

(2) The soils are generally more compact than sandveld soils but range from hard almost impenetrable soils on the pan floor to loose, well-drained soils on the pan dune.

(3) The soils have a higher mineral content than soils in the sandveld with the highest mineral concentrations on the pan floor.

Salt-licks on pans

A feature of pans in the Central Kalahari is the presence of one or more salt-licks on the pan (Parris and Child 1973). These salt-licks are characterized by:-

(1) Distinct game trails leading directly to the salt-lick, often from a fair distance off the pan.

(2) A heavily trampled area around the salt-lick (Fig. 21).

(3) One or more local depressions up to a metre deep in the otherwise flat pan floor where the soil has been scraped and eaten away by game (Fig. 22).

(4) Soil with a slightly or very salty taste often with saline crystals visible in the soil.

The soil at a number of salt-licks in the study area was sampled and compared with the soil from the same pan a little distance away from the salt-lick (Appendix 3). The chemical properties of the various salt-licks sampled are compared with the chemical properties of the adjacent pan floor soil in Table 5. All the salt-licks sampled were found to have a higher pH, electrical conductivity and total mineral

Figure 21 : Khutse 1 Pan, Central Kalahari, Botswana, showing the heavily trampled area around a typical pan salt-lick

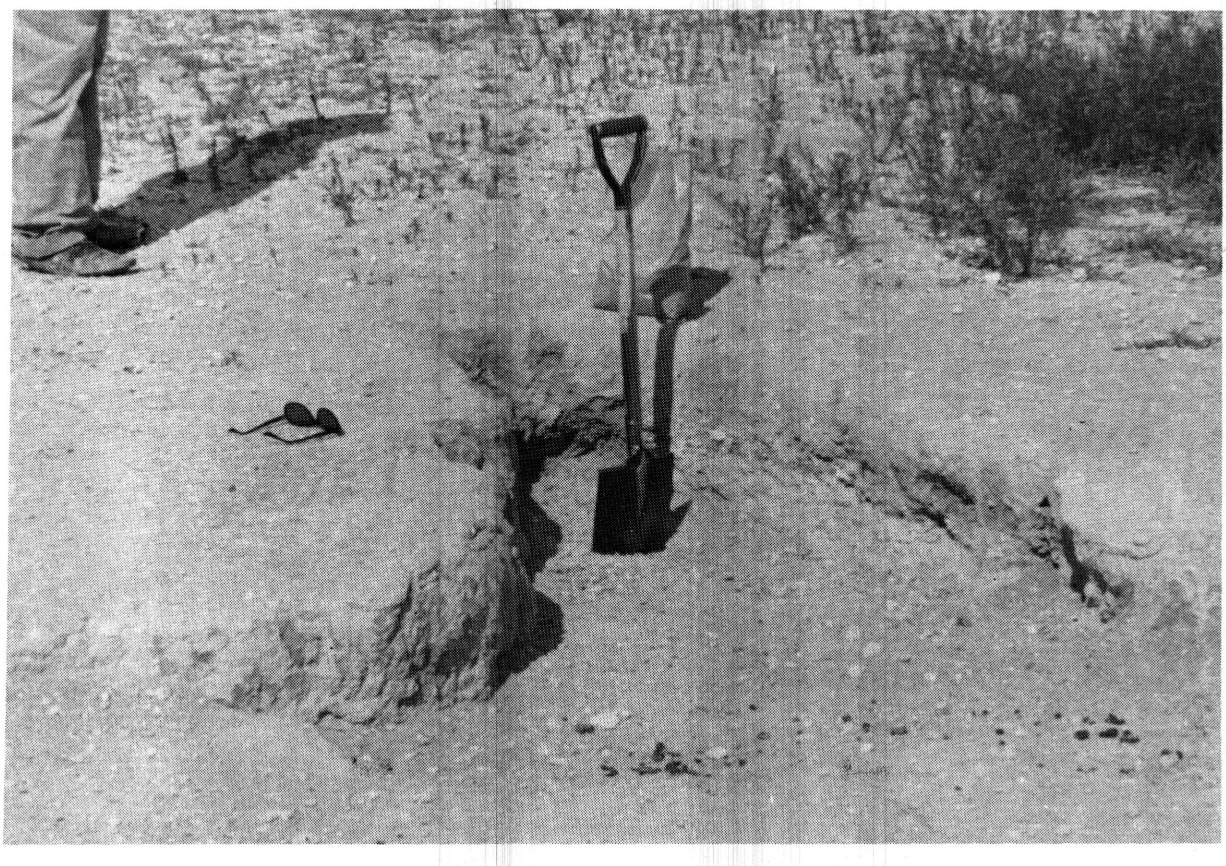


Figure 22 : A salt-lick on Khutse 1 Pan, Central Kalahari, Botswana, showing how animal use has created a depression in the otherwise flat pan floor

Table 5: Chemical properties of the soil at natural salt-licks on pans in the Central Kalahari, Botswana, compared with the chemical properties of the soil on the adjacent pan floor

Area	Site	pH	Electrical conductivity in U mhos	Per cent Ca CO_3	Chemical Properties										Per cent Carbon
					Gross extractable cations (Meg 100 g)				Saturated paste Soluble cations Me/100 g			Saturated paste Soluble anions Me/100 g			
					Na	K	Ca	Mg	Na	K	Ca+Mg	HCO_3	Cl	SO_4	
Khutse Game Reserve	Muhurushele pan floor	8,3	100	22	0,14	0,62	16,9	1,6	0,01	0,01	0,5	0,2	0,4	0,04	0,84
	Muhurushele salt-lick	8,4	1 300	39	5,4	2,4	20,1	0,8	5,0	1,3	2,9	0,2	7,6	0,8	0,83
	Khutse 1 pan floor	8,8	50	6	0,06	0,29	11,5	0,9	0,007	0,01	0,3	0,1	0,07	0,02	0,46
	Khutse 1 salt-lick	9,0	100	17	0,36	0,35	19	0,4	0,12	0,05	0,15	0,1	0,2	0,06	0,36
	Khutse 2 pan floor	9,0	60	17	0,10	0,48	18	1,6	0,02	0,02	0,3	0,1	0,06	0,03	0,76
	Khutse 2 salt-lick	9,2	90	21	0,26	0,32	19	1,1	0,09	0,5	0,2	0,15	0,1	0,09	0,60
Mabua Sehube Game Reserve	Mabua Sehube pan edge	9,0	100	15-30	1,4	1,3	16,8	2,1	0,10	0,06	0,15	0,18	0,04	0,07	0,31
	Mabua Sehube pan floor (used as a salt-lick)	9,9	15 000	15-30	169	8,5	20,0	1,3	67	1,5	0,03	2,2	53	13	0,29

content than the adjacent soil. However, as far as the individual mineral components are concerned, the various mineral fractions were not all found to be consistently higher in the salt-licks than in the adjacent soil. This agrees with the findings of Weir (1969, 1973) who found that the only consistent 'ingredient' of elephant salt-licks in the Wankie National Park in Rhodesia and in Parks in East Africa was the high salinity of the soil and that water soluble sodium was likely to be the main attraction.

The salinity is highest on the lowest-lying parts of the pan and salt-licks in the Central Kalahari are usually found on these sections of the pan. In the case of highly saline pans such as Mabua Sehube where the entire bare floor is salty, the salt-lick is not such a conspicuous feature of the pan as the animals eat the soil over a large area.

Sandveld soils have a low mineral content and salt-licks in the Central Kalahari are restricted to pans and parts of the fossil riverbeds.

Water-holes on pans

The entire Central Kalahari, with the exception of a few small isolated rocky out-crops and the area around pans and along the dry riverbeds, is covered by a layer of sand. This sand is extremely porous with the result that virtually all the rainfall is immediately absorbed and retained as capilliary water by the sand. It is in fact this property of the Kalahari soils rather than the mean annual rainfall (in many places as high as 400 mm per annum) that has resulted in the Kalahari being known as a desert. It is only on pans and dry river beds that a combination of slope and less porous soils results in a certain amount of localized run-off water.

Many authors refer to the fact that pans in the Central and Southern Kalahari hold open or surface water for short periods during the rainy season (Leistner 1967, Smithers 1971 and Parris 1972). The soil on pans has a relatively high silt and clay content and this feature combined with the inward-sloping banks results in a fairly high proportion of run-off water. This run-off water collects on the almost impermeable soil on the lowest parts of the pan and is held as surface water in the water-holes. The length of time that a pan holds surface water is determined by the rainfall pattern and the pan dimensions and because the rainfall in the Central Kalahari is highly variable, the presence of surface water on pans is correspondingly variable.

A typical water-hole on a pan is illustrated in Fig. 23. Although this particular water-hole has been slightly deepened by man, it nevertheless serves as a good example of a typical Kalahari water-hole. On Khutse 2 Pan, surface water in the water-holes was recorded daily as either present or absent during the two-year period from 10th January 1970 to 31st December 1971 (Appendix 4). During the dry season from May to September the water-hole was dry apart from two days in June 1971 and during the rainy season from October to March the water-hole held water for periods of up to a month depending on the preceding rainfall pattern. The results confirm that during a normal rainy season the water-holes on pans hold water for extended periods.

The calcrete outcrops and banks on pans often have numerous holes and cavities in the upper few metres which fill with water after heavy rains. Because the lower layers are usually impervious, these calcrete outcrops often retain this water just below the surface. Where the local topography is suitable this water drains out onto the pan to form a small natural spring, while in other cases it is exposed by local inhabitants through the excavation of shallow pits or wells. Kgothi* (*pers. comm.*) gave numerous examples of wells in the Central Kalahari and Leistner (1967) mentions the use of wells and pits in these calcrete outcrops by inhabitants of the Southern Kalahari. An old well-site in the calcrete on Monamudi pan is illustrated in Fig. 24.

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* M. KGOTHI, Dept. of Wildlife and National Parks, Tshabong, Botswana.

Figure 23 : Khutse 1 Pan, Central Kalahari, Botswana, showing a typical seasonal water-hole. These water-holes hold water for a few weeks after heavy rains

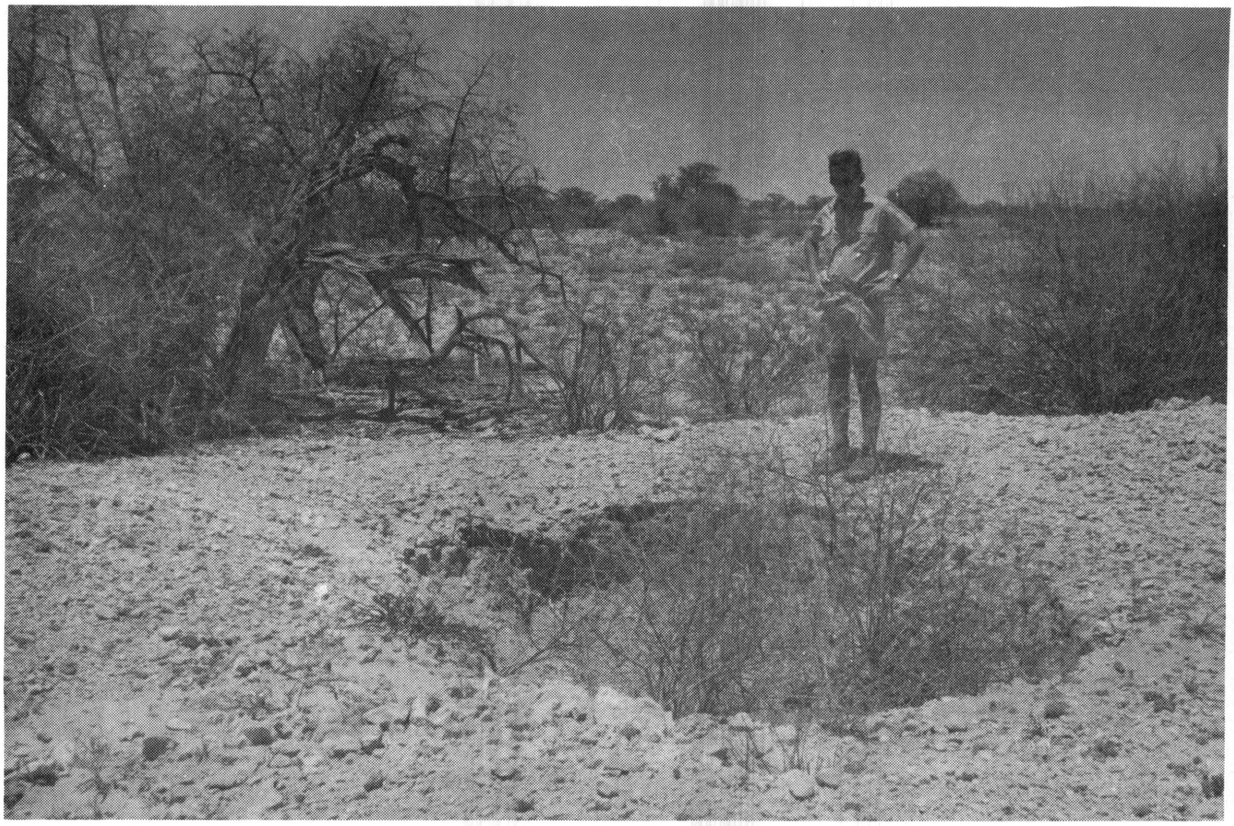


Figure 24 : Monamudi Pan, Central Kalahari, Botswana, showing an old well-site in the calcrete. Such wells have been sunk by pastoralists on many pans in the Kalahari

Pan vegetation

General

As described in the section on soils, the pan comprises a variety of soil types as well as numerous intermediate gradients of soil type, with the result that pans support a wide variety of plant species.

During the period September 1967 to January 1972 a total of 70 of the larger pans and numerous small pans in the Central Kalahari were visited. Although a detailed vegetation survey of each pan was not attempted, general similarities and differences between pans were noted. From this survey it was found that pans usually support various combinations of the same plant species, provided that pan salinity and annual rainfall are similar. As shown in Fig. 2 the annual rainfall in the Central Kalahari is highest in the northern and eastern areas and certain conspicuous plant species associated with pans, such as the shrub *Catophractes alexandri,* were only recorded on pans in the higher rainfall areas.

A characteristic feature of pans in the Southern and Central Kalahari is the concentric zonation of vegetation on the pan (Leistner 1967 and Parris and Child 1973). Soil analyses summarised in Figs. 17 and 18 show a decreasing silt and clay content from the centre of the pan floor outwards which is coupled with a decrease in effective rainfall from the centre outwards. The zonation of the vegetation on pans is therefore apparently a reflection of the different tolerances of plant species to differences in soil salinity, soil texture and inundation by water. The zonation on the banks is not always immediately obvious being masked by the soil differences such as calcrete gravel or loose sand.

In this treatise it is the role of the vegetation in protecting the soil surface from eroding factors that is of particular importance. The vegetative cover is poorest towards the end of the dry season before the first summer rains and for this reason discussion of the vegetation is mainly concerned with those plants which provide soil cover during the dry season. During the rainy season pans are generally covered by a fairly dense stand of forbs, annual grasses, perennial grasses and shrubs (Fig. 25) but most of the forbs and annual grasses disappear during the dry

Figure 25 : Khutse 2 Pan, Central Kalahari, Botswana, showing the pan floor vegetation in summer. After good summer rains pans (apart from highly saline ones) support a dense plant growth consisting of perennial grasses, shrubs, forbs and annual grasses

season. The following description of the vegetation therefore applies to the perennial grass and woody plant strata which provide some protection for the soil throughout the year.

Pan floor vegetation

Soil salinity is one of the most important factors affecting the vegetation on the pan floor. This has lead authors (Leistner 1967 and Blair-Rains and Yalala 1972) to divide pans into classes such as grassed pans, ungrassed pans and saline or salt-pans. There is, however, a gradient from highly saline ungrassed pans to moderately saline completely grass-covered pans with many pans showing an intermediate combination of both vegetation and soil characteristics. The grouping of pans into separate classes, although convenient, is therefore somewhat misleading as there is continual overlapping of the various classes. Boocock and Van Straaten (1962) give an example where all gradations occur on one pan.

In the case of a highly saline pan floor such as on Mabua Sehube Pan the pan floor is devoid of perennial vegetation (Fig. 26). Highly saline pan floors are however, less common in the Central Kalahari than partially or completely vegetated pan floors and of the 70 pans visited only 12 (17,1 per cent) had bare saline floors.

Where the pan floor is not highly saline it supports perennial vegetation (Fig. 27). It must again be stressed that there is both variation between pans and in the case of large pans there is even variation on the same pan on different parts of the pan floor. The particular perennial grass and shrub species growing on a pan appears to be determined mainly by a combination of soil salinity and rainfall.

On pans with a fairly high salinity the floor normally supports an almost pure stand of perennial grass such as *Sporobolus iocladus* or *S. rangei* while on pans with a lower salinity the floor usually carries both perennial grasses such as *Eragrostis truncata* and Karroid shrubs such as *Salsola* spp., *Pentzia* spp. and *Eriocephalus* spp. Trees and tall shrubs are conspicuously absent from pan floor vegetation although isolated individuals of *Acacia mellifera, Ziziphus mucronata* or *Boscia albitrunca* may occur.

Figure 26 : Mabua Sehube Pan, Central Kalahari, Botswana, showing the bare pan floor during the dry season. After heavy rains the pan floor is covered for a short period by a few centimetres of water

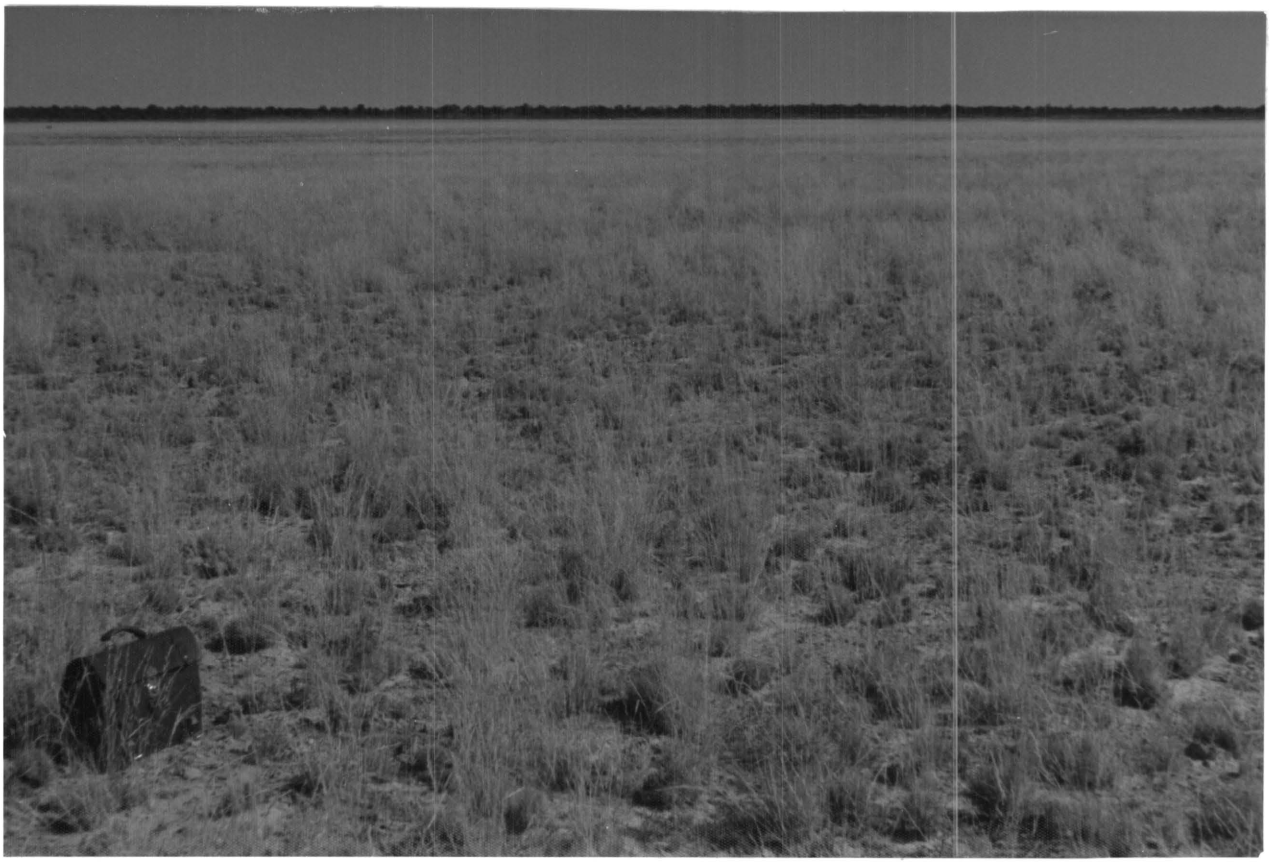


Figure 27 : Bosho Bogolo Pan, Central Kalahari, Botswana, showing an example of the dense perennial grass cover found on the floor of some pans

Seasonal water-holes are the only sites on the pan where aquatic vegetation can survive and are often encircled by tall moisture-loving perennial grasses (Fig. 23).

The vegetation on the floor of a typical pan during the dry season consists of short Karroid shrubs less than 300 mm in height and heavily grazed perennial grasses with large shrubs and trees rare or absent (Fig. 28). The vegetation on the pan floor is often patchy with alternate bare areas and vegetated areas.

Measurements of pan floor vegetation were done on that part of the floor that appeared to have the best perennial grass cover, and therefore reflect the tallest and most dense grass cover on the pan floor, and not the average grass cover. Highly saline pans have no perennial vegetation on the pan floor.

Measurements of plant height and plant cover i.e. rooted plant and plant canopy were made at the same site in consecutive years (Appendix 6) and the average height of pan floor grass and woody strata on different pans is given in Table 6. The results show that the pan floor vegetation, even on the part supporting the best perennial grass cover, is very short during the dry season. The average height of pan floor grass and woody strata is compared with the average height of these strata on and around a cross-section of six pans in Fig. 29.

Measurements of percentage ground cover of the pan floor vegetation on the part supporting the best grass cover is given in Appendix 5 and the average ground cover in Table 7. As these measurements were made on those parts of the pan that appeared to have the highest perennial grass density they reflect the best ground cover of the pan floor vegetation in the dry season. The average ground cover of pan floor vegetation at its densest part is compared with the average ground cover of the vegetation on and around a cross-section of six pans in Fig. 30.

Pan edge vegetation

The zonation of vegetation around pans referred to previously is particularly noticeable in pan edge vegetation and the concentric bands of different plant species

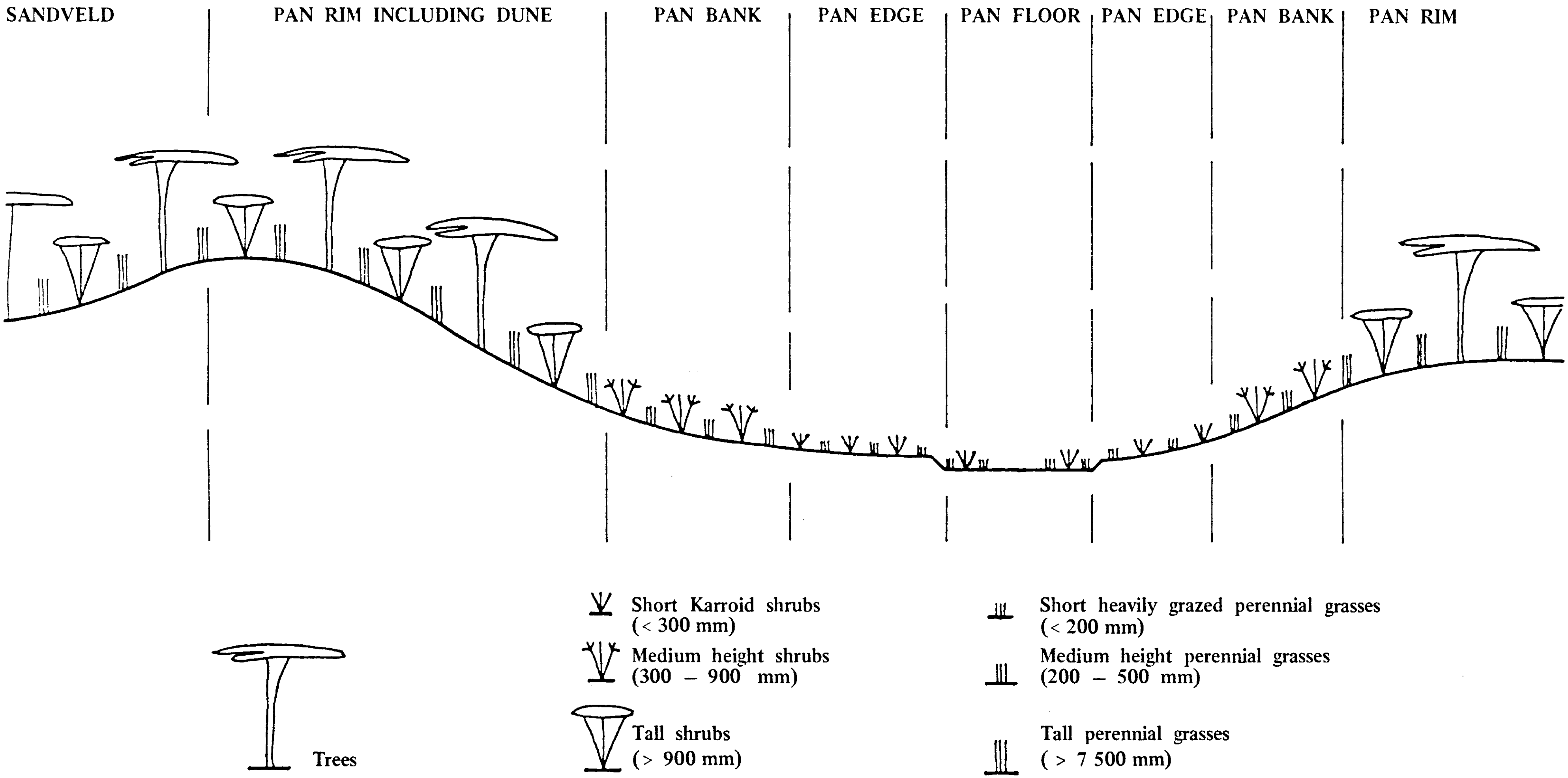


Figure 28 : Diagrammatic cross-section through a typical pan in the Central Kalahari, Botswana, showing the physiognomy of the vegetation during the dry season. The physiognomic types shown on the pan profile indicate the most common types on each section of the pan but overlaps often occur

Table 6 : Average dry season height in mm of the perennial grasses and woody plants (shrubs and trees) on and around pans in the Central Kalahari, Botswana

PAN	PLANT HEIGHT									
	Pan floor		Pan edge		Pan bank		Pan rim		Surrounding sandveld	
	Grasses	Woody plants	Grasses	Woody plants	Grasses	Woody plants	Grasses	Woody plants	Grasses	Woody plants
Mpatutlwa	50,3	165,1	42,3	152,1	–	–	721,3	1 513,8	529,2	1 718,7
Bosho Bogolo	168,9	126,8	28,7	130,4	325,4	409,5	575,7	1 117,6	464,6	1 341,1
Lesholwago	86,9	152,4	17,6	149,9	–	–	450,8	1 178,5	702,7	1 038,9
Khiding	242,9	–	10,3	145,6	–	511,1	–	–	–	–
Khutse 2	100,8	–	37,1	237,0	–	–	325,7	1 685,7	693,4	1 501,4
Sutswane	94,7	–	–	–	74,0	355,7	–	–	–	–

No data indicated as a dash.

Plant height was recorded during routine vegetation assessments (Appendix 6) and the figures are the average heights recorded during the study period (1968 to 1972). Measurements of pan floor vegetation were made on the section with the best perennial grass cover, and measurements of sandveld vegetation were made within 3,2 km of the pan.

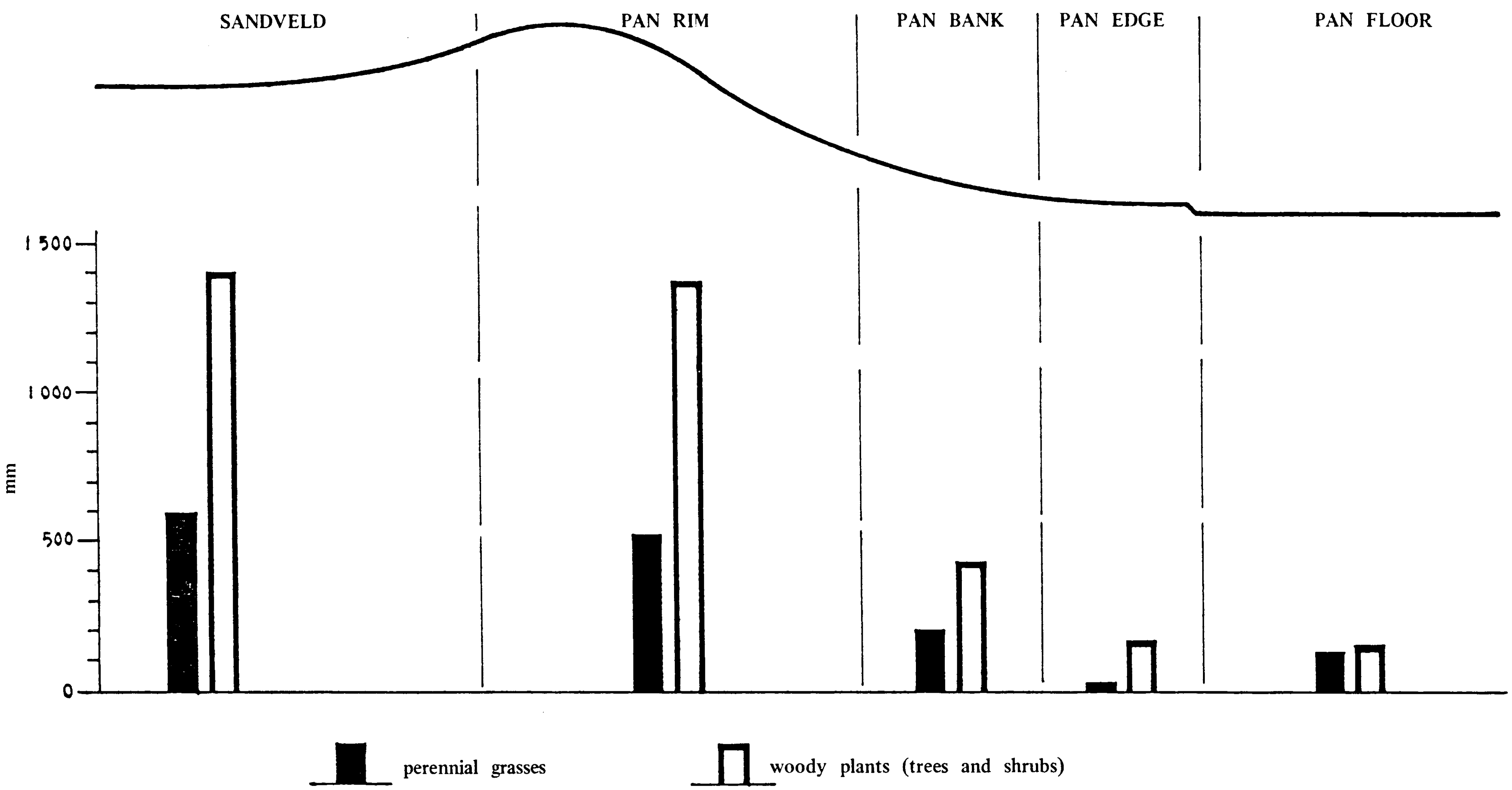


Figure 29: Average dry season height in mm of the perennial grasses and woody plants (shrubs and trees) on and around a cross-section of six pans in the Mabua Sehube and Khutse Game Reserves, in the Central Kalahari, Botswana. Plant height was recorded during routine vegetation assessments and the columns below the pan outline are the average of all perennial grass heights and the average of all woody plant heights recorded during the study period (1968 to 1972). Measurements of pan floor vegetation were made on the section with the best perennial grass cover

Table 7 : Average percentage ground cover of the perennial grasses and woody plants (shrubs and trees) during the dry season on and around pans in the Central Kalahari, Botswana

PAN	PERCENTAGE GROUND COVER									
	Pan floor		Pan edge		Pan bank		Pan rim		Surrounding sandveld	
	Grasses	Woody plants	Grasses	Woody plants	Grasses	Woody plants	Grasses	Woody plants	Grasses	Woody plants
Mpatutlwa	34,3	0,5	6,0	12,0	–	–	22,0	15,0	20,0	6,5
Bosho Bogolo	31,5	0,5	7,8	9,0	4,5	35,0	23,0	3,0	22,5	4,0
Lesholwago	25,3	0,3	7,0	10,0	–	–	15,0	15,0	10,0	8,5
Khiding	30,3	0,0	11,0	6,3	0,0	24,0	–	–	–	–
Khutse 2	14,0	0,0	6,3	5,0	–	–	23,0	19,0	27,0	9,0
Sutswane	17,7	0,0	–	–	11,7	7,7	–	–	–	–

No data indicated as a dash

Percentage ground cover was recorded during routine vegetation assessments (Appendix 5) and the figures are the average percentages recorded during the study period (1968 to 1972). Measurements of the pan floor vegetation were made on the section with the best perennial grass cover, and measurements of sandveld vegetation were made within 3,2 km of the pan

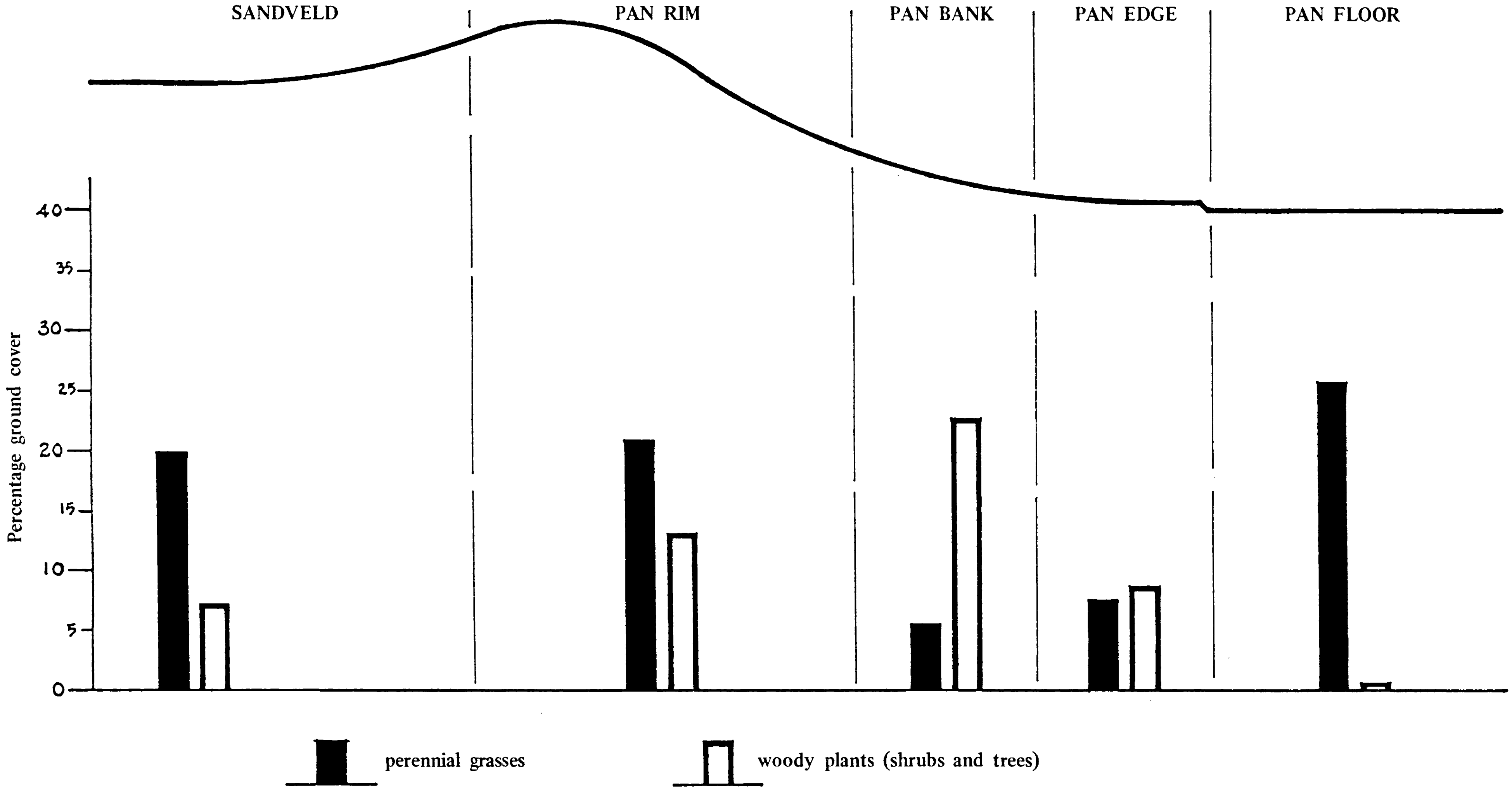


Figure 30 : Average percentage ground cover of the perennial grasses and woody plants (shrubs and trees) on and around a cross-section of six pans in the Mabua Sehube and Khutse Game Reserves, Central Kalahari, Botswana. Percentage ground cover was recorded during routine vegetation assessments and the columns below the pan outline are the average of all perennial grass cover percentages and all woody plant cover percentages recorded during the study period (1968 to 1972). Measurements of pan floor vegetation were made on the section with the best perennial grass cover

are often clearly distinguishable. The actual species growing in each zone on different pans appear to be determined by a combination of soil salinity and rainfall. On pans with a highly saline floor the innermost zone adjoining the bare floor is usually *Sporobolus iocladus* or *S. rangei* while the outer zones usually support Karroid shrubs including *Salsola* spp. and *Pentzia* spp. and perennial grasses such as *Eragrostis truncata* and *Stipagrostis obtusa*. Shrubs taller than 300 mm such as *Rhigozum trichotomum* and *Catophractes alexandri* are typically absent from pan edge vegetation, and trees and taller shrubs are also seldom present. The vegetation on the pan edge of a typical pan during the dry season consists of Karroid shrubs less than 300 mm in height and heavily grazed perennial grass with large shrubs and trees rare or absent (Fig. 28).

Measurements of the average height and percentage ground cover of pan edge vegetation were made during the dry season at the same site in consecutive years (Appendices 5 and 6). The average height of pan edge vegetation on different pans is given in Table 6 and the average height of pan edge vegetation is compared with the average height of the vegetation on and around the pan in Fig. 29. The average percentage ground cover of pan edge vegetation on different pans during the dry season is given in Table 7 and in Fig. 30 the average ground cover of pan edge vegetation is compared with the average ground cover of the vegetation on and around the pan.

Pan bank vegetation

The vegetation on pan banks is mainly influenced by the presence or absence of surface calcrete and on this basis it is conveniently divided into vegetation on pan banks with surface calcrete, and vegetation on pan banks without surface calcrete.

Banks with surface calcrete have an essentially Karroid vegetation and are often dominated by low Karroid shrubs (Fig. 14). Trees and tall shrubs are uncommon but individual specimens of *Acacia mellifera, A. erioloba* and/or *Boscia albitrunca* can occur. The height and percentage ground cover of the vegetation on calcrete outcrops is similar to the height and cover of pan edge vegetation although on calcrete outcrops the density of shrubs is normally higher and the density of perennial grasses lower than in pan edge vegetation.

The vegetation on pan banks devoid of surface calcrete consists mainly of medium height shrubs (0,3 – 1,5 m high) such as *Rhigozum trichotomum* and medium height perennial grasses such as *Stipagrostis obtusa* (Fig. 12). The density of the common grass or shrub species in pan bank vegetation appears to be determined by a combination of soil type, annual rainfall and grazing pressure, and the vegetation on pan banks is similar in many respects to the vegetation on the banks of dry rivers such as the Nossob River. On some pans the shrubs on the pan bank form a dense thicket (Fig. 31). Trees are uncommon and occur only as isolated individuals (Fig. 28).

Measurements of the height and percentage ground cover of pan bank vegetation i.e. the grass and woody plant strata were taken during the dry season at the same site in consecutive years (Appendices 5 and 6) and in Tables 6 and 7 the average height and density of the two strata are given. The average height of pan bank vegetation is compared with the average height of the vegetation on and around the pan (Fig. 29) and the average ground cover of pan bank vegetation is compared with the average ground cover of the vegetation on and around the pan (Fig. 30).

Pan rim vegetation

The soil on the pan rim (which includes the pan dune) consists of deep loose sand and the vegetation is generally similar to that found in the surrounding sandveld, i.e. trees, tall shrubs and tall perennial grasses (Fig. 28). This part of the pan is the only part where trees are common and may support a denser tree and shrub cover than the surrounding sandveld as shown for example on Mabua Sehube Pan (Fig. 10). The trees, shrubs and perennial grasses on the pan rim are essentially the same species as those that occur in the surrounding sandveld, and include *Acacia erioloba, A. mellifera, Boscia albitrunca, Grewia* spp., *Stipagrostis uniplumis* and *Eragrostis lehmanniana.*

Measurements of the height and percentage ground cover of pan rim vegetation (grass and woody strata) on different pans were taken during the dry season (Appendices 5 and 6) and the average height and percentage ground cover are given in Tables 6 and 7.

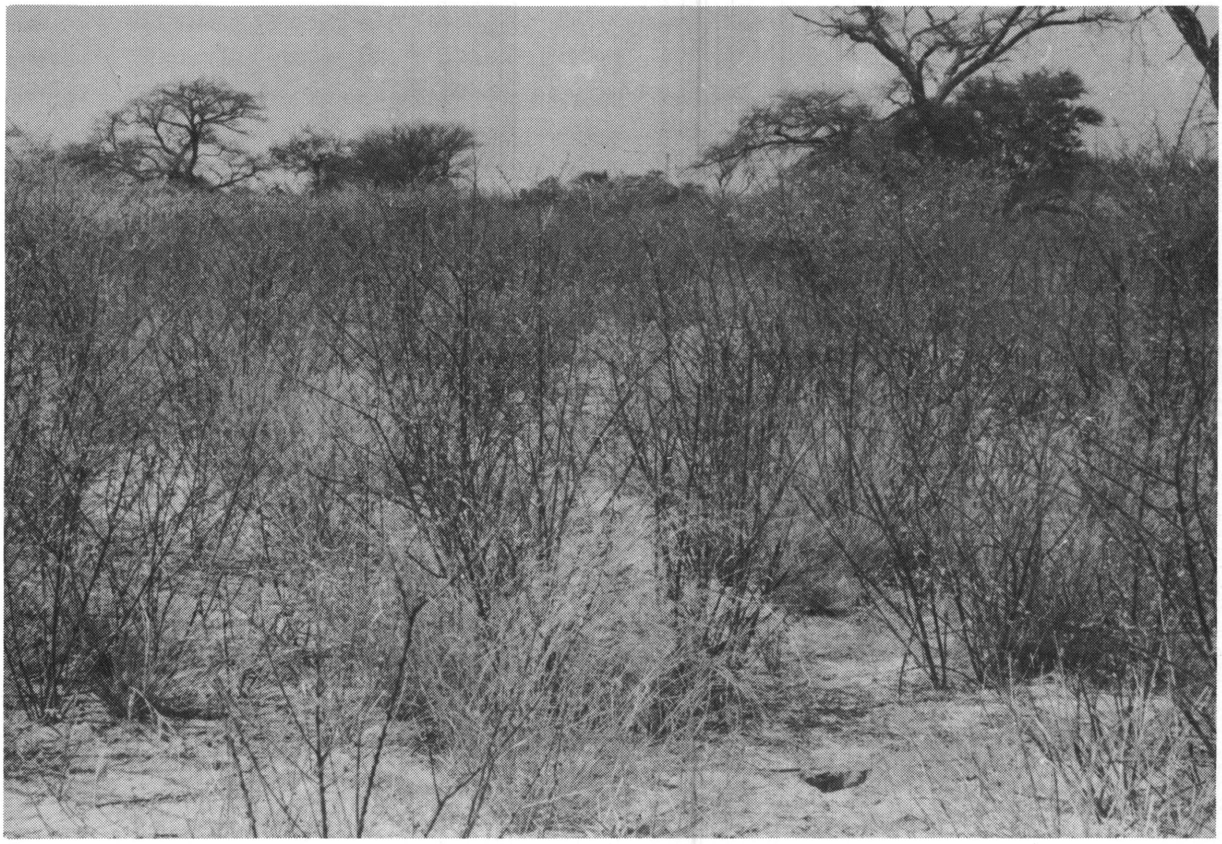


Figure 31 : **Pan rim vegetation on some pans in the Central Kalahari, Botswana, is dominated by a dense stand of shrubs such as this** *Catophractes alexandri* **thicket shown on Khutse 2 Pan rim**

The average height and percentage ground cover of pan rim vegetation during the dry season is compared with the height of the vegetation on and around pans in Figs. 29 and 30.

Measurements of the height and percentage ground cover of the sandveld vegetation surrounding the pans were taken for comparative purposes (Appendices 5 and 6) and are shown in all the above Figures and Tables as 'Surrounding Sandveld'.

Wildlife on pans

Smithers (1971) and Parris and Child (1973) reported that many of the wildlife species in the Central Kalahari make extensive use of pans. In Table 8 the larger mammals of the Central Kalahari are listed and their presence or absence on Mabua Sehube Pan and Khutse 2 Pan during a series of daily game counts is noted. All the larger mammal species were recorded on the pans (Table 8) except when the particular species was uncommon in the general area.

In Table 9 the smaller mammals of the Central Kalahari are grouped into their respective orders, and their presence on pans or pan-like habitat indicated. The table shows that the majority of small mammals was recorded on the pan habitat.

The home range of the smaller mammals when compared to the total area of the pan is such that if they were recorded on a pan then the major part or all of their daily activities would probably take place on the pan.

In the case of the larger mammals, however, their home range would probably always exceed the area of the pan, and therefore only part of their activities take place on the pan. Daily counts of the larger mammals were done at Mabua Sehube Pan during 1968 and at Khutse 2 Pan during 1970 and 1971 and weekly counts were done at Lesholwago, Khiding and Mpatutlwa pans during 1968.

The monthly daily mean number of the more common large mammals at the different pans appears in Appendix 8 and the annual daily mean number is given in Table 10. These results give a quantitative measure of the use of the pan habitat during

Table 8 : Presence of larger mammals on Mabua Sehube and Khutse 1 pans in the Central Kalahari, Botswana, during a series of daily game counts. Animals were counted daily on Mabua Sehube during 1968 and Khutse 1 during 1970 and 1971. Only the tracks of baboon and giraffe were recorded on Khutse 1 Pan .

MAMMAL	PRESENT ON THE PAN		REMARKS
	Mabua Sehube	Khutse 1	
Chacma baboon	No	Yes	Seasonal migrants only
Brown hyaena	Yes	Yes	Recorded regularly
Spotted hyaena	No	No	Population low in both areas
Cheetah	No	Yes	Population low in both areas and recorded only rarely on Khutse 1
Leopard	Yes	Yes	Single individuals recorded regularly
Lion	Yes	Yes	Recorded regularly
Wild dog	Yes	Yes	Recorded regularly
Warthog	No	Yes	Population low around Mabua Sehube
Giraffe	No	Yes	Do not occur near Mabua Sehube and the population low around Khutse 1
Common duiker	Yes	Yes	Recorded regularly
Steenbok	Yes	Yes	Recorded regularly
Kudu	Yes	Yes	Population low around Mabua Sehube but fairly high around Khutse 1
Springbok	Yes	Yes	Recorded regularly
Gemsbok	Yes	Yes	Recorded regularly
Eland	Yes	Yes	Recorded regularly
Blue wildebeest	Yes	Yes	Recorded regularly
Red hartebeest	Yes	Yes	Recorded regularly

Table 9 : Smaller mammals recorded on pans or pan-like habitat in the Central Kalahari, Botswana (after Smithers 1971). The mammals are grouped into their respective orders and the total number of species in each order and the number of species recorded on pans is indicated

Mammal order	Number of species in the order	Number of species regularly recorded on pans	Number of species with a wide habitat tolerance sometimes present on pans	Number of species seldom recorded on pans
Insectivora (elephant shrews and shrews)	3	2	1	0
Chiroptera (bats)	3	0	2	1
Pholidota (pangolins)	1	0	1	0
Lagomorpha (hares and rabbits)	2	1	1	0
Rodentia (rodents)	16	7	6	3
Carnivora (carnivores)	13	8	5	0
Tubulidentata (antbear)	1	0	1	0
TOTAL	39	18	17	4

the year by the different mammals. Giraffe, warthog and baboon were present only occassionally and are ommitted from Table 10, and the secretive nocturnal habits of brown hyaena make quantitative data unreliable.

Smithers (1964) recorded some 116 bird species as fairly common in the Central Kalahari and Maclean (1970) recorded a total of 148 species in the southern section of the Kalahari Gemsbok National Park. As in the case of the larger mammals, most bird species have home ranges far exceeding the area of a pan and Maclean (*op. cit.*) found mobility to be a feature of Kalahari avifauna.

Regular counts of ostrich on pans were carried out as part of the daily game counts on Mabua Sehube Pan during 1968 and Khutse 2 Pan during 1970 and 1971, and the once weekly counts on Lesholwago, Khiding and Mpatutlwa pans. The monthly daily mean number on each pan is given in Appendix 8 and the annual daily mean numbers were 6,0; 6,9; 6,5 and 0,5 on Mabua Sehube, Mpatutlwa, Lesholwago and Khutse 2 respectively.

Both the bird species density and the overall bird density in the Kalahari Gemsbok Park were shown to fluctuate considerably during the year with rainfall exerting the greatest direct and indirect influence on the birds (Maclean 1970).

Little quantitative data are available on reptiles or amphibia in the Central Kalahari *(Haacke *pers. comm.*) The wide range of habitats provided by a pan including the seasonal water-holes undoubtedly results in a relatively high reptile and amphibian density compared with the surrounding sandveld.

General observation indicated a high harvester ant, *Hodotermes* spp., density on pans particularly on the pan floor and pan edge. These harvester ants were particularly noticeable in the dry season when they were busy carrying dry plant material into their nests.

Man and his domestic stock on pans

Hunter-gatherers

The presence of pre-Chellean artifacts underneath the mantle of Kalahari sand (Du Toit 1954) indicates that early man has been associated with the Central

* W. HAACKE, Transvaal Museum, Box 413, Pretoria, South Africa.

Table 10 : Annual daily mean number of the common large mammals recorded on pans in the Central Kalahari, Botswana

PAN	MAMMAL							
	Springbok	Red harte-beest	Blue wilde-beest	Gemsbok	Kudu	Eland	Lion	Wild dog
Mabua Sehube	64,2	12,1	2,7	4,2	0,0	3,8	0,2	0,0
Mpatutlwa	56,4	8,5	0,5	9,3	0,0	1,8	0,2	0,0
Lesholwago	49,3	7,1	3,4	12,7	0,0	6,1	0,2	0,0
Khutse 2	35,1	8,1	2,8	0,1	0,2	0,0	0,03	0,2

The larger mammals were counted daily at Mabua Sehube Pan during 1968 and at Khutse 2 Pan during 1970 and 1971, and weekly at Mpatutlwa Pan and Lesholwago Pan during 1968 (Appendix 8)

Kalahari since the region obtained its present appearance. Stone age man needed both water and rocky material in this relatively water-less and stone-less habitat and will have been attracted to pans in the Central Kalahari from earliest times. Stone age implements were observed during the study at Nojane pan, Mabua Sehube pan and Tshabong pan, and an intensive search on pans would undoubtedly lead to the discovery of numerous artifacts.

Many Bushmen families still live as hunter-gatherers in Botswana and Silberbauer (1965) estimated the number of these Bushman in Botswana to be in the region of six thousand, about half of whom live in the Central Kalahari. Bushmen today are found throughout the Central Kalahari apart from the drier south-western parts.

Pastoralists

Kuper (1969), Campbell and Child (1971) and Devitt (1972) discuss the history of pastoralists in the Central Kalahari and consider the first pastoralists in the Central Kalahari to have been nomadic hottentots with small herds of cattle and sheep who appeared in the Ghanzi area and Nossob River between the 12th and 14th centuries. By about the same time the ba Kgalagadi had penetrated the eastern fringes of the Central Kalahari from the south-east.

Around 1700 the first large waves of ba Tswana settled in eastern Botswana forcing the ba Kgalagadi into the Central Kalahari. These ba Kgalagadi settled on some of the larger pans in the Central Kalahari and although they took with them a knowledge of subsistance agriculture and a few head of stock, the aridity of the area resulted in them following the example of Bushmen and becoming hunter-gatherers. Severe inter-tribal warfare in the Transvaal during the 1820's forced the ba Tswana living in eastern Botswana to move westwards into the eastern parts of the Central Kalahari and this in turn forced the ba Kgalagadi to move even further west into the western parts of the Central Kalahari and settlements at Lehututu near Tshane were established. By 1870 a large measure of stability was achieved which allowed the human and livestock populations to increase.

All human settlements were centered on pans or riverbeds and the drilling of boreholes during the last 30 years has now enabled fairly large human and livestock populations to become permanently established around Tshane, Kuli, Kang along the Molopo River and in the eastern parts of the Central Kalahari.

Characteristics of the pan ecosystem

From the foregoing descriptions of pans, pan soils, pan vegetation and pan fauna in the Central Kalahari it is seen that pans have a number of features that clearly distinguish them from the relatively flat homogenous sandveld. These distinguishing features of pans are:-

(1) Compact calcarious and mineralized soil, lying below the general level of the sandveld.

(2) Concentric bands of short vegetation with many Karroid features.

(3) A relatively high faunal density including several typical species.

(4) Seasonal water-holes and salt-licks on the pan floor.

When all these features are considered simultaneously it is seen that pans form distinct ecosystems or 'sub-ecosystems' which are distributed throughout the larger Central Kalahari ecosystem.

Major abiotic components of the pan ecosystem

Rain in the Central Kalahari falls mainly in the form of thundershowers during which the amount of rain falling per unit time is high. The shape of the pan and the fact that the pan soils on the lower pan banks and pan edge have a fairly high silt and clay content, results in some of this water being channeled inward towards the centre of the pan as run-off water. This water carries with it particles of soil, particularly the finer particles, organic matter, such as plant litter and faunal remains, and soluble soil minerals.

The action of run-off water therefore affects the pan in two ways:

(1) It moves soil downwards and inwards towards the centre of the pan, as illustrated by the erosion channels in Fig. 10.

(2) It concentrates fine soil particles, soil mineral and organic matter in the lower parts of the pan with the lowest part of the pan having the highest concentrations.

The impervious nature of the soils on the pan floor prevents runoff water from soaking rapidly into the ground and so results in the formation of temporary open water-holes.

The shape of the pan results in a higher effective rainfall on the lower parts of the pan and this combined with favourable physical and chemical properties enables these soils to support a dense vegetation.

During the rainy season when the pan vegetation is fairly dense and tall, the soils are moist and firm and the winds blowing across a pan have little effect on the pan soils. However, towards the end of the dry season the vegetation is short and sparse and the soils are dry and heavily trampled. Under these conditions the wind moves a fair amount of pan soil. When the wind blows over the pan in one direction soil is moved across the pan. When the bush kraals were erected on the pan floor of Khutse 1 and Khutse 2 pans the thorn branches lying on the pan floor intercepted wind-blown sand during the dry season and small piles of sand collected against the thorn branches. The dunes on the leeward side of most pans are an illustration of the extent of this wind erosion action on pans.

When the wind is in the form of an eddy, soil particles, particularly the finer ones, are carried into the air as shown in Fig. 32.

Major biotic components of the pan ecosystem

Mammals

The various mammals that make regular use of the pan ecosystem in the Central Kalahari are listed in Table 11 and their major activities while on the pan are indi-

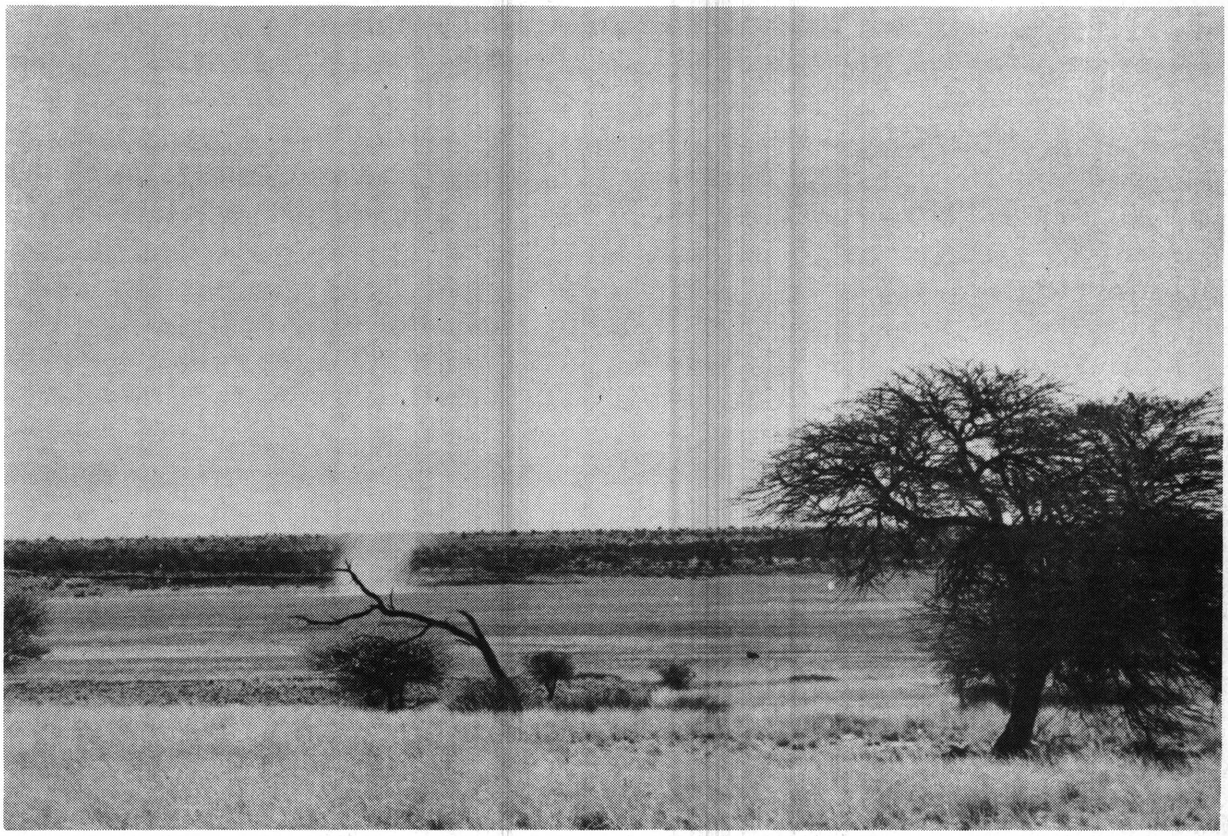


Figure 32 : Wind erosion is one of the factors that removes soil from the floor of pans in the Central Kalahari, Botswana, and a wind eddy on Mabua Sehube Pan is shown lifting soil particles off the pan floor

Table 11 : Major activities while on the pan of the mammals that make regular use of the pan habitat in the Central Kalahari, Botswana

MAMMAL	ACTIVITY					
	Feeding on other fauna	Feeding on pan vegetation	Utilizing salt-lick	Utilizing seasonal water-hole	Shallow digging during feeding	Excavating or enlarging burrow systems
Aardwolf	x				x	x
Wildcat	x					
Black-footed cat	x					
Cape fox	x				x	
Bat-eared fox	x				x	x
Black-backed jackal	x				x	
Suricate	x				x	x
Yellow mongoose	x					x
Scrub hare		x				
Cape hare		x				
Springhare		x			x	x
Ground squirrel		x				x
Brant's karroo rat		x				x
Four-striped mouse		x				x
Namaqua rock rat		x				x
Namaqua gerbil		x				x
Bushveld gerbil		x				x
Pouched mouse		x				x
Long-eared desert mouse		x				x
Brown hyaena	x			x		
Cheetah	x			x		
Leopard	x			x		
Lion	x			x		
Wild dog	x			x		
Warthog		x	x	x		
Giraffe		?	x	x		
Common duiker		x	x	x		
Steenbok		x	x	x		
Kudu		x	x	x		
Springbok		x	x	x		
Gemsbok		x	x	x		
Eland		x	x	x		
Blue wildebeest		x	x	x		
Red hartebeest		x	x	x		

cated in the respective columns. The relative numbers of animals taking part in each activity and the impact of their particular activity on the pan ecosystem are as follows:-

Feeding on fauna

As in any ecosystem it is axiomatic that the secondary and tertiary consumers, i.e. those feeding on other consumers, are far outnumbered by the primary consumers, i.e. those feeding on vegetation. This is clearly illustrated in Table 10 where large predators i.e. lion and wild dog are present in smaller numbers than the larger herbivores. In the case of small predators their numbers are higher than those for the large predators, but are still low compared with the small herbivores. The activity of these secondary consumers while on the pan i.e. the stalking, killing and eating of prey has relatively little direct impact on pan soil or pan vegetation, but it has an indirect impact on these components through its effect on the number of primary consumers.

Feeding on pan vegetation

Parris and Child (1973) showed that the common larger antelope (gemsbok, red hartebeest and springbok) concentrate on pans and in Table 8 all the large antelope are shown to make regular use of the pan habitat.

The annual daily mean number of individuals (Table 10) is remarkably similar on the different pans in the case of springbok and red hartebeest, while the difference in numbers of blue wildebeest, kudu, gemsbok and eland on the pans reflect differences in the populations of these species in the two areas (Mabua Sehube and Khutse Game Reserves), rather than inherent differences in their use of pans. In the case of springbok the results could be an indication of the carrying capacity of the respective pans.

Pellet densities of grazers, browsers and mixed feeders, and hares and springhares were determined (Appendix 9) and the relative use of the different parts of the pan by the grazers (i.e. gemsbok, red hartebeest and blue wildebeest), and the browsers and mixed feeders (i.e. kudu, eland and springbok) based on these pellet group counts are given in Table 12. The results show that the pattern of use of the different parts of the six pans remained fairly constant. The average number of pellet groups on the different parts of the pans for all pans is shown in Fig. 33.

According to Smithers (1971) springhares and cape hares, although not restricted to pans, show a preference for a short grass, open habitat as found on pans, and Butynski (1973) recorded high springhare densities on pans. The relative use of the different parts of the pans by springhares and hares based on pellet plot surveys are given in Table 12 and the results confirm that the density of springhares and hares on pans is generally high. The average use of the different parts of a pan for all pans sampled is shown in Fig. 33.

The use of the pans by steenbok and duiker is very light with an average of less than one pellet group per 20 plots when compared with other herbivores, and is not noticeably different to their use of the surrounding sandveld habitat.

The impact of the combined grazing and trampling pressure of the larger antelope, springhares and hares on pan vegetation is considerable. A 10 x 10 m plot on the pan bank on Mabua Sehube Pan was protected from large antelope, hares and springhares by means of a thorn bush fence from 1969 to 1972, and after three years the difference in the dominant perennial grass *Stipagrostis obtusa* between the protected plot and the adjacent unprotected area is dramatic, as illustrated in Figs. 34 and 35. A similar bush exclosure was erected on Khutse 2 Pan floor on the twenty second of January 1970 and after two years the difference in the protected vegetation was considerable as seen in Figs. 36 and 37.

Ground squirrel in the Central Kalahari are particularly associated with pans (Smithers 1971) and live in colonies of up to 30 individuals on the hard soils on the pan floor or pan edge. They feed up to 200 m from their burrows (Smithers *op. cit.*) and therefore have a considerable impact on the pan vegetation in the immediate vicinity of their burrows.

Of the seven types of small rodents found on pans (Appendix 7) one (the four-striped mouse) is associated with the heavier growth of grass in the local depressions

Table 12 : Average large ungulate, springhare and hare pellet densities on and around pans in the Mabua Sehube and Khutse Game Reserves, Central Kalahari, Botswana

PAN	PELLET DENSITY														
	Pan floor			Pan edge			Pan bank			Pan rim			Sandveld		
	G	M	H	G	M	H	G	M	H	G	M	H	G	M	H
Mabua Sehube		no data		5,2	21,2	10,7		no data		1,7	14,7	4,0	0,5	0,2	5,0
Mpatutlwa	3,7	14,8	3,4	1,4	22,1	2,4		no data		0,0	0,0	4,0	0,2	0,5	6,0
Bosho Bogolo	9,8	5,4	5,4	4,5	17,5	6,0	2,9	3,1	6,3	0,3	0,3	12,5	0,3	0,4	8,8
Lesholwago	4,7	14,6	6,0	1,7	26,8	2,5		no data		0,0	0,0	13,5	0,2	0,0	10,0
Khiding	14,8	4,9	3,3	9,2	9,7	3,5	3,0	1,7	10,5		no data			no data	
Khutse 2	2,8	9,3	4,0	0,9	6,2	7,7		no data		0,3	2,3	4,5	1,5	2,8	9,0

G = Grazing antelope (red hartebeest, blue wildebeest and gemsbok)
M = Browsing and mixed feeding antelope (kudu, eland and springbok)
H = Springhares and hares

Pellet counts were done in the dry season and the figures are the average pellet densities per twenty plots (each plot 3,8 m^2) recorded during the study period (1968 to 1972). Pellet counts on the pan floor were done on the section with the best perennial grass cover and pellet counts in the sandveld were done within 3,2 km of the pan

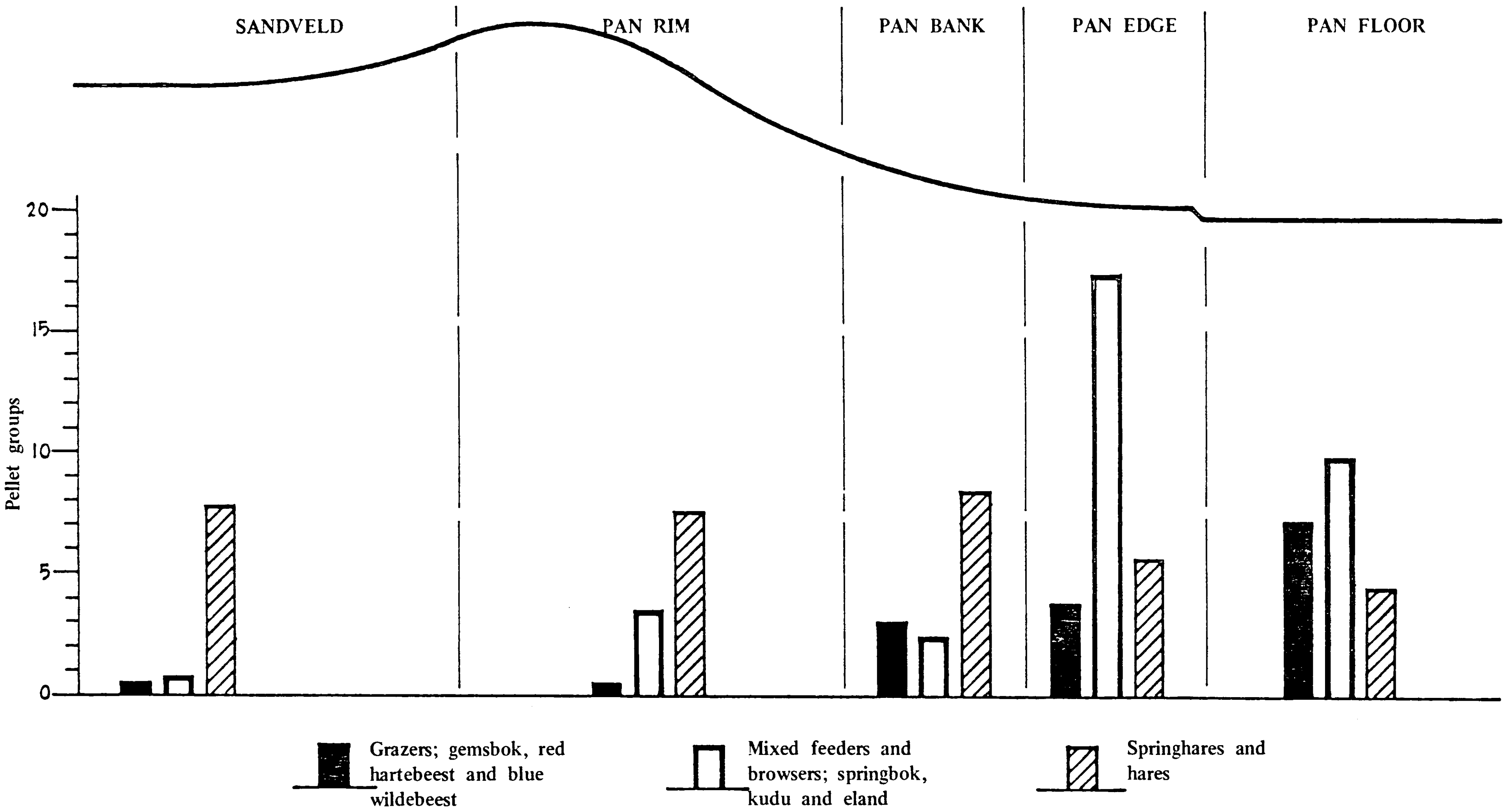
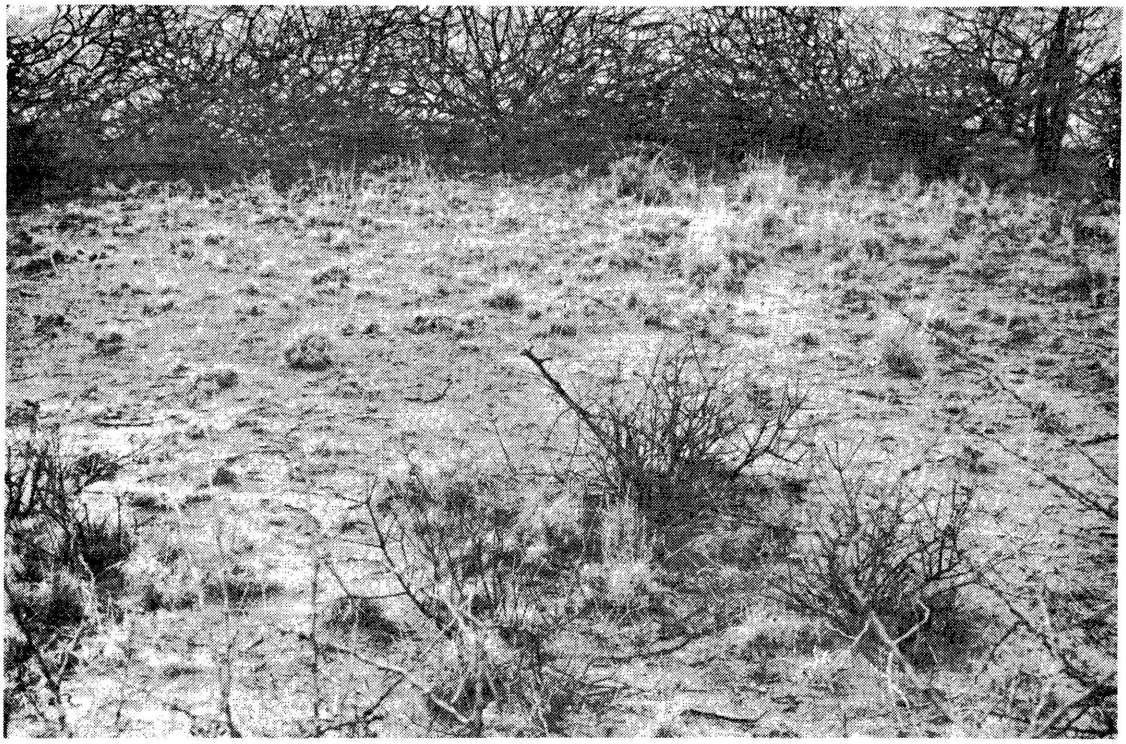
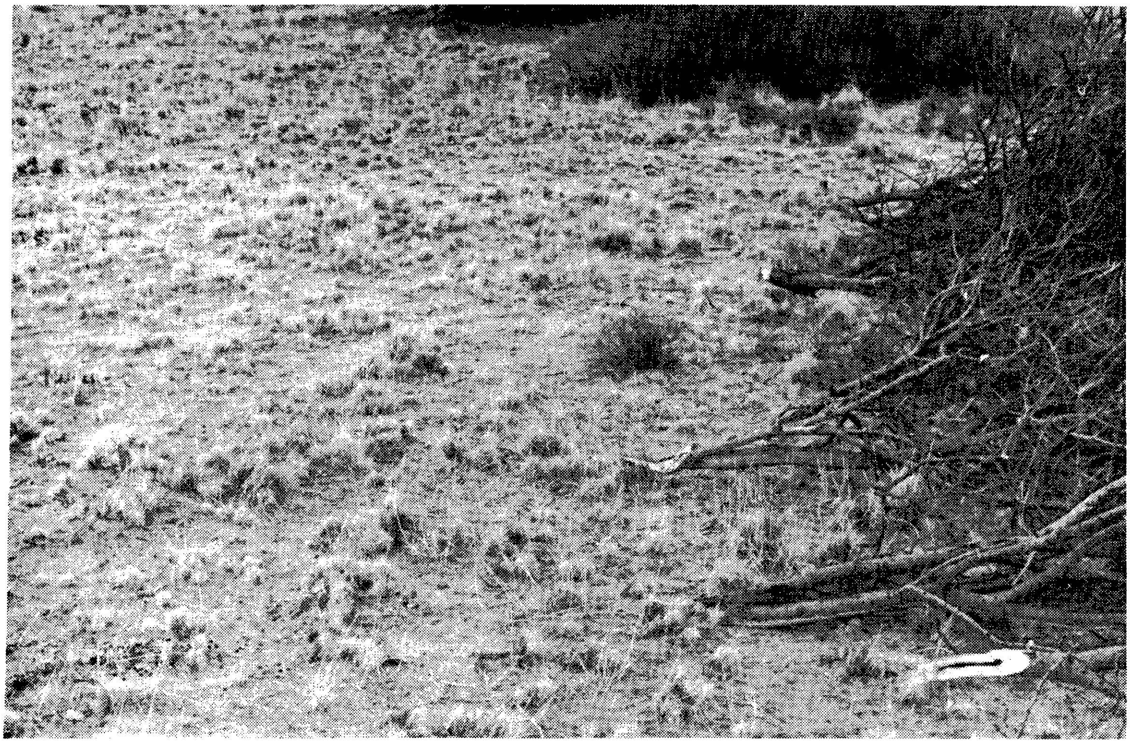


Figure 33 : Average number of pellet groups per 20 plots 3,8 m^2 each on and around a cross-section of six pans in the Mabua Sehube and Khutse Game Reserves, Central Kalahari, Botswana. Pellet densities of large ungulate grazers (gemsbok, red hartebeest and blue wildebeest), large ungulate browsers and mixed feeders (springbok, kudu and eland) and hares and springhares were recorded during the study period (1968 to 1972). The columns below the pan profile indicate the average of all pellet densities for the study period



(a)



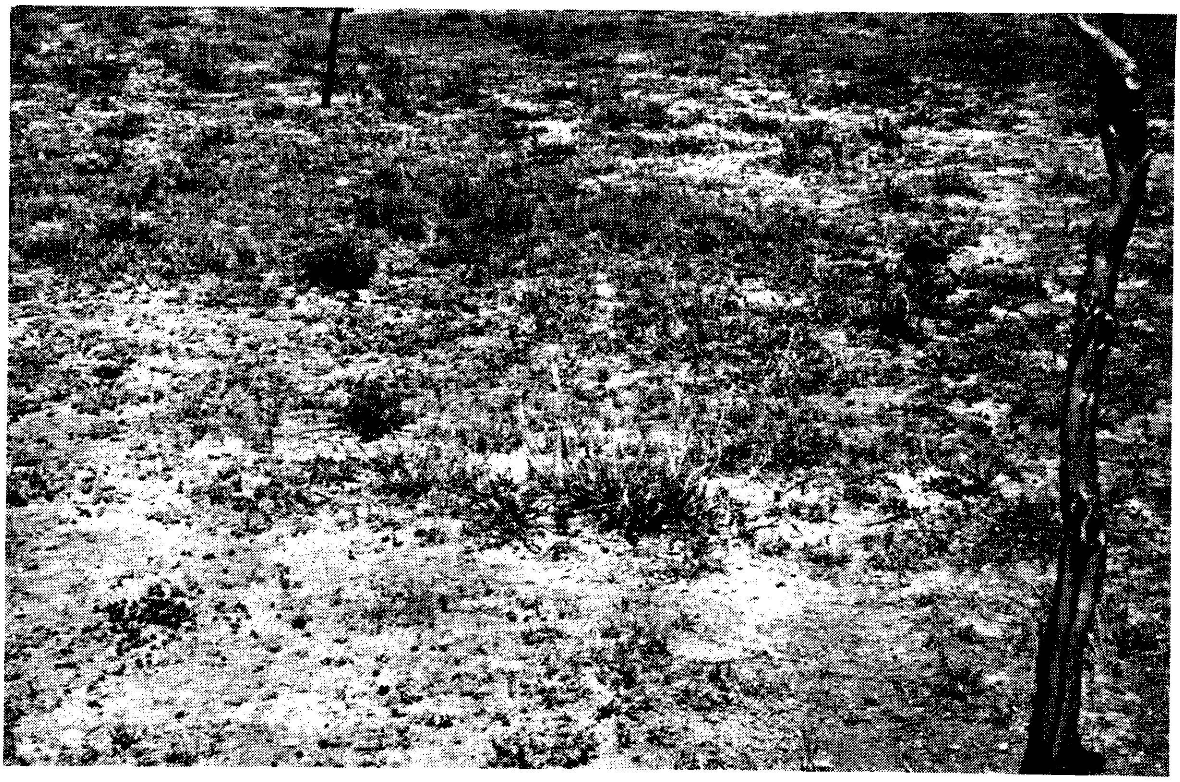
(b)

Figure 34 : A bush exclosure 10 by 10 m was erected on a section of pan bank vegetation on Mabua Sehube Pan, Central Kalahari, Botswana, on 6th November 1969. Photograph (a) shows the vegetation inside the bush exclosure shortly after erection and photograph (b) shows the vegetation outside and adjacent to the bush exclosure on the same day

(a)

(b)

Figure 35 : The bush exclosure illustrated in Fig. 34 was photographed again on 10th July 1972 i.e. three years after its erection. Photograph (a) shows the vegetation inside the bush exclosure and photograph (b) shows the vegetation outside and adjacent to the bush exclosure. The improvement in the grass cover in the area protected from large herbivore pressure is considerable

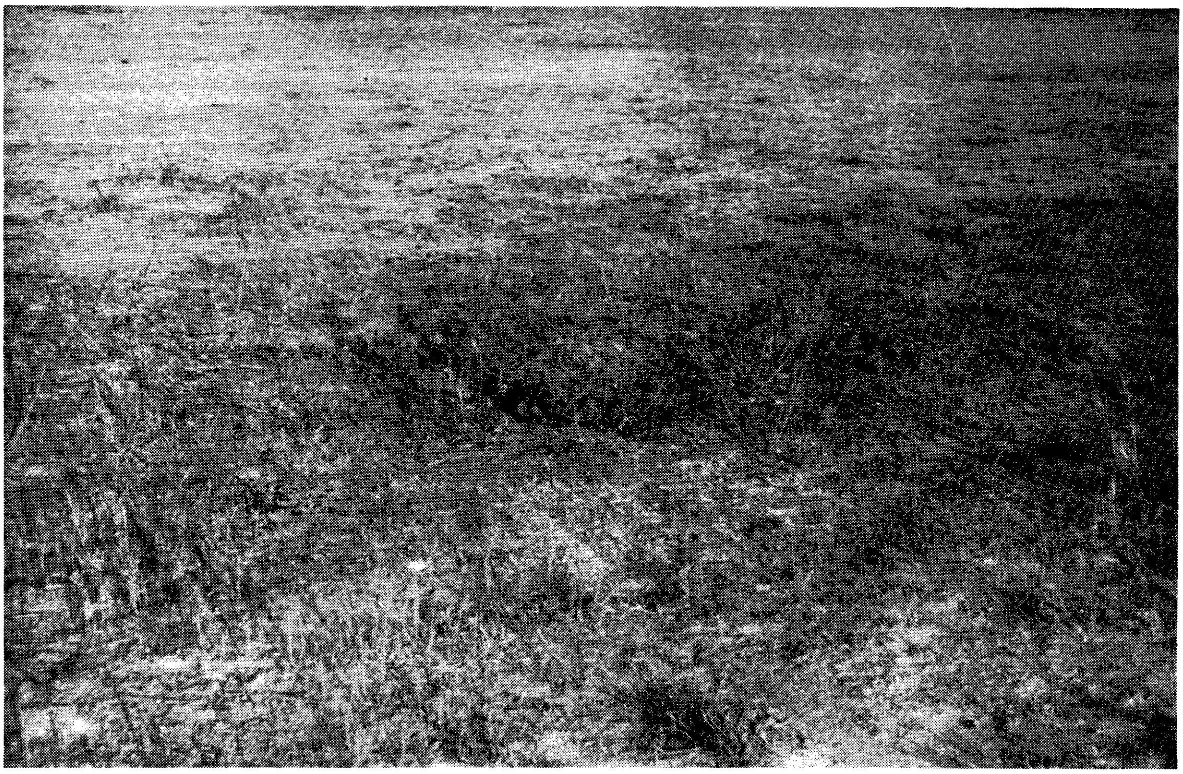


(a)

(b)

Figure 36 : The site of a bush exclosure 10 by 10 m which was erected on a section of Khutse 2 Pan floor in the Central Kalahari, Botswana, on 22nd January 1970. Photograph (a) shows the vegetation inside the bush exclosure shortly before its erection and photograph (b) shows the vegetation adjacent to the bush exclosure on the same day

(a)



(b)

Figure 37 : The bush exclosure illustrated in Fig. 36 was photographed again on 2nd October 1971 approximataly two years after its erection. Photograph (a) shows the vegetation inside the bush exclosure and photograph (b) shows the vegetation outside and adjacent to the bush exclosure. There is a noticeable improvement in the grass cover in the area protected from large herbivore pressure

or water-holes on the pan floor, one (the Namaqua rock-rat) is associated with calcrete outcrops, three (the bushveld gerbil, Brant's gerbil and the pouched mouse) are associated with pan banks, and two (the Namaqua gerbil and the long-eared desert mouse) are associated with short grass on hard ground such as occurs on the pan edge, or on calcrete banks with Karroid vegetation.

It can therefore be seen that the small rodents feed on all parts of the pan and on all types of pan vegetation. They are often responsible for extremely heavy use of pan vegetation, and may completely destroy the perennial vegetation in the immediate vicinity of the burrow (Fig. 38).

Utilisation of salt-licks or seasonal water-holes on a pan

Table 11 shows that it is the larger herbivores that regularly make use of the salt-licks on pans. The popularity of these salt-licks is demonstrated by the main game tracks on a pan which invariably lead directly to the salt-licks, and by the heavily trampled appearance of the area around the salt-lick (Fig. 21). Antelope eating the salt at these salt-licks is a common sight on pans (Fig. 39).

Large carnivores and large herbivores make use of the water-hole during the rainy season (Table 11) and the tracks of some of the smaller mammals are often seen around the water-holes. The use of both the water-holes and the salt-licks on the pan results in the removal of soil from the pan floor. In the case of the salt-licks the soil is actually eaten while in the case of the water-hole the soil adheres to the animals in the form of mud and is carried away from the pan. Young (1970) gives an excellent illustration of how buffalo in the Kruger National Park enlarge natural water-holes by a combination of trampling, rolling, and carrying away of the mud which adheres to the buffaloes, and the role of other animals such as warthog in this process is also discussed. Smithers (1971) also refers to the considerable amount of mud carried away by animals from the water-holes on pans in the Kalahari.

It is difficult to estimate the actual quantity of soil removed from the pan in this way, but what is of particular importance is that since both the salt-lick and the water-hole lie near the centre of the pan, soil is constantly removed from the deepest

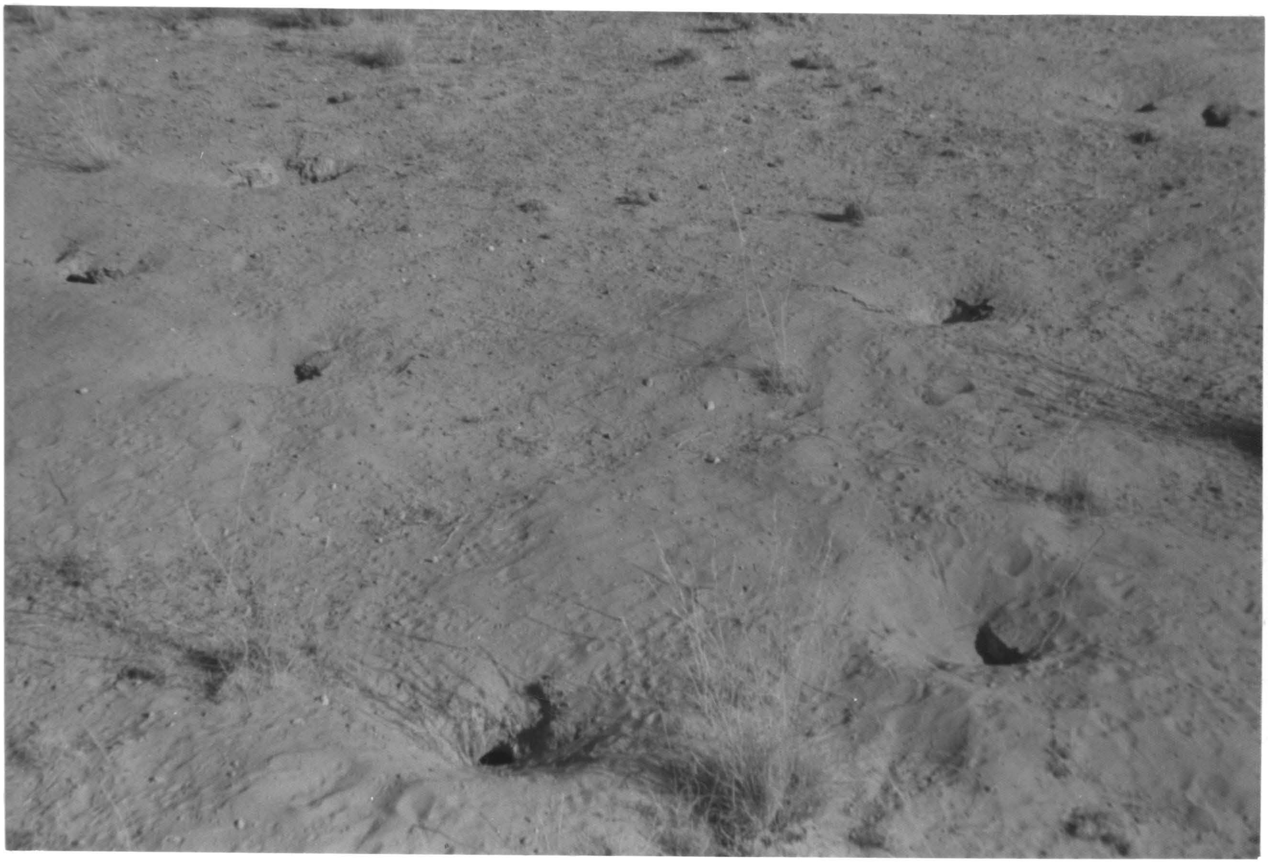


Figure 38: Rodent burrows are common on pan banks in the Central Kalahari, Botswana, and the area around these rodent burrows is often almost denuded of vegetation as shown by the rodent burrows photographed on Mabua Sehube Pan bank in September 1973

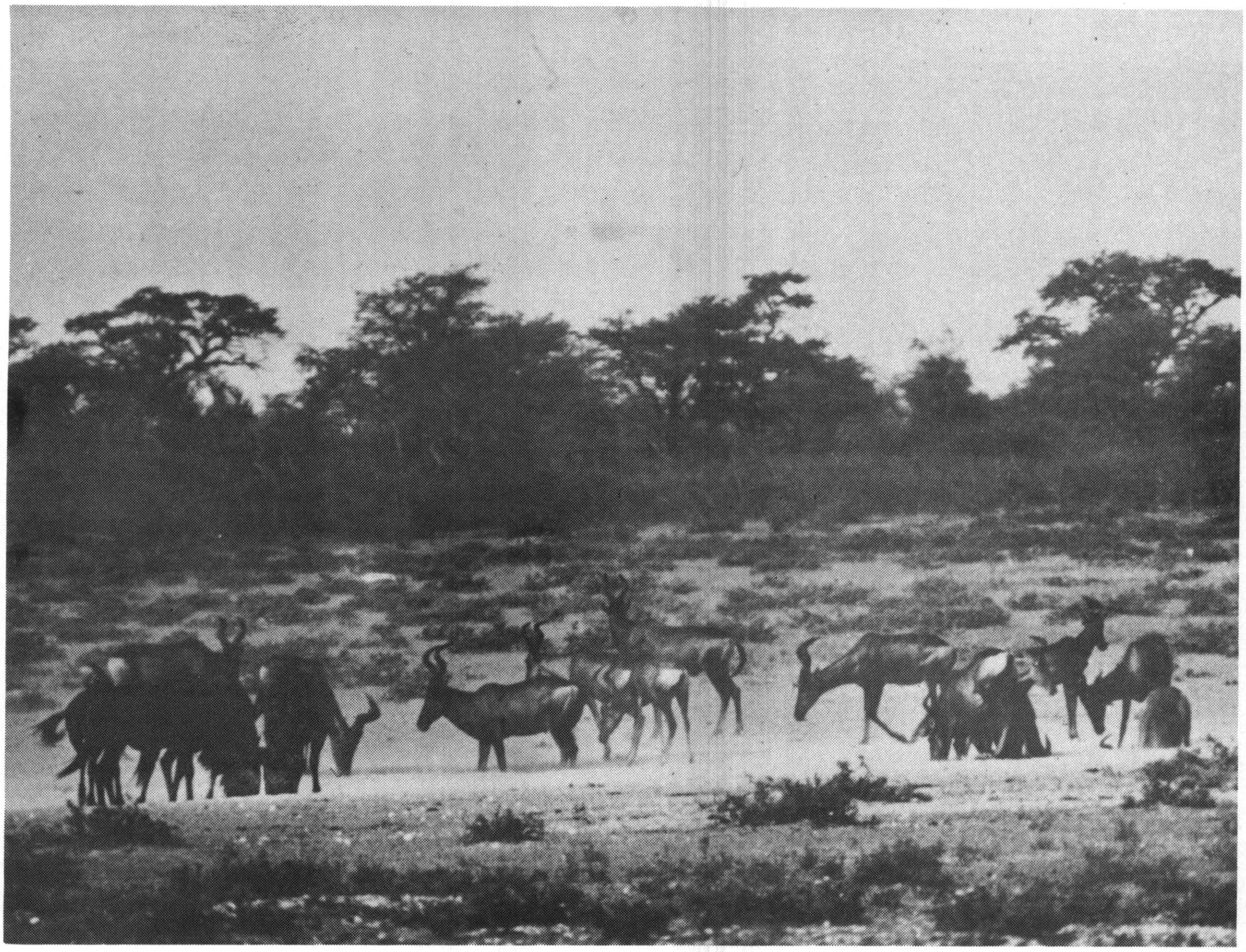


Figure 39 : All large antelope make regular use of the salt-licks on pans in the Central Kalahari, Botswana, and red hartebeest and blue wildebeest are shown eating salt at one of the salt-licks on Khutse 1 Pan

part of the pan. This removal of soil increases the depth of the pan floor relative to the pan rim and the surrounding sandveld.

Animal activity assisting in soil development

Many of the smaller carnivores and herbivores dig into the soil on the pans in search of food (Table 11) and Smithers (1971) describes some of the smaller carnivores such as the bat-eared fox and the suricate as avid diggers, digging even in the hardest soil.

Almost all the smaller herbivores have burrow systems (Table 11) and these burrow systems are a conspicuous feature of pans. They are found in both loose sand (Fig. 38) and in the hardest calcrete outcrops (Fig. 40), and on all sections of the pan. It is only on the bare floors of highly saline pans that burrows are rare or absent.

Springhares prefer to burrow in the deeper sand found on pan banks (Butynski 1973), while the yellow mongoose, suricate, ground squirrel and bat-eared fox prefer to burrow in the hard calcarious soil found on the pan edge, pan floor, and calcrete banks. Smaller rodents make burrows or tunnels in every type of soil from calcrete cliffs in the case of the Namaqua rock rat and calcrete banks in the case of the Namaqua gerbil to sandy banks in the case of the Bushveld and Brant's gerbil (Smithers *op. cit.*).

This constant and extensive digging and burrowing activity on pans results in a continuous mixing of the pan soils. When the burrows are excavated into surface calcrete or calcrete 'sub-soil' the calcrete is broken up and mixed with the sandy 'topsoil' (Fig. 41).

Birds, reptiles, amphibia and invertebrates

A similar breakdown of activities on the pan can be done in respect of the birds, reptiles, amphibia and invertebrates, and the impact on the pan ecosystem is probably essentially similar to that described for mammals.

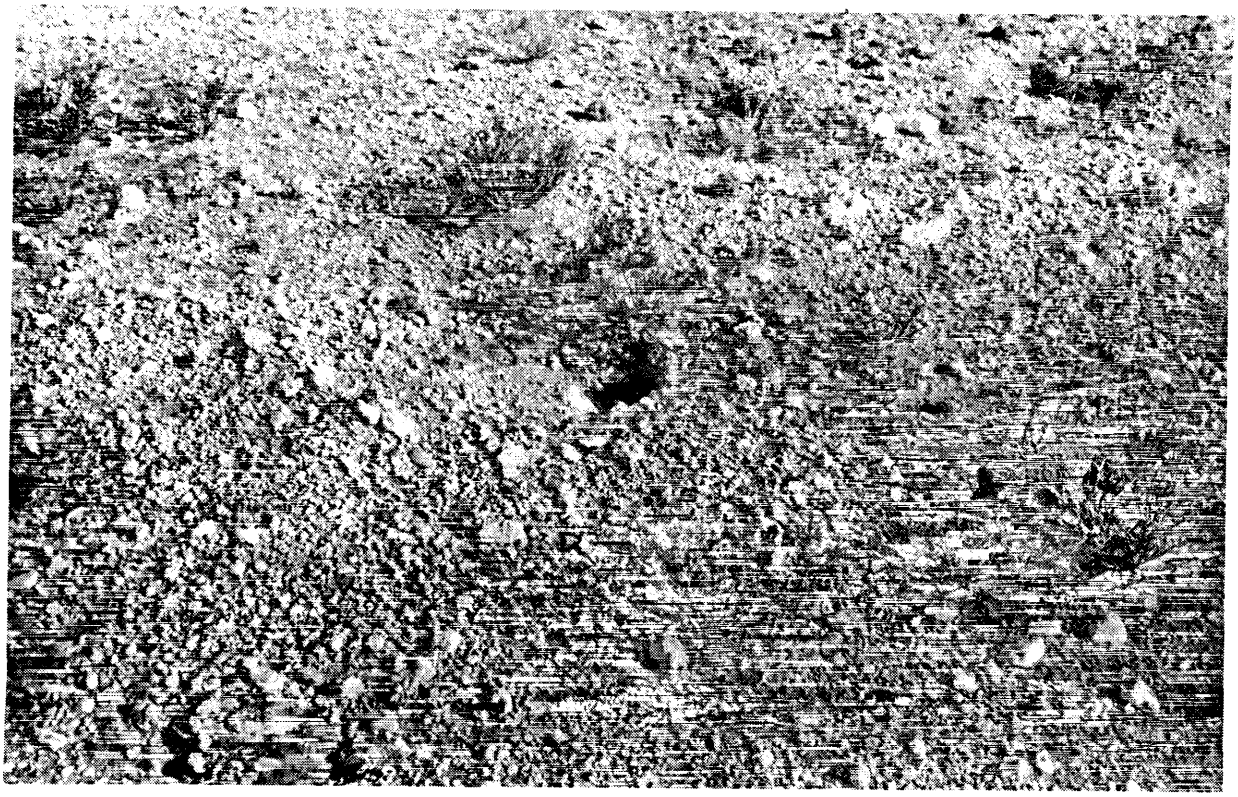


Figure 40 : Rodents excavate burrows on even the hardest calcrete areas on pans in the Central Kalahari, Botswana, as shown by the burrows in the calcrete bank of Khiding Pan

Figure 41 : Calcrete often lies a little below the surface of the pans in the Central Kalahari, Botswana, and burrowing activity breaks up this calcrete sub-soil and mixes it with the pan topsoil. An example of this activity is shown in the photograph of a ground squirrel burrow on Khutse 2 Pan edge

Feeding on pan fauna

Predatory birds, reptiles and invertebrates which feed on the primary consumers on the pan have the same impact on the pan ecosystem as the predatory mammals i.e. they affect the primary consumer numbers and so indirectly affect the pan vegetation and soil.

Feeding on pan vegetation

The largest herbivorous bird using the pan ecosystem is the ostrich. The home range of this large flightless bird undoubtedly far exceeds the area of the pan but it regularly visits pans and the results of daily and weekly counts showed that ostriches used the pan habitat in relatively high numbers. Robinson and Seely (1975) consider that heavy concentrations of ostriches could have a detrimental effect on arid grassland communities as a result of their uprooting of herbs and grasses.

The activity of many of the small herbivorous birds and invertebrates in the Central Kalahari is closely linked with rainfall, and their use of the pan vegetation therefore coincides with its period of densest plant growth. In the case of harvester ants (*Hodotermes* spp.), however, their activity is often highest when the vegetation is short and sparse, and their activity further reduces plant cover during the dry season.

Utilisation of the salt-lick and seasonal water-hole

Ostriches utilize salt-licks and seasonal water-holes and the larger carnivorous birds, particularly vultures, make regular use of the water-holes. The smaller granivorous birds also make considerable use of the water-holes.

This use of the salt-licks and water-holes results, as described for mammals, in a further removal of soil from the centre of the pan.

Excavating burrow systems

Many of the reptiles and invertebrates burrow into the soil on pans (Haacke *pers. comm.*) with barking geckos, scorpions and harvester ants particularly active in this respect.

This burrowing activity results in a further mixing of the soils on the pan.

Man and his livestock

Hunter-gatherers

Hunter-gatherers have no livestock and as hunters they have a similar effect on the pan herbivores as do other predators.

When herbivore numbers on a particular pan are high, the mobile predators, including man, concentrate their activity on that pan with the result that the herbivore numbers on such a pan are reduced either through direct predation or the movement of herbivores away from the pan due to disturbance.

Although there are a few plant species on pans that are utilized by hunter-gatherers, the hunter-gatherers generally have little impact on pan vegetation. Hunter-gatherers make regular use of the seasonal water-holes and often deepen these water-holes so that they hold water for longer periods.

Pastoralists

Parris and Child (1973) illustrated the marked reduction in perennial grass cover on and around pans where man has settled permanently with his livestock i.e cattle, sheep, goats, donkeys and horses. At pans where a large number of livestock have been grazed for a long time the vegetation has been so damaged that it is no longer capable of preventing the sand from shifting and considerable movement often occurs (Fig. 42).

Figure 42 : The sandy soil on the banks of undisturbed pans in the Central Kalahari, Botswana, is generally stable, but overgrazing of the pan banks leads to unstable conditions and this sandy soil is blown into small dunes as shown on Tshabong Pan bank

The presence of a large permanent village with its associated livestock, dogs, etc. was also shown to result in considerable reduction in the number of wild animals using the pan (Parris and Child 1973). The water-holes are fenced off with thorn branches and additional earth dams, pits and wells are usually excavated.

Vegetation

In spite of the severe herbivore pressure on the pan vegetation almost all parts of the pan except the pan floor of highly saline pans have a reasonable vegetative cover (Table 7). This vegetative cover provides protection for the soil both from the weather and from biotic factors such as trampling.

The vegetation on the pan therefore reduces the amount of soil moved during wind and water erosion.

CHAPTER 5

CONCLUSIONS

Pans in the Central Kalahari are hard-floored saucer-shaped depressions that lie well below the level of the surrounding sandveld, and support characteristic plants and animals. A close examination revealed that these 'depressions' are actively maintained and that without such active maintenance they would gradually become shallower and more like the surrounding sandveld. Examples of this process can be seen along some parts of the Okwa and Molopo dry rivers. The earlier steep banks and hard river beds have become shallow sandy troughs with gently sloping banks and the old river course is difficult to distinguish from the sandveld.

Interactions between the different components of an ecosystem are simultaneous and multi-directional and care must therefore be taken in attempting to separate the components of the pan ecosystem when discussing their roles in the ecosystem. However, in order to consider the factors responsible for the active maintenance of the pan ecosystem referred to above a certain degree of separation is necessary.

The most important features of the pan ecosystem are the physical dimensions of the pan and the distinctive properties of the soils, particularly those on and around the centre of the pan. The physical dimensions or shape of the pan is important because it results in the concentration of water, salts, etc., in the centre of the pan. The soils are important because it is their high mineral content and impervious nature which gives rise to the salt-licks and water-holes on the pan. The major components of the pan ecosystem which combine to maintain the shape of the pan and the properties of the soils can be grouped according to their function as follows:

Movement of soil on pans

Both biotic and abiotic factors are involved in the movement of soil on the pan and this movement is both towards and away from the centre of the pan.

Soil removed from the centre of the pan

Many animal species visit the pan to eat mineralized soil at the salt-licks and to utilize the water-holes. These salt-licks and water-holes are in the centre of the pan on the pan floor and their use results in a deepening of the pan floor relative to the pan banks and the surrounding sandveld, and in a net loss of soil to the centre of the pan (Fig. 43).

Pan vegetation is subjected to heavy use by the herbivores and the vegetation on the pan floor and pan edge is kept short during the dry season. The soil surface is also loosened by the high trampling pressure and as a result of these two factors wind erosion takes place. Since wind erosion in the surrounding sandveld is relatively small the wind erosion on the pan floor and pan edge results in a loss of soil to the centre of the pan (Fig. 43). The dune on the leewardside of the pan is an illustration of this loss of soil from the pan due to wind erosion.

Soil added to the centre of the pan

Water erosion on the banks of the pan moves soil downwards towards the centre of the pan, which results in a net gain of soil to the centre of the pan and raises the level of the pan floor relative to the pan banks and surrounding sandveld (Fig. 43).

The pan floor is lower than the pan bank, which in turn is lower than the pan rim. Any soil moved by such factors as scuffing of antelope hoofs will tend on average to be moved by the force of gravity downwards i.e. towards the centre of the pan. This results in a gain of soil to the centre of the pan (Fig. 43).

Development of the characteristic properties of pan soils

Geologically, loose sand was deposited as a discrete layer over a virtually solid calcrete layer in the Kalahari. The soils on pans are however, a combination of sand and calcrete with their own specific physical and chemical properties. It is certain of these properties such as the high silt and clay content that results in in-

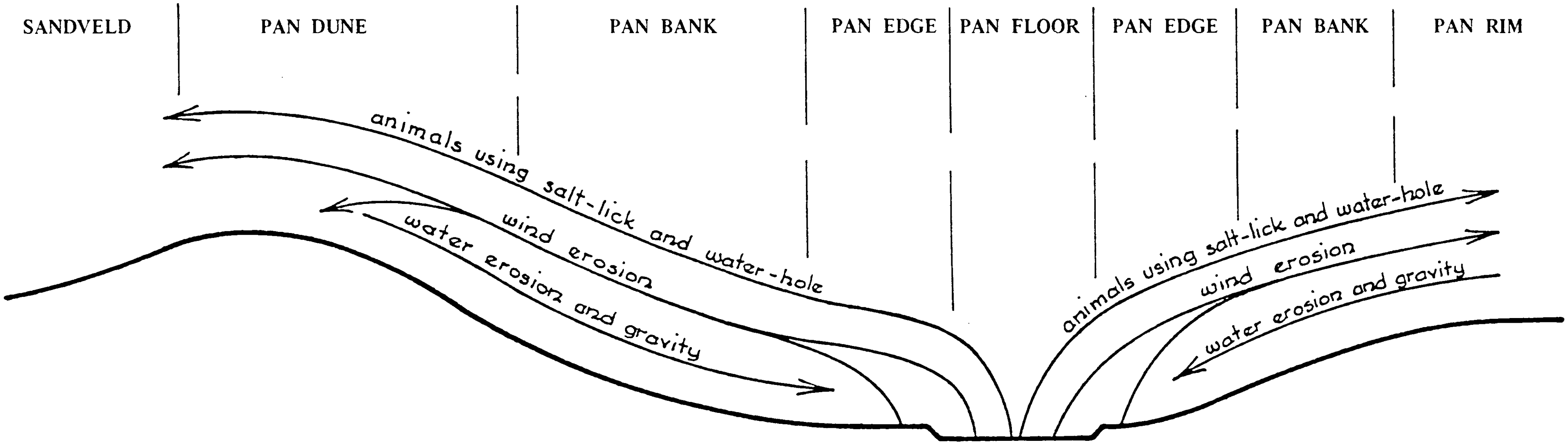


Figure 43 : Diagrammatic representation of soil movement in a pan ecosystem in the Central Kalahari, Botswana. The amount of soil moved by the various factors is small compared with the amount of soil on the pan but is sufficient to maintain the shape of the pan

creased runoff, the formation of water-holes, and the concentration of minerals in the pan centre.

Physical properties

There is extensive digging and burrowing activity on pans involving a wide range of animal species. The digging is both shallow and deep and takes place in even the hardest material. This continued burrowing breaks up the larger calcrete particles, mixes these particles with the sand, and exposes them to other natural soil forming agents. This leads to the development of the characteristic pan soils.

Chemical properties

Water which drains inwards from the banks towards the pan floor carries with it organic matter and minerals. In this way the concentration of minerals in the centre of the pan is increased and salt-licks are formed in this highly mineralized soil.

Stabilizing or damping factors

Certain components of the pan ecosystem play an important role in slowing down or damping the effects of other factors. Without this damping effect the ecosystem would be less stable and subject to greater extremes.

Pan vegetation is one of the main damping factors. This vegetative cover reduces both wind and water erosion and so slows down the rate at which these factors move soil on the pan. Without this damping effect provided by the vegetation wind and water erosion on the pan would probably become too rapid for the soil forming agents to replace the eroded soil.

Predators also play an important damping role in the pan ecosystem. Although a heavy herbivore pressure is necessary for the proper functioning of the pan ecosystem the herbivore pressure when it becomes too great will destroy the vegetation which in turn will lead to excessive wind and water erosion. An example of the results of such excessive herbivore pressure on pan bank vegetation is given in Fig. 42.

Predators help to prevent the herbivore pressure from becoming too great by damping herbivore numbers.

Odum (1971) states that ecosystems are capable of self-maintenance and self-regulation. The pan ecosystem has been shown in this study to be self-maintaining and examples of self-regulation and damping factors have been discussed. What is particularly striking is that it is the combined interactions of both the biotic and abiotic components that results in the maintenance of this valuable ecosystem in the Kalahari.

The conservation of these key pan habitats therefore not only requires the conservation of the pan itself but also the numerous components of the pan ecosystem. Many of these components are highly mobile and it is essential that this be taken into account in the planning and management of conservation areas in the Kalahari. Such areas must be large enough to allow for adequate animal-soil-plant interactions.

The factors that maintain the pan ecosystem also played a role in its formation and this aspect will be discussed in a separate paper.

Extensive areas of the Kalahari both in Botswana and South Africa have already been set aside as conservation areas and it is hoped that this study will contribute to a better understanding of the Kalahari and so assist in its conservation.

SUMMARY

Scattered throughout the Kalahari sandveld of Southern Africa are saucer-shaped depressions known as pans or salt-pans, which vary in size from less than 30 m in diameter to as much as 5 km in diameter.

A cross-section of these pans in the Mabua Sehube and Khutse Game Reserves in Botswana were studied from 1968 to 1972 as part of the overall wildlife research program in Botswana. The study included regular animal counts, pellet counts, measurements of vegetation and vegetation use, and determination of soil properties.

Pans were shown to be heterogeneous habitats in a relatively homogeneous sand-veld environment which support a characteristic vegetation with many Karroid features. They were also shown to be focal points for many wildlife species and are the sites of important wildlife salt-licks and seasonal water-holes which are not found in the sandveld. Human activity in the Kalahari was found to be largely concentrated around pans, although the recent drilling of boreholes is altering the pattern of human distribution.

The study further demonstrated how these valuable pan habitats or ecosystems are actively maintained by the combined interaction of their various biotic and abiotic components. An example of this interaction is that run-off water concentrates soluble minerals and fine soil particles, which form the basis of the salt-licks and water-holes, in the lower parts of the pan. The salt-licks and water-holes attract animals and animal use results in a removal of soil from these areas, which helps to maintain their depth and so ensure that further run-off water flows into them, thus completing the cycle. Other factors including herbivore pressure on the vegetation and wind erosion were also shown to play a role in maintaining the pan ecosystem.

The study underlines the need to conserve and understand ecosystems rather than individual species or groups of species, and it is hoped that these results will contribute to a better understanding of the Kalahari and so assist in its conservation.

OPSOMMING

In die Kalahari-sandvelddele van Suider Afrika kom panne of soutpanne wydverspreid voor. Hierdie panne is holtes in die sandveld en wissel van minder as 30 m tot soveel as 5 km in deursnee.

'n Reeks van hierdie panne in die Mabua Sehube en Khutse Natuurreservate in Botswana is gedurende die tydperk 1968 tot 1972 bestudeer as deel van die wildnavorsingsprogram in Botswana. Die studie het uit gereelde wildtellings, wildmisopnames, plantopnames, bepalings van plantegroeiverbruik, en bepalings van grondeienskappe, bestaan.

Dit is vasgestel dat die panhabitat heterogeen is in vergelyking met die homogene sandveldhabitat en dat die pan 'n kenmerkende plantegroei met heelwat Karoo-agtige eienskappe bevat. Dit is ook vasgestel dat panne fokuspunte vir baie wildsoorte is en dat belangrike soutlekke en tydelike watergate wat op panne aangetref word nie in die sandveld voorkom nie. Menslike aktiwiteite in die Kalahari is hoofsaaklik rondom panne gekonsentreer alhoewel die onlangse ontwikkeling van boorgate besig is om die patroon van menslike verspreiding te verander.

Die studie het verder aangedui hoe hierdie waardevolle habitatte of ekosisteme deur die gesamentlike wisselwerking van hulle biotiese en abiotiese komponente in stand gehou word. 'n Voorbeeld van hierdie wisselwerking is dat afloopwater die oplosbare minerale en fyn gronddeeltjies, wat die basis van die soutlekke en watergate vorm, in die laerliggende dele van die pan konsentreer. Die soutlekke en watergate lok wild en wild verwyder grond vanuit hierdie gebiede. Hierdie verwydering van grond verseker dat verdere afloopwater invloei, wat die siklus voltooi. Ander faktore soos plantverbruikerdruk op die plantegroei en winderosie speel ook 'n rol in die instandhouding van die pan ekosisteem.

Die studie beklemtoon die noodsaaklikheid om ekosisteme te bewaar en te ontleed eerder as om op een spesie of op 'n paar spesies te konsentreer.

Dit word vertrou dat hierdie resultate 'n bydrae tot 'n beter begrip van die Kalahari sal lewer en sodoende tot die bewaring daarvan sal lei.

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Appendix 1 : Soil properties on and around pans in the Central Kalahari, Botswana. Soil samples were taken at the sites and depths indicated and the figures are the results of a routine laboratory analysis

AREA	SITE	DEPTH IN MM	PARTICLE SIZE DISTRIBUTION IN PER CENT							pH		ELECTRICAL CONDUCTIVITY 1:5 SUSPENSION IN U mhos	PER CENT CALCIUM CARBONATE	GROSS EXTRACTABLE CATIONS Meg 100 g				SATURATED PASTE SOLUBLE CATIONS Me / 100 g			SATURATED PASTE SOLUBLE ANIONS Me / 100 g			PER CENT CARBON
			Fine earth	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Calcium chloride .02 N 1:5 suspension	Water 2:5 suspension			Na	K	Ca	Mg	Na	K	Ca + Mg	HCO_3	Cl	SO_4	
Mabua Sehube Game Reserve	Mabua Sehube pan floor	0-203	96	2	5	11	4	30	47	9,3	9,9	15 000	15-30	169	8,5	20,0	1,3	67	1,5	0,03	2,2	53	13	0,29
	"	203-355	58	12	7	7	2	34	38	9,3	9,9	18 000	15-30	140	2,4	16,4	1,3	97	1,7	0,03	3,7	68	25	0,30
	"	355+	37	41	11	8	2	16	23	9,3	9,9	18 500	15-30	230	3,6	11,4	1,0	92	1,4	0,03	2,9	69	19	0,31
	Mabua Sehube pan edge (inner)	0-381	99	13	27	37	10	7	9	8,2	9,0	100	15-30	1,4	1,3	16,8	2,1	0,10	0,06	0,15	0,18	0,04	0,07	0,31
		381-635	100	9	24	37	6	8	15	9,1	10,2	1 750	15-30	18	0,88	26,9	3,6	7,2	0,10	0,04	0,7	5,5	1,7	0,22
		635-914	41	17	22	30	5	10	16	9,3	10,0	2 800	15-30	27	1,5	26,0	1,5	12	0,26	0,06	0,7	9,0	3,1	0,29
	Mabua Sehube pan edge (outer)	0-609	99	13	26	40	9	6	7	8,2	9,0	85	15-30	0,87	0,68	18,1	1,7	0,06	0,03	0,17	0,13	0,10	0,04	0,34
		609-914	2								9,5	420	15-30											0,15
	Mabua Sehube pan bank	0-762	100	11	31	42	7	5	5	8,2	9,1	70	15-30	0,11	0,30	15,6	0,9	0,04	0,02	0,10	0,08	0,02	0,04	0,14
		762-1 524	100	5	28	43	9	7	7	8,3	9,2	90	15-30	0,23	0,49	16,4	1,8	0,07	0,03	0,05	0,09	0,04	0,03	0,12
	Mabua Sehube pan dune	0-609	100	5	36	45	7	3	4	7,6	8,8	40	0-1	0,02	0,16	2,0	0,7	0,02	0,02	0,09	0,07	0,03	0,02	0,12
		609+	100	3	34	47	9	3	5	8,1	9,2	50	2-5	0,06	0,08	7,8	0,9	0,02	0,01	0,12	0,09	0,03	0,02	0,11
Khutse Game Reserve	Khutse 2 pan floor	0-100	100	1	7	45	12	17	19	7,9	9,0	60	17	0,10	0,48	18,0	1,6	0,02	0,02	0,3	0,1	0,06	0,03	0,76
	Khutse 2 pan edge	0-100	100	1	10	64	13	3	8	7,8	8,2	50	4	0,05	0,18	9,6	0,6	0,005	0,02	0,2	0,2	0,05	0,02	0,30
	Khutse 2 pan bank	0-100	100	0,2	12	65	13	4	5	7,3	8,2	20	1	0,02	0,10	1,5	0,6	0,005	0,003	0,3	0,08	0,03	0,02	0,17
	Sandveld 100 m from Khutse 2 pan floor	0-100	100	0,3	10	64	18	3	4	6,5	7,7	20	0,5	0,01	0,15	1,2	1,0	0,005	0,01	0,1	0,01	0,04	0,03	0,21

Appendix 2 : Soil properties of various pan floor soils in the Central Kalahari, Botswana. Soil samples were taken at the sites and depths indicated and the figures are the results of routine laboratory analyses

AREA	SITE	DEPTH IN MM	PARTICLE SIZE DISTRIBUTION IN PER CENT							pH		ELECTRICAL CONDUCTIVITY 1:5 SUSPENSION IN U mhos	PER CENT CALCIUM CARBONATE	GROSS EXTRACTABLE CATIONS Meg 100 g				SATURATED PASTE SOLUBLE CATIONS Me / 100 g			SATURATED PASTE SOLUBLE ANIONS Me / 100 g			PER CENT CARBON
			Fine earth	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Calcium chloride .02 N 1:5 suspension	Water 2:5 suspension			Na	K	Ca	Mg	Na	K	Ca + Mg	HCO_3	Cl	SO_4	
Mabua Sehube Game Reserve	Khiding pan floor	0-100	100	1	6	17	5	21	50	8,1	8,5	1 100	47	4,3	2,3	18,7	6,8	3,5	0,5	3,4	0,1	4,2	1,9	1,06
	Lesholwago pan floor	0-100	96	5	10	26	8	21	30	8,9	9,5	5 200	48	32	44	13,8	0,8	28	3,1	0,4	0,7	25,2	5,0	0,76
Kuli-Nojane	Kuli pan floor	0-100	95	13	20	42	11	7	6	7,8	8,2	100	26	0,15	0,95	17,8	0,5	0,08	0,05	0,4	0,3	0,5	0,1	0,81
	Ukwi pan floor	0-100	100	2	7	19	8	12	52	8,3	8,8	5 050	36	36	2,6	17,0	4,3	25	0,73	2,0	0,2	28	0,6	0,33
Khutse Game Reserve	Khutse 1 pan floor	0-100	100	0,3	9	60	14	5	12	7,9	8,8	50	6	0,06	0,29	11,5	0,9	0,007	0,01	0,3	0,1	0,07	0,02	0,46
	Muhurushele pan floor	0-100	97	5	8	49	11	13	15	7,9	8,3	100	22	0,14	0,62	16,9	1,6	0,01	0,01	0,5	0,2	0,4	0,04	0,84

Appendix 3 : Soil properties of various salt-licks on pans in the Central Kalahari, Botswana, compared with the soil properties of the adjacent pan floor soil. Soil samples were taken at the sites and depths indicated and the figures are the results of a routine laboratory analysis

AREA	SITE	DEPTH IN MM	PARTICLE SIZE DISTRIBUTION IN PER CENT							pH		ELECTRICAL CONDUCTIVITY 1:5 SUSPENSION IN U mhos	PER CENT CALCIUM CARBONATE	GROSS EXTRACTABLE CATIONS Meg 100 g				SATURATED PASTE SOLUBLE CATIONS Me / 100 g			SATURATED PASTE SOLUBLE ANIONS Me / 100 g			PER CENT CARBON
			Fine earth	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	Calcium chloride .02 N 1:5 suspension	Water 2:5 suspension			Na	K	Ca	Mg	Na	K	Ca + Mg	HCO_3	Cl	SO_4	
Khutse Game Reserve	Muhurushele pan floor	0-100	97	5	8	49	11	13	15	7,9	8,3	100	22	0,14	0,62	16,9	1,6	0,01	0,01	0,5	0,2	0,4	0,04	0,84
	Muhurushele salt-lick	200-300	85	4	7	36	10	18	25	8,0	8,4	1 300	39	5,4	2,4	20,1	0,8	5,0	1,3	2,9	0,2	7,6	0,8	0,83
	Khutse 1 pan floor	0-100	100	0,3	9	60	14	5	12	7,9	8,8	50	6	0,06	0,29	11,5	0,9	0,007	0,01	0,3	0,1	0,07	0,02	0,46
	Khutse 1 salt-lick	200-400	89	2	8	44	13	13	21	8,1	9,0	100	17	0,36	0,35	19	0,4	0,12	0,05	0,15	0,1	0,2	0,06	0,36
	Khutse 2 pan floor	0-100	100	1	7	45	12	17	19	7,9	9,0	60	17	0,10	0,48	18	1,6	0,02	0,02	0,3	0,1	0,06	0,03	0,76
	Khutse 2 salt-lick	200-400	69	4	10	47	10	12	16	8,0	9,2	90	21	0,26	0,32	19	1,1	0,09	0,05	0,2	0,15	0,1	0,09	0,60
Mabua Sehube Game Reserve	Mabua Sehube pan edge	0-380	99	13	27	37	10	7	9	8,2	9,0	100	15-30	1,4	1,3	16,8	2,1	0,10	0,06	0,15	0,18	0,04	0,07	0,31
	Mabua Sehube pan floor (used as a salt-lick)	0-200	96	2	5	11	4	30	47	9,3	9,9	15 000	15-30	160	8,5	20,0	1,3	67	1,5	0,03	2,2	53	13	0,29

Appendix 4 : Presence of open water in the seasonal water-holes on Khutse 2 Pan, Central Kalahari, Botswana. The water-holes on Khutse 2 Pan were inspected daily during 1970 and 1971 and the presence of water in the water-hole recorded

Day of the month	WATER IN WATER-HOLES																							
	1970												1971											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
1	o	–	o	o	o	o	–	–	–	–	o	–	x	–	x	o	–	–	–	–	–	–	–	x
2	o	–	o	o	o	o	–	–	–	–	o	x	x	–	x	o	–	–	–	–	–	–	–	x
3	o	–	o	o	o	o	–	–	–	–	o	o	–	–	x	o	–	–	–	–	–	–	–	o
4	o	–	o	–	o	o	–	–	–	–	o	o	x	–	x	o	–	–	–	–	–	–	–	x
5	o	–	o	–	o	o	–	–	–	–	o	o	x	–	–	o	–	–	–	–	–	–	–	x
6	o	–	o	o	o	o	–	–	–	–	o	o	x	–	–	o	o	–	–	–	–	–	x	x
7	o	–	o	o	–	o	–	–	–	–	o	–	x	–	–	o	–	–	–	–	–	–	–	x
8	o	–	o	o	–	o	–	–	–	–	o	–	–	–	x	o	–	–	–	–	–	–	–	x
9	o	–	o	–	–	o	–	–	–	–	o	–	–	–	x	o	–	–	–	–	–	–	–	x
10	–	–	o	–	–	o	–	–	–	–	o	–	–	o	x	o	–	–	–	–	–	–	–	x
11	–	–	o	–	–	o	–	–	–	x	o	–	–	o	x	o	–	–	–	–	–	–	–	x
12	–	–	o	–	–	o	–	–	–	x	o	–	–	–	x	x	–	–	–	–	–	–	–	x
13	–	–	o	–	–	o	–	–	–	x	o	–	x	–	–	–	–	–	–	–	–	–	–	x
14	–	–	o	–	–	o	o	–	–	o	o	–	x	–	–	–	–	–	–	o	–	–	–	x
15	–	–	o	–	–	o	o	–	–	o	o	–	x	x	–	–	–	–	–	–	–	–	x	x
16	–	–	o	–	–	o	o	–	–	o	o	–	x	x	–	–	–	–	–	–	–	x	x	x
17	–	–	o	–	–	o	–	o	–	o	o	–	x	x	–	–	–	–	–	–	–	x	x	x
18	–	–	o	–	–	o	o	–	–	o	o	–	x	x	–	–	–	–	–	–	–	x	x	x
19	–	–	o	–	–	o	o	–	–	o	o	–	x	x	–	–	–	–	–	–	–	–	x	x
20	–	–	o	–	–	o	o	–	o	o	o	x	x	x	–	x	–	–	–	–	–	–	x	x
21	–	–	o	–	–	o	–	–	–	o	o	x	x	–	–	–	–	–	–	–	–	–	x	x
22	–	–	o	–	–	o	–	–	–	o	o	x	x	–	–	–	–	–	–	–	–	–	x	x
23	–	–	o	–	–	o	–	–	–	o	o	x	x	x	–	–	–	–	–	–	–	–	x	x
24	–	–	o	–	–	–	–	–	–	o	o	–	–	x	o	–	–	–	–	–	–	–	x	x
25	–	–	o	–	–	–	–	–	–	o	o	x	–	x	o	–	–	–	–	–	–	–	x	x
26	–	–	o	–	–	–	–	–	–	o	–	x	o	x	o	–	–	–	–	–	–	–	x	x
27	–	o	o	–	–	x	–	–	–	o	–	x	o	x	o	–	–	–	–	–	–	–	x	x
28	–	o	o	o	–	x	–	–	–	o	–	–	o	x	o	–	–	–	–	–	–	–	x	x
29	–		o	o	–	–	–	–	–	o	–	–	–		o	–	–	–	–	–	–	–	o	x
30	–		o	o	–	–	–	–	–	o	–	x	–		o	–	–	–	–	–	–	–	o	x
31	–		o		–		–	–		o		x	–		o		–		–	–		–		x

x = open water present   – = no water present   o = no data

Appendix 5 : Percentage ground cover (i.e. rooted plants and plant canopy) of perennial grasses and woody plants (shrubs and trees) on and around pans in the Central Kalahari, Botswana. The percentage ground cover was determined during the dry season at the sites indicated. Forbs and annual grasses did not contribute significantly to the dry season ground cover. Measurements of pan vegetation were done on the section of the pan floor with the best perennial grass cover. (No data indicated by a dash)

PAN	YEAR	PER CENT GROUND COVER											
		Pan floor		Pan edge		Pan bank		Pan rim		Sandveld 1,6 km from pan		Sandveld 3,2 km from pan	
		G	W	G	W	G	W	G	W	G	W	G	W
Mpatutlwa	1968	42	0	12	7	–	–	22	15	20	9	20	4
	1969	25	1	4	17	–	–	–	–	–	–	–	–
	1970	24	0	1	9	–	–	–	–	–	–	–	–
	1971	46	1	7	15	–	–	–	–	–	–	–	–
	mean	34,3	0,5	6,0	12,0			22,0	15,0	20,0	9,0	20,0	4,0
Bosho Bogolo	1968	29	0	11	6	11	30	23	3	21	3	24	5
	1969	38	1	7	9	2	42	–	–	–	–	–	–
	1970	33	0	10	13	4	33	–	–	–	–	–	–
	1971	26	1	3	8	1	35	–	–	–	–	–	–
	mean	31,5	0,5	7,8	9,0	4,5	35,0	23,0	3,0	21,0	3,0	24,0	5,0
Leshol-wago	1968	31	1	–	–	–	–	15	15	9	11	11	6
	1969	25	0	5	11	–	–	–	–	–	–	–	–
	1970	20	0	4	5	–	–	–	–	–	–	–	–
	1971	25	0	12	14	–	–	–	–	–	–	–	–
	mean	25,3	0,3	7,0	10,0			15,0	15,0	9,0	11,0	11,0	6,0
Khiding	1969	28	0	16	10	0	24	–	–	–	–	–	–
	1970	23	0	7	5	–	–	–	–	–	–	–	–
	1971	40	0	10	4	–	–	–	–	–	–	–	–
	mean	30,3	0,0	11,0	6,3	0,0	24,0						
Khutse 2	1969	23	0	7	6	–	–	23	19	24	10	30	8
	1970	12	0	5	3	–	–	–	–	–	–	–	–
	1971	7	0	7	6	–	–	–	–	–	–	–	–
	mean	14,0	0,0	6,3	5,0			23,0	19,0	24,0	10,0	30,0	8,0
Sutswane	1969	18	0	–	–	13	9	–	–	–	–	–	–
	1970	17	0	–	–	9	4	–	–	–	–	–	–
	1971	18	0	–	–	13	10	–	–	–	–	–	–
	mean	17,7	0,0			11,7	7,7						
All pans	mean	25,2	0,2	7,6	8,5	4,0	19,9	20,7	13,0	18,5	8,2	21,2	5,7

G = perennial grass W = woody plants

Appendix 6 : Average height in mm of the perennial grasses and woody plants (shrubs and trees) during the dry season on and around pans in the Central Kalahari, Botswana. Plant height was recorded as part of routine vegetation assessments from 1968 to 1972 at the sites indicated. Measurements of pan vegetation were done on the section of the pan floor with the best perennial grass cover (No data indicated by a dash)

PAN	YEAR	AVERAGE PLANT HEIGHT IN MM											
		Pan floor		Pan edge		Pan bank		Pan rim		Sandveld 1,6 km from pan		Sandveld 3,2 km from pan	
		G	W	G	W	G	W	G	W	G	W	G	W
Mpatutlwa	1968	51,5	–	76,2	123,3	–	–	721,3	1 513,8	444,5	1 608,6	613,8	1 828,8
	1969	28,7	177,8	14,2	161,3	–	–	–	–	–	–	–	–
	1970	12,1	–	6,3	174,9	–	–	–	–	–	–	–	–
	1971	108,7	152,4	72,5	149,0	–	–	–	–	–	–	–	–
	mean	50,3	165,1	42,3	152,1			721,3	1 513,8	444,5	1 608,6	613,8	1 828,8
Bosho Bogolo	1968	131,4	–	12,7	152,4	762,0	411,4	575,7	1 117,6	387,3	1 219,2	541,8	1 463,0
	1969	266,9	101,6	19,9	135,4	304,8	361,0	–	–	–	–	–	–
	1970	224,7	–	28,8	128,9	184,1	441,0	–	–	–	–	–	–
	1971	52,7	152,0	59,2	104,7	50,8	424,5	–	–	–	–	–	–
	mean	168,9	126,8	28,7	130,4	325,4	409,5	575,7	1 117,6	387,3	1 219,2	541,8	1 463,0
Leshol-wago	1968	88,9	152,4	–	–	–	–	450,8	1 178,5	440,2	1 188,7	965,2	889,0
	1969	160,5	–	12,7	154,7	–	–	–	–	–	–	–	–
	1970	37,4	–	25,4	162,5	–	–	–	–	–	–	–	–
	1971	60,9	–	–	132,4	–	–	–	–	–	–	–	–
	mean	86,9	152,4	17,6	149,9			450,8	1 178,5	440,2	1 188,7	965,2	889,0
Khiding	1969	263,9	–	17,4	160,0	–	511,1	–	–	–	–	–	–
	1970	28,7	–	7,2	162,5	–	–	–	–	–	–	–	–
	1971	436,2	–	6,3	114,3	–	–	–	–	–	–	–	–
	mean	242,9		10,3	145,6		511,1						
Khutse 2	1969	245,1	–	65,3	266,7	–	–	325,7	1 685,7	762,0	1 174,0	624,8	1 828,8
	1970	17,4	–	15,2	254,0	–	–	–	–	–	–	–	–
	1971	39,9	–	30,8	190,5	–	–	–	–	–	–	–	–
	mean	100,8		37,1	237,0			325,7	1 685,7	762,0	1 174,0	624,8	1 828,8
Sutswane	1969	159,4	–	–	–	100,6	423,3	–	–	–	–	–	–
	1970	34,3	–	–	–	29,6	273,0	–	–	–	–	–	–
	1971	90,3	–	–	–	91,8	370,8	–	–	–	–	–	–
	mean	94,7				74,0	355,7						
All pans	mean	124,1	148,1	27,2	163,0	199,7	425,4	518,4	1 373,9	508,5	1 297,6	686,4	1 502,4

G = perennial grass W = woody plants

Appendix 7 : Smaller mammals of the Central Kalahari, Botswana, (after Smithers 1971 and corrected for 1976 taxonomic status). The mammals are listed and their presence on pans or pan-like habitat indicated

MAMMAL		RECORDED ON PANS OR PAN-LIKE HABITAT
Common name	Species	
Short-eared elephant shrew	*Macroscelides proboscideus*	Yes (restricted to the extreme south-west)
Bushveld elephant shrew	*Elephantulus intufi*	Yes
Lesser red musk shrew	*Crocidura hirta*	Has a wide habitat tolerance
Egyptian freetailed bat	*Tadarida aegyptiaca*	Favours open country
Cape serotine bat	*Eptesicus capensis*	Has a wide habitat tolerance
Dent's horseshoe bat	*Rhinolophus denti*	No
Pangolin	*Manis temmincki*	Has a wide habitat tolerance
Aardwolf	*Proteles cristatus*	Yes
Caracal	*Felis caracal*	Has a wide habitat tolerance
Wild cat	*Felis libyca*	Yes
Blackfooted cat	*Felis nigripes*	Yes
Bat-eared fox	*Otocyon megalotis*	Yes, typically
Cape fox	*Vulpes chama*	Yes
Black-backed jackal	*Canis mesomelas*	Yes
Honey badger	*Mellivora capensis*	Has a wide habitat tolerance
Striped polecat	*Ictonyx striatus*	Has a wide habitat tolerance
Small-spotted genet	*Genetta genetta*	Has a wide habitat tolerance
Suricate	*Suricata suricatta*	Yes, typically
Yellow mongoose	*Cynictis penicillata*	Yes
Slender mongoose	*Herpestes sanguineus*	Has a wide habitat tolerance
Antbear	*Orycteropus afer*	Has a wide habitat tolerance
Scrub hare	*Lepus saxatilis*	Yes
Cape hare	*Lepus capensis*	Yes
Damara mole-rat	*Cryptomys damarensis*	No
Porcupine	*Hystrix africaeaustralis*	Has a wide habitat tolerance
Springhare	*Pedetes capensis*	Yes
Dormouse	*Graphiurus murinus*	Has a wide habitat tolerance
Ground squirrel	*Xerus inauris*	Yes
Brant's karroo rat	*Parotomys brantsii*	Yes (restricted to the south-west)
Four-striped mouse	*Rhabdomys pumilio*	Yes
Pygmy mouse	*Mus minutoides*	Has a wide habitat tolerance
Tree rat	*Thallomys paedulcus*	No
Namaqua rock rat	*Aethomys namaquensis*	Yes
Namaqua gerbil	*Desmodillus auricularis*	Yes
South African pygmy or lesser gerbil	*Gerbillurus paeba*	No
Bushveld gerbil	*Tatera leucogaster*	Has a wide habitat tolerance (not found in the extreme south-west)
Brant's gerbil	*Tatera brantsii*	Has a wide habitat tolerance
Pouched mouse	*Saccostomus campestris*	Has a wide habitat tolerance
Long-eared desert mouse	*Malacothrix typica*	Yes

Appendix 8 : Monthly and annual daily mean number of the larger animals recorded at pans in the Central Kalahari, Botswana. Daily animal counts were done at Mabua Sehube and weekly counts at Lesholwago and Mpatutlwa from 10th April 1968 to 31st March 1969, and daily counts were done at Khutse 2 from 10th January 1970 to 31st December 1971

ANIMAL	PAN	DAILY MEAN NUMBER OF ANIMALS												
		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Springbok	Mabua Sehube	51,7	61,0	68,9	33,8	64,8	54,9	124,7	63,5	43,9	26,7	13,3	162,6	64,2
	Lesholwago	40,0	19,0	80,5	67,0	89,3	56,0	84,3	46,6	76,3	18,3	5,3	10,0	49,3
	Mpatutlwa	42,7	27,5	79,0	137,5	42,3	85,3	61,8	43,6	62,2	13,5	31,8	49,0	56,4
	Khutse 2	29,7	68,3	146,0	29,4	24,4	10,7	11,2	10,8	7,8	8,7	31,7	42,8	35,1
Red hartebeest	Mabua Sehube	2,8	10,3	24,0	21,7	10,3	28,8	21,1	16,2	3,2	3,8	1,9	0,5	12,1
	Lesholwago	3,5	9,0	16,3	12,0	5,8	8,7	15,0	6,2	0,0	0,0	2,0	6,3	7,1
	Mpatutlwa	3,0	2,5	19,6	15,3	5,0	20,5	16,2	7,6	1,5	5,5	4,0	1,3	8,5
	Khutse 2	21,4	25,6	0,0	18,3	11,7	2,1	1,1	0,4	1,8	5,6	6,5	2,9	8,1
Blue wildebeest	Mabua Sehube	0,6	0,1	0,5	0,5	0,8	2,5	8,3	14,6	3,3	0,4	1,2	0,0	2,7
	Lesholwago	1,5	0,0	0,5	13,3	1,0	3,3	3,8	13,0	0,7	3,3	0,0	0,0	3,4
	Mpatutlwa	0,0	0,0	0,2	0,3	0,0	2,5	0,7	0,2	0,0	0,0	0,5	1,7	0,5
	Khutse 2	1,8	1,4	0,0	20,7	0,7	0,6	0,5	0,2	3,8	1,0	0,1	2,6	2,8
Gemsbok	Mabua Sehube	3,3	2,1	9,4	3,5	1,5	3,4	6,3	11,2	2,0	5,8	1,2	0,8	4,2
	Lesholwago	6,5	2,5	26,0	8,7	47,0	10,0	13,8	15,4	3,3	15,3	4,3	0,0	12,7
	Mpatutlwa	2,7	7,3	16,2	13,7	9,2	19,7	10,8	8,2	3,3	8,3	3,0	9,0	9,3
	Khutse 2	0,0	0,0	0,0	0,2	0,6	0,0	0 ,2	0,1	0,1	0,3	0,1	0,0	0,1
Kudu	Mabua Sehube	0,0	0,0	0,0	0,0	0,0	0,0	0, 0	0,0	0,0	0,0	0,0	0,0	0,0
	Lesholwago	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Mpatutlwa	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Khutse 2	0,1	0,0	0,0	0,1	1,4	0,2	0,3	0,1	0,3	0,0	0,0	0,0	0,2
Eland	Mabua Sehube	9,8	0,3	0,8	0,0	1,9	0,5	1,9	3,0	6,0	19,9	1,0	0,0	3,8
	Lesholwago	7,0	0,0	0,0	0,0	24,0	10,0	14,0	4,0	0,3	13,7	0,0	0,0	6,1
	Mpatutlwa	4,0	0,0	0,0	0,0	1,8	2,0	6,3	0,0	3,3	1,8	2,3	0,0	1,8
	Khutse 2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ostrich	Mabua Sehube	2,1	1,9	10,4	11,0	3,3	10,2	11,6	12,9	3,0	4,3	0,3	0,5	6,0
	Lesholwago	1,5	1,0	13,0	4,3	4,5	9,3	8,8	11,0	1,3	5,0	4,3	2,3	6,5
	Mpatutlwa	5,0	2,0	25,0	2,0	2,5	10,0	11,8	15,6	4,2	3,8	0,5	0,0	6,9
	Khutse 2	1,0	0,6	0,3	0,3	0,7	0,1	0,4	0,7	0,3	0,2	0,2	1,5	0,5
Lion	Mabua Sehube	0,1	0,1	0,0	0,7	0,3	0,2	0,5	0,0	0,2	0,0	0,0	0,0	0,2
	Lesholwago	0,3	0,0	0,0	0,7	0,3	0,0	0,7	0,0	0,0	0,0	0,0	0,0	0,2
	Mpatutlwa	0,0	0,3	0,0	0,3	0,0	0,8	0,2	0,0	0,0	0,0	0,8	0,0	0,2
	Khutse 2	0,0	0,0	0,0	0,2	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,03
Wild dog	Mabua Sehube	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Lesholwago	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Mpatutlwa	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	Khutse 2	0,0	0,1	0,7	0,1	0,2	0,1	0,1	0,0	0,0	0,0	0,2	0,1	0,2

Appendix 9 : Density of large ungulate, springhare and hare pellet groups on and around pans in the Central Kalahari, Botswana. The figures are the average number of pellet groups per 20 plots (each plot 3, 8 m^2) recorded during the dry season at the sites indicated. Pellet counts on the pan floor were done on the section with the best perennial grass cover. (No data indicated by a dash)

PAN	YEAR	NUMBER OF PELLET GROUPS																	
		Pan floor			Pan edge			Pan bank			Pan rim			Sandveld 1,6 km from pan			Sandveld 3,2 km from pan		
		G	M	H	G	M	H	G	M	H	G	M	H	G	M	H	G	M	H
Mpatutlwa	1968	6,3	27,7	0,5	0,7	13,3	0,5	–	–	–	0,0	0,0	4,0	0,0	0,3	6,0	0,3	0,7	6,0
	1969	1,0	9,3	2,5	2,7	25,0	3,0	–	–	–	–	–	–	–	–	–	–	–	–
	1970	4,0	15,3	10,5	1,7	31,3	3,0	–	–	–	–	–	–	–	–	–	–	–	–
	1971	3,3	7,0	0,0	0,3	18,7	3,0	–	–	–	–	–	–	–	–	–	–	–	–
	mean	3,7	14,8	3,4	1,4	22,1	2,4				0,0	0,0	4,0	0,0	0,3	6,0	0,3	0,7	6,0
Bosho Bogolo	1968	10,3	6,3	1,5	2,3	13,6	0,0	2,3	4,6	3,5	0,3	0,3	12,5	0,0	0,0	10,0	0,0	0,0	9,5
	1969	10,3	2,6	0,0	4,7	17,0	4,0	1,7	4,0	2,5	–	–	–	–	–	–	–	–	–
	1970	13,0	7,0	11,0	7,0	19,6	10,5	4,3	2,0	10,0	–	–	–	–	–	–	–	–	–
	1971	5,7	5,6	9,0	4,0	19,6	9,5	3,3	1,6	9,0	–	–	–	1,0	0,7	6,0	0,0	–	–
	mean	9,8	5,4	5,4	4,5	17,5	6,0	2,9	3,1	6,3	0,3	0,3	12,5	0,5	0,7	8,0	0,0	0,0	9,5
Lesholwago	1968	3,3	12,0	3,0	–	–	–	–	–	–	0,0	0,0	13,5	0,3	0,0	11,5	0,0	0,0	8,5
	1969	2,3	8,7	7,0	1,0	24,0	1,0	–	–	–	–	–	–	–	–	–	–	–	–
	1970	5,3	22,3	6,5	1,0	30,7	3,5	–	–	–	–	–	–	–	–	–	–	–	–
	1971	8,0	15,3	7,5	3,0	25,7	3,0	–	–	–	–	–	–	–	–	–	–	–	–
	mean	4,7	14,6	6,0	1,7	26,8	2,5				0,0	0,0	13,5	0,3	0,0	11,5	0,0	0,0	8,5
Mabua Sehube	1968	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0,0	0,0	4,0
	1969	–	–	–	2,7	20,7	10,5	–	–	–	–	–	–	–	–	–	–	–	–
	1970	–	–	–	6,7	16,3	11,0	–	–	–	–	–	–	–	–	–	–	–	–
	1971	–	–	–	6,3	26,7	10,5	–	–	–	1,7	14,7	4,0	1,0	0,3	6,0	–	–	–
	mean				5,2	21,2	10,7				1,7	14,7	4,0	1,0	0,3	6,0	0,0	0,0	0,0
Khiding	1969	10,7	5,0	7,0	12,0	11,7	6,5	3,0	1,7	10,5	–	–	–	–	–	–	–	–	–
	1970	21,7	7,0	3,0	8,7	10,7	4,0	–	–	–	–	–	–	–	–	–	–	–	–
	1971	12,0	2,7	0,0	7,0	6,7	0,0	–	–	–									
	mean	14,8	4,9	3,3	9,2	9,7	3,5	3,0	1,7	10,5									
Khutse 2	1969	1,7	9,0	2,0	0,3	5,3	8,5				0,3	2,3	4,5	0,3	3,3	8,0	2,0	2,3	10,0
	1970	4,3	8,3	1,0	2,0	7,3	6,5	–	–	–	–	–	–	–	–	–	–	–	–
	1971	2,3	10,7	9,0	0,3	6,0	8,0	–	–	–	–	–	–	–	–	–	–	–	–
	mean	2,8	9,3	4,0	0,9	6,2	7,7				0,3	2,3	4,5	0,3	3,3	8,0	2,0	2,3	10,0
All pans	mean	7,2	9,8	4,4	3,8	17,3	5,5	3,0	2,4	8,4	0,5	3,5	7,7	0,4	0,9	7,9	0,5	0,6	6,5

G = large ungulate grazers i.e. gemsbok, red hartebeest and blue wildebeest

M = large ungulate browsers and mixed feeders i.e. kudu, eland and springbok

H = springhares and hares

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