OBSERVATION ON WATERHOLE

UTILIZATION BY WILD GAME

IN TSAVO NATIONAL PARK (EAST)

BY

JULIUS SANDE OLALEYE AYENI

A THESIS SUBMITTED IN PART

FULFILMENT OF THE DEGREE OF MASTER

OF SCIENCE (BIOLOGY OF CONSERVATION)

IN

THE UNIVERSITY OF NAIROBI

1974

"AS THE HART PANTETH AFTER THE WATER BROOKS SO PANTETH MY SOUL AFTER THEE..............."

PSALMS 42:1

DECLARATIONS

1. I, Julius Sande Olaleye Ayeni declare that this thesis is my original work and has not been presented for a degree in any other University.

Signature------[signature]------

Date ---27th. November 1974---

2. I, John B. Sale declare that this thesis has been submitted for examination with my approval as University Supervisor.

Signature---John B. Sale---

Date---27 November 1974---

TABLE OF CONTENTS

ABSTRACT

The pattern of waterhole utilization was established for the 24-hours of the day and for the dry and rainy seasons. The utilization of artificial waterholes was dominated by the small ungulates during the daylight hours and by the larger ungulates during the night. When air temperature was high game visits were low. During the hours of darkness the average number of game visits per hour of observation was lower than during daylight hours. During the dry season wildlife visits were more frequent at the waterholes than during the rainy season.

The distribution of wildlife in relation to the artificial waterholes was determined. During the dry season wildlife species aggregated around the waterholes which still contained drinking water. The intensity of utilization of the artificial waterholes was highest during the dry season and lowest during the rains when wildlife dispersed away from the dry season water supplies drinking from the natural waterholes, formed in the zoogeneous clay pans.

The chemical composition of water samples from several natural and artificial waterholes was determined; it was found to fluctuate throughout the year, with low values during the rains and high values during the dry season. At the peak of the dry season the composition of the water samples from the boreholes was very high in several minerals.

The management implications of the study was discussed. It was noted that the patterns of utilization of artificial waterholes had resulted in the removal of woody vegetation from around the waterholes and this effect was most profound around Aruba dam, the largest and oldest artificial waterhole in the park. It was suggested that more studies should be undertaken to determine the effects of the high mineral contents of the water from the boreholes on the animals. It was recommended that further development of artificial waterholes in the soil types consisting primarily of montmorillonite clays should be discontinued.

ACKNOWLEDGEMENTS

The work reported here could not have been done without the assistance from many organizations and people particularly Dr. J. B. Sale, Associate Professor of Zoology, University of Nairobi, who kindly supervised the research, read through the manuscripts and gave useful suggestions about the Thesis. I am grateful to the Kenya National Parks for granting me the permission to work in Tsavo National Park (East) under the supervision of Dr. Walter Leuthold, Biologist of Tsavo Research Project. The Park Warden, Major D. L. W. Sheldrick; the Chief Biologist, Dr. P. E. Glover; Mr. T. R. H. Morgan, the East African Wildlife Society Pilot; and the junior members of Tsavo Research Project assisted me in various capacities during the field work. The Department of Zoology, University of Nairobi, provided me with a vehicle, and camping facilities; the Royal Netherlands Embassy funded my fellowship during the period of the research; and all soil, water, and plant samples collected during the study were analysed with the kind assistance of the National Agricultural Laboratories in Nairobi. I am grateful for the generous help from the organizations and persons concerned.

CHAPTER I

INTRODUCTORY ASPECTS OF WATERHOLE UTILIZATION IN TSAVO NATIONAL PARK (EAST), SOUTH OF VOI RIVER.

GENERAL INTRODUCTION

The Importance of drinking water to wildlife:

Water is a major nutrient requirement to all animals. Inspite of the importance of water to animals, very little research has been done to evaluate the significance of drinking water to the ecology of African wild game.

The water requirement of ruminants are supplied in part from water consumed voluntarily (through drinking), in part from water which is present in the food and from the water formed within the body as the result of oxidation in the tissues.

The daily requirement of African Wildlife for drinking water has been used to describe them as "Water-dependent" and "Water-independent" species. In the Amboseli ecosystem for instance the water-dependent species were regularly censused near drinking water supplies but the water-independent species were often encountered at over 18 kilometers from known sources of water (Western, 1973). No animal is truly water-independent but animals differ in their abilities to subsist on very little or in some cases no drinking water, and to withstand extreme drought conditions.

Various factors influence the volume of water-intake required for the maintenance of normal growth, fattening, later stages of pregnancy, and lactation. The water-intake of an animal varies with the ambient air temperature (Finch, 1972) and the physiological condition of the animal (A.R.C., 1965). Water intake per unit of dry matter is higher for low levels of dry matter eaten by wildlife (Jarman, 1973). High protein foods

(Taylor, Spinage and Lyman, 1969) and salty diets are associated with higher water intake (Macfarlane, Howard and Siebert, 1967).

African mammals differ in the ability to "economise" water and the difference are reflective of their relative ability to withstand aridity and to colonise habitats which are far away from free water supplies. In order to maintain water balance in an arid environment, animals economise water through the production of dry faeces, concentrated urine, and by reducing evaporative water losses (panting and sweating). The water turnover rate is closely correlated with metabolic rate which is high in some desert animals (eland) with high water turnover and low in others (oryx) which are more arid adapted and economise water better (Macfarlane and Howard, 1972).

In the wild, game species obtain drinking water through natural and sometimes artificial supplies. The natural sources of drinking water are: rivers, springs, lakes and natural waterholes (pans) filled with rain water. The artificial water supplies are: boreholes, dams and reservoirs. Thus, the quality and availability of water for wildlife vary according to the season and the location of the habitat.

Previous studies on waterhole utilization:

Despite the frequent occurrence of the natural waterholes and the management policies resulting in the creation of additional artificial waterholes in many Natural Parks and Game Reserves there has been no field study of waterholes utilization in East Africa. Only a few ecological studies at the Kruger National Park, South Africa (Young, 1970) and Rhodesia in Central Africa (Weir, 1960, 1971, and 1972) have shed some light on certain aspects of waterhole utilization by indigenous African wildlife.

Weir and Davidson (1965) recorded the daily occurrence of African game animals at waterholes in Wankie National Park, Rhodesia. The main defects of the study (Weir, and Davidson, 1965) were that the investigations provided information for only the few days during the dry season when the moon was full, and that there was no information on game visits to the waterholes during the nights. During moonlit nights some animals possibly grazed late and drank for a much longer period of the night than on moonless nights.

Jarman (1972) studied the seasonal distribution of large mammals in the unflooded Middle Zambezi Valley above Lake Kariba in Rhodesia. The study provided some quantitative evidence to substantiate his observations (Jarman, 1972) that some wildlife differentially utilized the areas near to the Lake during the dry season.

Weir (1960) described how some natural waterholes could have evolved in the erosion surfaces at the bases of termite mounds through the activities of wildlife at Wankie National

Park. The effects of creating additional artificial waterholes in the same Park were also studied by Weir (1971). He concluded that the creation of the artificial waterholes initiated processes which would eventually alter the environment, and necessitated continuous revision of management policies. Weir (1972) demonstrated that elephants were being attracted by the sodium content of the waterholes. The elephants aggregated around the waterholes with high concentrations of water soluble sodium at Wankie National Park.

The Objectives of the present study:

From April, 1973 to July, 1974 a study of artificial waterhole utilization by game in Tsavo National Park (East) was undertaken in order to assess the desirability of creating more artificial waterholes in the park. The objectives of the study were:

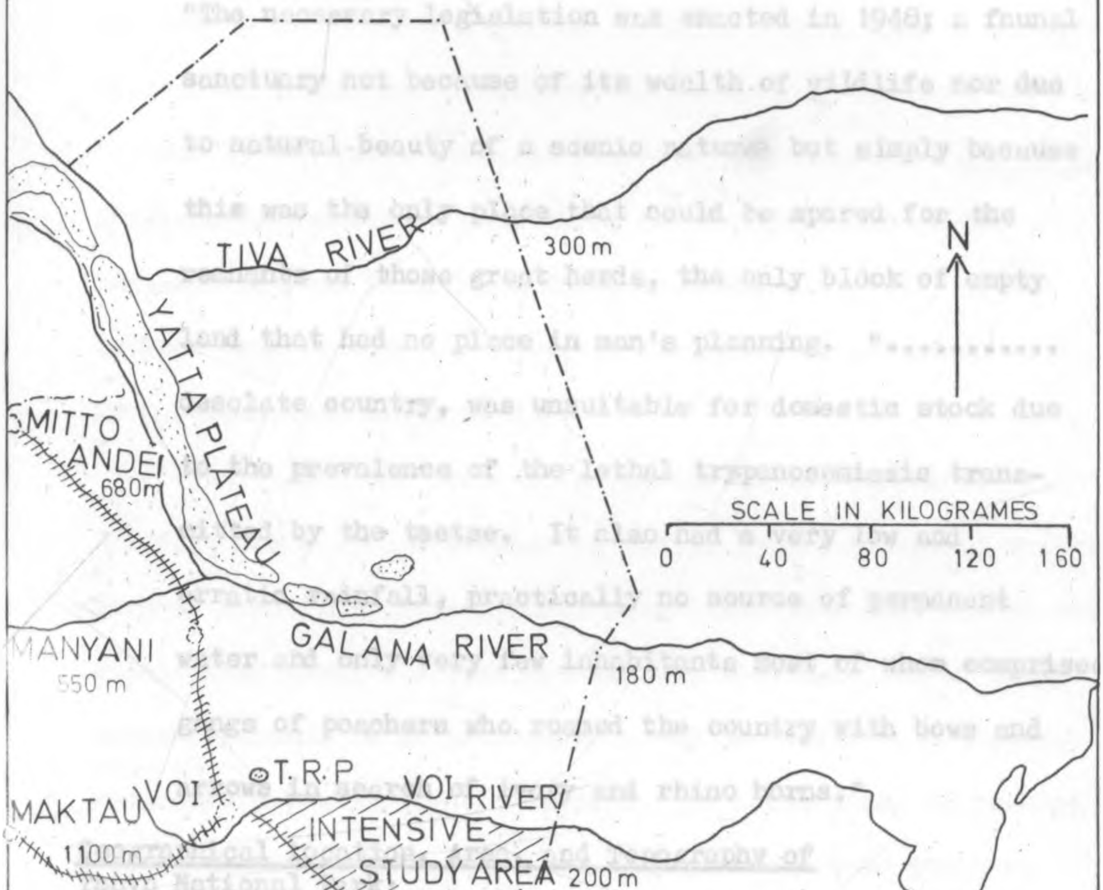
1) to establish the daily and seasonal patterns of waterhole utilization;
2) to describe the seasonal distribution of wild game in relation to the waterholes;
3) to determine the seasonal changes in the mineral content of water samples from the waterholes, and
4) to use 1), 2) and 3) in considering management implications of creating additional waterholes in the park.

EVENTS LEADING UP TO THE PRESENT STUDY

Creation of Tsavo National Park:

Tsavo National Park was carved out from an area of land which was considered to be unsuitable for agriculture and unlikely

Figure 1:1
A map showing the location of the intensive study area in Tsavo National Park (East), South Eastern Kenya.



to be required for any other form of land-use in the foreseeable future. Sheldrick (1973) summarised the background history of Tsavo National Park as follows:

"The necessary legislation was enacted in 1948; a faunal sanctuary not because of its wealth of wildlife nor due to natural beauty of a scenic nature but simply because this was the only place that could be spared for the remnants of those great herds, the only block of empty land that had no place in man's planning. "........... desolate country, was unsuitable for domestic stock due to the prevalence of the lethal trypanosomiasis transmitted by the tsetse. It also had a very low and erratic rainfall, practically no source of permanent water and only very few inhabitants most of whom comprised gangs of poachers who roamed the country with bows and arrows in search of ivory and rhino horns."

Geographical location, Area, and Topography of Tsavo National Park:

Tsavo National Park is an area of 20,000km^2 situated in south-eastern Kenya, roughly midway between Nairobi and Mombasa. The Nairobi-Mombasa railway-line and tarmac road divide the park into two administrative units; Tsavo National Park West (7,500km^2), and Tsavo National Park East (12,500km^2). Most of Tsavo East National Park (TsE) is flat country the altitude of the region increasing gently westwards from the Indian Ocean coast through the eastern border of the park (200m a.s.l.) to the western side of the park (500m a.s.l.) where occasional granitic hills reach about 900m above the sea level (Fig. 1:1)

History of Ecological Research at Tsavo:

In 1967 the Tsavo Research Project which was funded by the Ford Foundation at the request of the Government of Kenya, was set up in the park (TsE) to initiate a programme of wildlife ecological research. Glover (1974) summarised the work undertaken to-date by the Tsavo Research Project. The elephant (Loxodonta Africana Blumenbach) constituting about two-thirds of the ungulate biomass of TsE (Leuthold and Leuthold, 1973) is the largest game species and receives the greatest attention both from researchers and tourists.

TsE ecological problem number one is the elephant. Briefly, the elephant problem in TsE is their widespread destruction of the original woodland. Until 1969 when fire breaks were constructed along the park boundaries, the reduction of woody cover continued to be pronounced along the western, southern, and eastern boundaries of the park. In these areas incidental fires originating outside the park (and from honey poachers inside the park) Often penetrated into the park and impeded the regeneration of woody vegetation. Thus, in TsE the original Commiphora woodland is being degraded by elephants and until recently by fire, into varying degrees of open and semi-open mosaics of Boscia - Platycelyphium - Sericocomopsis wooded grassland. One of the initial effects of the change is believe to be an increase in the populations of grassland-adapted species such as zebra, oryx, and kongoni, whereas woodland-adapted species such as rhinoceros and lesser kudu are thought to have decreased (Glover, 1963; Napier-Bax and Sheldrick, 1963; Agnew, 1968;

Laws, 1969; and Glover, 1974).

The mortality of about 300 rhinoceros (Dioceros bicornis L.) during the 1961 drought, was believed to be due to the comparative inability of rhinoceros to compete with elephant for browse and shade (Napier-Bax and Sheldrick 1963; Glover and Sheldrick, 1964). Laws (1970) suggested that the only feasible solution to the elephant problem, though repugnant, was the reduction of elephant population(s) through cropping programmes.

Although there was a lot of concern over the consequencies of TsE elephant-induced habitat change, the suggested work-plan for the management of elephant based on systematic cropping led only to further controversy. During the 1970-1971 drought, a high mortality of some 6,000 elephants, occurred mainly in TsE. Corfield (1973) suggested that the mortality had selectively removed some reproductive females and young animals, and improved the chances of survival of the existing population of elephants within TsE habitat. Thus cropping may not be the only feasible way of reducing the numbers of elephants within TsE to the carrying capacity of the habitat.

Elephant and other game moved near the Galana river in the dry season (Glover, 1963). During prolonged drought, the aggregation of game on the narrow riverine belts of Galana river resulted in over-utilization of the habitat and ultimately high game mortality of rhinoceros and elephants occurred in 1960-61 and 1970-1971 respectively. Thus additional water supplies were being developed in TsE in order to attract wildlife around them and away from the Galana river, the only permanent natural water supply in the park during the dry season.

THE STUDY AREA

During the study period, reconnaissance surveys were made on the ground and by air over most of Tsavo but because of limited time and logistics, an intensive study area confined within TsE, south of Voi river (Figure 1:1) was selected for observations. This study area comprised of a more open portion of the park with abundant natural waterholes and many artificial waterholes.

Geology and Hydrology:

The Basement System rocks underlying most of TsE are made up of gneisses and schists. The greater part of the park is covered by darkish-red, sandy loam with occasional stretches of black cotton soil in areas of impeded drainage (Butler, 1959). The erosion surface south of Galana is entirely of end tertiary peneplain and is younger than the sub-Miocene surface on which the Yatta Phonolites rest (Sanders, 1959, 1963; and Miller, 1952). Structurally the area appears to have undergone faulting a major evidence of which is the fault line running roughly NNE-SSW as a boundary between the Precambrian Basement rocks to the west and the Perinotriassic recent calcareous sediments (Duruma Sandstone) to the east.

The park is traversed by the Galana river, and several seasonal rivers, the major two being the Tiva to the north and Voi to the south (Fig. 1:2). Apart from the Galana river which is

Figure 1:2
A map showing the locations of the borehole trial sites in Tsavo National Park (East).

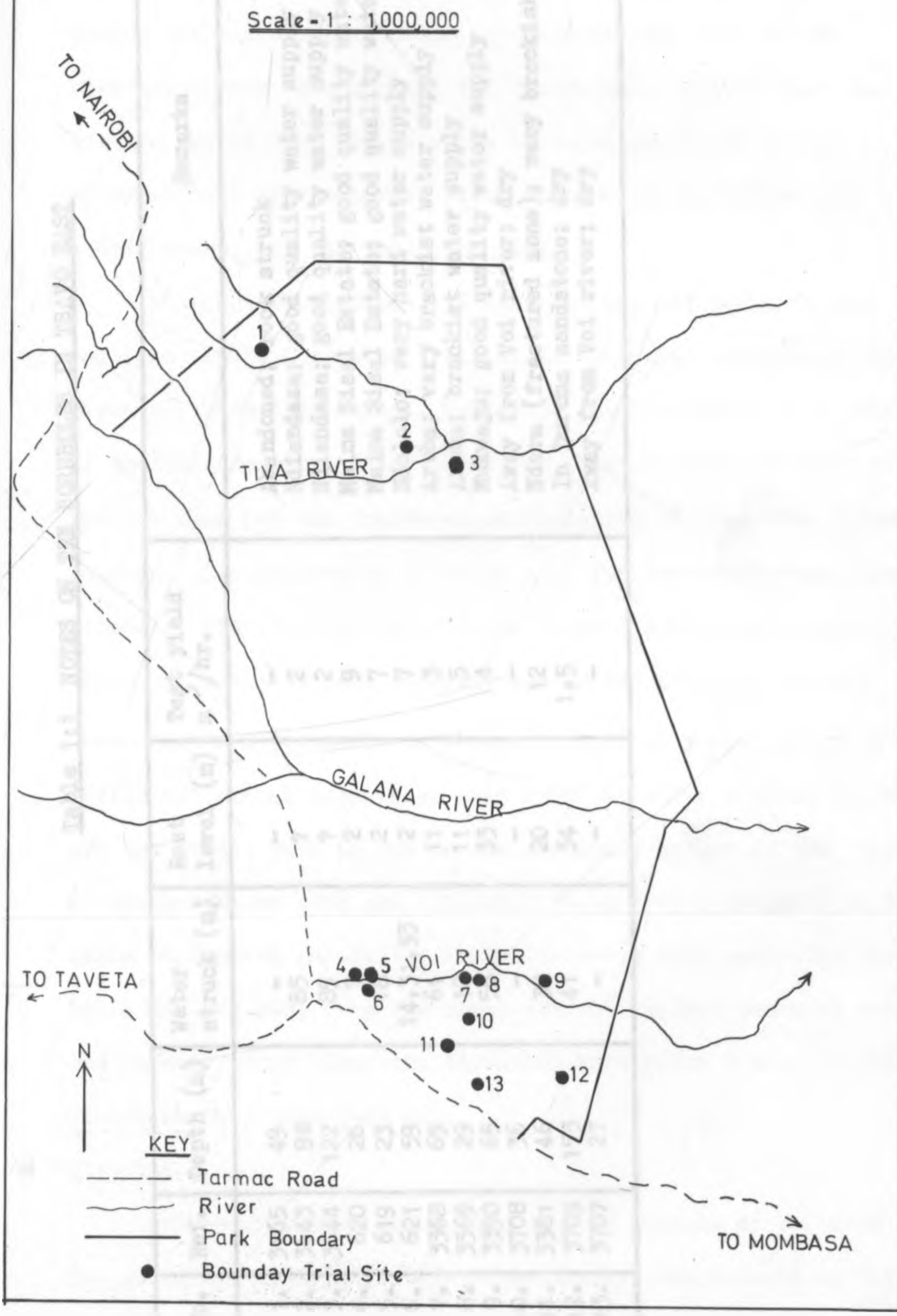


Table 1:1 NOTES ON THE BOREHOLES IN TSAVO EAST

No.	Ref.	Depth (m)	Water struck (m)	Rest level (m)	Test yield m^3/hr.	Remarks
1.	3165	49	-	-	-	Abandoned; rock struck
2.	3643	98	85	?	2	Ndiandaza; good quality water supply
3.	3644	122	85	?	2	Ndiandaza; good quality water supply
4.	620	26	7	2	9	Mzima Sisal Estate; good quality water supply
5.	619	23	18	2	7	Mzima Sisal Estate; good quality water supply
6.	621	59	14,31,53	2	7	Ndololo; very hard water supply
7.	3368	65	61	11	3	Aruba; very brackist water supply
8.	3369	29	12	11	5	Aruba; brackist water supply
9.	3390	65	58	33	4	Mukwaju; good quality water supply
10.	3708	36	-	-	-	Away from Voi river; dry
11.	3381	46	39	20	12	Ndara (fractured zone); very brackish
12.	3709	153	41	34	1.5	In Duruma sandstone; dry
13.	3707	27	-	-	-	Away from Voi river; dry

fed from catchment systems outside TsE all other rivers are sand-choked channels containing water for only short periods during the rains. Long after the intermittent flow of the seasonal rivers has ceased, the water-table remains near the surface and as such the majority of boreholes sited in the alluvial beds of the rivers yield water in the gneiss and schist underlying the weathered zone.

Figure 1:2 and Table 1:1 show the map and notes on the location of the boreholes trial sites (personal communications: Director, Water Department, Nairobi). Geologically, as a result of tectonic movements the underlying rocks in certain areas of TsE are fissured and fractured sufficiently to make them water bearing. The occurrence of water at a few locations, e.g. Ndara borehole, (no. 11, Fig. 1:2) is due to such localised fracture zones but owing to poor recharge system the water is saline.

Borehole prospects as a major source of pumped water to refill artificial waterholes away from the river courses in TsE are not good. This is due to the irregular nature of the base of the weathered zone and localised tight rock conditions in the areas of limited rainfall. Table 1:1 shows that generally, boreholes drilled away from the river courses yielded brackish water and in many other cases the boreholes have given either erratic yields or they have been dry.

Climate:

Long-term background data about the climate of Voi area was given by Woodhead (1968). Essentially, the climate of TsE

FIGURE 1:3

RAINFALL ZONES IN SOUTH-EASTERN KENYA

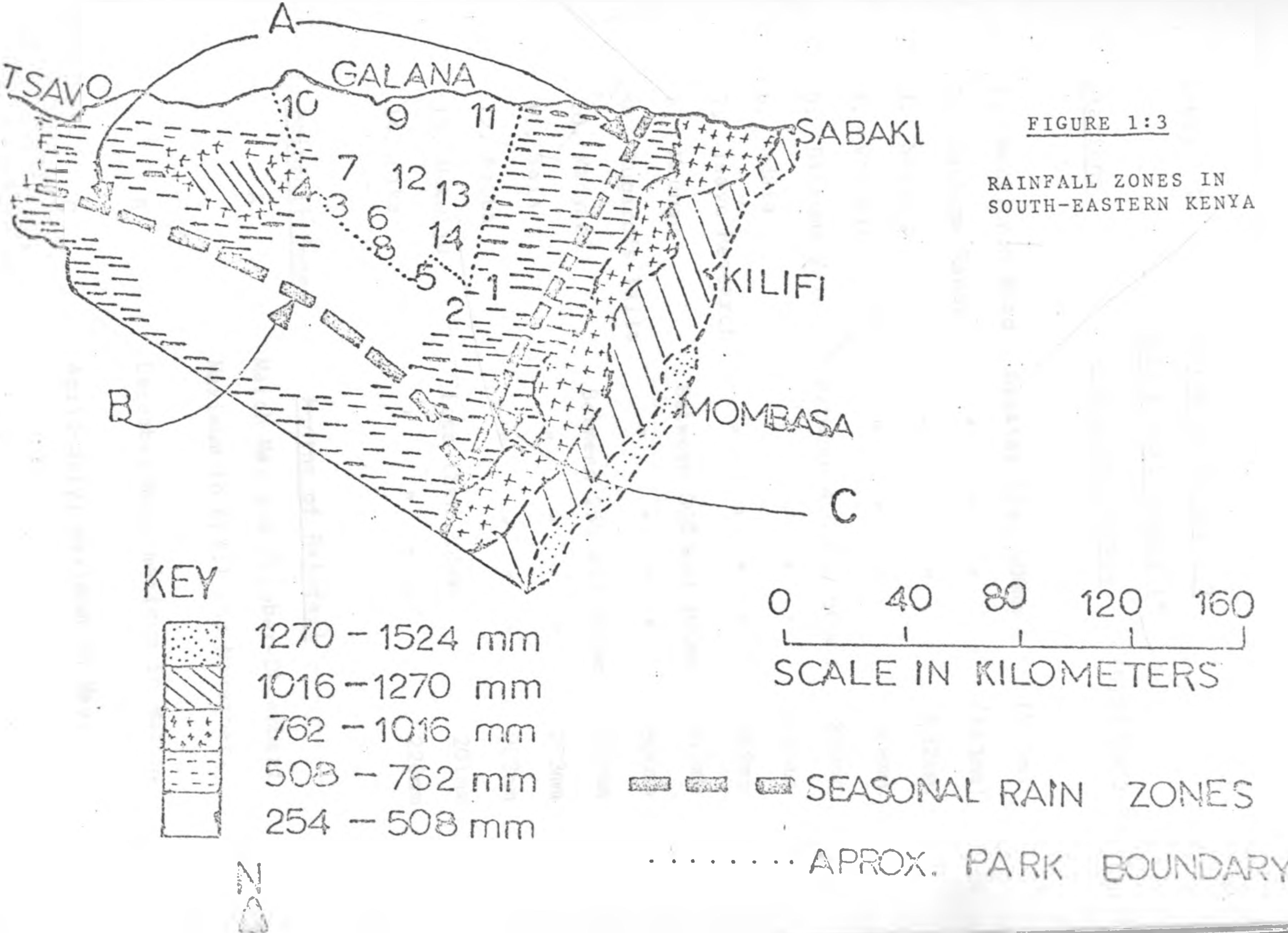


Table 1:2 Notes on Figure 1:3

Mean Annual rainfall*

Stations	Long-term Average	(1972)/1973 Total
1. Mackinnon Road	Greater than 500mm	(519mm)
2. Bachuma Range	" " "	(663mm)
3. Ndololo	" " "	532mm.
4. Voi Met.	" " "	468mm.
5. Bachuma Gate	Between 400 and 500mm	329mm
6. Ndara	" " " "	520mm
7. Tsavo Research	" " " "	468mm
8. Maungu	Between 300 and 400mm	322mm
9. Lugard's Falls	" " " "	308mm
10. Manyani	Between 255 and 300mm	298mm
11. Sala	" " " "	273mm
12. Aruba	" " " "	283mm
13. Mukwaju	Less than 255mm	201mm
14. Dika	" " " "	220mm

Rainfall Zone	Months of Rainfall
A	March-May and October-December; Maximum in April and November.
B	December-May; maximum in March.
C	April-July; maximum in May.

*See Appendix Table 2

and its environ is arid/semi-arid. Figure 1:3 illustrates the decrease in the mean annual rainfall values from the Indian Ocean Coast (1275-1525mm) through the eastern boundary of the park (508-762mm) into the park (254-508mm). Tyrrell (1972), analysing the rainfall figures for the Tsavo region from 1960 to 1971 noticed that rainfall varied in time and in space, according to the altitude.

Thermohydrographs were set up during the study period at the Tsavo Research Project Headquarters near Voi, at Aruba Dam, at Voi Safari Lodge, and at Dika plains. Although there was a great variation in the rainfall values between Voi (≥500mm), Aruba (255-300mm) and Dika (≤255mm) during the study period, the temperatures in the same stations and elsewhere (Bachuma and Voi gates) were fairly constant. Pant and Rwandusya (1971) used Thornthwaite's and Penman's empirical formulae (Thornthwaite, 1948; Penman, 1948) to classify the climate of Voi area as arid. An improved calculation of the same values based on Woodhead's data for 1938-62 and 1964-66 potential evapotranspiration was made in the appendix Table 1 to classify the climate of Voi as semi-arid (Obasi and Kiangi, 1973)

Since the variability in mean monthly temperatures, an important component of evapotranspiration was quite small in TsE, the long-term mean annual rainfall values could be justifiably used roughly to classify the climate of the Tsavo region (Brown and Cocheme, 1969). Over most of TsE the average annual rainfall was consistently lower than 255mm, its distribution was patchy within the year and very variable between the years. Towards the western side of the park the rainfall increased due to the orographic effects of few granitic hills and Mount Kilimanjaro from the foot of which the Tsavo river originates. Thus, the rainfall pattern of the study area suggests that the areas outside the park are semi-arid (≥500mm) but inside TsE is arid (≤255mm).

The rainfall in the study area was dependent on variations in the circulation patterns of the trade winds over Kenya as a whole. The three rainfall zones bordering the study area are shown on Figure 1:3. Table 1:2 shows the values of the mean annual rainfall within and immediately surrounding the intensive study area. The climate of TsE was characterized by alternating dry and rainy seasons: a long dry season from June to October, "short" rains in November, a short dry season from January to March and "long" rains in April/May. However this pattern was quite variable and often modified by "out of season" rains or dry spells.

Vegetation:

Napier-Bax and Sheldrick (1963) gave a list of the dominant plant species in TsE. A brief description of the vegetation changes (Agnew, 1968) and the vegetation types (Greenway, 1969) were made. Oral accounts from people long associated with the park (e.g. Park Warden, Sheldrick and Chief Biologist, Glover, pers. comm.) indicated that the entire park was originally covered by dense *Acacia-Commiphora* scrub with sparse understorey of various shrubs and *Sanseviera* spp. with little or no grass.

Some aerial photographs were taken in 1954, 1968 and 1972 in TsE, south-east of Aruba. The aerial photographs were analysed

TABLE 1:3 THE PROGRAMME COMPOSITION OF THE TEN MOST ABUNDANT PLANT GENERA ALONG TRANSECTS RUNNING ACROSS TWO WATERHOLES IN THE STUDY AREA

T.R. Hq. Artificial Waterholes

Genera	Age Classes	Percentage
Bauhinnia	1, 2	26.13
Grewia	1, 2	19.04
Solanum	1	7.70
Premna	1, 2	7.69
Directiletia	1, 2	7.43
Boscia	1, 2, 3	6.37
Combretum	1, 2	5.37
Xeromphis	1, 2	3.48
Commiphora	1, 2, 3	2.96
Sericocomopsis	1, 2	2.31
		88.48%

Bachuma Gate Natural Waterholes

Genera	Age Classes	Percentage
Strychnos	1,	20.37
Lannea	1, 2	16.33
Grewia	1, 2	10.83
Serococomopsis	1	10.28
Commiphora	1, 2, 3	6.24
Boscia	1, 2	4.95
Combretum	1, 2	4.59
Xeromphis	1	4.40
Hymenodictynon	1	3.49
Euphobia	1	3.49
		84.97%

Note: 1 = Regeneration (woody vegetation < 1m high)

2 = Replacement (" " 1m – 4m high)

3 = Emergent (" " > 4m high)

for changes in vegotation cover by Northon-Griffiths and the staff of Tsavo Research Project in 1972. Around Aruba dam vegetation destruction between 1954 and 1972 (Appendix Table 3) was quite profound (Northon-Griffiths, 1972). Between 26 and 33 percent of the woody vegetation cover was destroyed around the dam over the past 18 years.

The percentage composition of different age-class of woody vegetation was assessed through sampled transects running from a natural and an artificial waterhole. The transects were sampled at the beginning of the dry season in August, 1973 when many woody plants were still in leaf by running 3m belt transects 1 km long away from the waterholes. The first transect passed through an artificial waterhole near to Tsavo Research Headquarters and the second passed through a natural waterhole near Bachuma Gate. The percentage composition of the ten most abundant genera, (84-88% of the total woody genera) in the transects, are presented in Table 1:3.

The study area was typified by low numbers of emergent trees (>4m height) consisting of <u>Melia</u>, <u>Delonix</u> and <u>Commiphora</u> making up 1.33% of the woody vegetation. There were isolated pockets of even-aged replacement trees (1-4m height) which in some cases formed pure stands of such generas as <u>Platycelyphium</u> or <u>Lanea</u> forming 24.96% of the woody vegetation. The greater percentage (73.71%) of woody vegetation in the area consisted of regeneration (≤1m height). The gaps between the age-classes (i.e regeneration-emergent) are a result of destruction of the woody vegetation in the recent past.

FIGURE 1:4 AERIAL MAP OF THE DISTRIBUTION OF NATURAL WATERHOLES SOUTH-WEST OF TSAVO NATIONAL PARK (EAST).

The woody vegetation was often bashed, browsed, debarked or broken. About 73.84% of the overall woody vegetation in the transects were damaged in this manner, 23.36% were killed and only 2.88% remained undamaged.

Inspite of the high proportion of regeneration along the transects, the high incidence of browsing by wildlife prevented uniform recruitment of woody tree species into the emergent age-class. Many tree species which grew to the upper storey outside the park had been damaged within the park so that they remained in the herb and shrub layers. It was visually assessed that where the waterholes were large they attracted groups of , elephants to stay near them for a longer period and more woody vegetation were damaged near them than around smaller waterholes.

<u>Natural Waterholes</u>:

Over most of TsE the density of the natural waterholes was determined by aerial strip counts and checked on the ground along the park roads in the intensive study area. By the aerial estimates the density of natural waterholes was 0.52 ± 0.07 per km^2 and by ground checks the density was 0.59 per km^2. About 80% of all the waterholes were seen near termite mounds, the remaining ones being ephemeral pools formed in erosion surfaces or soil deflation near water courses and area of impeded drainage.

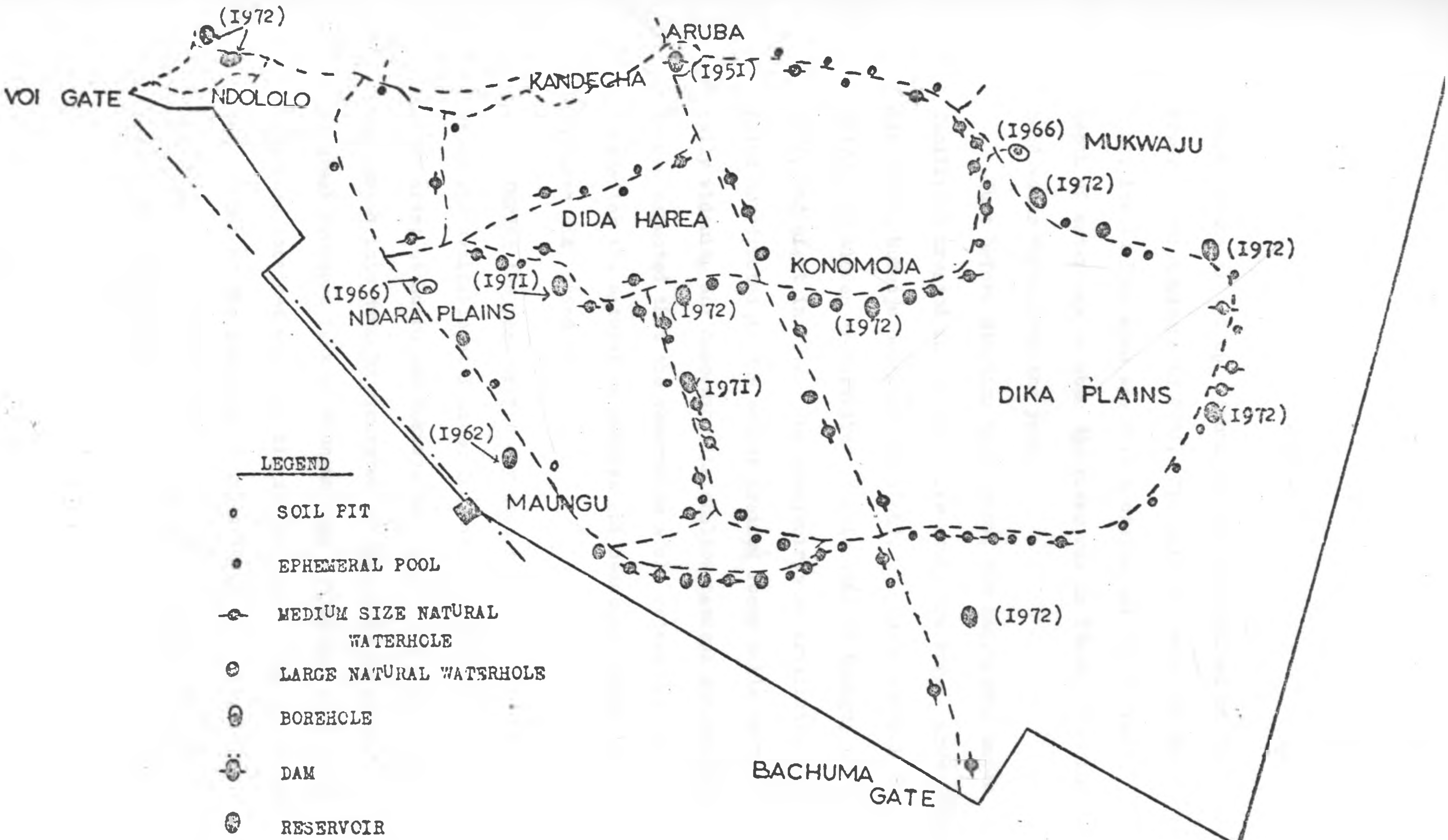
Figure 1:4 shows the distribution of natural waterholes drawn from aerial photographs (taken before 1968 by the Survey of Kenya) for the area south-west of TsE, south of Galana river. The most striking feature in the pattern of the distribution of the waterholes was the inverse relationship between their numbers and the distance of their location from the Galana river and its major tributaries. The waterholes were abundant in the well drained, darkish red, sandy loam soils where Macrotermes termitaria occurred in large numbers but they were infrequent along the river courses and in the area of impeded drainage where large Macrotermes termitaria were absent.

The plant species most commonly associated with the natural waterholes were a tree Lawsonia inermis (L), and a herb Glinus setiflorus (L.). Another tree Acacia tortilis (Forsk.) subspecies Spirocarpa (A.Rich.) was a common indicator of both natural waterholes and old termite mounds. The site of some incipient waterholes which had not been fully developed were often overgrown by the grass Cynodon dactylon (L. Pers.).

The natural waterholes contained water during the rains and intermittently throughout the short dry season (January-March) due to some out-of-season rains but they all dried up about July-August during the long dry season. During the peak of the rainy season, November-December, rain water filled up the numerous natural waterholes so that water became available within two kilometers of any animal in the intensive study area, and throughout most of TsE.

Artificial Waterholes:

The water development carried out within the intensive study area started in 1950 when the flood water from the Voi river was successfully led away into a shallow dam at Kandecha. In 1951, the Voi river slightly altered its course about Kandecha dam



LEGEND

- SOIL PIT
- EPHEMERAL POOL
- MEDIUM SIZE NATURAL WATERHOLE
- LARGE NATURAL WATERHOLE
- BOREHOLE
- DAM
- RESERVOIR
- BRAKE PRESSURE TANK ALONG THE PIPELINE
- ( ) DATE OF THE DEVELOPMENT OF THE 'WATERHOLE'

FIGURE 1:5 DISTRIBUTION OF WATERHOLES ALONG CENSUS ROUTES IN THE INTENSIVE STUDY AREA IN 1973-74.

which became silted up. Aruba dam was constructed on Voi river beyond Kandecha in 1951. The wall of Aruba was 8m high, its surface area was 85.4 hectares and the average depth of water was 4m when the river was in flood. The dam held water throughout the year.

Just before starting this study, the additional water facilities created in the intensive study are were: Aruba dam (in 1951), Mukwaju borehole (in 1966), Ndara borehole (in 1966), and eleven "reservoirs"; one in 1962 at Maungu; two in 1971, and eight in 1972. The reservoirs were artificial water-holes constructed in the better drained loamy soils by mechanically widening and deepening the shallow natural waterholes. It was expected that the reservoirs would retain rain water long after the natural waterholes and seasonal rivers in the area had dried up.

During the peak of the dry season (September - October) water was available at limited locations in the intensive study area; at Ndara and Mukwaju boreholes from which water was pumped into troughs excavated in the soil; at Aruba dam; at Break Pressure Tank at Maungun; and at Ndololo from where elephants obtained water by digging the sand along Voi river-bed. A map of the location of the waterholes within 600m belt along the park roads in the intensive study area is presented on Figure 1:5.

Table 1:4 LIST OF ANIMALS SEEN IN TSAVO NATIONAL PARK (EAST). SOUTH OF VOI RIVER

Herbivores:

Name	Remarks
Zebra (*Equus buchelli bohmi* Matschie)	Abundant in the grasslands near the water supplies
Elephant (*Loxodonta africana* Blumenbach)	abundant throughout the park.
Kongoni (*Alcelaphus buselaphus cokei* Gunther)	regularly seen throughout the study area.
Oryx (*Oryx gazella callotis* Thomas)	fairly common in the study area.
Eland (*Taurotragus oryx* Pallas)	often seen in mixed herds with zebra but ocassionally absent along the park roads in the study area.
Peter's gazelle (*Gazella grantii Petersi* Gunther)	Commonly seen in the plains.
Impala (*Aepyceros melampus* Lichtenstein)	abundant in herds (50-80) in the wooded grasslands.
Warthog (*Phacochoerus aethiopicus* Pallas)	fairly common in the grasslands with shrubs.
Ostrich (*Struthio africanus* (L.))	fairly common in the open grasslands.
Giraffe (*Giraffa camelopardalis* (L.))	frequently seen along the riverine bushes
Waterbuck (*Kobus ellipsiprymnus* Ogilby)	common along riverine grasslands.
Buffalo (*Syncerus caffer* Sparrman)	fairly common herds (150-250) near water supplies in the grasslands.
Rhino (*Dioceros bicornis* (L.))	scattered and mainly solitary records of individual rhinos in the medium bushlands.
Baboon (*Papio anubis* J.P. Fisher)	commonly seen near the river.
Lesser kudu (*Tragelaphus imberbis* Blyth)	restricted distribution under dense riverine bush.

Table 1:4 (cont'd)

Gerenuk (Lithocranius walleri Brooke)	Isolated records under shrubby cover.
Bushbuck (Tragelaphus scriptus Pallas)	isolated record at Ndololo under forest cover.
Steinbok (Raphicerus campestris Thuriberg)	scarce in the plains
Oribi (Ourebia ourebi Zimmermann)	" " " "
Kirk's dikdik (Rhychotragus kirki Gunther)	common throughout the park.
Reedbuck (Redunca redunca Pallas)	few at Kanderi swamp.
Carnivores:	
Lion (Panthera Leo (L.))	low population and very bobile at night.
Spotted hyena (Crocuta crocuta Erxleben)	scarce
Stripped hyena (Hyaena hyaena (L.))	scarce
Cheetah (Acinonyx jubatus (L.))	isolated sightings at waterholes near hills.
Hunting dog (Lacaon pictus Temminck)	scarce
Sliver backed jackal (Canis mesomelas Schreber)	scarce
Bat-eared fox (Octocyon megalotis Desmarest)	scarce
White tailed mongoose (Ichneumia albicauda G. Cuvier)	scarce
Banded mongoose (Mungo mungo Gmelin)	scarce

Fauna:

A list of various wildlife species recorded in the study area is presented in Table 1:4. The following game species were frequently recorded in the area: zebra, elephant, giraffe, eland, oryx, kongoni (Coke's hartebeest), common or ringed waterbuck, impala, Peter's gazelle, warthog, the African buffalo, ostrict and black rhinoceros. There were limited records and information on the few carnivores (mainly lion, hyaena, and cheetah), and lesser kudu at the waterholes. Gerenuk, baboon, bush-buck, steinbock, reedbuck, dikdik, hunting dog, bateared fox, and mongoose also occurred in the study area but the elusive habits of some of them and the nocturnal behaviour of the others precluded accurate estimation of their numbers.

CHAPTER II

DIURNAL AND SEASONAL PATTERNS OF WATERHOLE UTILIZATION IN TSAVO NATIONAL PARK (EAST), SOUTH OF VOI RIVER.

INTRODUCTION

In order to assess whether the creation of the artificial waterholes was of some touristic value in the park some observations were made on the patterns of waterhole utilization. The data presented in this chapter were derived in part from 487 hours of observations at selected artificial waterholes (Dida-harea reservoir, Ndara and Mukwaju boreholes, Aruba dam, and Voi Safari Lodge) during the dry season (August-October, 1973 and March, 1974). The rest of the data presented in the chapter were derived from monthly records of wildlife drinking at Aruba dam between June, 1973 and May, 1974.

OBJECTIVES

The main objectives of this chapter were:

1) to establish the seasonal and diurnal patters of waterhole utilization;
2) to establish the periodicity of individual wildlife species at artificial waterholes;
3) to ascertain whether the aggregation of wildlife around the artificial waterholes resulted in interspecific competition; and
4) to investigate whether the artificial waterholes enhanced the touristic value of the park.

METHODS

Between August and October, 1973 a total of 392 hours of observations were spent at five artificial waterholes in TsE, south of Voi river. In March, 1974 another 95 hours of observations were made from a blind at Voi Safari Lodge, 3km north of the intensive study area. During the study the following information were recorded on a standard form in respect of each species drinking at the waterholes:

i) name, number, sex-class and age-class;

ii) times and directions of arrival and departure; and

iii) total time of drinking and other activities at the waterholes.

In order to simplify the final analysis of the data derived from the artificial waterholes the results were presented on a 24-hour basis irrespective of the waterhole from which they were derived or the dry season month in which the observations were carried out.

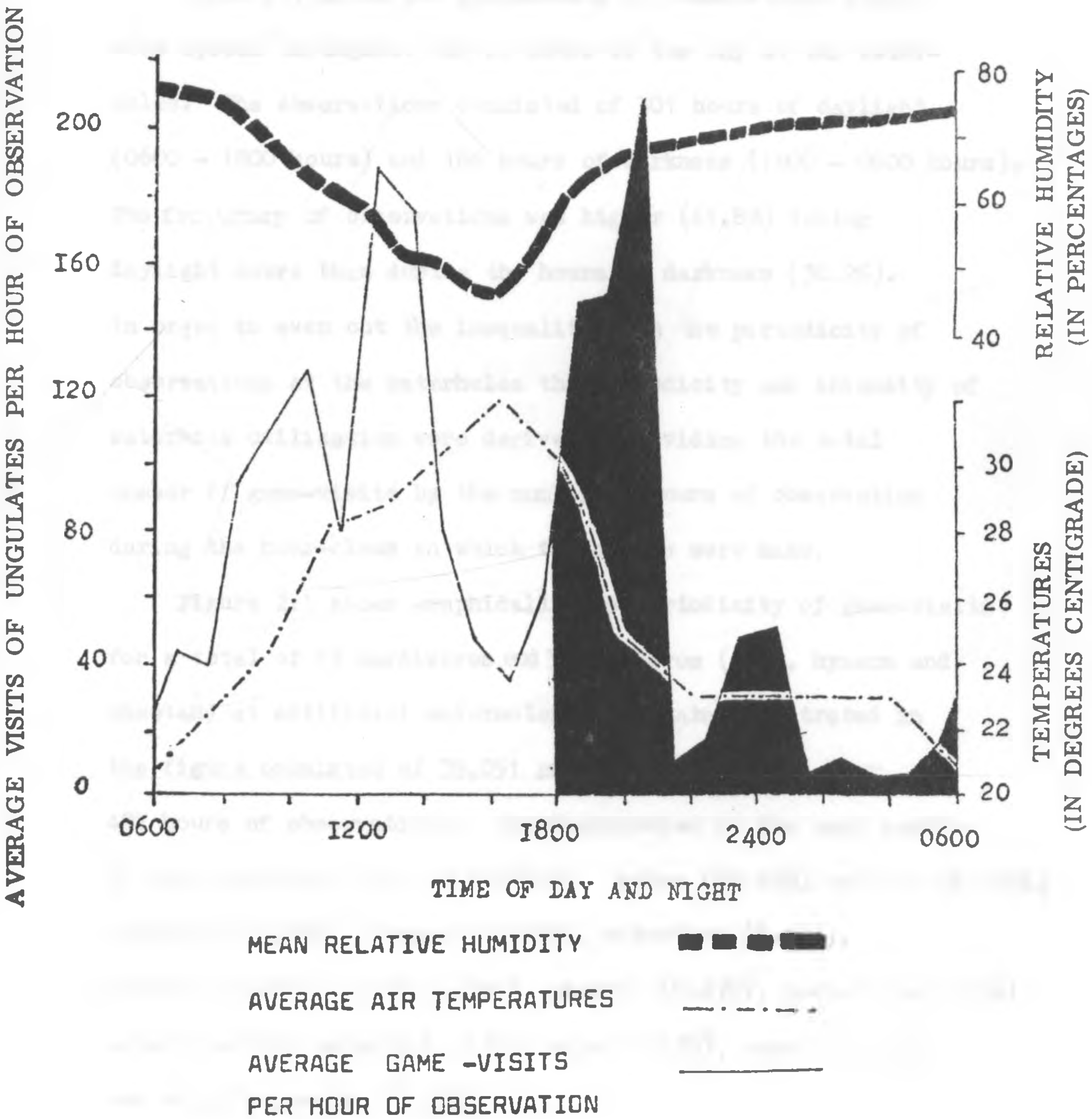
The grand total of 487 hours of observations and 39,051 game-visits to the artificial waterholes were used graphically to categorise the periodicity of waterhole utilization for 13 herbivores and carnivores (lion, hyaena, and cheetah). The average monthly numbers of the game species drinking at Aruba dam were also graphically presented to illustrate the seasonal changes in the visits of game species to an artificial waterhole in the study area. The proportions of pairs of game species occurring together at the waterholes were calculated on a 24-hour basis and the relationships between the coincidence of pairs of species were used to

Table 2:1 Periodicity and frequency of observation at artificial waterholes in Tsavo National Park (East), mainly South of Voi river during the dry season (1973-74)

Hours class		Hours of observation	%
0600-0700		30	6.16
0700-0800		27	5.54
0800-0900		29	5.95
0900-1000		31	6.36
1000-1100		31	6.36
1100-1200		30	6.16
1200-1300		18	3.69
1300-1400		19	3.90
1400-1500		15	3.08
1500-1600		20	4.10
1600-1700		25	5.13
1700-1800		26	5.33
1800-1900		33	6.77
1900-2000		17	3.49
2000-2100		15	3.08
2100-2200		15	3.08
2200-2300		15	3.08
2300-2400		14	2.87
2400-0100		13	2.66
0100-0200		13	2.66
0200-0300		11	2.25
0300-0400		12	2.46
0400-0500		12	2.46
0500-0600		16	3.28
Total		487	100.00
Total daylight hours	0600-1800	301	61.86
Total hours of darkness	1800-0600	186	38.14

FIGURE 2: 1

THE RELATIONSHIPS BETWEEN PERIODICITY OF UNGULATES' VISITS TO ARTIFICIAL WATERHOLES, AIR TEMPERATURE, AND RELATIVE HUMIDITY DURING THE DRY SEASON (1973-74) IN TSAVO NATIONAL PARK (EAST) MAINLY SOUTH OF THE VOI RIVER.



investigate how a measure of ecological separation could be attained among the wildlife species drinking at the waterholes.

RESULTS

Periodicity of observations and frequencies of Wildlife at the waterholes:

Table 2:1 gives the periodicity of observations which were spread throughout the 24 hours of the day at the waterholes. The observations consisted of 301 hours of daylight (0600 - 1800 hours) and 186 hours of darkness (1800 - 0600 hours). The frequency of observations was higher (61.8%) during daylight hours than during the hours of darkness (38.2%). In order to even out the inequalities in the periodicity of observations at the waterholes the periodicity and intensity of waterhole utilization were derived by dividing the total number of game-visits by the number of hours of observation during the hour-class in which the counts were made.

Figure 2:1 shows graphically the periodicity of game-visits for a total of 13 herbivores and 3 carnivores (lion, hyaena and cheetah) at artificial waterholes. The data illustrated in the figure consisted of 39,051 game-visits recorded over 487 hours of observations. The frequencies of the game species at the waterholes were as follows: zebra (37.19%), buffalo (31.96%), elephant (10.70%), kongoni (8.93%), waterbuck (5.46%), warthog (4.02%), rhino (0.49%), giraffe (0.27%), carnivores(0.23%), eland (0.21%), ostrich (o.17%), oryx (0.17%), impala (0.14%), and Peter's gazelle (0.05%).

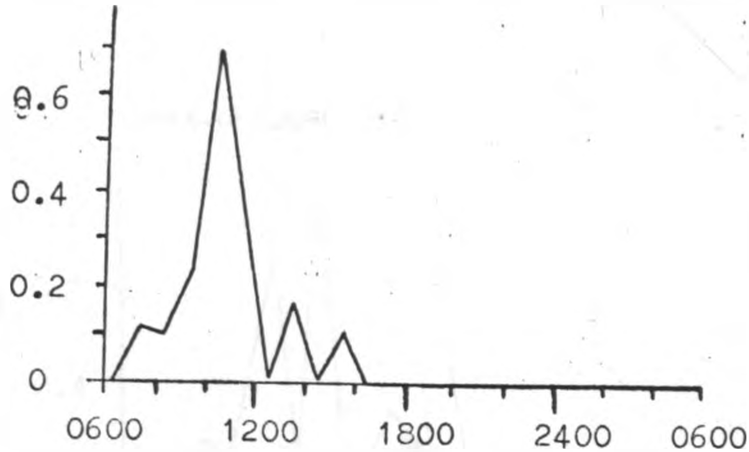
TABLE 2: 2

EXPLANATION ON FIGURES 2: 2-15

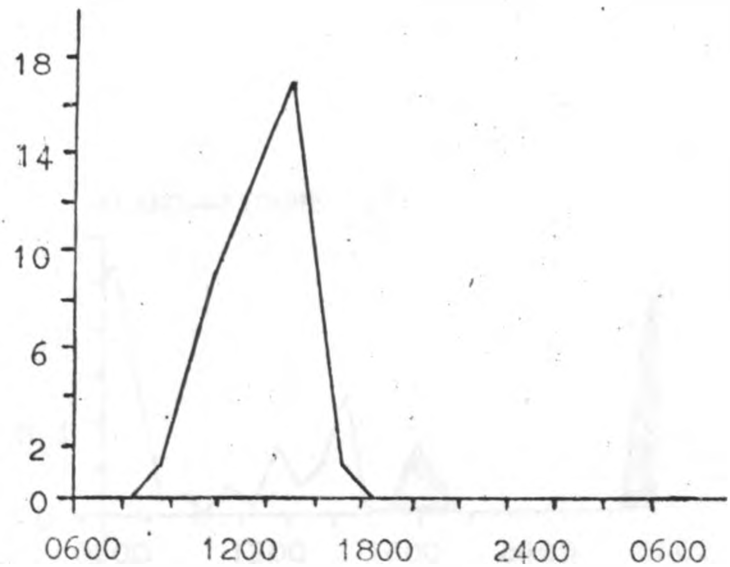
Figures 2:2-15 show the periodicity of waterhole utilisation for individual species of herbivores and carnivores (lion, hyaena, and cheetah). The data illustrated in the figures are derived from 39,501 game-visits recorded during 487 hours of observatio in Tsavo National Park (East) during the dry seasons 1973- 74. In each case, the vertical axis shows the number of animals drinking per hour-class at the artificial waterholes, and the horizontal axis shows the hour-class during which the observation was carried out.

FIGURE 2:2 PETER'S GAZELLE
FIGURE 2:3 WARTHOG
FIGURE 2:4 IMPALA
FIGURE 2:5 WATERBUCK
FIGURE 2:6 ORYX
FIGURE 2:7 ELAND
FIGURE 2:8 ZEBRA
FIGURE 2:9 KONGONI
FIGURE 2:10 CARNIVORES
FIGURE 2:11 OSTRICH
FIGURE 2:12 GIRAFFE
FIGURE 2:13 ELEPHANT
FIGURE 2:14 RHINOCEROS
FIGURE 2:15 BUFFALO

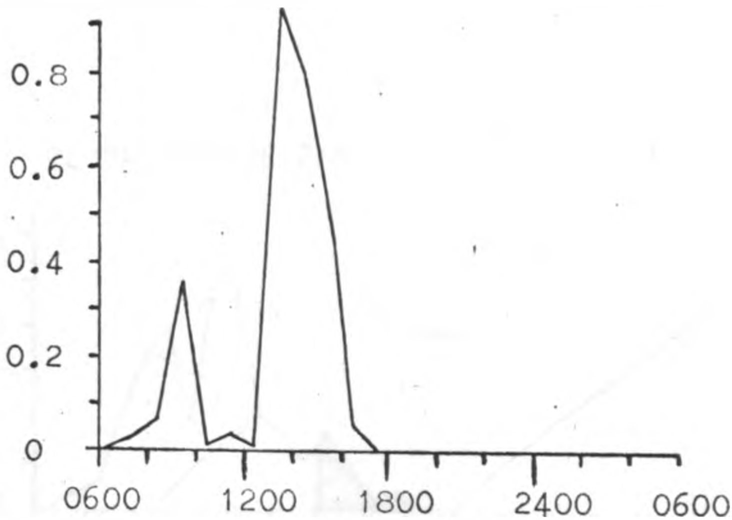
PETER'S GAZELLE--FIGURE 2:2



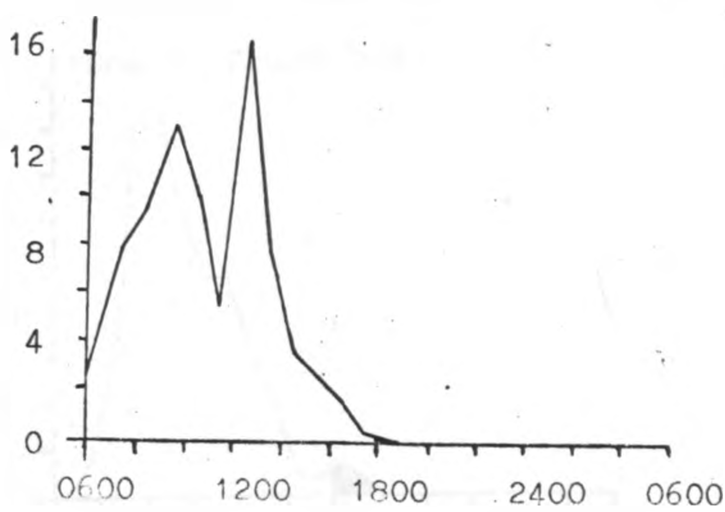
WARTHOG--FIGURE 2:3



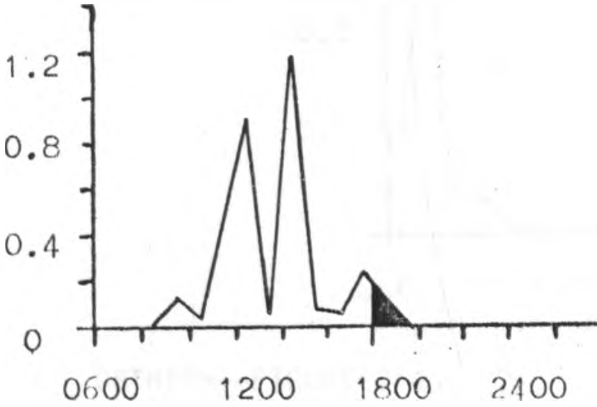
IMPALA--FIGURE 2:4



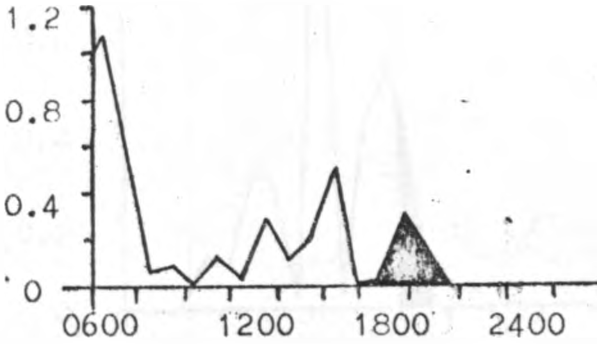
WATERBUCK--FIGURE 2:5



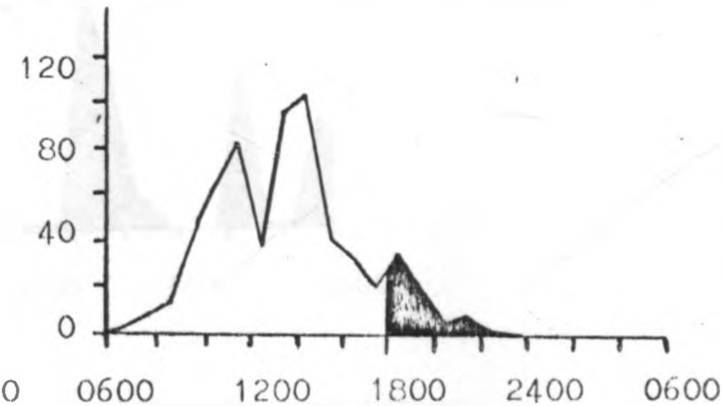
ORYX--FIGURE 2:6



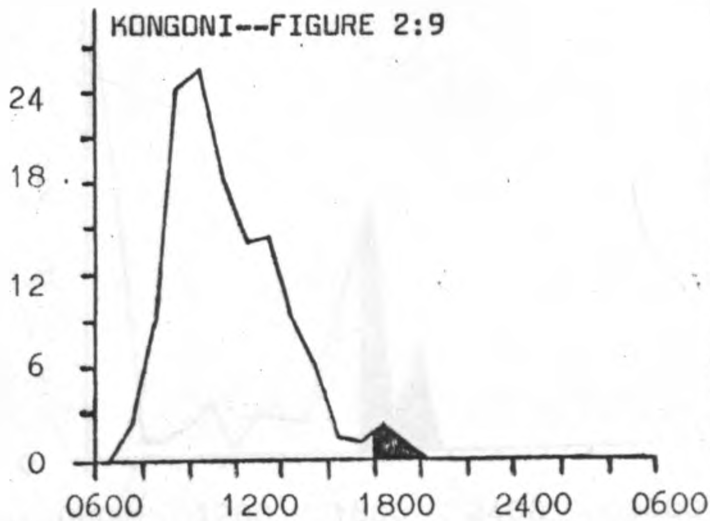
ELAND--FIGURE 2:7



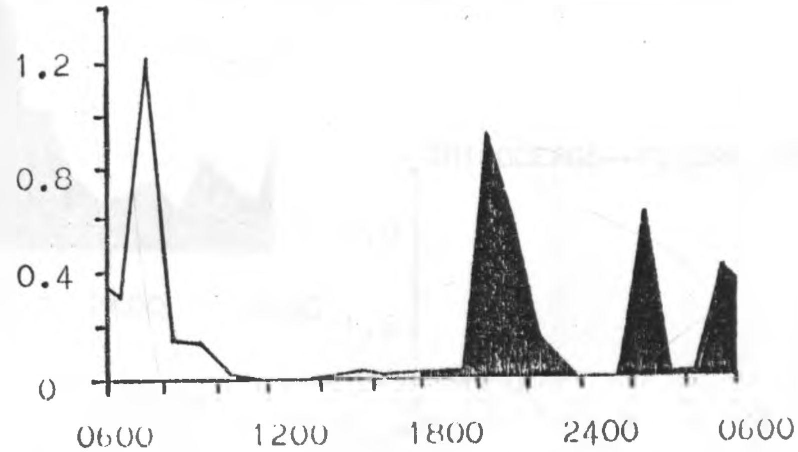
ZEBRA--FIGURE 2:8



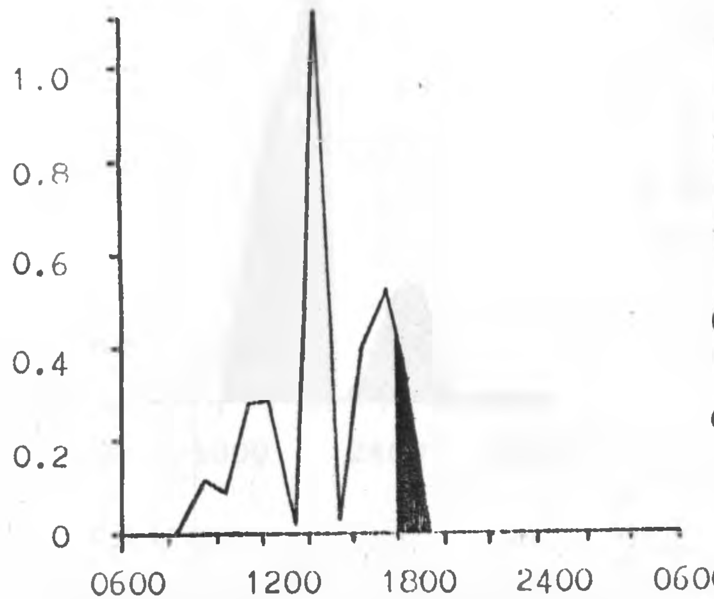
KONGONI--FIGURE 2:9



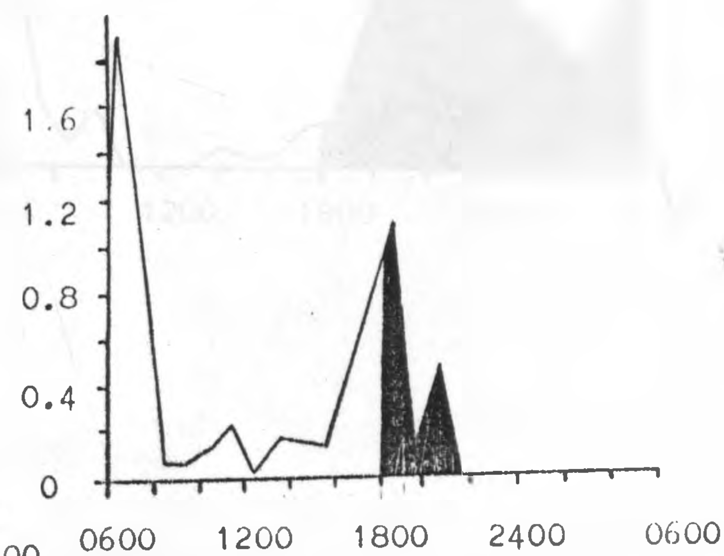
CARNIVORES --FIGURE 2:10



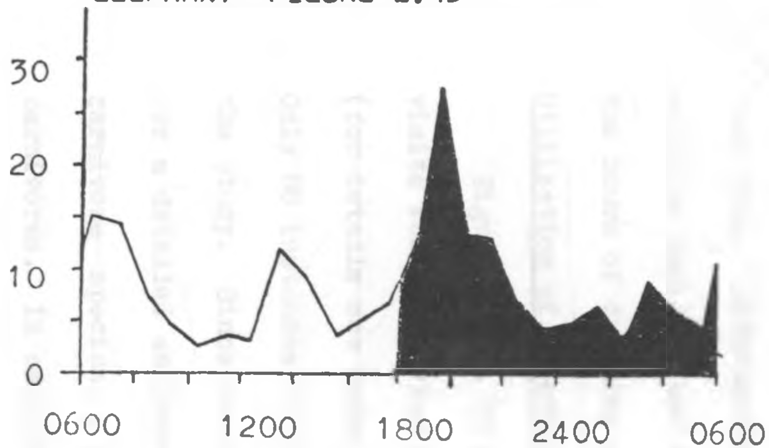
OSTRICH--FIGURE 2:11



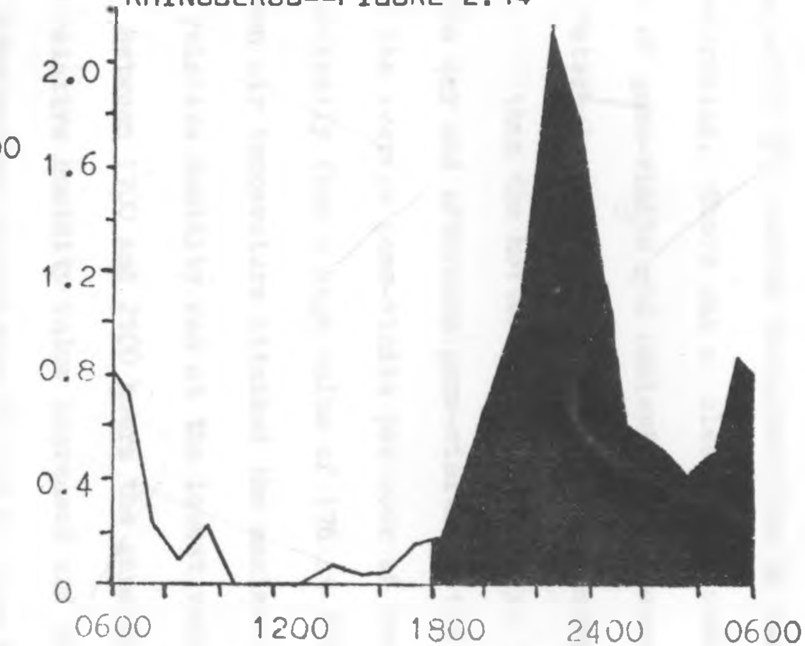
GIRAFFE--FIGURE 2:12



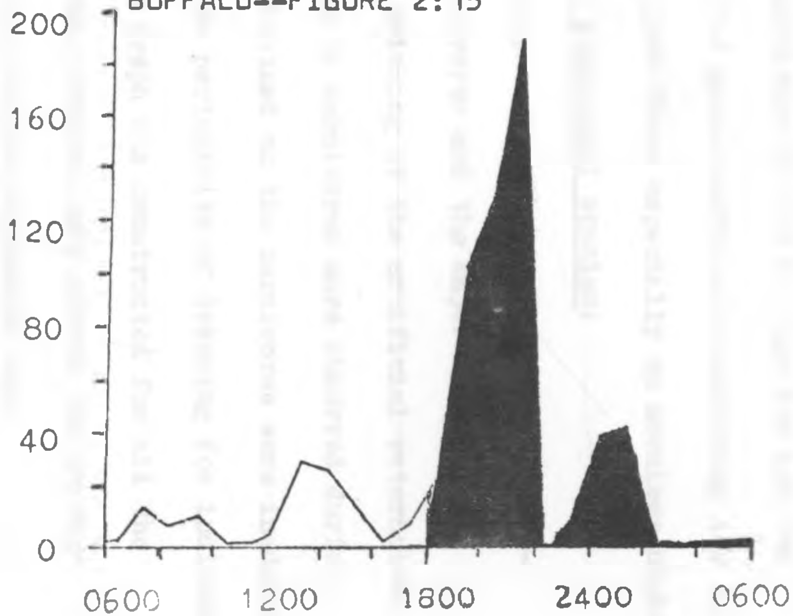
ELEPHANT--FIGURE 2:13



RHINOCEROS--FIGURE 2:14



BUFFALO--FIGURE 2:15



Diurnal pattern of waterhole utilization:

Drinking activity occurred throughout the 24 hours of the day at the waterholes. There was a clear relationship between the incidence of game-visits and ambient air temperatures in the study area. Waterhole utilization was more intensive in the cooler hours than the hotter hours of the day. Between the dawn of the day and afternoon game-visits to the waterholes increased but the average game-visits per hour of observation decreased drastically from a high value of 176 at 1330 hours to 35 at 1630 when air temperature attained the maximum value of 32^{o}C and the relative humidity was at the lowest value of 48 per cent. Between 1700 and 2100 hours the game-visits increased again as the relative humidity value increased and the air temperature fell. Although the temperature of the air was low and the relative humidity was high, the game-visits were relatively low in the hours of darkness after 2200 hours especially on moonless nights.

Utilization of waterholes by individual species:

Figures 2:2 - 15 show graphically the periodicity of game-visits for 13 species of herbivores and the major carnivores (for details see Table 2:2) drinking at the artificial waterholes. Only 88 instances of drinking by carnivores were observed during the study. Since the data obtained on the carnivores were inadequate for a detailed analysis of the periodicity of drinking for individual carnivore species, a single graph was constructed for all the carnivores. In each graph the vertical axis showed the average number of game-visits per hour and the horizontal axis showed the hour-class when the observations were made.

The portion of the graphs during the hours of darkness were shaded out to assist visual differentiation between the day-time and the night-time patterns of waterhole utilization by game species.

There was a relationship between the size of some herbivores and the period of the day during which they drank at the artificial waterholes. The larger species of herbivores utilized the waterholes more in the cooler hours of the day but the smaller species utilized the waterholes more during the warmer daylight hours. Thus, the day-time drinkers were largely small-medium sized species whereas the night-time drinkers were predominantly the larger game species, and carnivores.

Temporal separation of species:

An inspection of the times of arrival and departure, and the peaks of the visits of each game species showed that it was possible to make a further subdivision of the broad classification of the periodicity of the populations of drinking species at the artificial waterholes. Among the day-time drinkers in the paragraph above the peak of game-visits for the eland was in the early morning near to dawn; and for Peter's gazelle, and kongoni it was late morning, but for warthog, impala, ostrich, oryx, waterbuck and zebra, it was in the afternoon. Among the large herbivores the peaks of game-visits for rhino, buffalo and elephant were between the evening and midnight. For giraffe the peaks of drinking activity occurred early in the morning and late in the evening. The rigid time-table at the waterholes where the times of arrival and departure of different game species were spaced out in time could result in a measure of ecological separation.

FIGURE: 2:16

SEASONAL VARIATIONS IN THE RELATIVE FREQUENCY OF GAME SPECIES TO ARUBA DAM IN TSAVO NATIONAL PARK (EAST), SOUTH OF VOI RIVER

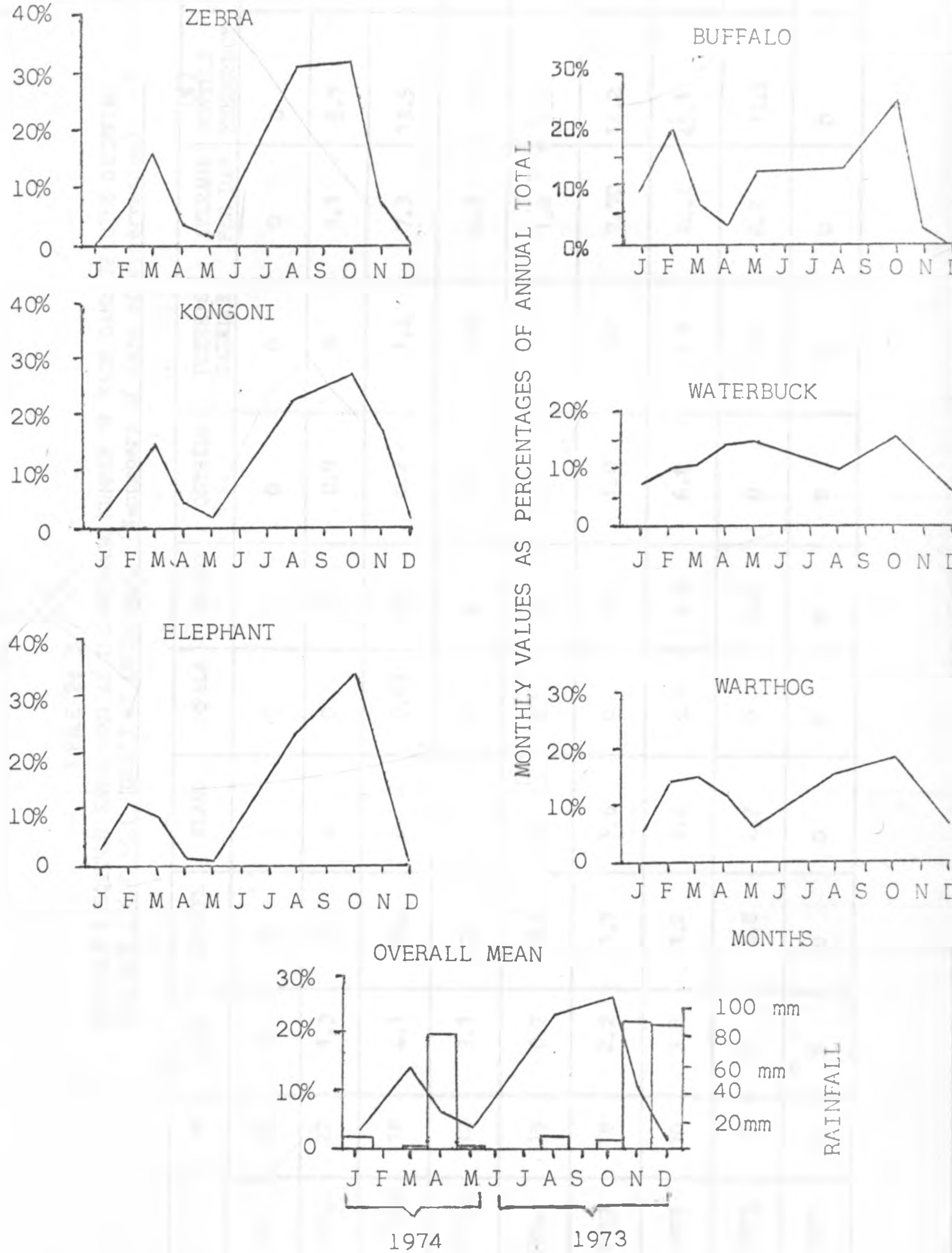


TABLE 2: 3

MONTHLY FREQUENCY EXPRESSED AS THE AVERAGE NUMBER OF EACH GAME SPECIES DRINKING PER DAY (0600-1800 HOURS) AT ARUBA DAM. (N=numbers of days of observation)

	N	ORYX	GIRAFFE	ELAND	IMPALA	RHINO	OSTRICH	PETER'S GAZELLE	AVERAGE PER DAY	(%) MONTHLY FREQUENCY	RAINFALL (MM)
Jan. 1974	20	0	0	0	0	0	0	0	0	0	8.3
Feb. 1974	22	1.3	0.6	0	0	0.3	0.9	0	3.1	5.7	0.0
March 1974	18	4.1	0.4	0	0.63	0.6	0.2	1.4	7.3	13.5	2.0
April 1974	12	3.1	0	0	0	0	0.3	0.8	4.2	7.7	82.4
May 1974	19	0.7	0.5	0	0	0	0	0	1.2	2.2	2.5
Aug. 1973	18	2.2	1.7	1.6	0	0.4	1.0	0.8	7.70	14.2	9.1
Oct. 1973	10	3.2	1.2	2.4	4.0	3.2	6.8	3.6	24.4	45.1	5.8
Nov. 1973	5	0	0.8	2.7	0	1.2	0	1.5	6.2	11.5	90.3
Dec. 1973	5	0	0	0	0	0	0	0	0	0	87.9

Seasonal variation in game-visits to Aruba dam:

The Figures in 2:16 show the seasonal variations in the visits of some game species to Aruba dam. The data presented here were based on the observations carried out between 0600 and 1800 hours of the day. The graphs showed that during daylight hours the number of the following game species: buffalo, warthog, elephant, kongoni and especially zebra increased during the rains.

The species listed above constituted over 90 percent of the total (39,051) observed game-visits to the artificial waterholes during the dry season. Since buffalo had been shown (in the section above) to be a night-time drinker, the data presented here for buffalo may not be as representative of the animal as the data for the other species in Fig. 2:16.

Table 2:3 shows the monthly frequencies for rhino, giraffe, impala, oryx, P.gazelle and carnivores which constituted less than 5% of the total game-visits to the waterholes. Both Figure 2:16 and Table 2:3 showed that during the dry season months the number of game-visits were higher for each drinking species than during the rains. During the dry season wildlife aggregated around the few artificial waterholes containing water but during the rains wildlife dispersed more evenly throughout the study area drinking from the natural waterholes formed in the clay pans filled with rain water. The number of waterbuck alone was consistently high around Aruba dam throughout the year showing no seasonal fluctuations.

Only a few impala were recorded at Aruba dam throughout the year though many drank regularly at Mukwaju and at the sand diggings at Ndololo during the dry season. The absence of shade

TABLE 2: 4 A table illustrating the method of calculating the coincidence of the percentages for three pairs of species drinking together at Artificial waterholes in TsE, mainly South of Voi River

Elephant %	Buffalo %	Coincidence of percentage for elephant & Buffalo	Zebra %	Kongoni %	Coincidence of percentage for Zebra & Kongoni	Elephant %	Warthog %	Co of fo
6.92	2.24	2.24	1.29	1.83	1.29	6.92		
3.50	0.04	0.04	2.18	6.80	2.18	3.50	0.43	
2.22	1.71	1.71	6.84	18.50	6.84	2.22	1.89	
1.30	0.15	0.15	9.83	19.49	9.83	1.30	8.00	
1.74	0.04	0.04	13.72	14.06	13.72	1.74	13.38	
1.69	0.87	0.87	6.14	10.77	6.14	1.69	16.43	
5.95	4.82	4.82	16.02	11.31	11.31	5.95	20.07	
4.65	4.27	4.27	17.12	7.49	7.49	4.65	24.87	
1.98	2.25	1.98	7.00	4.89	4.89	1.98	12.65	
2.76	0.14	0.14	5.60	1.22	1.22	2.76	1.89	
3.48	0.15	0.15	3.49	0.99	0.99	3.48	0.29	
7.46	0.13	0.13	5.86	1.75	1.75	7.46	0.05	
13.46	16.49	13.46	3.56	0.84	0.84	13.46	0	
6.73	20.77	6.73	0.78	0	0	6.73	0	
5.95	29.70	5.95	1.45	0	0	5.95	0	
3.43	0.07	0.07	0.06	0	0	3.43	0	
2.13	1.69	1.69	0	0	0	2.13	0	
2.37	6.25	2.37	0	0	0	2.37	0	
3.29	6.65	3.29	0	0	0	3.29	0	
1.74	0.07	0.07	0.03	0	0	1.74	0	
4.45	0.10	0.10	0.04	0	0	4.45	0	
2.85	0.01	0.01	0	0	0	2.85	0	
2.42	0.06	0.06	0	0	0	2.42	0	
7.31	0.21	0.21	0.04	0	0	7.31	0	
			52		69			

TABLE 2:5 **DAILY COINCIDENCE OF PERCENTAGE OF PAIR SPECIES DRINKING FROM ARTIFICIAL WATERHOLES DURING DRY WEATHER**

GROUP I	Peters' gazelle	Impala	Ostrich	Warthog	Kongoni	Oryx	Waterbuck	Zebra	Average % Coincidence
Peters' gazelle	-	38	43	46	54	28	51	55	45
Impala	38	-	32	63	42	36	51	53	45
Ostrich	43	32	-	51	31	65	33	48	43
Warthog	46	63	51	-	60	54	64	72	58
Kongoni	54	42	31	60	-	33	81	69	52
Oryx	28	36	65	54	33	-	32	43	41
Waterbuck	56	51	33	64	81	32	-	75	56
Zebra	55	53	48	72	69	43	75	-	59

1 = Coincidence of percentage between species that are smaller in size than an eland.

TABLE 2:5 cont.

GROUP II	Eland	Buffalo	Giraffe	Rhino	Elephant	Carnivore	Average % Coincidence
Eland	-	23	68	19	42	24	35
Buffalo	23	-	21	33	52	38	33
Giraffe	68	21	-	19	42	24	34
Rhino	19	33	19	-	54	39	32
Elephant	42	52	42	54	-	40	46
Carnivore	24	38	24	39	40	-	33

II = Coincidence of percentage between species equal to or larger than the size of an eland. (including Carnivores)

TABLE 2:5 cont.

GROUP III	Peters' gazelle	Impala	Ostrich	Warthog	Kongoni	Oryx	Waterbuck	Zebra	Eland	Average % Coincidence
Eland	32	32	19	22	43	12	39	38	-	29
Buffalo	6	14	7	15	18	11	18	23	23	15
Giraffe	15	13	34	15	20	21	26	30	68	26
Rhino	2	4	2	2	7	2	9	10	19	6
Elephant	16	21	22	22	28	22	35	41	42	27
Carnivore	7	7	-	3	9	1	12	10	24	8

III = Coincidence of percentage between species in (I) and (II) trees around Aruba dam possibly accounted for the low numbers of impala, baboon, lesser kudu, and giraffe there since giraffe and baboon especially were recorded at higher frequencies drinking elsewhere, under woody riverine vegetation cover during the peak of the dry season.

Coincidence between species at the waterholes:

Any two species (e.g. zebra and kongoni) which occurred together during the same hour class at the waterholes were called "paired species". Table 2:4 gives an example of how the co-incidence of percentages of paired species at waterholes was calculated.

Table 2:5 summarised the coincidence data based on 39,051 game-visits during 487 hours of observations at various artificial waterholes in the study area. The average coincidence of percentages of paired species were calculated for 13 herbivores and carnivores over the 24 hours of the day. Group I consisted of species which were smaller than the eland, but Group II consisted of animals of the size of an eland or larger. Group I species were paired with Group II species to form Group III. The relationships between the Groups indicated that :

i) the members of Group I species (small sized herbivores) coincided more often at the waterholes than they did with Group II species (larger herbivores and carnivores); and

ii) Group I species coincided less often with predators than they did with species (other than rhino) in Group II.

The prey species (Group I) utilized the waterholes primarily during daylight hours when they could see better. Better vision could enhance the chances of the prey species to escape predation on their way to and from the waterholes. The record of the lower jaws of freshly killed animals around the waterholes showed that 19 buffalo, 14 eland, 11 waterbuck, 7 kudu, 6 zebra, 4 oryx, 2 kongoni and 1 giraffe were killed by predators during the study. The numbers of the animals killed in the vicinity of the waterholes were more crudely reflective of the coincidence of buffalo (38), eland (24), waterbuck (12), zebra (10), kongoni (9), oryx (1), and giraffe (24) with the predators than the relative frequencies of the herbivores at the waterholes.

The coincidence of carnivores with large species; elephant (40) and rhino (39) which were not utilized as prey species was higher than the coincidence of the carnivores with the small prey species; eland (24), zebra (10), waterbuck (12), kongoni (9) and impala (7). Except with warthog the coincidence of rhino with both groups I and II species were very low. This was consistent with the solitary habits of rhino.

DISCUSSION

When water was freely available, the species which drank water regularly were at an advantage if they utilized the waterholes during the cool hours of the day when water losses through evaporative cooling (sweating and panting) for the reduction of heat load were at the minimum level. For some species this pattern of waterholes utilization could raise some problems.

At mid-day insolation accounted for the greater percentage of the total heat load on the animals' bodies (Finch, 1972). The species utilizing the waterholes were more exposed to direct solar radiation during the middle of the day than at any other periods of the day. Also, during the cool hours of the day many predators were present at and drinking from the waterholes. Thus, in order to escape predation some small sized prey species utilized the waterholes during mid-day when it was hot but safe. The physiological requirements of the small species for drinking water were possibly over-ridden by their need to escape predation. Thus, some small species either dispensed with daily drinking or were more frugal with the water they drank.

In order to equilibrate in heat or maintain water balance in the hot and arid environment (e.g. TsE), oryx (Taylor, 1969; Robertshaw and Taylor, 1969), Peter's gazelle (Taylor, 1972) and ostrich (Crawford and Schmidt-Nielsen, 1967) and other small species tolerated varying degrees of elevated body temperatures during the middle of the day. By allowing their body temperatures to rise above those of their environment the species avoided the evaporative water-loss which was required for heat dissipation. These species were the relatively arid adapted wildlife which utilized the waterholes only sparingly even at the peak of the dry season when the intensity of waterholes utilization by the larger species was maximum.

Robertshaw and Taylor (1969) suggested that the pattern of evaporative cooling was more related to the size of an animal than its phylogenetic position. The smaller animals: oryx, hartebeest and Peter's gazelle equilibrated in heat primarily by panting whereas the larger species buffalo and eland sweat (Robertshaw and Taylor, 1969; Finch, 1972). The skin temperature of an animal which pants could equal or exceed that of the environment but conversely the skin temperature of an animal which sweats must be considerably cooler than the temperature of the environment since the latent heat of evaporation is taken from the surface of the skin of the animal that sweats. The environmental heat load could reach precarious levels more easily for an animal in an arid environment if it dissipated all its heat load by sweating rather than panting. The heat load could reach precarious levels more easily in the case of larger species with larger volume: surface area ratio than for the smaller species.

By storing heat in their bodies and by panting primarily the smaller game were physiologically adapted to utilize the waterholes more during daylight hours when it was hotter. The larger game species on the other hand utilized the waterholes more during the cooler hours of the day because they sweat primarily and they were unable to tolerate high body temperatures above those of their environment. At night the heat load gained during daylight hours was dissipated by simple convectional current between the air and the skins of the smaller animals. Warthog (Bradley, 1968) for instance, retired at night into the cool burrow. By seeking shade during the hot hours of the day many large species, elephant, buffalo, and rhino with high water turn-over rates further improved the chances of economising water which they drank in the dry season. Excessive heat was carried from the large pinnae of the elephant (Buss and Estes, 1971) by simple physical convectional current between the ear lobes and the air, also by wallowing at the waterholes heat was carried from the bodies of elephant, rhino buffalo and warthog by conduction.

The abilities of some species (hartebeest and eland) to withstand mid-day insolation at the waterholes could be due to the large proportion of short-wave radiation which was reflected from their coats. The heat re-radiated (Macfarlane, Morris and Howard, 1958) from the dense fur of the waterbuck could also reduce the environmental heat load on the animal's body.

The inability of waterbuck (Taylor, Spinage and Lyman, 1969) to exploit some of the strategies for economising water resources during the dry season e.g. the production of dry faeces and concentrated urine (Taylor, 1969), selection of food with high percentage of water as in impala (Jarman, 1973), giraffe (Foster, 1966) and oryx (Root, 1972), and by reducing the rate of metabolism when dehydrated explained its restricted distribution and abundance near water (Aruba dam) throughout the study period.

Ecological separation at the waterholes:

At the waterholes the smaller species were observed to always give way to the larger species. As a result, inter-specific aggressions (Fisher, 1964; Henshaw, 1972) were infrequent. It was interesting that the frequencies of the small sized prey species were lowest at the waterholes when the carnivores and large herbivores were most likely to be drinking there.

By using different waterholes during the rains and drinking at a slightly different period of the day at the same waterhole during the dry season game species possibly reduced the frequency of their coincidence with other species thus minimising competition for space and water. Also by keeping to a time-table in which the times of arrival and departure, and the peak of drinking varied for each wildlife species the animals attained a measure of ecological separations at the waterholes.

Touristic value of the waterhole:

The diurnal and seasonal patterns of waterhole utilization suggested that there was scope to use the waterholes as management tool to enhance the touristic potential of the park. During the dry season wildlife aggregated around the few artificial waterholes containing water. Since the waterholes concentrated animals in areas of good visibility along the park roads, they could be used to improve game viewing, and photography for tourists and adapted as inexpensive areas of conducting animal studies when hides are constructed near them. At the Voi Safari Lodge for instance hides for game viewing were advantageously utilized by many tourists for many months throughout the year. Between 0800 and 1400 hours were most suitable for viewing small-medium sized animals and between 1700 and 2100 hours were best for viewing large animals at the waterholes.

CHAPTER III

DISTRIBUTION OF WILDLIFE IN RELATION TO WATERHOLES IN TSAVO NATIONAL PARK (EAST), SOUTH OF VOI RIVER.

INTRODUCTION

In order to investigate whether the artificial waterholes could be used as management tool to bring about an even distribution of wildlife throughout the park observations were carried out on the seasonal patterns of wildlife distribution.

The data presented in this chapter were derived from both ground and aerial censuses in TsE mainly south of Voi river where artificial waterholes were developed to distribute wildlife more evenly from Aruba dam along Voi river.

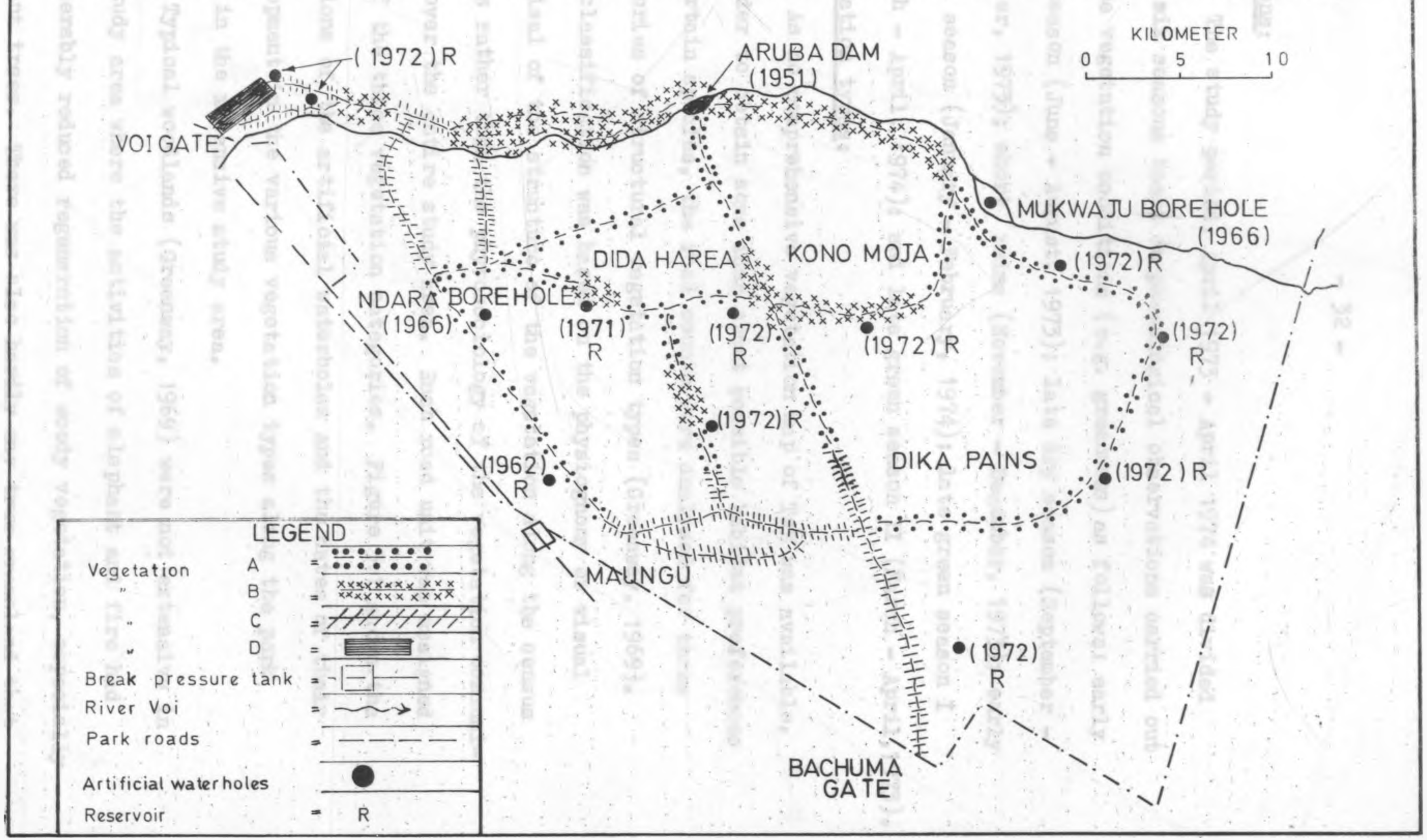
OBJECTIVES

The main objectives of the work reported in this chapter were:

1) To determine the distribution of wildlife in relation primarily to the few artificial waterholes where the animals obtained drinking water during the dry season; and

2) to determine the relative influences of vegetation types, seasons and other residual factors on the distribution of wildlife species in the intensive study area.

Figure 3:1
A map showing the locations of the artificial waterholes and the dates of their development in various vegetation types along the park roads, South of Voi river in Tsavo National Park (East)



Seasons:

The study period, April 1973 - April 1974 was divided into six seasons based on phenological observations carried out on the vegetation conditions (e.g. greenness) as follows: early dry season (June - August, 1973); late dry season (September - October, 1973); short rains (November - December, 1973); early green season (January - February, 1974); late green season I (March - April, 1974); and late green season II (March - April, 1973).

Vegetation types:

As no comprehensive vegetation map of TsE was available, in order to obtain some idea about possible habitat preferences of certain species, the road counts were analysed for three categories of structural vegetation types (Greenway, 1969). This classification was based on the physiognomy or visual appraisal of the structure of the vegetation along the census routes rather than the phytosociology of the vegetation communities over the entire study area. Each road unit was assigned one of the three vegetation categories. Figure 3:1 shows the locations of the artificial waterholes and the dates of their development in the various vegetation types along the park roads in the intensive study area.

Typical woodlands (Greenway, 1969) were not extensive in the study area where the activities of elephant and fire had considerably reduced regeneration of woody vegetation, especially emergent trees. There was also hardly any true grassland that was without trees and shrubs in its composition.

FIGURE 3:8

THE DISTRIBUTION OF PARK ROADS IN THE INTENSIVE STUDY AREA, SOUTH OF VOI RIVER IN TSAVO EAST.

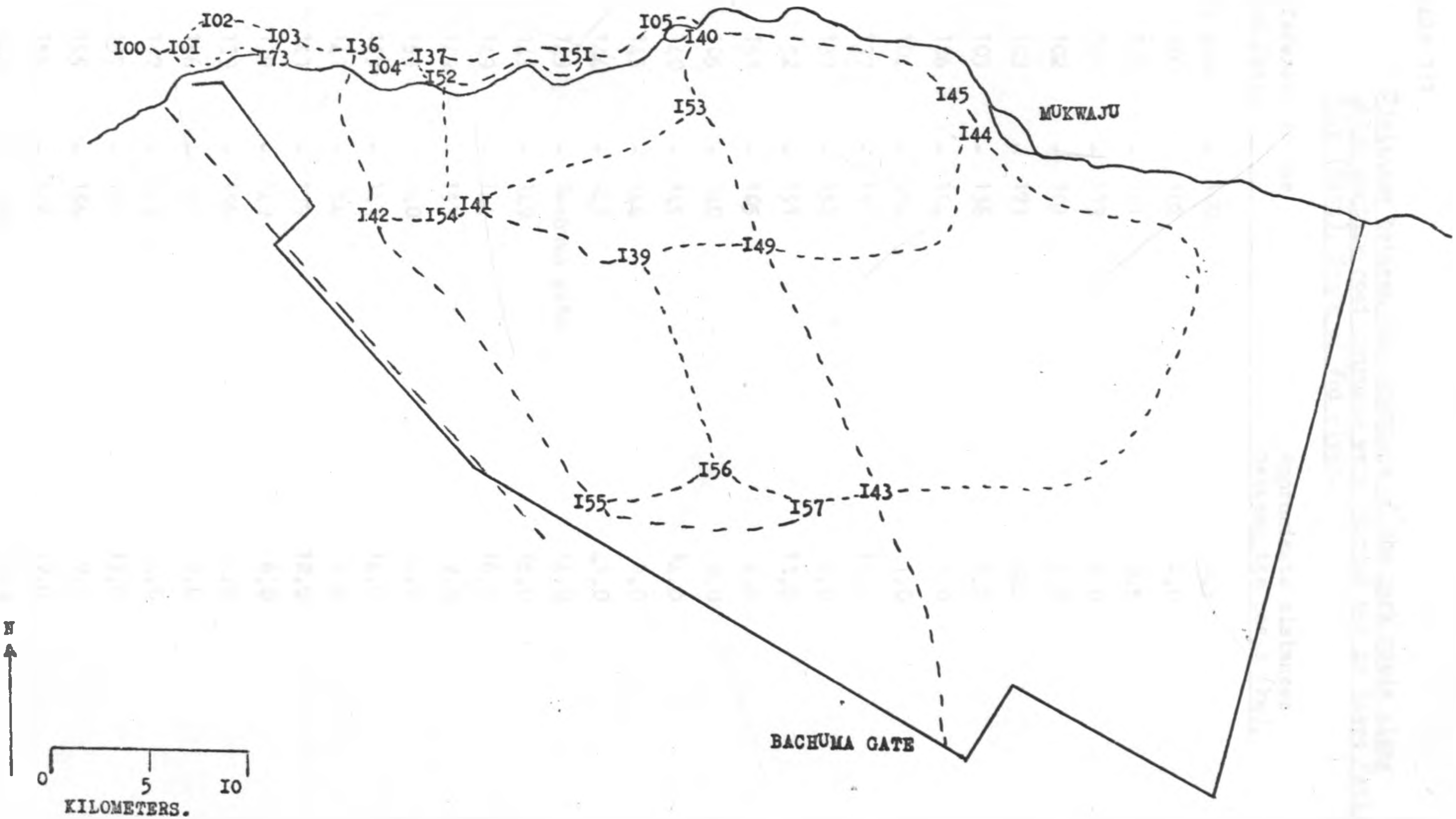


Table 3:1

Distances between the junctions of the park roads along which monthly road censuses were carried out in Tsavo National Park (East), South of Voi river.

References to the Road Posts			Approximate distances between the posts (km).
Voi gate	-	100	0.5
100	-	102	2.0
100	-	101	0.5
101	-	173	5.0
102	-	103	4.0
103	-	173	0.5
103	-	136	5.0
136	-	104	1.0
104	-	134	1.0
137	-	151	10.0
137	-	152	2.0
152	-	151	11.0
151	-	105	4.0
105	-	140	2.0
140	-	145	14.0
145	-	144	2.0
144	-	143	41.0
143	-	Bachuma gate	14.0
143	-	149	16.0
149	-	144	16.0
149	-	153	7.0
153	-	140	4.0
153	-	141	14.0
141	-	154	1.0
141	-	139	12.0
139	-	149	6.0
139	-	156	12.0
156	-	157	7.0
157	-	143	4.0
157	-	155	13.0
155	-	156	7.0
155	-	142	17.0
142	-	136	9.0
142	-	154	4.0
154	-	152	7.0

Vegetation A; Grassland:

This was land covered with grass and perennial herbs, sometimes with evergreen or deciduous trees or shrubs either very scattered or in small isolated groups, in either case not covering more than 10% of the ground.

Vegetation B; bushland:

This was land with more than 50% cover of shrubs and small trees growing densely together. The bushes could be evergreen and had clearly defined boles. Herbs were ephemeral and or succulent and grasses were mostly annuals forming ground cover under deciduous bushland.

Vegetation C: woodland-wooded grassland:

This consisted of land with an open cover of trees, their crowns not forming a thickly interlaced canopy except along the fringing forest between Voi and Ndololo along Voi river. Scattered evergreen shrubs were present but not conspicuous. Herbs and perennial or annual grasses formed the ground cover. Trees and shrubs in the wooded grassland covered less than 50% of the ground.

METHODS

Road counts:

Counts of game species were made during daylight hours by two observers in a Toyota Land Cruiser. The road counts were made every month from April, 1973 to April, 1974 except in January, 1974. As much as possible, a sampling strip 300m wide was maintained on each side of the vehicle. Figure 3:2 and Table 3:1 show the pattern of the distribution of the census routes and the distances between the road junctions in the intensive study area.

The intensive study area was divided into 40 unequal units identified by permanent features such as road junctions and artificial reservoirs. The frequencies of sighting various species of animals per kilometer of road were calculated for each sampling unit. At the peak of the long dry season, September to October, 1973 the precise locations of the dry season water supplies (DSWS) where drinking water was available for wildlife within the intensive study area were surveyed and mapped. Concentric circles were drawn around the water supplies and each of the road units was assigned a distance to the nearest DSWS.

<u>Aerial counts</u>:

Since there were more artificial waterholes along the tourist routes than elsewhere in the study area, in order to obtain an unbiased estimate of distribution of wildlife in relation to the waterholes aerial census was carried out.

In March, August and September, 1973 three aerial censuses were carried out by a colleague Mr. S. M. Cobb in the intensive study area. During each of the three censuses all the natural waterholes in the area had dried out. Another seven aerial counts were made by the author; one each month from the end of October, 1973 to April, 1974. In each month the latter counts were made after it had rained sufficiently for some natural waterholes to contain enough water for utilization by game.

A Piper Super-cub aeroplane (PA-18) with high wing was used during the aerial census, and the number of game and waterholes seen were recorded using a tape-recorder when the observations fell within a strip whose projection on the ground was 300m wide. A mechanical counter was used when a lot of animals were seen together. Systematic flight lines five kilometers apart were maintained throughout the counts. The counted strip being demarcated by two streamers attached to the strut of one wing of the aeroplane.

From the results of the seven wet-months' and three dry-months' aerial censuses, distribution maps of game species were constructed by dividing the total number of animals seen in all counts in each 25 km^2 grid within the intensive study area by the number of times (or months) that the square was counted.

The aerial and ground censuses were undertaken to provide quantitative evidence on the distribution of wildlife in relation to the waterholes in the intensive study area. It was necessary to embark on both aerial and ground counts because the larger species: elephant and buffalo which moved about in large, closely packed herds could only be counted reliably by air while the smaller species: Peter's gazelle, warthog, etc........ were more difficult to sight from the air than on the ground. Also without recourse to driving research vehicle off the park roads (against Park regulations), the distribution and the conditions of the waterholes away from the census routes could only be assessed reliably from the air.

Analysis of data:

In considering differences between the frequencies of observation of animals in areas of unequal size, the number (X) observed in the smaller area (A), and the number (Y) in the larger area (B) were compared with the number that would be expected if the animals had been distributed at random over the intensive study area. Thus, if $X + Y = N$ and $A + B = Z$, there would be $(A/Z)N$ animals in A, and $(B/Z)N$ animals in B. A comparison was made of X with $(A/Z)N$ and Y with $(B/Z)N$, i.e. the observed and the expected values respectively. The significance of the difference was determined by d-test using the ratios of the percentages of observation of game and those of expected values based on random distribution for $N \geq 30$ (Bailey, 1964).

The Kendall rank correlation coefficient (Siegel, 1956) was calculated in order to evaluate the degree of association between frequencies of species (x), vegetation types (y), distances to DSWS (z), and seasonality (w). Although seasonality (w) was an important factor which influenced x, y, and z, the factor was not considered in the final analysis because information about relationship between z and w were not consistently collected during the study. The coefficients of correlation (r_{xy}, r_{yz}) were generalised to partial correlation coefficient ($r_{xy.z}$, $r_{xz.y}$) in order to separate out the relative influences of vegetation types, and distances to drinking water on the observed frequencies of game species (Siegel, 1956).

Table 3:2 - The proportions of the park roads and the vegetation types represented in the monthly road censuses at various distances from the dry season water supplies (waterholes)

Distance from DSWS	Park Roads km	% of Park Roads	Kilometers of Vegetation Types A	B	C
0-5 km	64	25	39	20	5
5-10km	81	33	40	32	9
> 10km	104	42	55	6	43
Total km	249	100	135	58	57
			54%	23%	23%

Table 3:3 - Relative proportions of the three vegetation types at various distances from dry season water supplies

Distance from DSWS	Vegetation Types A	B	C	Total	Vegetation Types A	B	C
0-5 km	61	31	8	100	29	35	9
5-10km	40	40	11	100	30	55	16
> 10km	53	6	41	100	41	10	75
					100%	100%	100%

Table 3:4 The mean annual numbers of game per kilometer of park road at TsE

Species	Mean ± SD
Zebra	1.127 ± 0.604
Elephant	1.103 ± 0.351
Impala	0.533 ± 0.194
Kongoni	0.480 ± 0.144
Oryx	0.453 ± 0.130
Peter's gazelle	0.303 ± 0.172
Warthog	0.197 ± 0.136
Ostrich	0.080 ± 0.044
Giraffe	0.070 ± 0.056
Waterbuck	0.513 ± 0.440
Buffalo	0.333 ± 0.108

RESULTS AND DISCUSSIONS

Tables 3:2 and 3:3 give the lengths of the park roads and the relative proportions of the three categories of structural vegetation types A, B and C at various distances from the DSWS. Twenty-five percent of the surveyed road lengths were at 0-5km from DSWS and 42% of the roads were at $\geq$10km from the DSWS. A greater percentage of the area was open grassland; the vegetation type A constituted 54% of the entire area surveyed. Along the census routes vegetation C was more represented (75%) at >10km from the DSWS but vegetation B was more (55%) at 5-10km from the DSWS.

The Frequencies of game along the park roads:

The mean annual frequencies of observing some animals within a 600m belt along monthly census routes mainly south of Voi river are presented in Table 3:4. The mean frequencies of sighting game per kilometer of census routes varied from 0.070 (giraffe) to 1.127 (zebra). Zebra were the most common species seen along the census routes in the intensive study area.

Distribution of Surface water and game species by seasons:

During the long rains (November-December) and the short rains (April-May) many natural waterholes were filled with rain

Figure 3:3

A graph showing the ranked relationship between monthly rainfall and the number of natural waterholes containing water in Tsavo National Park (East), 1973-74; South of Voi river. The Spearman's rank correlation coefficient, $r_s = + 0.8095$.

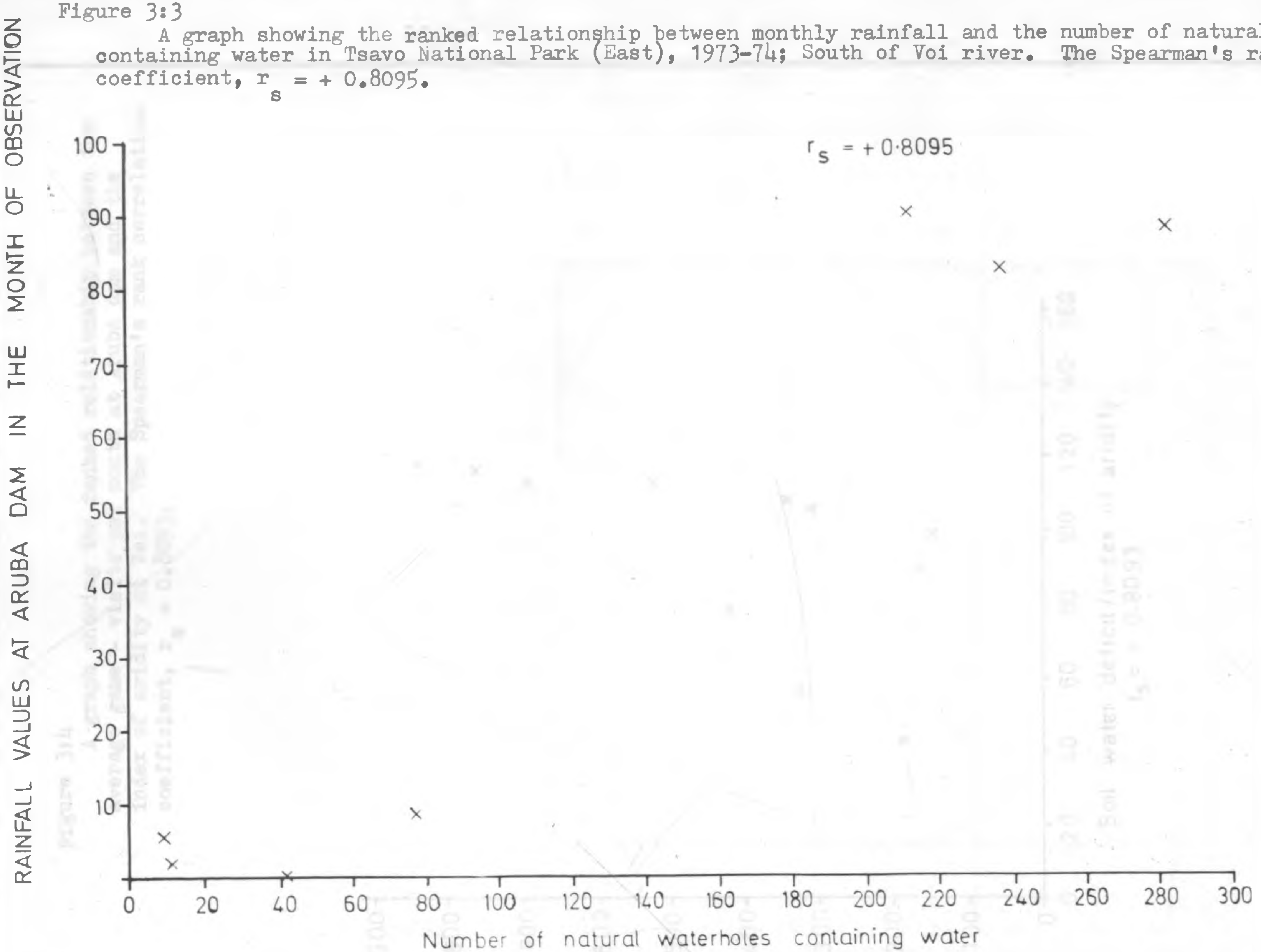


Figure 3:4

A graph showing the ranked relationship between the average game - visits per month at Aruba dam and the index of aridity at Voi. The Spearman's rank correlation coefficient, r_s = 0.8093.

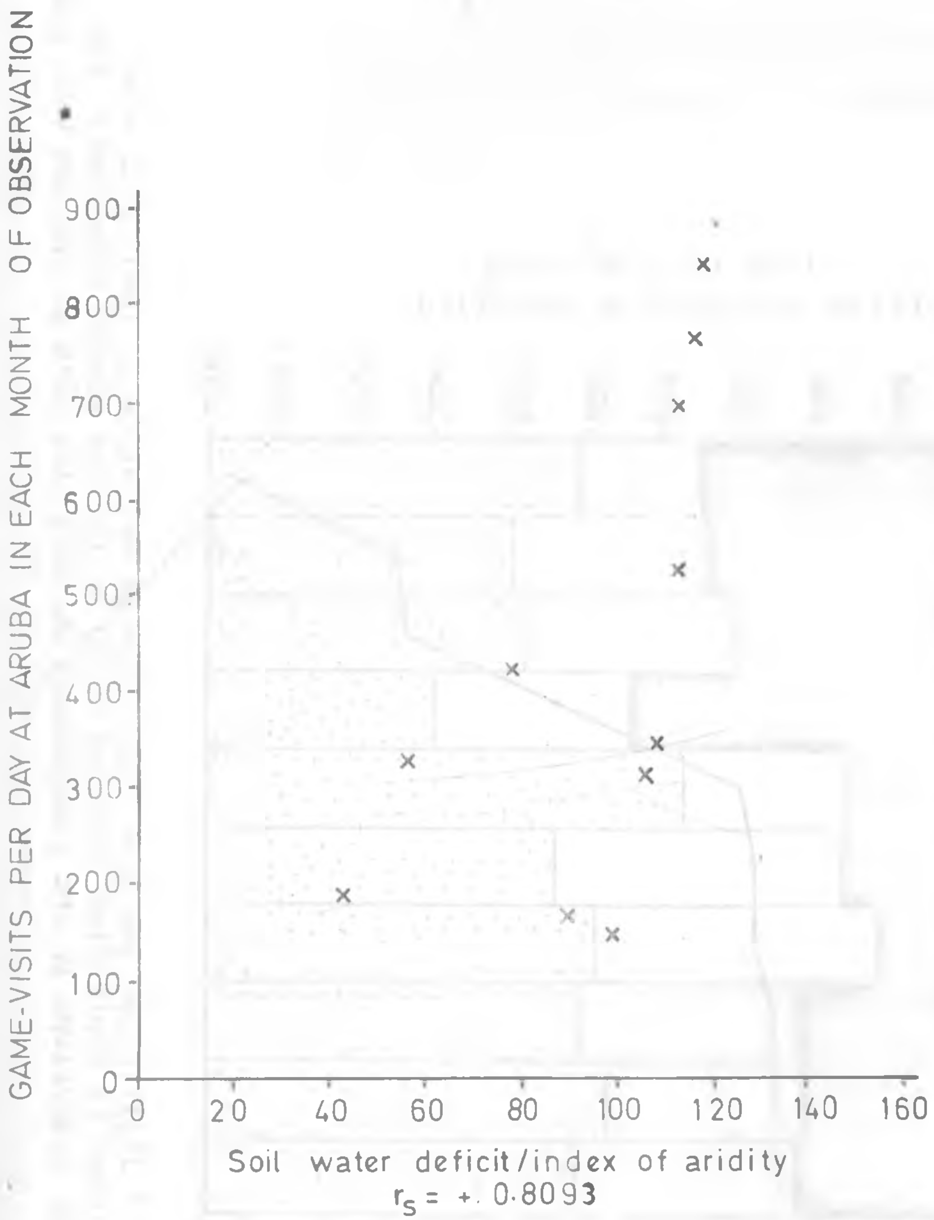
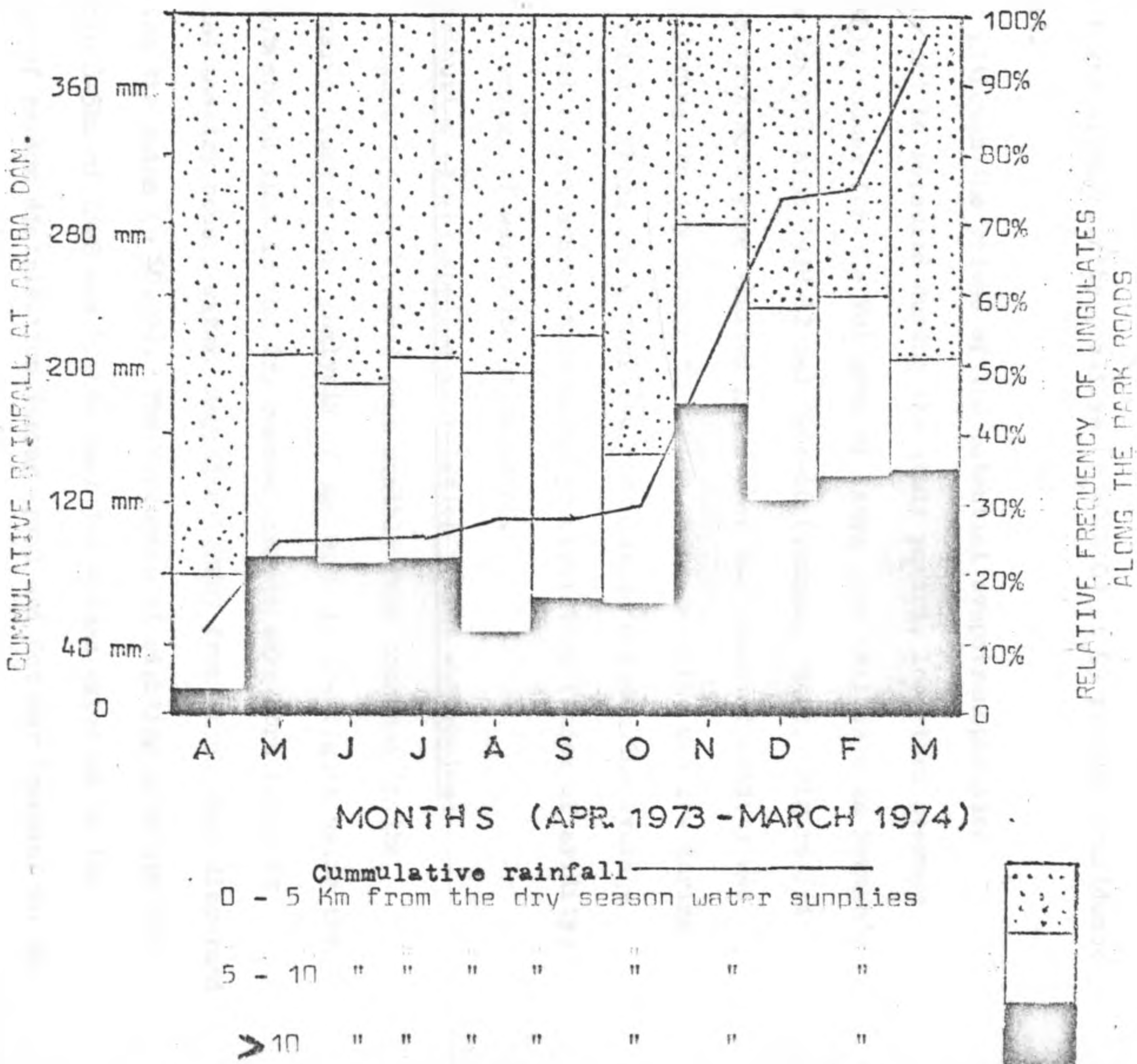


FIGURE 3:5

SEASONAL VARIATIONS IN THE FREQUENCIES OF UNGULATES NEAR TO AND FAR AWAY FROM THE WATERHOLES CONTAINING DRINKING WATER IN THE DRY SEASON (SEPTEMBER AND OCTOBER, 1973) ALONG THE PARK ROADS SOTH OF VOI RIVER IN TSAVO EAST PARK.



water and drinking water was available within 2km from all animals. The natural waterholes dried out about July-August during the long dry season (June-October). Figure 3:3 shows the positive correlation between the number of natural waterholes containing water and the monthly rainfall between August, 1973 and April, 1974 when aerial surveys of the numbers and conditions of the waterholes were carried out. The Spearman Rank correlation coefficient between rainfall and the number of waterholes containing water was significantly positive (r_s=0.810) at 99 percent confidence limit.

Although the values of the potential evapotranspiration could not be measured during the study period, long term average monthly values for the Voi area of Kenya were available in Penman's data for Voi area 1938-62 and 1964-66 (Penman, 1948). Figure 3:4 shows that more game visited Aruba when the index of aridity was high during the dry season than when the same value was low during the rains. There was a positive correlation between the average potential evapotranspiration minus precipitation (index of aridity) and intensity of waterhole utilization.

Distribution of all species in relation to the waterholes:

Figure 3:5 was derived from monthly road censuses in the intensive study area. Analysis of the data in the figure using the d-tests showed that in the dry season animals were more frequent around the dry season water supplies (DSWS) from which they dispersed during the rains ($p \leq 0.05$). The frequency of sighting game species within 0-5km of DSWS was higher than the values expected on the basis of random distribution during April and October (peaks of the dry

Table 3:5 **The significance of the difference between the percentages of game censused per kilometer of road and those that would be expected from a distribution that is uninfluenced by the distances of animals from Dry season water supplies (D.S.W.S).**

Distance from DSWS	Frequency (%) Dry season	Wet season	d - test Dry season	Wet season
Zebra				
0-5 km	48	23	+ve	NS
5-10 km	35	26	NS	NS
>10 km	17	51	-ve	NS
Elephant				
0-5 km	56	31	+ve	NS
5-10 km	36	34	NS	NS
>10 km	8	54	-ve	NS
Impala				
0-5 km	84	31	+ve	NS
5-10 km	3	10	-ve	-ve
>10 km	13	59	-ve	+ve
Kongoni				
0-5 km	44	21	+ve	NS
5-10 km	21	39	NS	NS
>10 km	36	40	NS	NS
Oryx				
0-5 km	37	20	NS	NS
5-10 km	43	28	NS	NS
>10 km	20	52	-ve	NS
Peter's gazelle				
0-5 km	55	35	+ve	NS
5-10 km	14	34	-ve	NS
> 10 km	31	31	NS	NS
Warthog				
0-5 km	84	31	+ve	-ve
5-10 km	3	10	-ve	-ve
>10 km	13	59	-ve	+ve
Ostrich				
0-5 km	67	25	+ve	NS
5-10 km	18	10	-ve	-ve
> 10 km	15	65	-ve	+ve
Giraffe				
0-5 km	74	90	+ve	+ve
5-10 km	25	10	NS	-ve
> 10 km	1	0	-ve	-ve
Waterbuck				
0-5 km	85	83	+ve	+ve
5-10km	15	16	-ve	-ve
> 10 km	0	1	-ve	-ve

Table 3:5 Continued.

Distance from DSWS	Frequency (%) Dry season	Wet season	d - test Dry season	Wet season
Buffalo				
0-5 km	44	0	+ve	-ve
5-10 km	56	0	+ve	-ve
> 10 km	0	0	-ve	-ve

Percentages expected on the basis of randown distribution to DSWS:

0-5 km	= 25%
5-10 km	= 33%
10 km	= 42%

+ve = Higher than expected values at p = 0.001
-ve = Lower than expected values at p = 0.001
NS = Not significantly different from expected values at p = 0.001

seasons) ground counts. In November and May after it had rained, animals moved away from the artificial water supplies and were randomly distributed throughout the study area especially at distances ⊳10km away from the DSWS where their frequencies had previously been significantly lower than expected values (d-test, $p \leq 0.001$).

Distribution of individual species in relation to the Waterholes:

Table 3:5 contrasts the seasonal frequencies of individual game species at various distances from DSWS during the peaks of the more defined dry and rainy seasons with expected frequencies on the basis of a random distribution. Elephant, and zebra aggregated around the DSWS in the dry season. The result agreed with the findings of Leuthold and Sale (1973) suggesting a restricted dry season range near permanent water for elephant. Statistically, the frequency of sighting elephant and zebra per kilometer of park roads was significantly positive ($p \leq 0.05$) at 0-5km to the DSWS and significantly negative at ≥10km from DSWS at the peak of the dry season (September-October). The animals, (elephant and zebra) were randomly distributed at 5-10km from DSWS during the same period, showing that they were able to move away for a distance of up to 10km in-between drinking. In November-December, at the peak of the rainy season when drinking water was abundant throughout the park elephant and zebra were randomly distributed at all distances away from the DSWS in the intensive study area.

In the dry season, the frequency of kongoni was higher than the expected values at 0-5km from DSWS but unlike the zebra and elephant, kongoni were randomly distributed at ≥5km from water. The result for kongoni agreed with the findings of Squires and Wilson (1971) who demonstrated that as the distance between food and water increased, water and food intake of Merino and Border Leicester sheep decreased in semi-arid areas of Australia.

The frequencies of waterbuck and giraffe at 0-5km from DSWS were consistently higher than values expected on the basis of random distribution during the peaks of the rainy and the dry seasons. The Kolmogorov-Simirnov non-parametric test (Siegel, 1956) was carried out on all the species which regularly drank at Aruba dam. The test showed that the frequency of waterbuck only was consistently higher than expected throughout the year, the converse being the case at ≥5km from water. The high physiological requirement of waterbuck for regular drinking water was consistent with its restricted distribution near water.

Giraffe showed restricted dry season distribution along the Voi river near water about Kandecha-Ndololo. During the rains the frequency of giraffe decreased as they moved out to the north of the intensive study area. The impala, ostrich, warthog and buffalo moved near permanent DSWS in the dry season but moved away from the same area during the rains. Jarman (1973) observed that 40 populations of impala

Table 3:6

AERIAL MAPS OF THE DISTRIBUTION OF GAME SPECIES IN TSAVO NATIONAL PARK (EAST). SOUTH OF VOI RIVER

KEY

1. Solid black = Frequent
2. hatches = common
3. stripes = fairly common
4. dots = few
5. x = isolated records

blank = not seen

black circle = Dry season water supply

Figure	Species	Number per 25 km 2				
		(1)	(2)	(3)	(4)	(5)
6a and b	Zebra	10	5-10	3-5	1-3	1
7a and b	Elephant	25	15-25	10-15	3-10	3
8a and b	Impala	5	1-5	1		
9a and b	Haitebeest	2	1-2	1		
10a and b	Oryx	5	1-5	0.5-1	0.5	
11a and b	Peter's gazelle	5	1-5	0.5-1	o.5	
12a and b	Warthog	1-5	0.5-1	0.5		
13a and b	Ostrich	1	0.5-1	0.5		
14a and b	Rhino	0.3-0.5	0.1-0.3	0.1		
15a and b	Giraffe	1-5	0.5-1	0.5		
16a and b	Eland	1	0.5-1	0.5		

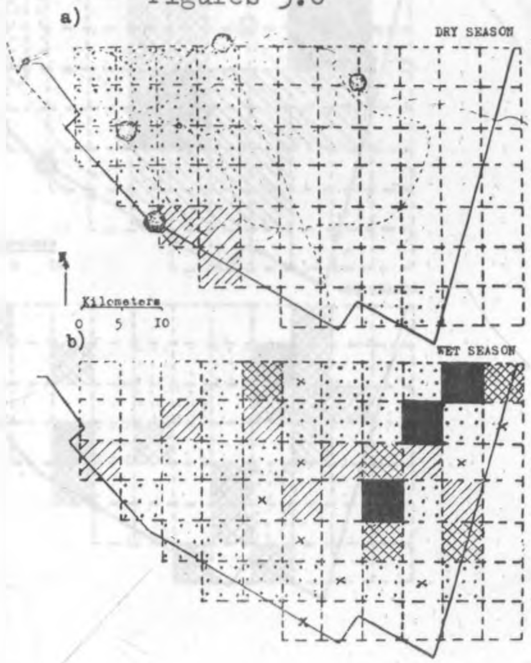
The maps are based on the mean number of individuals regardless of size and sex. All distribution maps are divided into portions; (a) dry season, and (b) wet season.

Figures 3:6 - 9

The maps of the results of aerial censuses showing seasonal distribution of zebra, elephants, impala, and hartebeest in relation to the waterholes containing drinking water during the dry season in Tsavo National Park (East), South of Voi river, 1973-74.

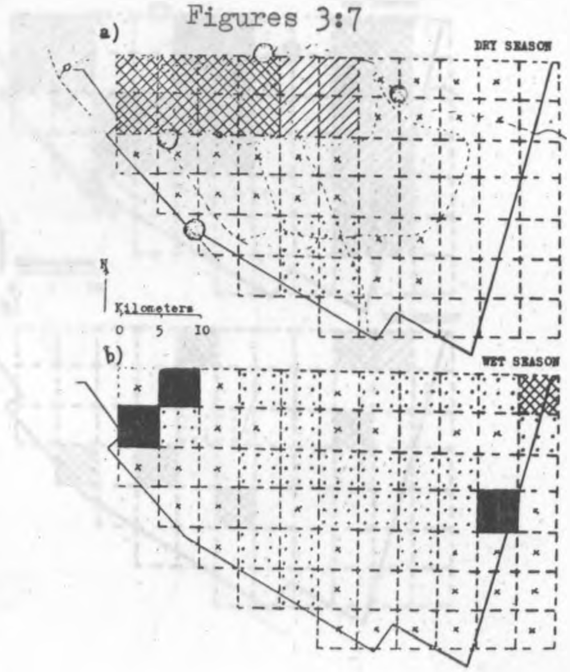
ZEBRA

Figures 3:6



ELEPHANTS

Figures 3:7

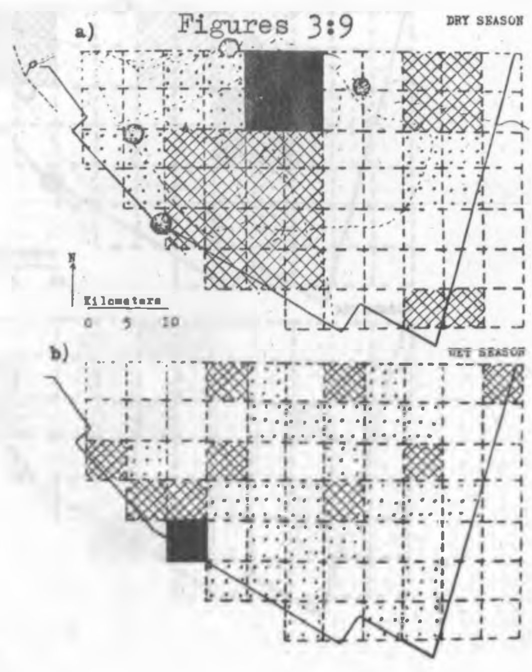


IMPALA

Figures 3:8

HARTEBEEST

Figures 3:9

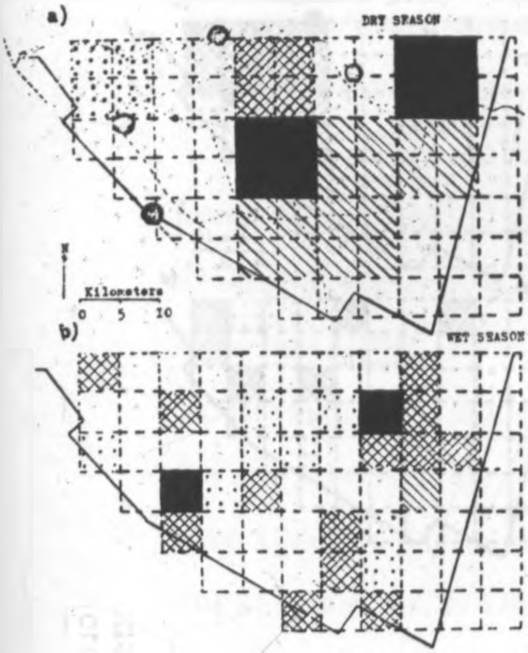


Figures 3:10-13

The maps of the results of aerial censuses showing seasonal distribution of oryx, peter's gazelle, warthog and ostrich in relation to the locations of the waterholes containing drinking water during the dry season in Tsavo National Park (East), South of Voi river, 1973-74.

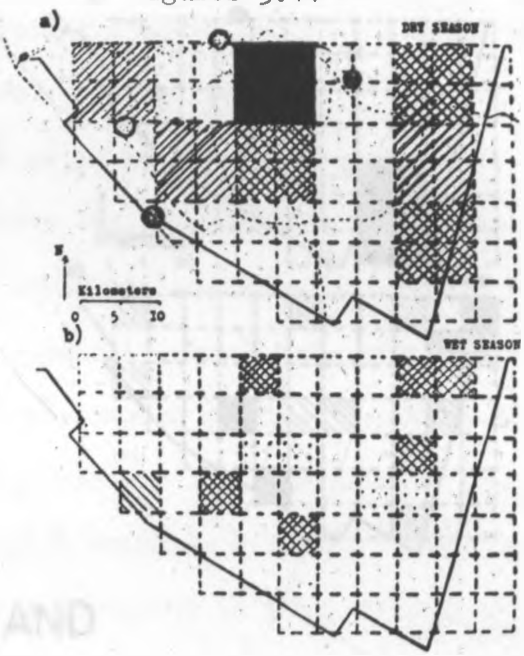
ORYX

Figures 3:10



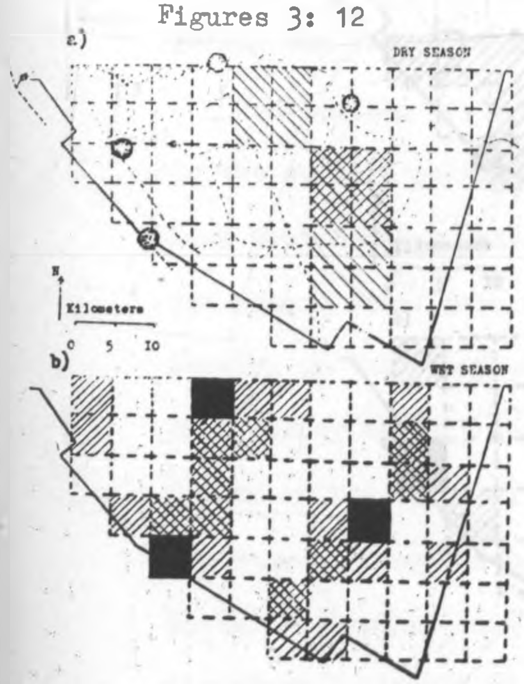
PETERS GAZELLE

Figures 3:11



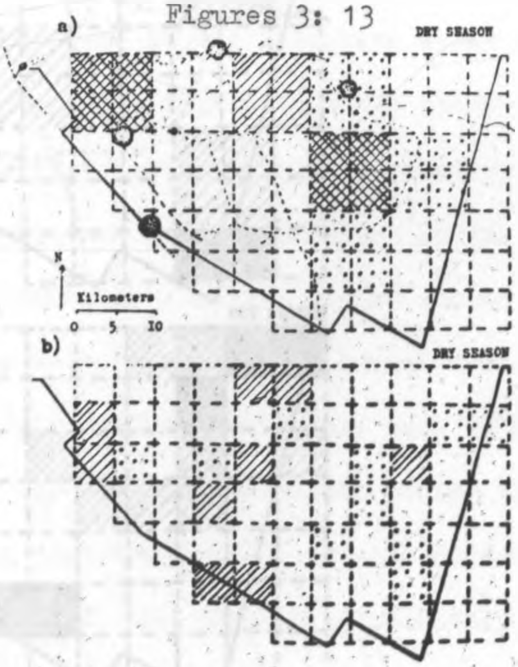
WARTHOG

Figures 3: 12



OSTRICH

Figures 3: 13

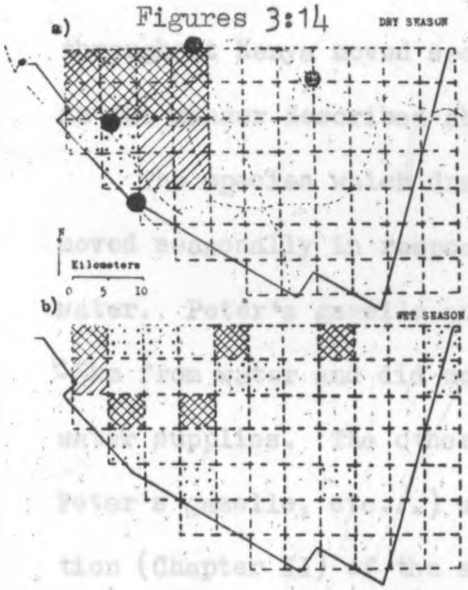


Figures 3:14 - 16

The maps of the results of aerial censuses showing seasonal distribution of rhino, giraffe, and eland in relation to the locations of the waterholes containing drinking water during the dry season in Tsavo National Park (East), South of Voi river, 1973-74.

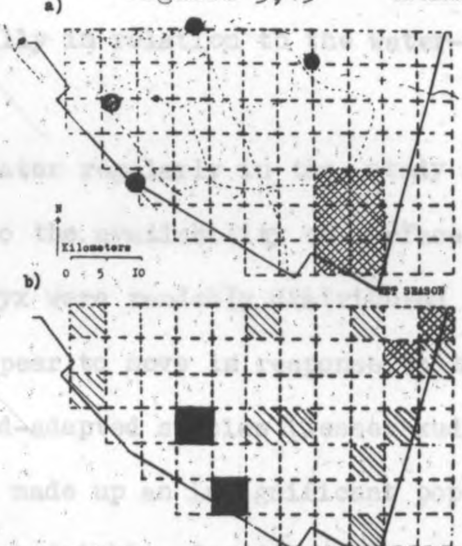
RHINO

Figures 3:14



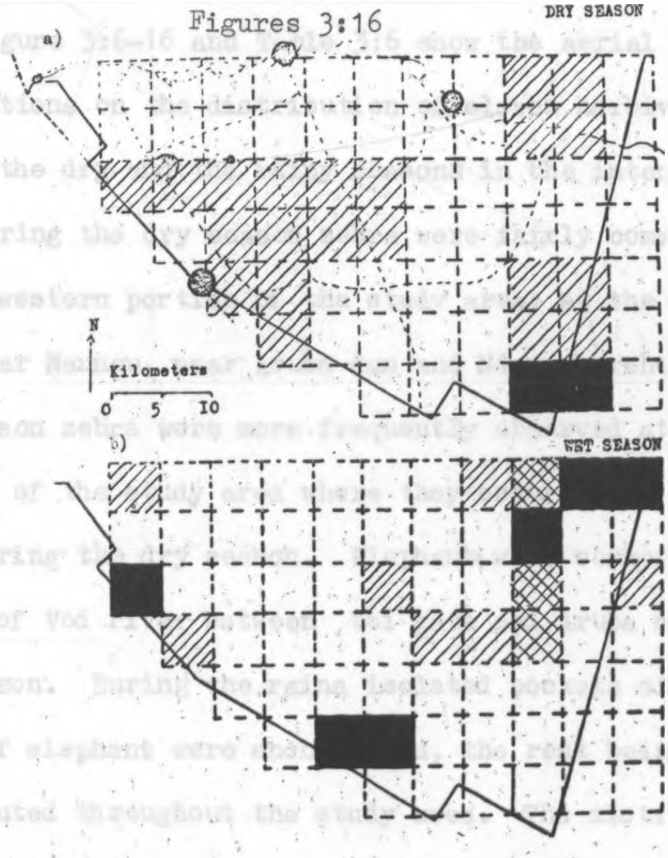
GIRAFFE

Figures 3:15



ELAND

Figures 3:16



throughout Kenya moved seasonally in relation to the water-courses in the manner described above.

The species which drank water regularly in the study area moved seasonally in response to the availability of surface water. Peter's gazelle and oryx were randomly distributed at ≥5km from water and did not appear to move in response to the water supplies. The other arid-adapted species (lesser kudu, Peter's gazelle, etc...) which made up an insignificant population (Chapter II) of the species drinking from the waterholes did not seasonally fluctuate appreciably in their distribution in relation to the waterholes.

Aerial surveys of wildlife distribution:

Figure 3:6-16 and Table 3:6 show the aerial maps and the explanations on the distribution of eleven herbivore species during the dry and the rainy seasons in the intensive study area.

During the dry season zebra were fairly commonly observed in the western portion of the study area; at the Pressure Break Tank near Maungu, near Aruba dam and Ndara borehole. During the wet season zebra were more frequently observed at the eastern section of the study area where they occurred in larger herds than during the dry season. Elephants were commonly seen within 0-10km of Voi river between Voi gate and Aruba dam during the dry season. During the rains isolated pockets of well packed herds of elephant were encountered, the rest being uniformly distributed throughout the study area. The distribution of

Table 3:7 The seasonal percentages of species populations and the significance of their difference from random distribution in three vegetation types:

a) Zebra

Seasons	Vegetation types: % of species populations			d - test		
	A	B	C	A	B	C
Late green II	45	7	48	NS	-VE	+VE
Early dry	78	18	4	+VE	NS	-VE
Late dry	76	22	2	+VE	NS	-VE
Short rains	65	20	15	NS	NS	NS
Early green	79	17	4	+VE	-NS	-VE
Late green I	87	3	10	+VE	-VE	NS
Mean Annual	72	14	14	+VE	NS	NS

b) Elephant

Seasons	Vegetation types: % of species populations			d - test		
	A	B	C	A	B	C
Late green II	81	10	9	+VE	-VE	NS
Early dry	50	28	22	NS	NS	NS
Late dry	72	12	16	+VE	-VE	NS
Short rains	64	7	29	NS	-VE	NS
Early green	86	4	10	+VE	-VE	NS
Late green I	65	11	24	NS	-VE	NS
Mean annual	70	12	18	+VE	NS	NS

Table 3:7 continued.

c) Impala

Seasons	Vegetation types: % of species populations A	B	C	d - test A	B	C
Late green II	62	6	32	NS	-VE	+VE
Early dry	41	14	43	-VE	NS	+VE
Late dry	56	15	29	NS	NS	NS
Short rains	32	14	54	-VE	NS	+VE
Early green	64	17	19	NS	NS	NS
Late green I	43	6	51	-VE	-VE	+VE
Mean annual	50	12	38	NS	NS	+VE

d) Hartebeest

Seasons	Vegetation types: % of species populations A	B	C	d - test A	B	C
Late green II	56	20	24	NS	NS	NS
Early dry	60	17	23	NS	NS	NS
Late dry	77	14	9	+VE	NS	NS
Short rains	69	10	21	+VE	-VE*	NS
Early green	83	9	8	+VE	-VE	-VE*
Late Green I	70	21	9	+VE	NS	NS
Mean annual	69	15	16	+VE	NS	NS

e) Oryx

Seasons	Vegetation types: % of species populations A	B	C	d - test A	B	C
Late green II	44	34	22	NS	NS	NS
Early dry	44	13	43	NS	NS	+VE
Late dry	71	6	23	+VE	-VE	NS
Short rains	50	12	38	NS	-VE	+VE
Early green	79	17	4	+VE	NS	-VE
Late green I	84	5	11	+VE	-VE	NS
Mean annual	62	15	23	NS	NS	NS

Table 3:7 continued.

f) Peter's gazelle

Seasons	Vegetation types: % of species populations A	B	C	d - test- A	B	C
Late green II	66	28	6	NS	NS	-VE
Early dry	78	17	5	+VE	NS	-VE
Late dry	76	9	15	+VE	-VE	NS
Short rains	73	9	18	+VE	-VE	BS
Early green	76	4	20	+VE	-VE	NS
Late green I	93	4	3	+VE	-VE	-VE
Mean annual	77	11	12	+VE	NS	NS

g) Warthog

Seasons	Vegetation types: % of species populations A	B	C	d - test A	B	C
Late green II	15	85	0	-VE	+VE	-VE
Early dry	66	25	9	NS	NS	NS
Late dry	21	38	41	-VE	+VE	+VE
Short rains	79	11	10	+VE	-VE*	NS
Early green	30	59	11	-VE	+VE	NS
Late green I	13	45	42	-VE	+VE	+VE
Mean annual	37	45	18	-VE	+VE	NS

h) Ostrich

Seasons	Vegetation types: % of species populations A	B	C	d - test A	B	C
Late green II	74	21	5	+VE	NS	-VE
Early dry	68	20	12	+VE	NS	NS
Late dry	79	13	8	+VE	NS	-VE*
Short rains	47	28	25	NS	NS	NS
Early green	95	3	2	+VE	-VE	-VE
Late green I	98	0	2	+VE	-VE	-VE
Mean annual	75	15	10	+VE	NS	NS

Table 3:7 continued.

i) Giraffe

Seasons	Vegetation types: % of species populations A	B	C	d- test A	B	C
Late green II	45	10	45	NS	-VE*	+VE
Early dry	4	11	85	-VE	-VE*	+VE
Late dry	2	9	89	-VE	-VE	+VE
Short rains	21	6	73	-VE	-VE	+VE
Early green	3	6	91	-VE	-VE	+VE
Late green I	28	22	50	-VE	NS	+VE
Mean annual	17	11	72	-VE	-VE*	+VE

j) Waterbuck

Seasons	Vegetation types: % of species populations A	B	C	d - test A	B	C
Late green II	75	23	2	+VE	NS	-VE
Early dry	26	40	34	-VE	+VE	+VE
Late dry	8	69	23	-VE	+VE	NS
Short rains	57	41	2	NS	+VE	-VE
Early green	19	67	14	-VE	+VE	NS
Late green I	16	51	33	-VE	+VE	NS
Mean annual	34	48	18	-VE	+VE	NS

	Vegetation types: % of species populations A	B	C	d - test A	B	C
% expected on the basis of random distribution (i.e. proportional to relative size of vegetation types)	54	23	23	NS	NS	NS

+VE = positively significant at p=0.001
-VE = negatively " " p=0.001
NS = not significantly different from expectations
* = value tested at p=0.01

Late green II = April-May 1973 Early dry = June-August 1973
Late dry = September-October 1973 Short rains = Nov.-Dec. 1973
Early green = January - February 1974
Late greenI= March - April 1974

zebra, elephant and rhino appeared to have shifted from the west around DSWS during the dry season to the east away from the DSWS during the rains.

It was more difficult to relate the distribution of the other species-impala, hartebeest, oryx, Peter's gazelle, warthog, ostrich, giraffe and eland - to the DSWS from the aerial counts. During the rains the species moved in all directions slightly away from their dry season distribution areas.

Distribution by vegetation types:

Table 3:7 shows the mean annual percentage of ten wildlife species in the intensive study area. The result showed that the frequencies of the species which were adapted to live in open plains e.g. graziers; hartebeest, zebra, Peter's gazelle and ostrich were, as expected, high in the grassland whereas those of the browser, e.g. giraffe, were high in the woodland.

The oryx preferred the grasslands in the green season, but moved into the wooded grasslands during the dry season. Although elephants were randomly distributed in vegetation type C throughout the year its frequency was higher than expected in vegetation type A in the green season. This finding was consistent with the catholic feeding habits of the elephant; i.e. grazing during the green season and browsing in the dry season.

The waterbuck and warthog showed preference for vegetation type B. The species were frequently encountered around Aruba dam where the bush had been reduced mechanically during the creation of the dam and by subsequent utilization by wildlife.

Table 3:8

THE KENDAL RANK CORRELATION CO-EFFICIENT AND PARTIAL CORRELATION ANALYSIS

	r_{xy}	r_{xz}	r_{xw}	$r_{xy.z}$	$r_{xz.y}$
Oryx	-0.078	+0.380*	-0.067	-0.143	+0.374
Buffalo	+0.172	-0.778*	+0.552	+0.101	-0.768
Waterbuck	-0.062	-0.860*	-0.067	-0.361	-0.879
Warthog	-0.174	-0.426*	-0.345	-0.261	-0.462
Giraffe	+0.593*	-0.773*	+0.207	+0.770	-0.866
Kongoni	-0.343*	-0.265	+0.600*	-0.398	-0.337
P.Gazelle	-0.312*	-0.164	+0.207	-0.343	-0.221
Ostrich	-0.424*	-0.237	+0.207	-0.480	-0.331
Zebra	-0.343*	-0.140	+0.067	-0.370	-0.202
Elephant	-0.250	-0.385*	+0.467	-0.550	-0.438
Impala	+0.157	-0.094	+0.333	+0.146	-0.074

$r_{yz} = 0.14$

* = the coefficient of correlation is signigicant at $p \leq 0.05$
x = density frequency per kilometer
y = vegetation types
z = distances to DSWS
w = seasons.

The restricted distribution of waterbuck throughout the year in the vicinity of drinking water was consistent with its frequency which was high in all seasons in vegetation type B near Aruba dam.

Giraffe and impala showed preference for vegetation type C; giraffe being a browser preferring vegetation type C, (woodland) near Voi river and impala being a grazier preferring the vegetation type C, (wooded grassland) along the water courses.

Degree of association between frequency of wildlife and factors of the habitat:

Table 3:8 shows the correlation coefficients r_{zy}, r_{xw} and the partial correlation coefficients $r_{xy.z}$ and $r_{xz.y}$ for eleven herbivores. There was a significantly high positive correlation between the density of giraffe and vegetation types ranked in ABC order and direction but the correlation between the densities of zebra, Peter's gazelle, kongoni and ostrich in the same ranked order and direction were negative ($p \leq 0.05$). The giraffe (a browser) increased in frequency from vegetation type A to C while ostrich, kongoni, Peter's gazelle and zebra (graziers) decreased in density from vegetation type A to C. There was also a positive correlation between the density of oryx and distance to DSWS. The frequency of oryx, an arid adapted species, increased away from the DSWS, but on the other hand the frequencies of giraffe, buffalo, waterbuck, elephant and warthog the less arid-adapted species decreased away from the DSWS.

Table 3:9

Summary of the results of the Kendall Rank Correlation Analysis

Species influenced more by distance to water

Species increasing away from the DSWS	Species decreasing away from the DSWS
Oryx	Buffalo waterbuck warthog

Species influenced more by vegetation types

Species increasing from vegetation A to C	Species increasing from vegetation C to A
	Kongoni Peter's gazelle Ostrich Zebra

Species influenced by both vegetation and distance to water

Elephant
Giraffe

Species influenced by factors other than those above

Impala

The association between frequencies of species and vegetation types holding distance to water ($r_{xy.z}$) gave a higher partial coefficient of correlation in the case of ostrich, kongoni, Peter's gazelle, elephant and zebra, than the association between the frequencies of the species and distance to DSWS. The associations between the frequencies of species and distances to DSWS, holding vegetation types as constants ($r_{xz.y}$) were higher for giraffe, buffalo, waterbuck, oryx and warthog than the associations between frequency and vegetation types.

Summary of results:

Table 3:9 summarises the results of the analysis of partial correlation coefficient for the eleven herbivore species. The regular drinkers: buffalo, waterbuck and warthog increased in frequencies near DSWS whereas the irregular drinkers e.g. oryx, decreased in frequency near DSWS. Also the graziers: kongoni, Peter's gazelle, zebra and ostrich increased from vegetation type C to A. The correlations between the frequency of giraffe in relation to vegetation types was very high indicating preference of giraffe for vegetation type C. The correlation of frequency with vegetation types and distances to DSWS were very low in the case of impala showing that factors other than these two (x, z,) influenced the distribution of the animal.

GENERAL DISCUSSION

During the dry season the natural waterholes and seasonal rivers dried out and the vegetation especially the grasses dried up. Seasonality affected the quality and quantity of food, availability of drinking water and distribution of game biomass in the various vegetation types. A residual factor which also affected the assessment of the frequency of wildlife was the visibility of various sizes of animals within the sampling strip. The larger species were more easily seen from a moving Vehicle in the woodier vegetation types whereas the smaller species were less easily sighted. The nocturnal habits of some species and the periodicity of the censuses also influenced the determination of the frequencies of game-species during the road counts. In the dry season for instance, rhinos might not be sighted at all throughout a month due to the intense heat from which they sought shade at mid-day but during the rains they were frequently recorded in both aerial and road counts and appeared to become more active during day-light hours. The carnivores on the other hand were more active at night when they were often encountered at the waterholes than during the daylight hours.

The kongoni appeared to be an "obligate drinker" a term suggested because of its some-what opportunistic drinking tendency; that is, an aggregation of kongoni near water when drinking water supplies were at less than five kilometers distance and a distribution uninfluenced by distance to DSWS when water supplies were further away.

The frequencies of waterbuck and giraffe were consistently higher than expected ($p \leq 0.05$) near the permanent water supplies. The high physiological requirement of waterbuck was consistent with its restricted distribution near water. The giraffe on the other hand drank sparingly preferring the riparian forest and the riverine vegetation types. Thus the frequent occurrence of giraffe near water was to obtain browse from the trees along the river.

The moderately high coefficient of partial correlation values showed that both vegetation types and distance to water were important co-determinants of frequencies of elephant. This was consistent with the catholic/voracious feeding habits of the elephant (grazing mainly in wet season and browsing primarily in the dry season) and the fact that Elephants, especially nursing mothers and their calves frequented water more regularly in the dry season. The numbers of buffalo were consistently higher than expected values (d-test $p \leq 0.05$) close to water in the dry season, the converse being the case with respect to Oryx and arid adapted species.

CONCLUSIONS

In this chapter some of the major determinants of density (frequency of animals) in relation to the waterholes were evaluated. For some species, e.g. waterbuck with high physiological requirement for water, and buffalo - a large, sweating species - the distance from water was an important determinant of frequency. Waterbuck and buffalo were distributed close to water in the dry season, the converse being the case with respect to oryx, an arid adapted species.

At the levels of the present analysis, of course, it appeared that the vegetation type more than distance to water determined the distribution of graziers (zebra, ostrich, kongoni and Peter's gazelle) and browser (giraffe) in the study area. Unfortunately there were no previous records on the distribution of various species before the creation of the artificial waterholes in the study area. Thus, it was not possible to compare the present study with studies carried out before the artificial waterholes were created. Broadly, it appeared that the wildlife species that regularly drank water had a restricted distribution near DSWS from which they dispersed during the rains. Thus, some wildlife could be attracted to the other parts of the park away from the only permanent river in the park by creating additional waterholes in other parts of the park where the vegetation types preferred by individual species exist.

CHAPTER IV

THE COMPOSITIONS OF THE SOIL, WATER, AND PLANT SAMPLES WHICH WERE COLLECTED IN RELATION TO THE WATERHOLES IN TSAVO NATIONAL PARK (EAST).

INTRODUCTION

The artificial waterholes were developed by mechanically widening and deepening some natural waterholes. Apart from knowing that the artificial waterholes had greater volume than the natural waterholes nothing was known about whether the biology, the physical and chemical characteristics, and further evolution of the natural waterholes were affected. This chapter contains results and discussions of the various analysis carried out on soil, water, and plant samples collected in relation to the natural and the artificial waterholes in the intensive study area.

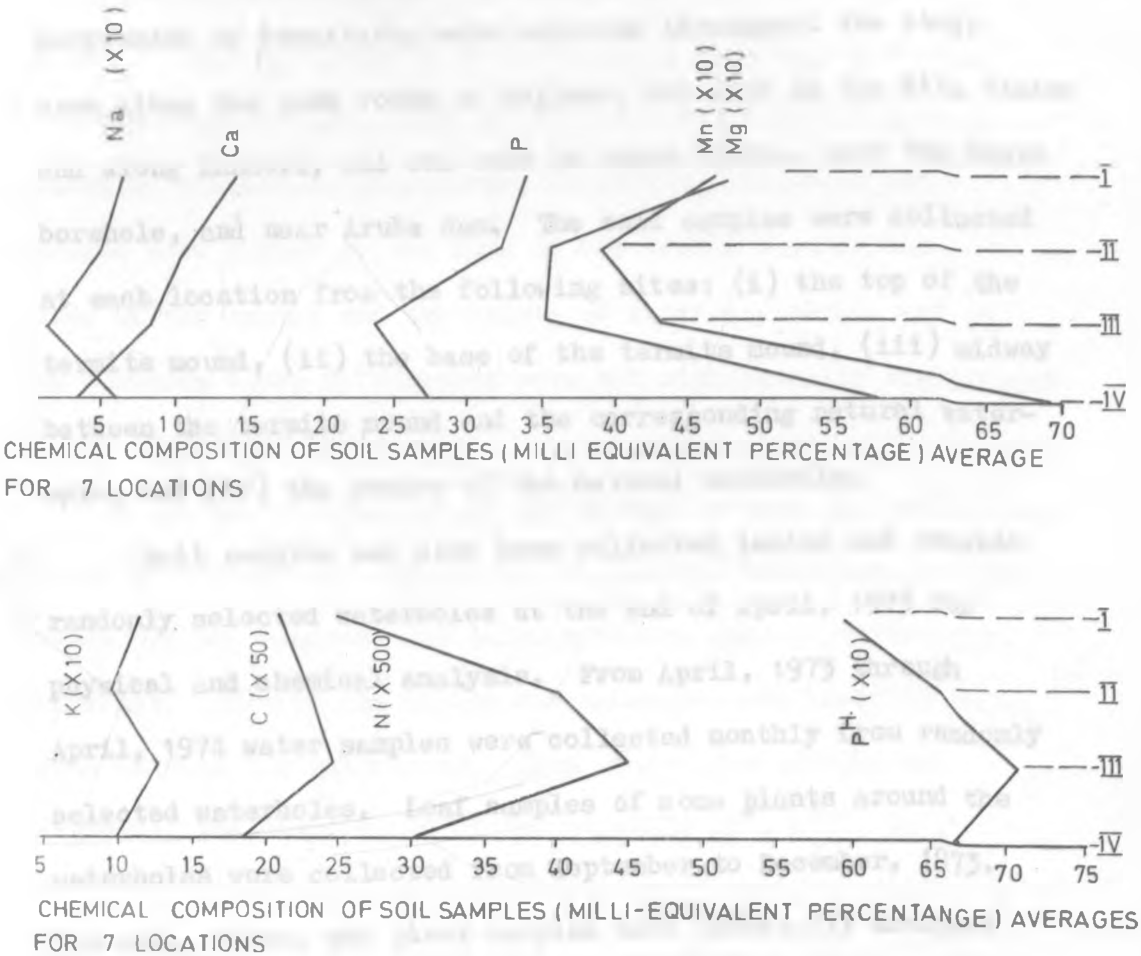
OBJECTIVES

The objectives of the present chapter were:

1) to determine how the natural waterholes in TsE could have evolved;
2) to investigate whether the creation of artificial waterholes by mechanically widening and deepening the natural waterholes affected the chemical and physical characteristics of the waterholes; and
3) to isolate any mineral(s) that might be sought after by the animals utilizing the waterholes.

Figure 4:1

Graphs illustrating the results of the chemical analysis of soil samples collected from the natural waterholes and termitaria in Tsavo National Park (East), South of Voi river.



SITES

I SOIL SAMPLES FROM THE TOPS OF TERMITE MOUNDS

II SOIL SAMPLES FROM THE BASES OF TERMITE MOUNDS.

III SOIL SAMPLES TAKEN FROM MIDWAY BETWEEN WATERHOLES AND TERMITE MOUNDS.

IV SOIL SAMPLES FROM THE CENTERS OF THE NATURAL WATERHOLES.

METHODS

In March, 1974 suitable location with natural waterholes surrounded by termitaria were selected throughout the study area along the park roads as follows: two each in the Dika Plains and along Kanderi, and one each in Ndara Plains, near the Ndara borehole, and near Aruba dam. The soil samples were collected at each location from the following sites: (i) the top of the termite mound, (ii) the base of the termite mound, (iii) midway between the termite mound and the corresponding natural waterhole, and (iv) the centre of the natural waterhole.

Soil samples had also been collected inside and outside randomly selected waterholes at the end of April, 1973 for physical and chemical analysis. From April, 1973 through April, 1974 water samples were collected monthly from randomly selected waterholes. Leaf samples of some plants around the waterholes were collected from September to December, 1973. The soil, water, and plant samples were chemically analysed at the National Agricultural Laboratory in Nairobi.

RESULTS AND DISCUSSION

Mineral contents of termitaria and Natural Waterholes:

Figure 4:1 shows graphically the result of the chemical analysis of soil samples from termite mounds, natural waterholes, and mid-way between the termite mounds and the waterholes. The average values of the mineral contents had been multiplied by the figures shown in bracket on the graphs in order to stagger out their differences for quick visual comparison.

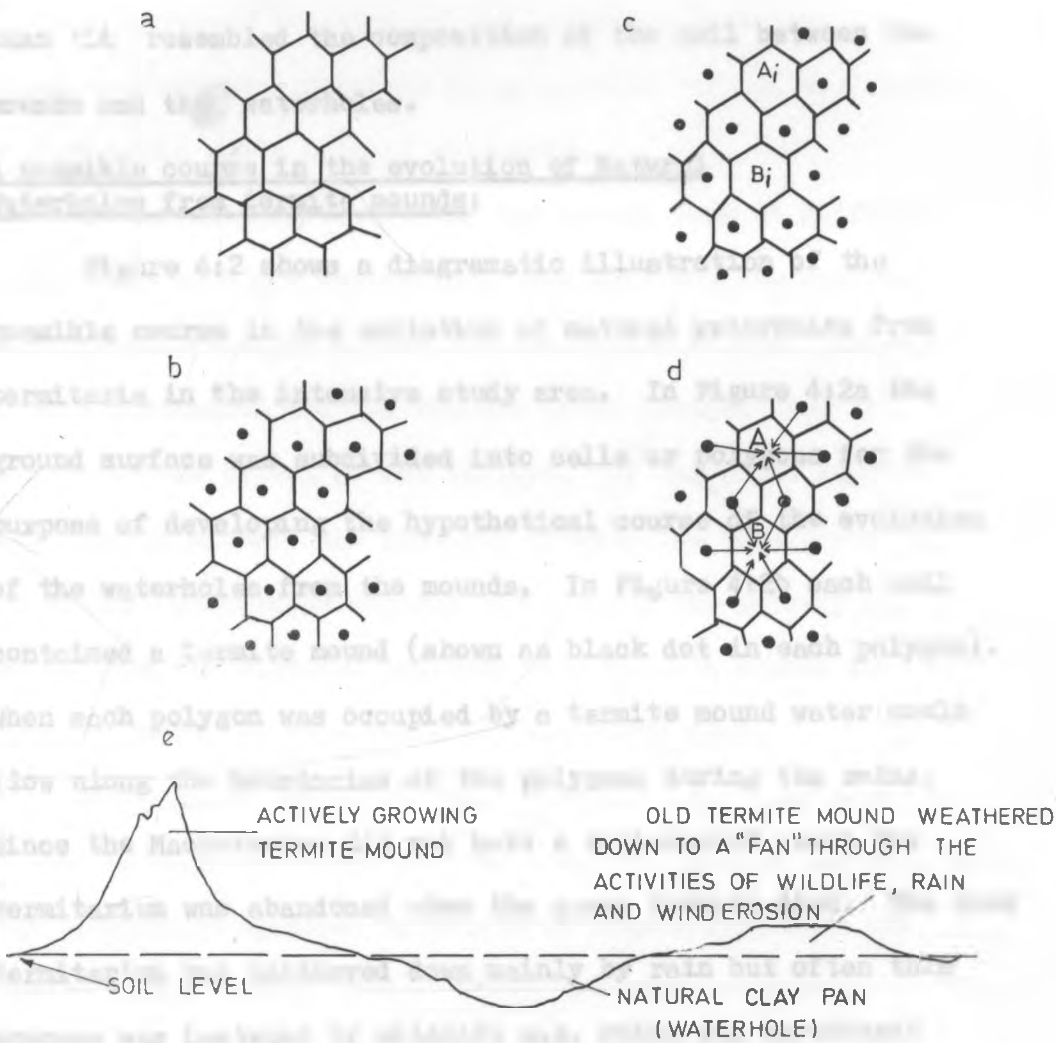
The student's t-test was carried out on the original values of mineral contents at the various sampling sites, and the result showed that although the average values of various minerals: potassium, phosphorus, magnesium, manganese and calcium were higher at the tops of the mounds than at the bases of the mounds and the values of nitrogen, carbon and pH the converse these differences were not statistically significant at 95% confidence limit.

There was no significant difference between the pH, sodium, magnesium and carbon contents in the natural waterholes and the mounds but the maganese and calcium values were significantly different. Calcium was higher but manganese was lower in the mound than in the waterholes. Thus except for calcium and manganese, the composition of the minerals (K^{+}, N^{+++}, Na^{+}, C^{++++}; Mn^{+++} and Ca^{++}) in miliequivalent percent, hydrogen ion concentration (pH) and phosphorus in parts per million in the natural waterholes resembled those of the termite mounds.

The alkalinity index (pH) and sodium content of termite mounds (sites i and ii) were significantly different from those of the points mid-day between the mounds and the natural water-holes (sites iii). The pH value was higher in sites (iii) than in sites (i) and (ii), the converse being the case in respect of sodium content. Sodium, magnesium, and manganese values were higher in the waterholes (sites iv) than in sites (iii) but the result was also the converse with respect to carbon and nitrogen.

Figure 4:2

A diagrammatic illustration of the possible course in the evolution of natural waterholes from termite mounds in Tsavo National Park (East).



a) THE HYPOTHETICAL PLANE SURFACE OF THE GROUND IS SUB-DIVIDED INTO POLYGONS

b) EACH POLYGON CONTAINS A TERMITE MOUND (SHOWN AS BLACK DOT)

c) THE TERMITE MOUNDS IN Ai AND Bi ARE WEATHERED AWAY BY RAIN, WILDLIFE AND WIND.

d) WATER DRAINS FROM THE ADJACENT POLYGONS INTO A AND B (INCIPIENT WATEHOLES)

e) A VERTICAL CROSS SECTION THROUTH TWO STAGES OF TERMITARIA AND A NATURAL WATERHOLE.

The mineral composition of sites (iii) differ significantly from those of sites (i and ii) and sites (iv) with regards to sodium, magnesium, manganese, and carbon content. Thus, the chemical composition of the soil from natural waterholes resembled that of the soil from termitaria more consistently than 'it resembled the composition of the soil between the mounds and the waterholes.

A possible course in the evolution of Natural Waterholes from termite mounds:

Figure 4:2 shows a diagramatic illustration of the possible course in the evolution of natural waterholes from termitaria in the intensive study area. In Figure 4:2a the ground surface was subdivided into cells or polygons for the purpose of developing the hypothetical course of the evolution of the waterholes from the mounds. In Figure 4:2b each cell contained a termite mound (shown as black dot in each polygon). When each polygon was occupied by a termite mound water could flow along the boundaries of the polygons during the rains. Since the Macrotermes did not have a replacement queen the termitarium was abandoned when the queen termite died. The dead termitarium was weathered down mainly by rain but often this process was hastened by wildlife e.g. rhino and hartebeest rubbing their bodies against the mound, and by wind erosion. Figure 4:2c showed that in cells A; and B; the termite mounds were weathered below soil surface by rain, wildlife and wind. In Figure 4:2d water drained from the adjacent cells into A; and B; in the directions of the arrows.

Elephant and warthog were observed to dig out such incipient waterholes during the rains. Buffalo, warthog and rhino drank and wallowed in the natural waterholes in the rainy season and further increased the size of the natural waterholes. Figure 4:2 showed a vertical cross section through two stages of termitaria and a natural waterholes.

In the natural conditions the mounds were at different stages of growth and weathering. The soil surface was also more irregular in the nature than the plain surface assumed in this discussion and the run-off water drained from the hills into the bottom of the valleys. On the plain surface with termite mounds, the gradient between the termitaria and the natural waterholes drained water along the primary game trails from the elevated polygons with termite mounds into polygons where the termitaria had weathered away,

Although it was often not very clear what relationships existed between the termite mounds, and the natural waterholes, that waterholes appeared to evolve in association with the termite mounds (Weir, 1960). There was such a striking similarity in the mineral composition of the termite mounds and the soil samples from the natural waterholes in TsE to suggest that the natural waterholes could have been created in many cases by the activities of wildlife, wind and rain erosion in the

Figure 4:3

A map show the locations of the waterholes from which soil samples were collected in Tsavo National Park (East), South of Voi river.

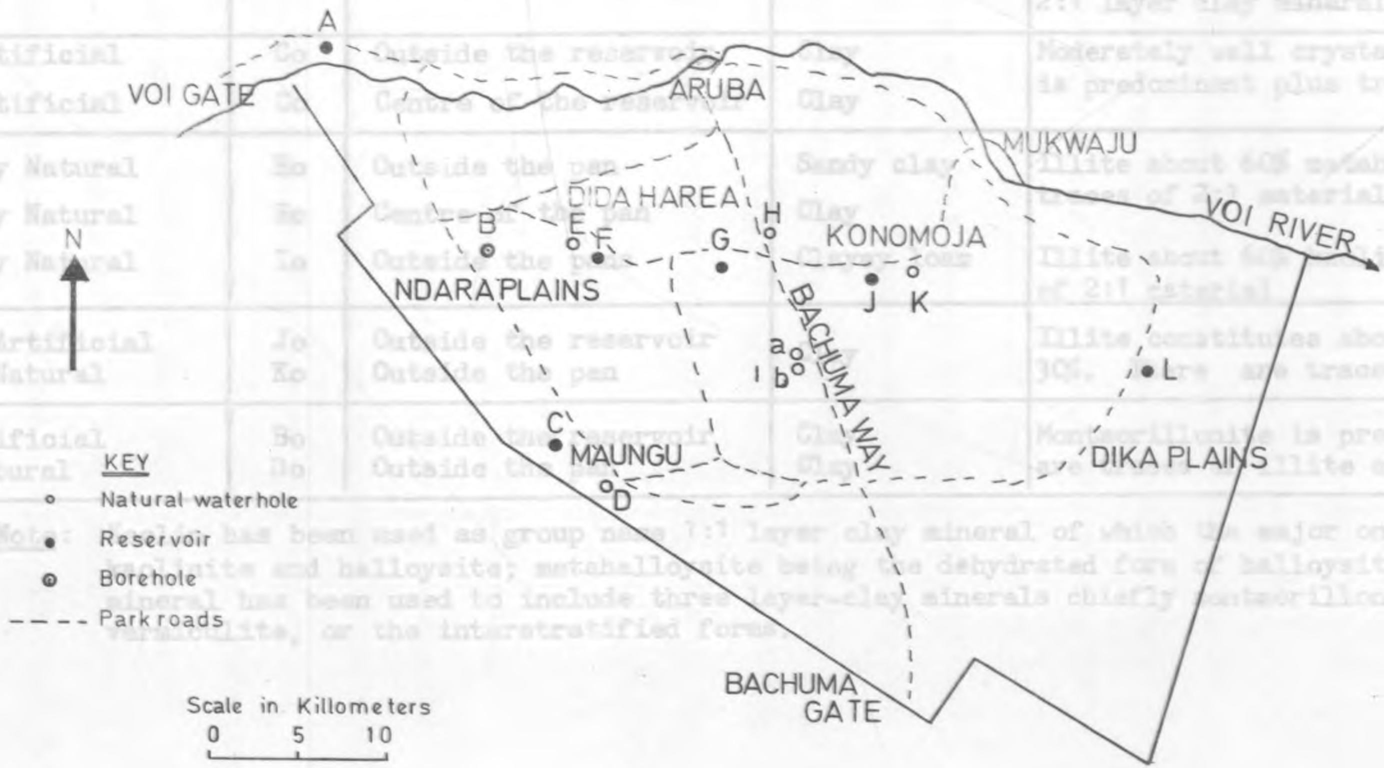


Table 4:1 ANALYSIS OF THE COMPONENTS OF CLAY MINERALS IN SOIL SAMPLES COLLECTED FROM VARIOUS NATURAL AND ARTIFICIAL WATERHOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER IN APRIL 1973

	Ref.	Location of Sample	Texture grade	Clay mineral present
Didaharea Natural	Eo	Outside the pan	Sandy Clay	Poorly crystallized illite is predominant in addition to traces of montmorillonite. Metahalloysite and illite are present in about the same proportion plus traces of 2:1 layer clay mineral.
Didaharea Natural	Ec	Centre of the pan	Clay	
Didaharea Artificial	Fo	Outside the reservoir	Clay	
Didaharea Artificial	Fc	Centre of the reservoir	Clay	
Maungu Artificial	Go	Outside the reservoir	Clay	Moderately well crystallized monthmorillonite is predominant plus traces of metahalloysite.
Maungu Artificial	Go	Centre of the reservoir	Clay	
Buchumaway Natural	Ho	Outside the pan	Sandy clay	Illite about 60% metahallosite 40% plus traces of 2:1 material
Bachumaway Natural	Hc	Centre of the pan	Clay	
Buchumaway Natural	Io	Outside the pans	Clayey loam	Illite about 60% kaolin 40% plus traces of 2:1 material
Konomoja Artificial	Jo	Outside the reservoir	Clay	Illite constitutes about 70% and Kaolin 30%. There are traces of 2:1 material
Konomoja Natural	Ko	Outside the pan		
Ndara Artificial	Bo	Outside the reservoir	Clay	Montmorillonite is predominant but there are traces of illite and kaolin.
Maungu Natural	Do	Outside the pan	Clay	

Note: Kaolin has been used as group name 1:1 layer clay mineral of which the major ones are kaolinite and halloysite; metahalloysite being the dehydrated form of halloysite 2:1 mineral has been used to include three layer-clay minerals chiefly montmorillonite vermiculite, or the interstratified forms.

positions where some termite mounds had been weathered.

Since many minerals were deposited in the termitaria the wildlife species obtained the water soluble minerals by utilizing the natural waterholes which evolved from the termitaria in the intensive study area. The accumulation of various soluble soil chemicals was commonly found in the basal regions of termite mounds (Griffiths, 1938; Milne, 1947; Wild, 1952). Such salt accumulations had been attributed to various causes, one of the most likely being the high rate of evaporation of water (moved by termites through the soil) from large termite mounds (Hesse, 1955). This evaporation was attributable in part to the large surface area of the cavities in the mounds and in part to the ventilation of the mounds by the termites (Weir, 1973).

Soil types:

Figure 4:3 shows the locations of the waterholes from which other soil samples were collected. Table 4:1 shows the types of clay minerals as well as the textural grade of selected soil samples from the inside and the outside of some randomly selected waterholes in the study area. The centres of the natural waterholes (ref: Ec and Hc Table 4:1) were clayey but their outside (ref: Eo, Io, Ho, and Do Table 4:1) were sandy. The centres of the natural waterholes consisted of clay pan from which water could not quickly soak away.

The centres of the artificial waterholes were also clayey but their steep sides (area between the edge and bottom) were often exposed due to erosion. Water soaked away through this profile in which the sandy soil layers were clearly visible.

Before developing artificial waterholes efforts should be made to identify the clay minerals present since this influenced the waterholding capacity of the waterholes. The Kaolinite, Halloysite and Metahalloysite clays for instance, had negligible expansion capacity on wetting, small shrinkage or cracking tendency when dried and were very low in cation exchange capacity. Montmorillonite and Vermiculite on the other hand expanded when wet, cracked when dehydrated, and were high in cation exchange capacity. The Illite clays had crystalline lattice similar to the Montmorillonite but with a potassium bridge, and physical characteristics intermediate to those of Montmorillonite and Kaolinite clays (Buckman and Brady, 1960).

Most of the clay minerals in the red, well drained soils of the study area consisted of the Illite and the Kaolinite clays. The water in the reservoirs derived from the natural zoogeneous clay pans formed in Illite and Kaolinite clays dried up very slowly. At Didaharea (ref: Fc, Fo, Table 4:2) for instance, the reservoir held water long into the dry season because their clays flocculated; slowly losing water rather than shrank into hard plastic when dehydrated. The reservoirs at Ndara and Maungu (ref: Co, Cc, Bo, Do; Table 4:2) in the seasonally water logged areas on the other hand consisted

Table 4:2 SUMMARISED RESULTS OF THE CHEMICAL ANALYSIS OF SOIL SAMPLES FROM NATURAL AND ARTIFICIAL WATERHOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER

	pH	me% Na	me% K	me% SO_4	me% Ca	me% Cu	me% Mg	me% Mn	me% Fe	me% Zn	me% HCO_3	Ec.	N
i CNWH	6.8	205	1,113	48.5	14.4	1.19	3.6	3.2	194.0	1.8	374	0.12	6
ii CAWH	7.4	475	374	26.7	29.9	0.21	22.0	1.9	86.3	1.0	360	0.87	6
iii ONWH	6.8	246	325	5.3	16.6	0.48	6.1	1.7	26.8	0.6	250	0.30	5
iv OAWH	6.7	333	274	15.9	5.5	0.35	7.6	1.8	35.0	0.4	183	0.75	6
i cf ii	*	*	*	*	-	-	-	-	-	-	-	-	
iii cf iv	-	-	-	-	-	-	-	-	-	-	-	-	
ii cf iii	-	-	*	*	-	-	-	*	-	-	*	*	
i + ii cf iii + iv	-	-	*	*	-	-	-	*	*	*	-	-	

CNWH = Mean values for the mineral content of soil samples collected from the centres of natural pans.
CAWH = " " " soil samples collected from the centres of reservoirs
ONWH = " " " " " " 100m from centres of natural pans.
OAWH = " " " " " " " " " " reservoirs
i cf ii = comparison of values from CNWH with those from CAWH
iii cf iv = " " " " ONWH " " " OAWH
ii cf iii= " " " " CNWH " " " ONWH
i+ii cf iii+iv= " " " " CNWH + CAWH with those from ONWH + OAWH

* = values significantly different at 95% confidence limit
\- = " note " " " " " "

of Montmorillonite clays and as soon as they were heated by the sun the clay shrank and cracked with deep fissures through which water quickly soaked away. The Maungu reservoir (ref: C ; Fig. 4:3) could not hold water as long as the nearby natural waterhole (ref: D ; Fig. 4:3) with smaller volume. The Didaharea, reservoir (ref: F ; Fig. 4:3) in the well drained red soil held water much longer than the adjacent natural waterhole (ref: E ; Fig. 4:3) during the study..

Soil mineral composition:

Table 4:2 gives the results of the chemical analysis of the soil samples collected from the waterholes. The table summarised the results of students t-test analysis carried out on the average values of the water soluble components by comparing: (i) the mineral contents at centres of natural waterholes with those from the centres of the artificial waterholes; (ii) 100 meters outside the natural waterholes with the same distance from artificial waterholes; (iii) centres of natural waterholes with their outside; and (iv) centres of all waterholes with outside all waterholes.

The hydrogen ions concentration (pH) was compared using 1:1 and 1:5 soil-water mixtures, and 1:5 soil-potassium chloride solution mixture. At $p \leq 0.05$ the soil-water mixture results showed that the soil samples scraped from the centres of the reservoirs were more alkaline than those from the natural pans. The third method did not yield any significant differences. William (1962) in Nez Perce National Forest, Idaho County, confirmed that water was undoubtedly the carrier of the

Fig. 4.4. A MAP SHOWING THE LOCATIONS OF THE WATERHOLES FROM WHICH WATER SAMPLES WERE COLLECTED IN TSAVO EAST.

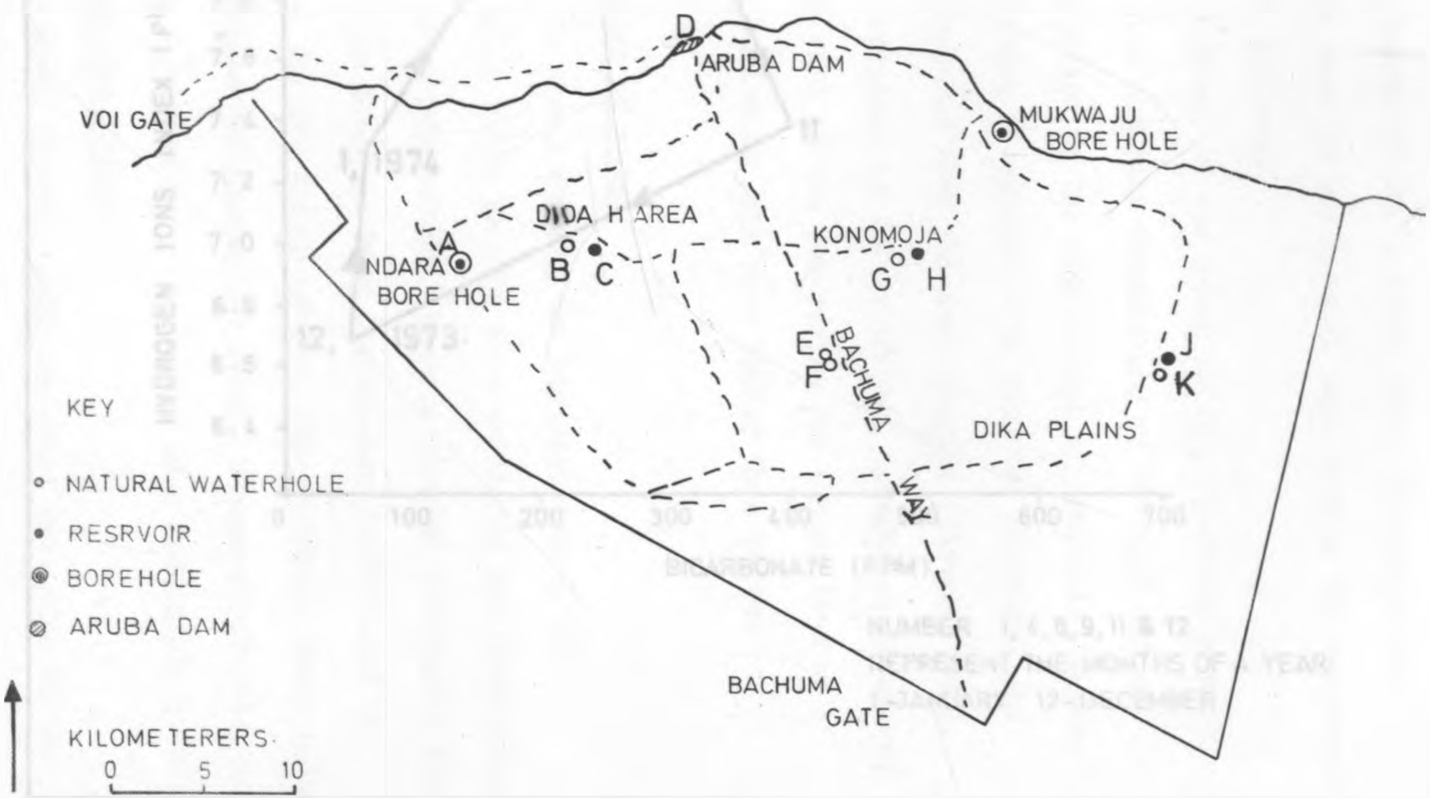
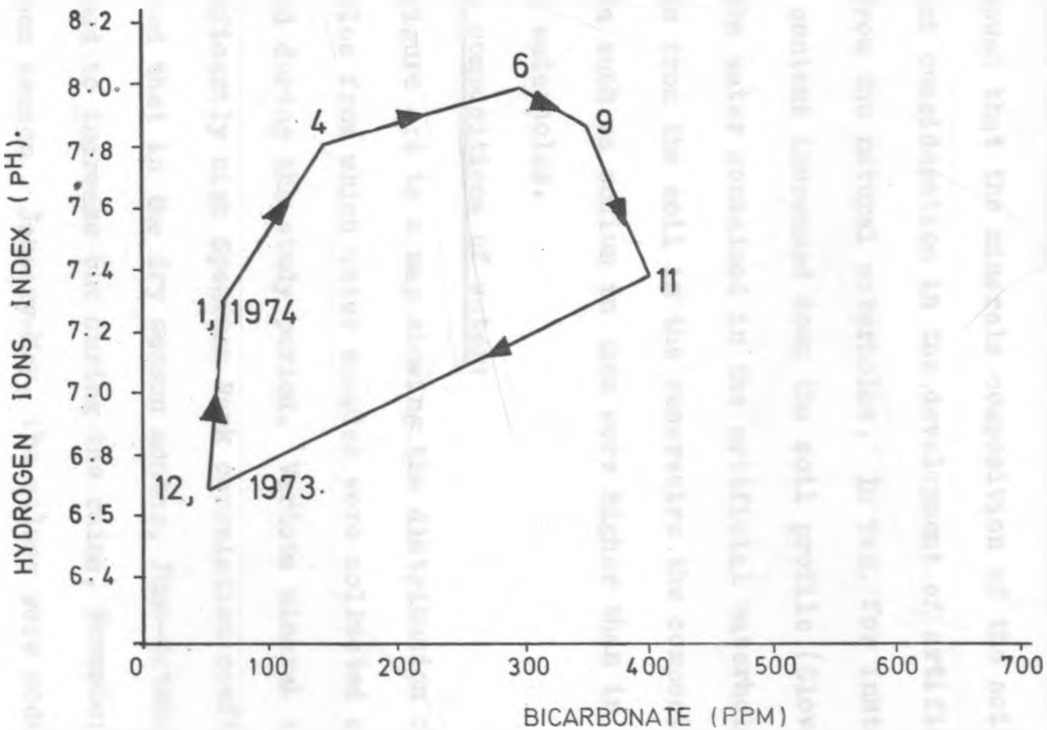


Figure 4:5

A map showing seasonal variations in the bicarbonate alkalinity of water samples collected from the Dida-harea artificial reservoir in Tsavo National Park (East), June, 1973 - May, 1974.



NUMBER 1, 4, 6, 9, 11 & 12 REPRESENT THE MONTHS OF A YEAR.
1-JANUARY 12-DECEMBER

natural minerals sought by big-game.

The reservoirs had pH values slightly more alkaline than the natural pans. The centres of the reservoirs contained more sodium than the centres of the natural pans. Potassium and sulphate ions were more in the natural pans than in the reservoirs, and areas outside the pans.

Thus, the findings of the water soluble fraction of this work showed that the minerals composition of the soil was an important consideration in the development of artificial waterholes from the natural waterholes. In TsE, for instance, the sodium content increased down the soil profile (Glover, 1970). Since the water contained in the artificial waterholes dissolved minerals from the soil in the reservoirs the composition of minerals such as sodium in them were higher than in the natural waterholes.

Mineral compositions of water:

Figure 4:4 is a map showing the distribution of the waterholes from which water samples were collected and chemically analysed during the study period. Various mineral components showed a significantly high Spearman Rank correlation coefficient that indicated that in the dry season months, June-October, their values continued to increase but during the rains, November-December, and the green season , January-May, the values were moderately lower.

(a) Bicarbonate alkalinity:

Figure 4:5 shows typical cyclic seasonal variation in the

SEASONAL FLUCTUATIONS IN THE ELECTRICAL CONDUCTIVITY OF WATER SAMPLES FROM ARUBA DAM AND NDARA BOREHOLE, AND THE CORRESSPONDING GAME-VISITS AT ARUBA DAM AND MUKWAJU BOREHOLE

FIGURE 4: 6

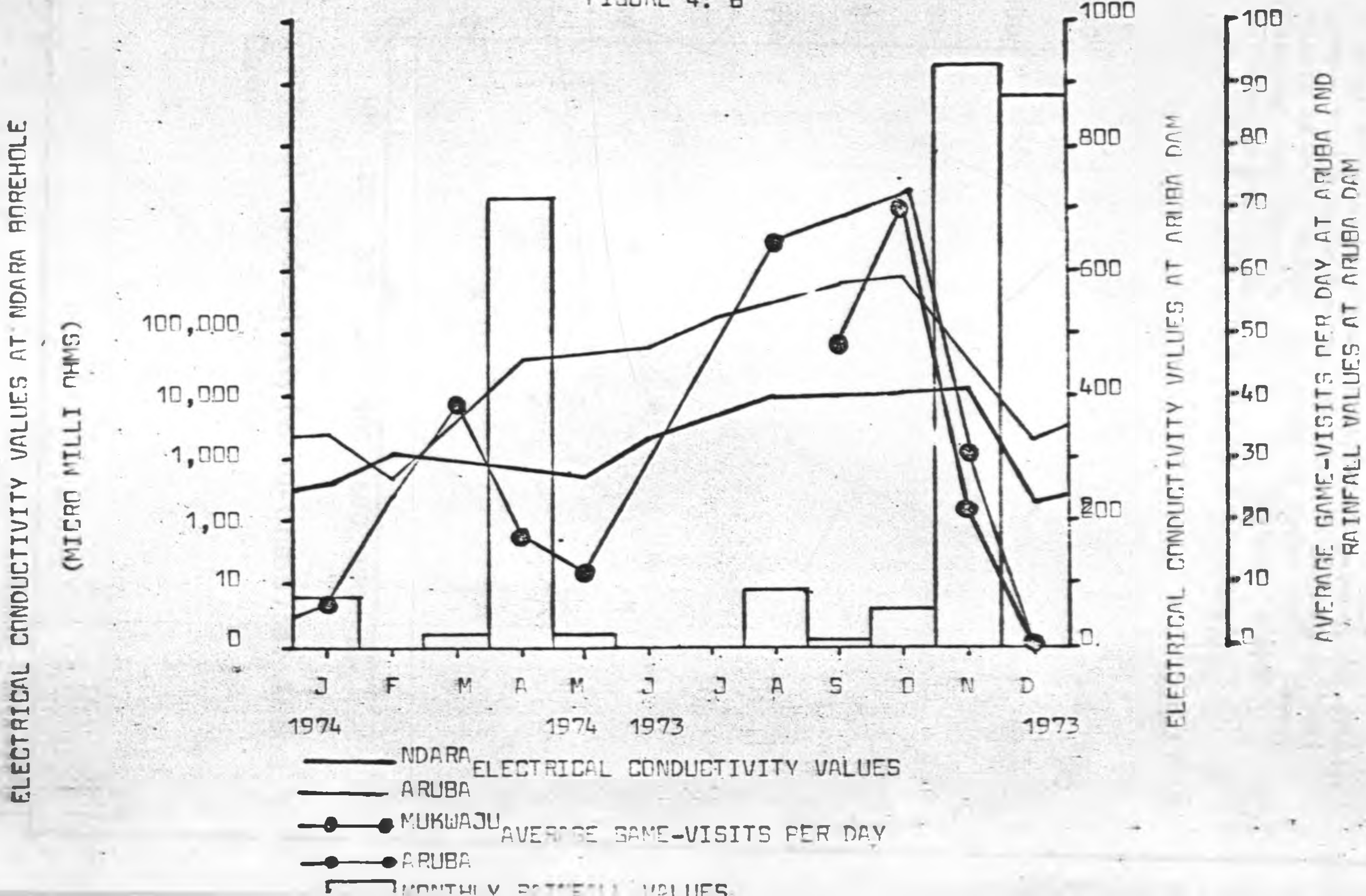
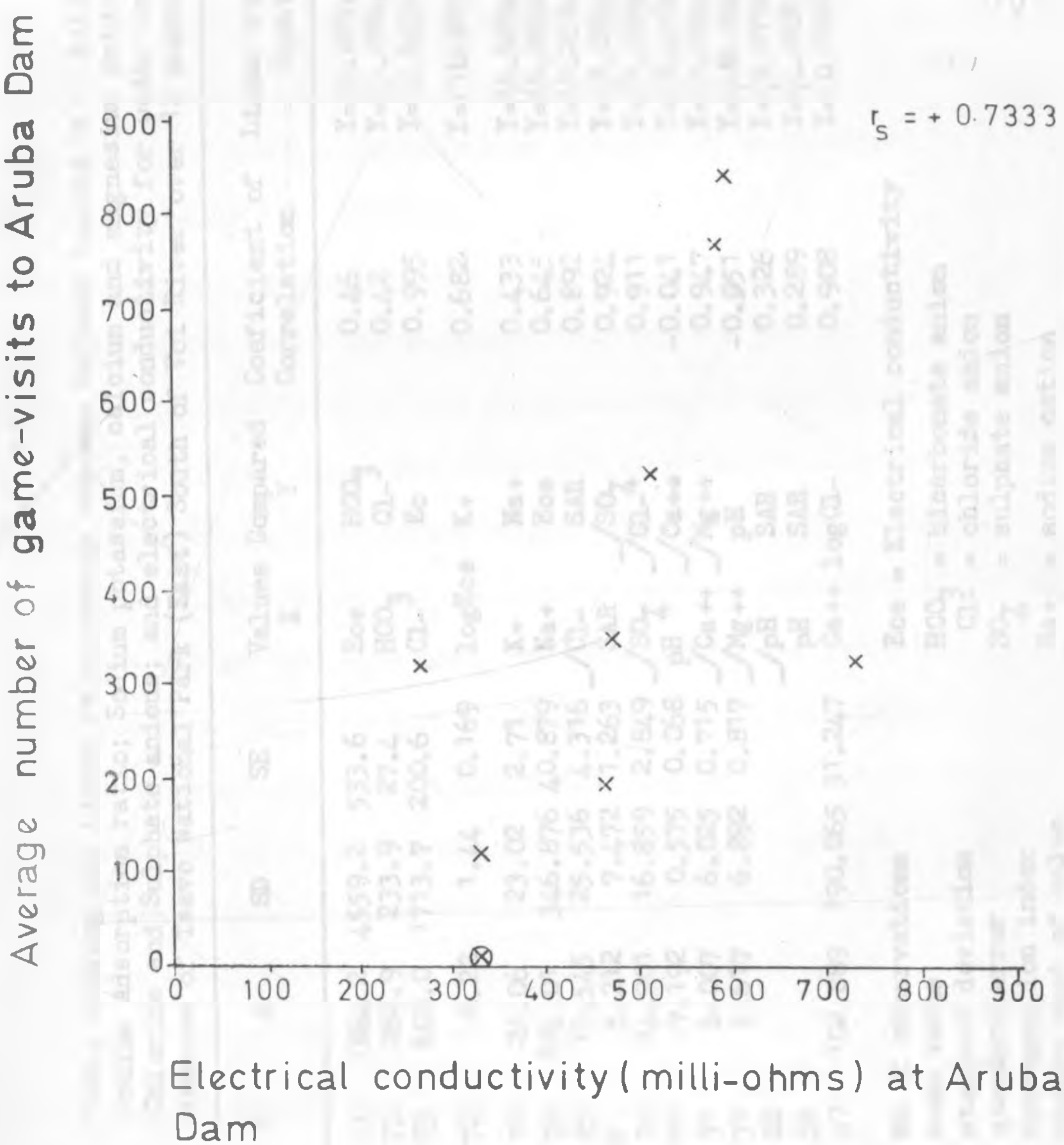


Figure 4:7

A graph showing the ranked relationship between the average game - visits per month and the electrical conductivity values of water samples collected at Aruba dam in Tsavo National Park (East), 1973-74. The Spearman's rank correlation coefficient, $r_s = + 0.7333$.



total bicarbonate alkalinity at Didaharea reservoir. In November-December during the rains the pH and bicarbonate values dropped but for the rest of the year alkalinity values increased, the bicarbonate values increasing from January to early December. Thus, the species which utilized drinking water from the artificial waterholes put up with a high degree of alkalinity variations in the course of the year. A similar seasonal variation in alkalinity of waterholes in Rhodesia was described by Weir (1968).

(b) Electrical conductivity:

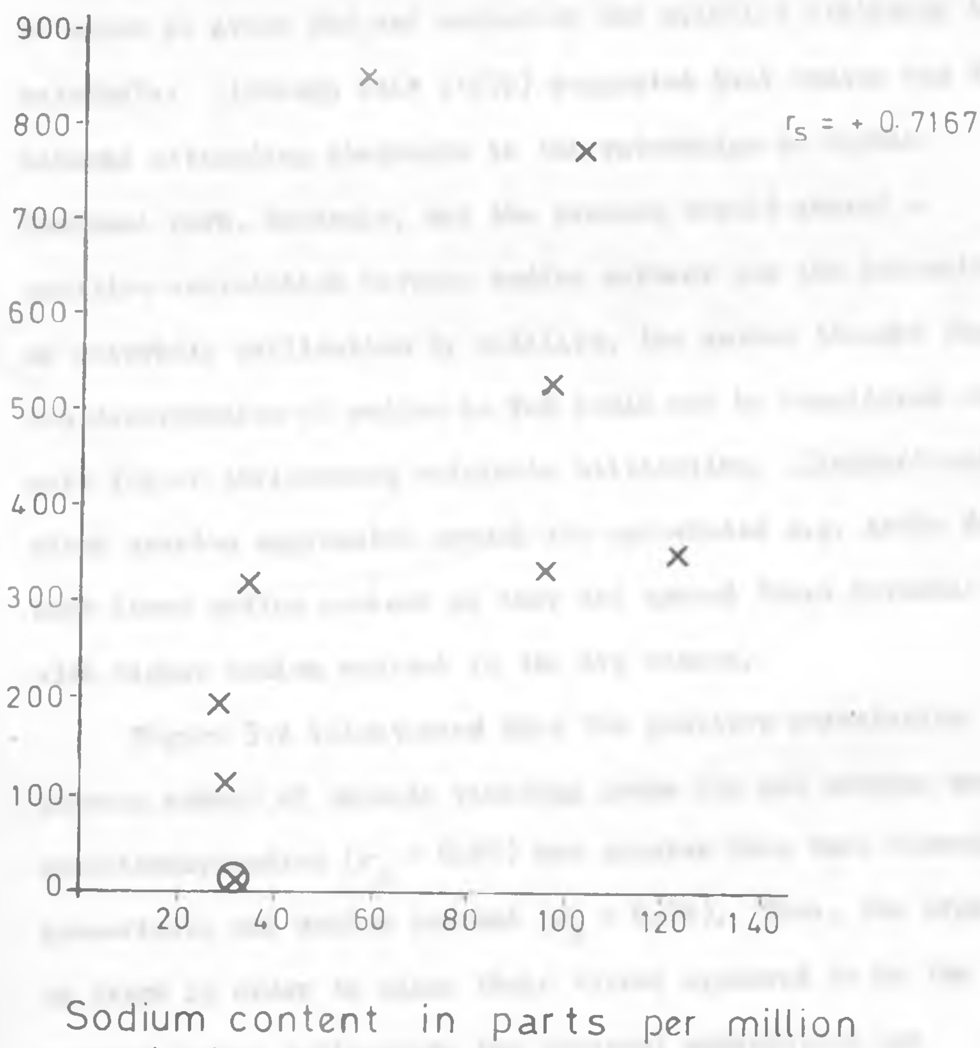
Figure 4:6 shows the seasonal fluctuations in the electrical conductivity values of water samples from Ndara borehole and Aruba dam. The conductivity value was a measure of the electrochemically active components in the water samples. Since game sightings at Aruba dam were recorded over most of the study period and at Mukwaju borehole during the peaks of the dry season and the short rains season the relationship between the number of game species drinking at the artificial waterholes and electrical conductivity values correlated positively as presented in Figure 4:7. During the rains, the electrical conductivity and game-visits per day dropped increasing again during the dry season.

(c) Linear relationships between minerals:

Table 4:3 shows the linear relationships between various minerals in the water samples. Increases in the electrical conductivity values correlated positively with increases in the chloride, sodium, potassium and sodium absorption ratio. The

Figure 4:8

A graph showing the ranked relationship between the average number of game - visits per month and sodium content values for the water samples collected from Aruba dam in Tsavo National Park (East), 1973-74. The Spearman's rank correlation coefficient, $r_s = + 0.7167$.



chloride values correlated with sulphate but the pH correlated negatively with increasing values of calcium and magnesium. Thus, changes in alkalinity values affected the solubility of various metallic elements in the water samples.

Game visits and mineral content of water:

Figure 4:8 gives the relationship between sodium content of water at Aruba dam and number of the wildlife utilizing the waterhole. Although Weir (1972) suggested that sodium was the mineral attracting elephants to the waterholes at Wankie National Park, Rhodesia, and the present result showed a positive correlation between sodium content and the intensity of waterhole utilization by wildlife, the author thought that the distribution of sodium in TsE could not be considered as the main factor influencing waterhole utilization. Elephant and other species aggregated around the waterholes e.g. Aruba dam with lower sodium content as they did around Ndara borehole with higher sodium content in the dry season.

Figure 3:4 illustrated that the positive correlation between number of animals visiting Aruba dam and average monthly evapotranspiration ($r_s = 0.81$) was greater than that between game-visits and sodium content ($r_s = 0.71$). Thus, the urge to drink in order to slake their thirst appeared to be the greater factor influencing the seasonal aggregation and dispersion of wildlife around and away from the artificial waterholes in TsE.

Table 4:4 The average ionic concentration of fluid samples from the sea, blood of typical vertebrate, borehole, dam and reservoir.

	pH	Na+	K+	Cl-	Mg++	Ca++	SO_4^-	(m. eq/lit.)
Sea water	-	459	9.7	535	105	9.98	55	*
Blood	7.4	150	4.5	120	2	5	1	
Ndara Borehole	7.2	34.7	1.9	81.7	30.7	21.6	20.1	Dry season
"	6.9	32.1	0.8	65.2	25.1	16.5	4.0	Rainy season
"	7.2	6.7	0.5	3.4	3.7	2.8	2.0	Green season
Didaharea Reservoir	7.3	5.9	0.52	3.4	0.64	0.54	1.3	Dry season
"	6.7	3.6	0.32	1.9	0.52	0.24	1.9	Rainy season
"	7.3	2.3	0.52	1.8	0.56	0.64	0.3	Green season
Aruba dam	7.4	4.16	0.8	2.7	1.5	1.5	2.2	Dry season
"	7.7	3.34	0.4	2.4	1.4	1.5	1.6	Rainy season
"	7.9	1.32	0.1	1.5	0.7	1.7	0.9	Green season

* Barnes, H. 1954

Some tables for the ionic composition of seas water J. Exp.

Biol. 31: pp. 582-588

Animals' physiological requirement for minerals:

Table 4:4 gives a summary of the average values of seasonal ionic concentration of water samples from artificial waterholes: Aruba dam, Ndara borehole and Didaharea reservoir. The average values were compared with standard values for sea water and blood of typical higher vertebrates in order to postulate on the possible effect of the water on the wildlife species utilizing the waterholes.

Sodium and chloride (Table 4:4) were macro-nutrients required in high concentrations than those present in the drinking water supplies. Sodium could be reabsorbed in the colon and kidney of the animals in order to maintain the high requirement of the mineral in the blood. Thus, by drinking water in proportion to their body size (Young, 1970) and retaining some mineral constituents of the water in their bodies, wildlife in e.g. TsE could satisfy a high proportion of their sodium, and chloride requirements. During the dry season, sodium was lost from the body through sweating and the higher concentration of sodium especially in the boreholes could be favourable to wildlife but it was doubtful if the dietetic value of the waterholes for any mineral in particular could account most significantly for the aggregation of wildlife in TsE around the water supplies during the dry season.

The ionic concentration of blood being low in potassium, magnesium, calcium and sulphate the drinking water alone could adequately supply the animals with their daily requirement of these minerals in TsE. In the boreholes magnesium, calcium and

Table 4:5 Average chemical composition of leaf samples around waterholes in Tsavo National Park (East) South of Voi River

Percentage by dry weight

	Dicotyledons (n=58)	Monocotyledons (n=18)	Standard feed A.R.C., 1965)
Nitrogen	3.03 ± 1.15	1.51 ± 1.00	3.10
Phosphorus	0.16 ± 0.09	0.09 ± 0.06	0.39
Calcium	2.39 ± 1.81	0.69 ± 0.70	0.28
Magnesium	0.70 ± 0.48	0.22 ± 0.16	0.12
Potassium	1.97 ± 0.94	1.17 ± 0.83	0.35
Sulphur	0.55 ± 0.74	0.26 ± 0.18	-

Parts per million dry matter

	Dicotyledons (n=18)	Standard feed (A.R.C., 1965)-
Copper	18.9 ± 3.6	5 gm/kg dry matter
Iron	490 ± 500	30 " "
Zinc	32.4 ± 24.1	50 " "
Manganese	186 ± 297	40 " "

sulphate ions attained very high values in the dry season but it was not within the scope of this study to investigate whether or not the levels adversely affected the animals' physiology. Although Pierce (1957) and Wilson (1966) suggested that high concentrations of minerals in drinking water was detrimental to appetite and health, food intake and water turnover rates in sheep living in the arid areas of Australia, these effects had not been studied in wildlife ecology.

Various physiological studies had shown the significance of environmental water soluble minerals to the ecology of animals in free range. In livestock, it was known that the mineral composition of food (Macfarlane et al., 1967) and the salt content of water (Jones et al., 1970) influenced the water turnover rates, water intake, and frequency of drinking in sheep. In wildlife ecology, an acquired taste (Murie, 1951) alkaline pH (Stockstad, Melvin and Lory, 1953) sodium (Weir, 1969 and Ayeni, 1972) and micro-nutrients (Cowan and Brink, 1949) have been suggested as the factors attracting big-game to the natural mineral licks. The natural mineral licks from which water soluble mineral could be obtained by wildlife were quite uncommon in TsE. In TsE only three natural mineral licks had been noticed to attract few game species and this they did very infrequently (Warden, Sheldrick; personal communications).

Mineral composition of plants:

Table 4:5 summarises the result of the chemical analysis of the leaf samples which were collected around waterholes in the study area. A detailed result of the chemical analysis of some leaf samples representing over 20 families and about 50 genera were presented in the Appendix Table 5.

Dougal et al. (1964) pointed out that sodium averaged very low in the vegetable diet of wildlife throughout Kenya. The present study did not investigate the sodium contents of the leaves. The chemical composition of the leaves, Table 4:5 were compared with those of standard grass feeds for cattle (A.R.C., 1965).

There were generally very few investigations about the micro-nutrient (sulphur, manganese, zinc, copper and iron) requirements of both livestock and wildlife. The present investigation showed that the levels of macro-nutrients were generally higher in the dicotyledons than in the monocotyledons. This could be due to the fact that the graminae were sampled only during the dry season when the nutrient status of the grasses was lower. Since wildlife had higher metabolic rate and were known to survive under more frugal feeding conditions than livestock, it was thought by the author that the average values of the macro-nutrients (calcium, phosphorus, magnesium and potassium) in TsE were not low in the plants. Although only 18 samples were analysed for the micro-nutrients, it was suggested that some plants were rich in the micro-nutrients (copper, manganese and iron) and could be sought after or rejected by wildlife because of this composition, depending on the physiological condition of the animals.

CONCLUSIONS

Although it was not clear what relationships existed between the termite mounds and the natural waterholes, there were frequent association between the termite mounds and the natural waterholes. There was also such a striking similarity in the mineral composition of the termite mounds and the soil samples from the natural waterholes to suggest that the waterholes could have been created by wildlife activities in the places where some termite mounds had been weathered.

The development of artificial waterholes in the positions of some natural waterholes in TsE had not been very successful. Out of eleven of such reservoirs in the study area only one at Didaharea held water for some time into the dry season. The others dried up soon after the beginning of the long dry season. The lack of a plastic layer over the entire surface of the reservoirs and the erosion of their side walls were the main reasons why they did not hold water over a much longer period. At Maungu the nature of clay material (Montmorillonite) which cracked and shrank when dehydrated leaking away the water from the reservoir located in the black cotton soil was another reason for the failure of the waterhole to hold water during the dry season.

The development of artificial waterholes by digging out some natural waterholes had influenced the mineral composition of the waterholes. In TsE the sodium content increased down the soil profile (Glover, 1970). The water in the deeper reservoirs was richer in sodium than the natural waterholes. The Ndara Borehole was also richer in sodium, sulphates, chlorine, magnesium and calcium than the natural waterholes, Aruba dam, and the reservoirs especially during the dry season. It was suggested that sodium which averaged very low in the vegetable diets of wildlife in Tsavo could be made up for by wildlife species drinking from the saline boreholes in the dry season, and from other waterholes evolved from weathered termitaria during the rains.

It was not possible to relate the intensity of the utilization of the waterholes to the values of any of the minerals which increased in the dry season and fell during the rains. It was suggested that seasonal changes in the availability of drinking water was the main factor which resulted in the aggregation of wildlife species around the few water supplies in the dry season and their dispersal during the rains when drinking water was abundant throughout the park.

CHAPTER V

MAJOR CONCLUSIONS. RECOMMENDATIONS AND MANAGEMENT IMPLICATIONS OF WATERHOLE STUDIES IN TSAVO NATIONAL PARK (EAST)

MANAGEMENT IMPLICATIONS

Touristic value of the waterholes:

In the arid/semi-arid environment of TsE permanent natural water supplies were very few. The rainfall was consistently low and unevenly distributed. During the rains, wildlife dispersed throughout the parks drinking from natural waterholes in the clay pans filled with rain water. In the dry season all the natural waterholes and the seasonal rivers dried out and animals aggregated along the narrow riverine belt of the Galana, the only permanent river traversing the park. During the dry season a large portion of the park was not utilized by wildlife whereas the zone within walking distance to drinking water was over utilized (Glover, 1963). Kenya earned appreciable foreign exchange through tourism. A park was not likely to be economically viable in East Africa if wildlife were not readily seen by the tourists in the dry season. Thus, in order to enhance the touristic potential of TsE throughout the year, artificial waterholes were developed in the park to distribute game evenly away from the Galana river-beds. In the intensive study area, many roads were aligned in order to channel surface run-off into the natural waterholes. Some natural waterholes were also widened and deepened mechanically in order to retain water in the reservoirs so formed long after the seasonal rivers and natural waterholes had dried out. The soil removed during the process of developing the reservoirs from the natural waterholes was piled on the tourist tracks to give them an elevated spot from which panoramic views of the countryside could be obtained.

Along the seasonal rivers, boreholes and a dam were also developed. The Aruba dam for instance was developed along Voi river. Aruba dam was the largest waterhole in the park. It trapped the flood water of Voi river during the rains and held water throughout the year. At Aruba dam, a tourist lodge was built. Here tourists relaxed in "bandas" watching wildlife species utilizing the dam throughout most of the 24 hours of the day.

Again, at Voi Safari Lodge just north of the intensive study area, three artificial waterholes were utilized by wildlife throughout most of the year. These waterholes were fed with water through pipe-borne water. A blind near to the waterholes was used for close-up photography during the nights when the area around the waterholes was floodlit. All these features of waterhole development certainly enhanced the touristic value of the park.

The patterns of waterhole utilization and the distribution patterns of wildlife in relation to the waterholes showed that there was more scope to use the waterholes as a management tool to distribute wildlife more evenly in the park and to enhance the touristic potential of the park. An even distribution of wildlife away from the river-beds could be achieved through the development of a network of small sized artificial waterholes which could be refilled by pipe-borne water from the boreholes, the rivers, and the Voi-Mombasa pipeline along the western boundary of the park.

Since the waterholes concentrated animals in areas of good visibility they could be of management significance in improving game viewing and photography for tourists and to adapt as inexpensive areas of conducting animal studies (possibly including censusing) when hides and tracks are constructed to them. The more open section of TsE south of Galana river was managed for game viewing while the north was a wilderness area or strict nature reserve. The grand total of 487 hours of observations and the periodicity of 39,051 game-visits during dry weather showed that between 0800 and 1400 hours were most suitable for viewing small-medium sized animals and between 1700 and 2100 hours were best for viewing the larger game species at the waterholes.

The development and utilization of the artificial water-holes in TsE immediately raised two problems: namely; vegetation destruction and problems related to the soil types and quality of water. Also, since so much contact between species, urination, defaecation and wallowing occurred at the waterholes, the possibilities of pest and disease transference could be investigated around the waterholes. The waterholes sites were likely to be heavily infested with pests, cysts, and nematodes from the dungs of diseased animals, hence the possibilities of disease transference in the park should be better ascertained and prevented at the waterholes.

Vegetation destruction:

During the dry season wildlife aggregated around the few artificial waterholes containing water. Around the artificial waterholes which were regularly refilled with water, e.g. the Mukwaju and Ndara boreholes and Voi Safari Lodge reservoirs, the intensity of tree bashing and browsing increased towards the centre of the waterholes; the heights of the herbs and shrubs also decreased towards the centres of the waterholes whose edges were often devoid of grasses and herbs during the dry season. Around Aruba dam the removal of woody vegetation was particularly profound (Norton-Griffiths, 1972). During the dry season the areas around the dam were covered by network of game trails and trampled red soil.

Habitat degradation around the waterholes appeared to be a time-specific phenomenon. Where the waterhole was small e,g. natural waterhole, and contained water for a short period during the rains, removal of woody vegetation cover through feeding and hoof action around the waterhole was only slight. But where the waterholes were large, e.g. Aruba dam, and contained water throughout the year the removal of woody vegetation cover was quite pronounced since wildlife aggregated there throughout the dry season up to 7 months of the year. Thus, it could be suggested that many medium size waterholes were better than a few large waterholes in TsE if the rate of destruction of woody vegetation cover was to be reduced. It was not known whether the plant species which were preferred by the game species were disappearing around the large artificial waterholes and this aspect should be investigated.

<u>Soil types and water quality:</u>

The soil structure, texture and mineral composition were important considerations in the development of waterholes in TsE. The mineral composition for each area should always be determined prior to the creation of waterholes. It was the chemical nature of the soil in an area that largely determined the chemical composition of the water samples from the waterholes in the area.

At the peak of the dry season the composition of the water samples from the boreholes was very high in several minerals: sulphate, magnesium, chloride, calcium, etc...., and electrical conductivity. Since waterhole utilization was most intense during the dry season it could be suggested that the water from the boreholes should be treated by passing it through a tank or trough where the saline contents could be precipitated out before being fed to wildlife. Very little, of course, was known of the effects of brackish water on wildlife and more information was required in this direction.

The artificial waterholes which were developed in the black cotton soils, e.g. at Irima and Maungu, held water for a much shorter period than the natural waterholes close to them. The artificial waterholes were located in the soils dominated primarily by the Montmorillonite clays. It was characteristic of the Montmorillonite clays to crack and give up their water content easily when dehydrated by sun. During the dry season, the artificial waterholes in this type of soil cracked with deep fissures through which water in them drained off. It would therefore be a bad management policy in future to continue to develop further reservoirs in the park in areas of impeded drainage which often consisted of Montmorillonite clays.

Out of the eleven reservoirs within the intensive study area only one at Didaharea (made in 1971) held water until

September, just one and a half months after the other natural waterholes in the area had dried out. Various factors were responsible for the failure of the other reservoirs to contain water for a much longer period of the year than the natural waterholes. The centres of the reservoirs were sandy whereas the centres of the natural pans were clayey. During the process of creating the reservoirs from the natural waterholes the clay layers on the surface of the natural pans were mechanically removed and no effort was made to create an impervious layer through which water in the reservoirs could not drain off. It would take a long time for wildlife to create the plastic effect at the bottoms of the reservoirs which they puddled to improve their ability to retain water. It would be desirable to mechanically roll-in wet soil over the surfaces of the reservoirs in order to improve their water holding capacity.

Further development of artificial waterholes in Tsavo East:

Western (1973) suggested 18km as the distance from water at which the density of the "water-dependent" species started to decrease significantly in Amboseli. In TsE, of course, the frequencies of sighting the species fell off significantly at distances greater than 10km from drinking water. Thus, if every 10km grid were to contain water, 125 additional artificial waterholes would be required in the park. This meant that one out of every 50 natural waterholes in the area should be widened. The distribution of the waterholes should decrease towards the Galana river; just as the numbers of the natural waterholes which had the effects of spreading wildlife during the rains increased away from the

Galana river and its major water courses. The gradient leading into the artificial waterholes must be very gentle so as to reduce the erosion of their side walls and the chances that the larger species might get stuck in the waterholes. It was advisable that the edges of the artificial waterholes should be planted with grasses to improve the scenic beauty around them.

Although it was apparent that if waterholes which contained water in the dry season were abundant in the park wildlife would utilize more of the park throughout the year, it was not as clear whether such an expense was necessary at all. It could be argued that an increase in the number of waterholes in the park might lead to a further increase in the population of the herbivores especially the elephant. Increases in the numbers of elephant could lead to a further destruction of woody vegetation, an effect which had already reached deplorable proportion in the park. It could also be argued that elephant and rhinoceros died in the park more as a result of starvation rather than thirst since most of the carcasses were distributed near permanent water supplies (Corfield, 1973). If the animals could live on water rather than food throughout the drought then the mortalities of rhino and elephant, already referred to, could have been averted by the development of the waterholes, but since this was the contrary, and since the provision of water might not result in an improvement of food quality around the additional waterholes, it was doubtful if a large scale water development as was intended over TsE would be able to prevent a high game die-off as a result of drought in the future.

Land-use outside the park:

Again, it could be argued that if additional waterholes were not developed in TsE, wildlife would migrate into the adjacent ranches. The park was surrounded by ranches where big water development projects were being undertaken to provide water for the livestock. It was thought that a corresponding development of additional waterholes within the park was required in order to counteract the effects of the water development programmes outside the park. Here quantitative studies of game movements which were necessary in order to ascertain whether game movements from the park into the areas outside the park occurred and were directly related to the creation of additional water supplies on the ranches were not available. It was suggested that a separate study should be undertaken to monitor and to evaluate the effects of land-use and human populations outside the park on the TsE.

RECOMMENDATIONS AND CONCLUSIONS

Since the artificial waterholes concentrated animals in areas of good visibility during the dry season, they could be used judiciously to improve game viewing and photography for tourists and adapted as in-expensive areas of conducting animal studies when hides and tracks are constructed to them.

At the Voi Safari Lodge in TsE, for instance, hides for game viewing was advantageously utilized by many tourists for many nights throughout the study period. It was recommended that if hides and tracks were made to the waterholes tourists should go on game viewing between 0800 and 1330 hours and between 1700 and 2100 hours, in TsE south of Voi river.

It was recommended that although small waterholes topped up with pipe-borne water could be utilized to evenly distribute wildlife in the park during the dry season, what would be most suitable are sub-surface weirs along the seasonal streams and rivers in TsE. During the rains the rivers would be silted up so that in succeeding dry season water would be trapped in the silt where elephant could dig out the sand and obtain drinking water for itself and other species.

Finally it was recommended that further development of artificial waterholes in the soil types which consisted primarily of Montmorillonite clays should be discontinued, because the waterholding capacity of the waterholes in such soil types was very poor during the dry season.

Briefly the management implications of the study were that research must precede the creation of artificial waterholes in all Parks in order to ensure:

1) that such waterholes were indispensable to the object of management of the park, and that the number and the distribution of the required waterholes were known;

2) that the physical characteristics of the soil could suitably meet the waterholding requirements and the soil erosion likely to arise as a result of the action of the hooves of wildlife at the waterholes;

3) that the mineral composition of the soil at the depth corresponding to the anticipated bottom of the artificial waterhole did not make more soluble minerals available than the physiological requirements and tolerance levels of wildlife species using the waterholes would warrant;

4) that the effects of the creation of the artificial waterholes on the ecology of the microflora and fauna living in the natural pans were fully understood; and

5) that various aspects such as the exposure of wildlife to predator ; rate of soil and mineral removal and methods of their replacement; rate of vegetation removal and or destruction; and possibilities of pest and disease transferrence at the waterholes were better anticipated.

Only continuous research along the baseline already reported in this Thesis could reveal the ultimate effects and desirable revision of management policies required to meet the ecological and touristic implications of developing more waterholes in TsE. Further studies should be carried out to investigate:

1) the effects of the minerals which were high in the artificial waterholes on the physiology of wildlife species;

2) the possibilities of pest and disease transferrence between wildlife species drinking together at the waterholes; and

3) the rate at which plant species which are palatable to wildlife, disappear around the waterholes.

GENERAL SUMMARY

The work reported in the Thesis was carried out in Tsavo National Park (East), south-eastern Kenya from April, 1973 to July, 1974. The objective of the study was to assess the desirability of developing more artificial waterholes in Tsavo East National Park (TsE).

The climate of TsE is arid and apart from the Galana river other rivers are sand-choked channels containing water for short periods during the rains. In the dry season wildlife moved near Galana river but during the rains wildlife dispersed throughout the park drinking from temporary natural waterholes formed in clay pans filled with rain water.

In TsE, south of Voi, some artificial waterholes were recently developed for utilization by wildlife. There was no scientific investigation preceeding the creation of the artificial waterholes and it was uncertain whether any more artificial waterholes should be developed in other parts of the park. In order to assess the desirability of developing more waterholes in TsE the present study was carried out to investigate the following points:

(a) the daily and seasonal patterns of waterholes utilization by wild game;

(b) the seasonal distribution of wild game in relation to the waterholes;

(c) the seasonal changes in the mineral content of water samples collected from the waterholes; and

(d) the ecological and management implications of developing more waterholes in other parts of the park.

A grand total of 487 hours of observation during which 39,051 game-visits were recorded was used to establish the periodicity of 13 individual herbivores and carnivores at the waterholes throughout the 24 hours of the day. A basic pattern of waterhole utilization dominated by small (adult-size) herbivores during day-time 0600 - 1800 hours and larger species and carnivores at night 1800 - 0600 was determined. The numbers of herbivores utilizing Aruba Dam increased during the dry season but fell during the rains. The separation in the times that wildlife species arrived at or departed from the waterholes, and separations in the periods when waterhole utilization was at the peak for each wildlife species, as well as the frequency at which two species of wildlife drank together at the waterholes were used to show how wildlife attained a measure of ecological separation at the waterholes. The physiological and behavioural adaptations of wildlife to meet the ecological requirements of the arid TsE environment and the touristic value of the waterholes in the park were discussed.

The distribution of wildlife was determined in relation to vegetation types, seasons, and distance to the waterholes which contained water during the peak of the dry season. Some wildlife moved near to the artificial waterholes in the dry season but moved away from them during the rains when they drank from natural waterholes formed in clay pans filled with rain water.

Thus in the dry season the artificial waterholes could be used to attract wildlife away from the only permanent river in the park.

The chemical composition of water samples collected from some waterholes were determined. The composition of various minerals were high during the dry season but low during the rains. The seasonal fluctuation in the mineral content of the samples from the waterholes which were filled with water pumped from boreholes was the greatest. Thus, wildlife species utilizing the artificial waterholes put up with a higher degree of mineral content fluctuations in the course of the year than the species drinking from the rivers and natural waterholes. No single mineral could be determined as being the major attraction for the animals utilizing the waterholes.

A possible course in the ovolution of natural waterholes from the termitaria was described. It was observed that the development of artificial waterholes by excavating some natural waterholes resulted in the destruction of soil structure, and suggestions were made for improving the waterholding capacity of the artificial waterholes.

The removal of woody vegetation by wildlife was most pronounced around Aruba Dam, the largest artificial waterhole in the park. It was feared that continued aggregation of wildlife especially the elephant around many artificial waterholes still to be developed in TsE would further aggravate an already alarming rate of destruction of vegetation cover in the park, and as such it was concluded that a park-wide development of artificial waterholes in TsE should be discouraged. It was also recommended that further studies should be undertaken to determine:

(i) the possible effects of the high mineral contents of the waterholes on the wildlife during the dry season;

(ii) the possibilities of pests and disease transference between wildlife species at the waterholes; and

(iii) the rate of removal of plant species by wildlife through feeding and hoof action at the waterholes.

References cited in the Thesis

A.R.C., (1965)
The nutrient requirements of farm livestock.
Technical Reviews and Summaries, Ruminants; No. 2
Agricultural Research Council, London.

Agnew, A.D.Q. (1969)
Observations on the changing vegetation of Tsavo National Park East. E. Afr. Wildl. J. 6: 75 - 80

Ayeni, J.S.O. (1972)
Chemical analysis of some soil samples from the natural licks of Yankari Game Reserve, North-eastern State, Nigeria. Nig. J. of For. 2 (i): 16 - 21

Bailey, N.T.J. (1964)
Statistical Methods in Biology. (2nd Impression)
English Universities Press, London.

Buckman, H.O., and Brady, W.C. (1960)
Reaction of saline and alkali soil.
Nature and Properties of Soils 6th Ed.
The Macmillan Company, New York.

Buss, I.O., and Estes, J.A. (1971)
The functional significance of movement and positions of the pinnae of the African elephant Loxodonta africana
Jour. of Mammology 52 (1): 21 - 27

Butler, R.J. (1959)
Atlas of Kenya. The survey of Kenya, Nairobi.

Bradley, R.M. (1968)
Some aspects of the ecology of warthog.
M.Sc. Thesis. University of Nairobi.

Brown, L.H. and Cocheme, J. (1969)
A study of agrclimatology of highlands of Eastern Africa. (W.M.O. Technical Notes No. 125).
Geneva, Switzerland.

Corfield, T.F. (1973)
Elephant mortality in Tsavo National Park, Kenya.
E. Afr. Wildl. J. 11: 339 - 368

Cowan, I.McT. and Brink, V.C. (1949)
Natural game licks in the Rocky Mountains National Parks of Canada. J. of Mamm. 30 (4): 379 - 387

Crawford, E.C. and Schmidt-Nielson, K. (1967)
Temperature regulation and evaporative cooling in ostrich. Am. J. Physiol. 212: 347 - 353

Dougall, H.W. Drysdale, V.M. and Glover, P.E. (1964)
The chemical composition of Kenya browse and pasture herbage. E. Afr. Wildl. J. 2: 86 - 121

Finch, V.A. (1972)
The effects of solar radiation, on temperature regulation, and heat balance in two East African antelopes, the eland and the hartebeest.
Am. J. Physiol. 222: 1374 - 1379

Fisher, J. (1964)
Intraspecific aggression. In: The natural history of aggression (Eds. J.D. Carthy and F.J. Ebling), Academic Press, London and New York.

Foster, J.B. (1966)
The giraffe of Nairobi National Park: Home range, sex ratios, the herd and food. E. Afr. Wildl. J.4: 139-148.

Glover, P.E. and Sheldrick, D.L.W. (1964)
An urgent research problem on the elephant and rhino population of the Tsavo National Park in Kenya.
Bull. epiz. Dis. Afr. 12: 33 - 38

Glover, P.E. (1970)
Tsavo Research Project (Report 1968-70).
Kenya National Parks, Nairobi.

Glover, P.E. (1974)
A short history and summary of work undertaken by the Tsavo Research Project (Mimeographed Report)
Kenya National Parks, Nairobi.

Glover, J. (1963)
The elephant problem at Tsavo
E. Afr. Wildl. J. 1: 30 - 39

Greenway, P.J. (1969)
A checklist of plants recorded in Tsavo National Park, East. J.E. Afr. Nat. Hist. Soc. 27: 169 - 209

Griffith, G.A. (1938)
A note on termite hills. E. Afr. Agric. J. 4: 70 - 71

Henshaw, J. (1972)
Notes on conflict between elephant and some bovids and on other interspecific contacts in Yankari Game Reserve, N.E. Nigeria. E. Afr. Wildl. J. 10: 151 - 153

Hess, P.R. (1955)
A chemical and physical study of soils of termite mounds in East Africa. J. Ecol., 43: 449 - 461

Jarman, P.J. (1972)
Seasonal distribution of large mammal populations in the unflooded Middle Zambezi Valley.
J. appl. Ecol. 9: 283 - 299

Jarman, P.J. (1973)
The free water intake of impala in relation to the water content of their food. East African Agricultural and Forestry Journal Vol. XXXVIII, No. 4: 343 - 351

Jones, G.B. Potter, B.J. and Reid, C.S.W. (1970)
The effect of saline water ingestion on water turn-over rates and tritiated water space in sheep.
Aust. J. agric. Res. 21: 927 - 932

Laws, R. M. (1969)
Tsavo Research Project.
J. Reprod. Fert.; suppl. 6: 495 - 531

Laws, R.M. (1970)
Biology of African Elephants.
Sci. Prog. Oxf. 58: 251 - 262

Leuthold, W. and Leuthold, B. (1973)
Ecological Studies of ungulates in Tsavo National Park (East), Kenya. (Research Report) Kenya National Parks, Nairobi.

Leuthold, W. and Sale, J.B. (1973)
Movements and patterns of habitat utilization of elephants in Tsavo National Park, Kenya. E. Afr. Wildl. J. 11: 369 - 384

Macfarlane, M.V., Morris, R.J.H., and Howard, B. (1958)
Heat and water in Tropical Merino Sheep.
Aust. J. Agric. Res. 9: 217-28

Macfarlane, M.V. Howard, B. and Siebert, B.D. (1967)
Water metabolism of Merino and Border Leicester sheep grazing saltbush. Aust. J. agric. Res. 18: 947 - 58

Marfarlane, M.V. and Howard, B. (1972)
comparative water and energy economy of wild and domestic mammals. Symp. zool. soc. London. 31: 261 - 296

Murie, O.J. (1951)
The elk of North America.
The stackpole Company, Harrisburg, Penn. 376 pp.

Miller, J,M. (1952)
Geology of Mariakani - Mackinon Road Area.
Geological Survey of Kenya. Government Printer, Nairobi.

Milne, G. (1947)
Soil reconnaisance journey through parts of Tanganyika Territory. J. Ecol. 34: 192 -265

Napier-Bax, P. and Sheldrick, D.L.W. (1963)
Some preliminary observation on the food of elephants in Tsavo Royal National Park (East) of Kenya.
E. Afr. Wildl. J. 1: 40 - 53

Norton-Griffiths, M. (1972)
Report on the aerial photography carried out in the Tsavo National Parks in June 1972 with recommendation for a park-wide sampling design. Serengeti Ecological Monitoring Programme S.R.I. Arusha, Tanzania.

Obasi, G.O.P. and Kiangi, P.M.R. (1973)
Monthly and annual water balance components for Kenya.
In press as E.A.M.D. Techn. Memo. E.A., community, Nairobi.

Pant, P.S. and Rwandusya, E.M. (1971)
Climate of East Africa. Technical Memorandum No. 18
East African Metrological Department, E.A. Community, Nairobi.

Penman, H.L. (1948)
Natural evaporation from open water, bare soil, and grass.
Proc. Roy. Soc. (London) 193: 120 - 145

Pierce, A.W. (1957)
The tolerance of sheep for sodium chloride in the drinking water. Aust. J. agric. Res. 8: 711 - 722

Robertshaw, D. and Taylor, C.R. (1969)
A comparison of sweat gland activity in eight species of East African bovids. J. Physiol. Lond. 203: 135 - 143

Root, A. (1972)
Fringe-eared oryx digging tubers in Tsavo National Park (East). E. Afr. Wildl. J. 10: 155 - 157

Sanders, L.D. (1959)
Geology of the Mid-Galana area. Ministry of Commerce and Industry. Geological Survey of Kenya. Government Printer, Nairobi.

Sanders, L.D. (1963)
Geology of Voi - South Yatta area. Ministry of Commerce and Industry. Geological Survey of Kenya. Government Printer, Nairobi.

Sheldrick, D. (1973)
The Tsavo Story. Collins and Harvil Press, London.

Siegel, S. (1956)
Nonparametric Statistics for the behavioural Sciences.
McGraw-Bill Book Company Inc. New York, Toronto, London.

Stockstad, D.S. Melvin, S.M. and Lory, E.C. (1953)
Chemical characteristics of natural licks used by
big-game animals in Western Montana.
Trans. N. Am. Wildl. Conf. 18: 247 - 257

Squires, V.R. and Wilson, A.D. (1971)
Distance between food and water supply and its effect on
drinking frequency, food and water intake of Merino and
Border Leicester sheep. Aust. J. agric. Res. 22: 283 - 90

Taylor, C.R. (1969)
The eland and oryx. Scientific Am. 220 (1): 88 - 95

Taylor, C.R. (1972)
The desert gazelle: a paradox resolved.
Symp. zool. Soc. Lond. 31: 215 - 227

Taylor, C.R. Spinage, C.A. and Lyman, C.P. (1969)
Water relations of the waterbuck, an East African
antelope. Am. J. Physiol. 217: 630 - 634

Thornthwaite, C.W. (1948)
An approach towards a rational classification of climate.
Geography Review. 38: 35 - 38

Tyrrell, J.G. (1972)
Aspects of water balance of Tsavo East (Research Progress Report). Unpublished. Kenya National Parks, Nairobi.

Weir, J.S. (1960)
A possible course of evolution of animal drinking holes (pans) and reflected change in their biology.
Proc. 1st Fed. Sci. Cong. Salisbury. Mardon & Co., Salisbury.

Weir, J.S. (1968)
Seasonal variation in alkalinity in pans in Central Africa. Hydrobiologia 32: 69 - 80

Weir, J.S. (1969)
Chemical properties and occurrence on Kalahari sands of salt licks created by elephants. J. zool. 158: 293 - 310

Weir, J.S. (1971)
The effect of the creation of additional water supplies in a Central African National Park. Scientific Management of Plant and animal communities for conservation (Ed. by E. Duffey and A. Watt), pp. 367 - 385. Blackwell Scientific Publications, Oxford.

Weir, J.S. (1972)
Spatial distribution of elephants in an African National Park in relation to environmental sodium. Oikos, 23: 1 - 13

Weir, J.S. (1973)
Air flow, evaporation and mineral accumulation in mounds of Macrotermes Subhyalinus (Rambur) J. Anim. Ecol 42: 509 - 520

Weir, J.S. and Davison, E.C. (1965)
Daily occurrence of African game animals at waterholes in dry weather. Zool. Afr. 1: 353 - 368

Western, D. (1973)
The structure, dynamics and changes of the Amboseli Ecosystem. Ph. D. Thesis. University of Nairobi.

Wild, H. (1952)
The vegatation of southern Rhodesia termitaria. Rhod. agric. J. 49: 280 - 292

William, T.R. (1962)
The significance of salt and natural licks in elk management. M.Sc. Thesis. University of Idaho. Moscow.

Wilson, A.D. (1966)
The value of Atriplex (saltbush) and Kochia (Bluebush) species as food for sheep. Aust. J. agric. Res. 17: 147 - 53

Woodhead, T. (1968)
Studies of potential evaporation in Kenya, E.A.A.F.R.O., Nairobi.

Young, E. (1970)
Water as factor in die Ekologie van Wild in die Nasional Krugerwildtruin. D.Sc. Thesis. Pretoria University.

APPENDIX TABLE [illegible]

[illegible] BASED ON CLIMATIC RECORDS (19[illegible] - 1962 AND 1964 - 1966) FROM A [illegible]

APPENDICES

	J	F	M	A	M	J	J	A	S	O	N	D
Evapotranspiration (mm)	[illegible]	187	[illegible]	[illegible]	166	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Potential evapotranspiration (mm)	139	142	[illegible]	[illegible]	126	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Precipitation (mm)	[illegible]	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	124
Precipitation minus Potential evapotranspiration	-108	-112	[illegible]	[illegible]	-96	[illegible]	[illegible]	[illegible]	[illegible]	-115	[illegible]	[illegible]
Accumulated Potential Water Loss	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	-958	[illegible]	[illegible]			[illegible]
Soil Water Storage	[illegible]	[illegible]	[illegible]	[illegible]	13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Change in Soil Water Storage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	+15	[illegible]
Actual Evapotranspiration	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Soil Water Deficit	99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Soil Water Surplus												

Field capacity = 250 mm.

Im = Moisture Index or [illegible] effectiveness Index

Im = [illegible] = Climatic type D = Semi Arid Climate.

[illegible]

[illegible]

APPENDIX TABLE 1

WATER BALANCE FOR TSAVO NATIONAL PARK (EAST) BASED ON CLIMATIC RECORDS (1938 - 1962 AND 1964 - 1966) FROM A SYNOPTIC, EAST AFRICAN METEOROLOGICAL STATION, VOI, (3 Km. OUTSIDE NATIONAL PARK BOUNDARY).

	J	F	M	A	M	J	J	A	S	O	N	D
Evapotranspiration (mm)	183	187	198	176	166	158	156	162	174	189	182	175
Potential evapotranspiration (mm)	139	142	151	134	126	120	119	123	132	143	138	133
Precipitation (mm)	31	30	79	94	30	7	3	8	15	28	97	124
Precipitation minus Potential evapotranspiration	-108	-112	-72	-40	-96	-113	-116	-115	-117	-115	-41	-9
Accumalated Potential Water Loss	-675	-787	-633	-729		-842	-958	-1073	-1190			-567
Soil Water Storage	16	10	16	19	13	8	5	3	2	5	20	25
Change in Soil Water Storage	-9	-6	+6	+3	-6	-5	-3	-2	-1	+3	+15	+5
Actual Evapotranspiration	40	36	73	91	36	12	6	10	16	25	82	119
Soil Water Deficit	99	106	78	43	90	108	113	113	116	118	56	14
Soil Water Surplus												

Field capacity = 250 mm.

Im = Moisture Index or Precipitation effectiveness Index

$$Im = \frac{-60 \times 1054}{1600} = -39{\cdot}53$$ = Climatic type D = Semi Arid Climate.

For details about calculation procedures see Pant and Rwandusya (1971)

where:-

$$IM = \frac{100s - 60d}{n}$$

and n = Annual Potential Evapotranspiration.

s = Annual Water surplus

d = Annual Water deficit

Thornthwaite K = 100 and 60

APPENDIX TABLE 2 AVERAGE RAINFALL FIGURES FOR VARIOUS STATIONS INSIDE AND AROUND THE STUDY AREA

Name of station	Period:	J	F	M	A	M	J	J	A	S	O	N	D	Average in mm. Y	(N)
Mackinon Road	1963-1972	49.1	30.2	75.6	66.7	54.9	28.9	17.5	20.7	30.2	54.5	90.4	66.1	584.8	10
Buchuma Range	1967-1972	40.8	38.4	62.5	64.0	49.3	20.9	21.2	23.2	61.6	46.1	86.1	52.7	566.8	6
Buchuma Gate	1969-1973	51.3	29.6	30.9	46.4	47.2	15.2	13.8	16.8	42.8	26.0	65.3	56.3	441.6	5
" "	1973	10.8	6.4	27.3	70.6	43.8	16.7	6.1	10.7	3.8	27.0	82.1	24.0	329.3	*
Voi meteorological	1905-1971	32.4	30.1	81.7	92.5	29.0	7.2	3.1	8.2	15.0	28.0	99.5	122.4	549.1	66
" "	1955-1972	34.9	38.4	106.6	128.6	24.6	6.1	5.7	8.1	17.4	30.0	133.5	100.1	634.0	18
" "	1973	27.4	36.4	70.0	60.4	30.6	.2	.6	1.8	5.1	14.3	203.7	18.4	468.9	*
T.N.P.Headquarters	1971-1973	16.5	21.9	23.7	67.6	71.9	2.2	1.5	5.4	16.9	6.6	13.1	58.3	304.7	3
	1973	12.2	4.1	64.8	68.8	35.1	.0	.0	.0	.0	8.3	203.8	44.9	442.0	*
T.R.P.Headquarters	1969-1973	5.7	18.0	80.9	55.6	49.7	1.8	1.2	8.0	17.7	25.1	115.1	56.9	433.9	5
	1973	13.1	3.9	116.3	65.3	29.7	.0	.0	.0	.1	9.1	189.5	41.2	468.2	*
Ndololo	1971-1973	24.8	27.6	66.7	73.8	79.1	.4	1.9	1.1	34.9	12.0	149.0	50.7	522.0	3
	1973	13.0	5.8	153.3	82.2	21.6	.0	.0	.3	.3	15.3	215.9	24.6	532.6	*
Campsite	1971-1973	16.7	30.2	55.9	66.8	73.7	1.3	.5	1.0	14.5	4.9	137.9	55.2	458.6	3
	1973	7.4	3.3	105.33	73.6	26.6	.0	.0	.0	.0	6.9	175.3	36.2	434.6	*
Ndara	1971-1973	15.5	9.9	27.2	45.4	44.8	3.2	1.6	1.2	34.2	9.9	121.5	145.8	464.2	3
	1973	4.4	13.2	.0	95.1	68.9	23.0	.0	.8	1.6	15.1	243.7	54.4	520.2	*
Maungu station	1964-1971	32.0	21.5	77.8	46.6	27.3	21.5	2.1	4.0	12.8	36.1	63.1	68.2	413.0	7
Maungu Park road	1973	1.5	32.0	3.8	12.4	68.5	7.6	.0	3.1	6.7	11.2	72.6	102.6	322.0	*
Aruba	1969-1973	22.1	12.5	21.9	27.5	17.3	2.4	1.4	8.1	8.1	12.8	82.9	66.9	283.9	5
	1973	.0	2.5	.0	45.0	40.8	1.8	.0	9.1	.7	5.8	90.3	87.9	283.9	*
Dika	1973	8.1	6.7	8.1	29.3	37.5	6.3	.0	3.0	.0	20.9	51.9	48.4	220.2	*
Mukwaju	1971-1973	23.6	15.0	2.2	15.2	44.5	4.4	4.1	5.8	13.0	14.2	21.9	41.7	205.6	3
	1973	14.2	4.1	.0	14.6	61.4	5.3	.0	2.4	3.1	17.0	44.3	34.7	201.1	*

Note:- * = Value for the study period, 1973.
(N) = number of years for which average values represent.

Average annual rainfall 1969-1973: Manyani 298.98 mm.; Sala 273.62 mm.; Lugard's Falls 308.37 mm.

REFERENCES		Nov. 1954-Feb. 1955 X% COVER	May, 1965 X% COVER	1954-1968 ANNUAL CHANGE	June, 1972 X% COVER	1954-1972 ANNUAL CHANGE
083 9KE41	1	33.75 ± 3.36	0.94 ± 0.55	2.34	1.87 ± 0.84	1.77
	2	23.75 ± 1.92	0.94 ± 0.89	1.63	1.25 ± 0.84	1.25
	3	27.19 ± 1.62	1.56 ± 0.00	1.83	0.93 ± 0.89	1.46
	4	30.31 ± 2.88	0.31 ± 0.45	2.14	1.25 ± 0.54	1.57
	5	34.69 ± 2.17	0.00 ± 0.00	2.48	0.62 ± 0.55	1.89
	6	21.25 ± 1.82	2.81 ± 0.45	1.32	1.87 ± 1.30	1.08
	7	33.75 ± 1.67	5.94 ± 0.84	1.99	2.34 ± 0.84	1.75
	8	31.56 ± 1.92	1.25 ± 0.84	2.17	1.87 ± 0.45	1.65
	9	39.38 ± 1.30	7.19 ± 0.89	2.30	0.93 ± 0.55	2.14
	10	39.38 ± 1.48	5.31 ± 0.89	2.43	1.25 ± 0.45	2.12
	11	36.88 ± 2.79	4.06 ± 0.55	2.34	1.25 ± 0.84	1.98
	12	38.13 ± 0.55	2.81 ± 0.84	2.52	1.87 ± 0.84	2.01
	13	38.75 ± 1.92	2.50 ± 0.55	2.59	1.56 ± 0.71	2.07
	14	40.00 ± 3.78	0.63 ± 0.55	2.81	1.25 ± 0.84	2.15
	15	40.31 ± 4.09	2.81 ± 0.84	2.68	1.56 ± 0.00	2.15
	16	43.13 ± 2.07	3.13 ± 1.22	2.86	3.12 ± 1.00	2.22
	17	37.50 ± 1.87	2.50 ± 0.89	2.50		
	18	40.63 ± 1.58	3.13 ± 1.00	2.68		
	19	43.13 ± 2.88	0.63 ± 0.55	3.04		
	20	35.00 ± 1.34	4.06 ± 0.89	2.21		
	21	30.63 ± 2.07	1.25 ± 0.45	2.10		
	22	31.88 ± 1.82	1.25 ± 0.84	2.19		

Mean annual % vegetation Cover Change 1.83 ± 0.35

Mean annual % vegetation cover change = 2.33 ± 0.41

APPENDIX TABLE 3

The Mean annual percentage change in vegetation cover obtained by comparing the 1954 sets of aerial photographs with 1968 and 1972 sets using dot-grid method for the area South-east of Aruba dam, in Tsavo National Park (East).

APPENDIX TABLE 4 MEAN MONTHLY TEMPERATURES FOR VOI 1937-1968; ARUBA MAY 1973-APRIL 1974; AND DIKA PLAINS JUNE 1973-APRIL 1974

		June 1973	July 1973	August 1973	Sept. 1973	Oct. 1973	Nov. 1973	Dec. 1973	Jan. 1974	Feb. 1974	March 1974	April 1974	May 1974
East African Meteorological Station Voi	Mean maximum	28.9	27.9	27.9	29.1	30.8	31.3	30.8	31.7	33.2	33.3	31.6	29.7
	Mean minimum	18.3	17.4	17.3	17.6	18.9	20.1	20.6	20.2	20.3	20.9	20.2	20.0
Aruba Thermohydrograph readings	0600	22.2	19.5	20.7	20.8	21.5	27.8	23.0	22.9	21.5	22.7	22.9	23.3
	1200	29.2	26.4	26.3	28.8	31.0	32.9	27.2	25.6	24.7	28.9	27.6	29.4
	1800	26.3	24.5	26.4	25.7	27.2	30.2	25.9	29.1	30.9	30.2	30.4	27.7
	2400	23.6	20.6	22.4	22.1	22.7	27.8	23.2	23.5	22.5	23.2	23.6	24.4
Dika Thermohydrograph readings	0600	22.0	19.9	20.1	20.0	21.5	24.7	23.4	23.1	22.9	22.6	24.2	--
	1200	27.8	27.4	27.5	27.8	27.8	29.2	27.7	28.1	25.6	29.5	26.9	--
	1800	28.1	24.0	25.0	26.3	28.5	28.9	28.3	30.1	30.9	27.8	29.7	--
	2400	22.1	20.9	21.4	21.6	22.7	25.1	23.4	23.7	23.8	23.7	24.8	--

APPENDIX TABLE 5:

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PART PER MILLION			
		N	P	S	Ca	Mg	K	Cu	Fe	Zn	Mn
	ACANTHACEAE										
**	Disperma kilimandscharica (Lindau)	2.99	0.15	0.45	4.80	2.60	1.85	17.2	400	30	56
**	Anisotes parvifolius (Oliv.)	3.43	0.19	0.40	2.90	1.04	3.90	17.2	800	127	120
*	Anisotes parvifolius (Oliv.)	4.50	0.15	2.51	2.28	0.62	2.20				
**	Barleria eranthemoides (Hucks)	3.38	0.19	0.54	3.60	1.80	2.92	21.4	400	29.6	34
	AMARANTHACEAE										
*	Achyranthes aspera (L.)	2.86	0.064	0.240	2.25	1.312	1.30				
*	Gomphrena celosioides (Marts)	2.00	0.100	0.225	1.24	0.56	2.40				
	ANACARDIACEAE										
*	Lannea triphylla (A. Rich)	2.07	0.13	0.10	0.60	0.36	1.04	17.2	640	22.6	720
	ASCLEPIADACEAE										
*	Calotropis procera (Ait.)	4.35	0.30	0.060	0.80	0.74	4.00				

APPENDIX TABLE 5: Cont.

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PART PER MILLION			
		N	P	S	Ca	Ng	K	Cu	Fe	Zn	Mn
	BORAGINACEAE										
*	Cordia ovalis (R.Br.)	1.84	0.085	0.110	8.12	0.384	1.70				
**	Heliotropium steudner (Vatke)	4.02	0.22	0.36	3.00	2.04	2.65	28.2	1920	28.4	126
*	Heliotropium steudneri (Vatke)	4.36	0.17	0.72	6.72	1.00	2.40				
*	Cordia gharaf (Forsk.)	3.35	0.140	0.125	3.68	0.32	2.00				
	CUCURBITACEAE										
*	Cucumis aculeatus (Cogn.)	2.35	0.190	0.310	6.20	1.072	0.80				
	CAPPARIDACEAE										
*	Thylachium thomasii (Gilg)	4.45	0.12	3.05	1.84	0.85	3.90				
**	Thylachium thomasii (Gilg)	2.15	0.11	2.25	2.00	1.44	3.11	15.2	200	24.6	38
*	Maerua edulis (Gilg & Ben.)	5.33	0.064	0.790	1.03	0.92	2.20				
*	Boscia coriacea (Pax)	2.56	0.043	0.660	0.27	0.20	1.20				
*	Capparis tomentosa (Lam.)	4.28	0.12	0.790	1.76	0.72	2.80				
*	Maerua subcordata (Gilg)		0.05	0.060	0.56	0.39	2.90				

APPENDIX TABLE 5: Cont.

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER.

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PARTS PER MILLION			
		N	P	S	Ca	Mg	K	Cu	Fe	Zn	Mn
	CAESALPINIACEAE										
*	Cassia occidentalis (L.)	5.50	0.20	0.21	1.22	0.46	2.10				
(twig) *	Cassia abbreviata (Oliv.)	3.31	0.090	0.147	1.76	0.276	1.30				
*	Cassia abbreviata (Oliv.)	4.84	0.17	0.21	1.00	0.44	1.80				
*	Delonix elata (L.)	3.36	0.21	0.190	0.94	0.17	1.60				
*	Tamarindus indica (L.)	1.79	0.091	0.920	3.30	0.46	0.80				
	COMBRETACEAE										
*	Terminalia orbicularis (Engl.& Diels)	2.61	0.20	13.10	0.84	0.40	1.60				
	GRAMINEAE										
*	Cenchrus ciliaris (L.)	1.38	0.075	0.210	0.40	0.70					
*	Chloris roxburghiana (Schult.)	1.30	0.050	0.125	0.76	0.19	0.80				
*	Sporobolus helvolus (Trin.)	1.17	0.064	0.125	0.43	0.08	0.50				
(stem) *	Cynodon dactylon (L.)	0.96	0.110	0.155	0.43	0.29	1.10				
*	Cynodon dactylon "	4.34	0.20	0.47	0.28	0.22	2.30				
*	Cynodon plectostachyus (K.Schum.)	1.88	0.110	0.210	2.70	0.17	1.80				

APPENDIX TABLE 5: Cont.

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER.

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PART PER MILLION			
		N	P	S	Ca	Mg	K	Cu	Fe	Zn	Mn
	GRAMINEA										
*	Eragrostis caespitosa (Chiov.)	0.86	0.055	0.35	0.22	0.18	0.60				
*	Cymbopogon pospischilii (K.Schum.)	0.61	0.013	0.060	1.30	0.084	0.30				
*	Bothriochloa radicans (Lehm.)	1.33	0.090	0.080	0.32	0.104	1.00				
*	Enteropogon macrostachyus (A.Rich.)	1.59	0.080	0.210	0.76	0.252	1.10				
*	Aristida adscensionis (L.)	0.60	0.044	0.660	0.30	0.160	0.50				
*	Panicum meyerianum (Nees)	2.12	0.200	0.410	0.35	0.21	2.90				
	ICACINACEAE										
*	Pyrenacantha malvifolia (Engl.)	4.41	0.18	0.155	2.03	0.60	1.70				
*	Pyrenacantha malvifolia (Engl.)	3.08	0.18	0.15	3.00	0.88	1.10	14	300	16.6	38
	LILIACEAE										
**	Asparagus Asiaticus (L.)	1.75	0.13	0.10	0.88	0.24	0.30	18.8	380	20.4	38
	LOGANIACEAE										
*	Strychonos decussata (Pappe.)	1.28	0.04	0.08	2.45	0.536	0.60				
	LYTHRACEAE										
**	Lawsonia Inermis (L)	1.77	0.19	0.10	0.42	0.32	0.90	18.8	200	22.6	22

APPENDIX TABLE 5 Cont.

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER.

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PART PER MILLION			
		N	P	S	Ca	Mg	K	Cu	Fe	Zn	Mn
	MALVACEAE										
**	Sida ovata (Forsk.)	2.89	0.19	0.10	3.40	0.44	1.74	22.4	144	36.0	56
*	Abutilon fruticosum (Guill & Perr.)	3.24	0.15	0.91	4.34	0.49	2.40				
(Whole plant) *	Abutilon fruticosum (" " ")	2.40	0.13	0.60	1.58	0.69	2.40				
	MELIACEAE										
*	Melia volkensii (Guerke)	4.00	0.19	0.80	1.11	0.224	2.80				
	MIMOSACEAE										
**	Acasia spp.	3.57	0.19	0.40	3.00	0.92	1.74	16.8	400	28.0	40
*	Acacia tortilis (Forsk.)	3.47	0.11	0.21	1.43	0.52	0.90				
	OCHNACEAE										
**	Ochna inermis (Forsk.)	2.17	0.13	0.10	0.62	0.22	0.96	22	240	32.0	680

APPENDIX TABLE 5: Cont.

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER.

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PART PER MILLION			
		N	P	S	Ca	Mg	K	Cu	Fe	Zn	Mn
	PAPILIONACEAE										
*	<u>Platycelyphium voense</u> (Engl.)	1.63	0.120	0.90	2.83	0.16	0.70				
*	<u>Dolichos uniflorus</u> (Lam.)	2.65	0.16	0.15	1.80	0.32	2.00				
**	<u>Indigofera arrecta</u> (A.Rich.)	3.93	0.17	0.11	2.50	1.00	1.26	22.0	260	30.0	92
*	<u>Indigofera arrecta</u> (A. Rich.)	4.55	0.20	0.175	2.80	0.49	1.40				
	PORTULACACEAE										
**	<u>Calyptrotheca taitensis</u> (Pax & Vatke)	2.56	0.15	0.20	1.80	1.72	4.28	18.8	200	27.8	96
	RUBIACEAE										
**	<u>Xeromphis keniensia</u> (Tennant)	2.39	0.18	0.10	0.80	0.44	1.95	16.2	300	27.2	36
**	<u>Hymenodictyon parvifolium</u> (Oliv.)	2.70	0.17	0.11	1.70	0.72	1.62	22.6	1640	35.2	84
	SALVADORACEAE										
*	<u>Dobera glabra</u> (Forsk.)	1.60	0.03	3.48	5.64	0.736	0.70				
**	<u>Dobera glabra</u> (Forsk.)	2.29	0.11	1.75	2.00	1.08	2.92	15.6	200	23	1040
*	Salvadora persica (L.)	2.91	0.13	2.7	6.40	0.49	2.30				

APPENDIX TABLE 5: Cont.

CHEMICAL ANALYSIS OF LEAF SAMPLES COLLECTED AROUND NATURAL AND ARTIFICIAL WATER HOLES IN TSAVO NATIONAL PARK (EAST) SOUTH OF VOI RIVER

REMARKS	SPECIMEN	PERCENTAGE BY WEIGHT						PART PER MILLION			
		N	P	S	Ca	Mg	K	Cu	Fe	Zn	Mn
	SOLANACEAE										
**	Datura metel (L.)	2.68	0.18	0.16	6.40	0.72	1.60	15.6	200	22.6	38
*	Datura metel (l.)	5.99	0.20	0.241	1.41	0.536	4.10				
*	Solanum incanum (L.)	3.28	0.12	0.241	1.70	0.75	1.80				
*	Solanum dubium (Fres.)	4.20									

* = Specimen collected in the dry season (August-September.)
** = Specimen collected towards the end of the rainy season (December).